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Magnetic Monopole Searches

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Magnetic Monopole Searches

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Magnetic Monopoles

Monopole Production Cross Section — Accelerator Searches

X-SECT (cm ²)	MASS (GeV)	CHG (g)	ENERGY (GeV)	BEAM	DOCUMENT ID	TECN
<2.5E-37	200-6000	1	13000	pp	1 ACHARYA	17 INDU
<2E-37	200-6000	2	13000	pp	1 ACHARYA	17 INDU
<4E-37	200-5000	3	13000	pp	1 ACHARYA	17 INDU
<1.5E-36	400-4000	4	13000	pp	1 ACHARYA	17 INDU
<7E-36	1000-3000	5	13000	pp	1 ACHARYA	17 INDU
<5E-40	200-2500	0.5-2.0	8000	pp	2 AAD	16AB ATLS
<2E-37	100-3500	1	8000	pp	3 ACHARYA	16 INDU
<2E-37	100-3500	2	8000	pp	3 ACHARYA	16 INDU
<6E-37	500-3000	3	8000	pp	3 ACHARYA	16 INDU
<7E-36	1000-2000	4	8000	pp	3 ACHARYA	16 INDU
<1.6E-38	200-1200	1	7000	pp	4 AAD	12CS ATLS
<5E-38	45-102	1	206	e ⁺ e ⁻	5 ABBIENDI	08 OPAL
<0.2E-36	200-700	1	1960	p \bar{p}	6 ABULENCIA	06K CNTR
<2.E-36		1	300	e ⁺ p	7.8 AKTAS	05A INDU
<0.2.E-36		2	300	e ⁺ p	7.8 AKTAS	05A INDU
<0.09E-36		3	300	e ⁺ p	7.8 AKTAS	05A INDU
<0.05E-36		≥6	300	e ⁺ p	7.8 AKTAS	05A INDU
<2.E-36		1	300	e ⁺ p	7.9 AKTAS	05A INDU
<0.2E-36		2	300	e ⁺ p	7.9 AKTAS	05A INDU
<0.07E-36		3	300	e ⁺ p	7.9 AKTAS	05A INDU
<0.06E-36		≥6	300	e ⁺ p	7.9 AKTAS	05A INDU
<0.6E-36	>265	1	1800	p \bar{p}	10 KALBFLEISCH	04 INDU
<0.2E-36	>355	2	1800	p \bar{p}	10 KALBFLEISCH	04 INDU
<0.07E-36	>410	3	1800	p \bar{p}	10 KALBFLEISCH	04 INDU
<0.2E-36	>375	6	1800	p \bar{p}	10 KALBFLEISCH	04 INDU
<0.7E-36	>295	1	1800	p \bar{p}	11,12 KALBFLEISCH	00 INDU
<7.8E-36	>260	2	1800	p \bar{p}	11,12 KALBFLEISCH	00 INDU
<2.3E-36	>325	3	1800	p \bar{p}	11,13 KALBFLEISCH	00 INDU
<0.11E-36	>420	6	1800	p \bar{p}	11,13 KALBFLEISCH	00 INDU
<0.65E-33	<3.3	≥2	11A	197Au	14,15 HE	97
<1.90E-33	<8.1	≥2	160A	208Pb	14,15 HE	97
<3E-37	<45.0	1.0	88-94	e ⁺ e ⁻	PINFOLD	93 PLAS
<3E-37	<41.6	2.0	88-94	e ⁺ e ⁻	PINFOLD	93 PLAS
<7E-35	<44.9	0.2-1.0	89-93	e ⁺ e ⁻	KINOSHITA	92 PLAS
<2E-34	<850	≥0.5	1800	p \bar{p}	BERTANI	90 PLAS
<1.2E-33	<800	≥1	1800	p \bar{p}	PRICE	90 PLAS
<1.E-37	<29	1	50-61	e ⁺ e ⁻	KINOSHITA	89 PLAS
<1.E-37	<18	2	50-61	e ⁺ e ⁻	KINOSHITA	89 PLAS
<1.E-38	<17	<1	35	e ⁺ e ⁻	BRAUNSCH...	88B CNTR
<8E-37	<24	1	50-52	e ⁺ e ⁻	KINOSHITA	88 PLAS
<1.3E-35	<22	2	50-52	e ⁺ e ⁻	KINOSHITA	88 PLAS
<9.E-37	<4	<0.15	10.6	e ⁺ e ⁻	GENTILE	87 CLEO
<3.E-32	<800	≥1	1800	p \bar{p}	PRICE	87 PLAS
<3.E-38		<3	29	e ⁺ e ⁻	FRYBERGER	84 PLAS
<1.E-31		1,3	540	p \bar{p}	AUBERT	83B PLAS
<4.E-38	<10	<6	34	e ⁺ e ⁻	MUSSET	83 PLAS
<8.E-36	<20		52	pp	16 DELL	82 CNTR
<9.E-37	<30	<3	29	e ⁺ e ⁻	KINOSHITA	82 PLAS
<1.E-37	<20	<24	63	p \bar{p}	CARRIGAN	78 CNTR
<1.E-37	<30	<3	56	pp	HOFFMANN	78 PLAS
			62	pp	16 DELL	76 SPRK
<4.E-33			300	p	16 STEVENS	76B SPRK
<1.E-40	<5	<2	70	p	17 ZRELOV	76 CNTR
<2.E-30			300	n	16 BURKE	75 OSPK
<1.E-38			8	ν	18 CARRIGAN	75 HLBC
<5.E-43	<12	<10	400	p	EBERHARD	75B INDU
<2.E-36	<30	<3	60	pp	GIACOMELLI	75 PLAS
<5.E-42	<13	<24	400	p	CARRIGAN	74 CNTR
<6.E-42	<12	<24	300	p	CARRIGAN	73 CNTR
<2.E-36		1	0.001	γ	17 BARTLETT	72 CNTR
<1.E-41	<5		70	p	GUREVICH	72 EMUL
<1.E-40	<3	<2	28	p	AMALDI	63 EMUL
<2.E-40	<3	<2	30	p	PURCELL	63 CNTR
<1.E-35	<3	<4	28	p	FIDECARO	61 CNTR
<2.E-35	<1	1	6	p	BRADNER	59 EMUL

• • • We do not use the following data for averages, fits, limits, etc. • • •

<1.3E-40	200-4000	1	13000	pp	19 AAD	20G ATLS
<5.6E-40	500-4000	2	13000	pp	19 AAD	20G ATLS
	200-5000	2	13000	pp	20 ACHARYA	19B INDU
	200-5000	1	13000	pp	21 ACHARYA	18A INDU

- The search was sensitive to monopoles which had stopped in aluminium trapping volumes. Monopoles with spins 0 and 1/2 were considered; mass-dependent spin 1/2 monopole limits are quoted here.
- AAD 16AB model-independent 95% CL limits estimated using a fiducial region of approximately constant acceptance. Limits are mass-dependent.
- ACHARYA 16 limits at 95% CL estimated using a Drell-Yan-like production mechanism for scalar monopoles.
- AAD 12CS searched for monopoles as highly ionising objects. The cross section limits are based on an assumed Drell-Yan-like production process for spin 1/2 monopoles. The limits are mass- and scenario-dependent.
- ABBIENDI 08 assume production of spin 1/2 monopoles with effective charge $g\beta$ ($n=1$), via $e^+e^- \rightarrow \gamma^* \rightarrow M\bar{M}$, so that the cross section is proportional to $(1 + \cos^2\theta)$. There is no z information for such highly saturated tracks, so a parabolic track in the jet chamber is projected onto the xy plane. Charge per hit in the chamber produces a clean separation of signal and background.
- ABULENCIA 06K searches for high-ionizing signals in CDF central outer tracker and time-of-flight detector. For Drell-Yan $M\bar{M}$ production, the cross section limit implies $M > 360$ GeV at 95% CL.
- AKTAS 05A model-dependent limits as a function of monopole mass shown for arbitrary mass of 60 GeV. Based on search for stopped monopoles in the H1 Al beam pipe.
- AKTAS 05A limits with assumed elastic spin 0 monopole pair production.
- AKTAS 05A limits with assumed inelastic spin 1/2 monopole pair production.
- KALBFLEISCH 04 reports searches for stopped magnetic monopoles in Be, Al, and Pb samples obtained from discarded material from the upgrading of DØ and CDF. A large-aperture warm-bore cryogenic detector was used. The approach was an extension of the methods of KALBFLEISCH 00. Cross section results moderately model dependent; interpretation as a mass lower limit depends on possibly invalid perturbation expansion.
- KALBFLEISCH 00 used an induction method to search for stopped monopoles in pieces of the DØ (FNAL) beryllium beam pipe and in extensions to the drift chamber aluminium support cylinder. Results are model dependent.
- KALBFLEISCH 00 result is for aluminum.
- KALBFLEISCH 00 result is for beryllium.
- HE 97 used a lead target and barium phosphate glass detectors. Cross-section limits are well below those predicted via the Drell-Yan mechanism.
- This work has also been reinterpreted in the framework of monopole production via the thermal Schwinger process (GOULD 17); this gives rise to lower mass limits.
- Multiphoton events.
- Cherenkov radiation polarization.
- Re-examines CERN neutrino experiments.
- AAD 20c give limits for Drell-Yan production with spin-0 and spin-1/2 monopoles. The above limit is for spin = 0 at mass = 3 TeV.
- ACHARYA 19b limits both β -dependent and β -independent on monopoles with spins 0, 1/2, and 1 and with magnetic charges ranging from one to five times the Dirac charge in mass ranges between 200 GeV and 5000 GeV.
- ACHARYA 18A provide limits on monopoles with spins 0, 1/2, and 1 and with magnetic charges ranging from two to five times the Dirac charge.

Monopole Production — Other Accelerator Searches

MASS (GeV)	CHG (g)	SPIN	ENERGY (GeV)	BEAM	DOCUMENT ID	TECN
> 610	≥1	0	1800	p \bar{p}	1 ABBOTT	98K D0
> 870	≥1	1/2	1800	p \bar{p}	1 ABBOTT	98K D0
>1580	≥1	1	1800	p \bar{p}	1 ABBOTT	98K D0
> 510	88-94	e ⁺ e ⁻			2 ACCIARRI	95C L3

- ABBOTT 98K search for heavy pointlike Dirac monopoles via central production of a pair of photons with high transverse energies.
- ACCIARRI 95C finds a limit $B(Z \rightarrow \gamma\gamma) < 0.8 \times 10^{-5}$ (which is possible via a monopole loop) at 95% CL and sets the mass limit via a cross section model.

Monopole Flux — Cosmic Ray Searches

"Catty" in the charge column indicates a search for monopole-catalyzed nucleon decay.

FLUX (cm ⁻² s ⁻¹ sr ⁻¹)	MASS (GeV)	CHG (g)	COMMENTS ($\beta = v/c$)	EVTs	DOCUMENT ID	TECN
<1.5E-18		1	$\beta > 0.6$	0	1 ALBERT	17 ANTR
<2.5E-21		1	$1E8 < \gamma < 1E13$	0	2 AAB	16 AUGE
<1.55E-18			$\beta > 0.51$	0	3 AARTSEN	16B ICCB
<1E-17		Catty	$1E-3 < \beta < 1E-2$	0	4 AARTSEN	14 ICCB
<3E-18		1	$\beta > 0.8$	0	5 ABBASI	13 ICCB
<1.3E-17		1	$\beta > 0.625$	0	6 ADRIAN-MAR.	12A ANTR
<6E-28	<1E17	Catty	$1E-5 < \beta < 0.04$	0	7 UENO	12 SKAM
<1E-19		1	$\gamma > 1E10$	0	8 DETRIXHE	11 ANIT
<3.8E-17		1	$\beta > 0.76$	0	9 ABBASI	10A ICCB
<1.3E-15	$1E4 < M < 5E13$	1	$\beta > 0.05$	0	5 BALESTRA	08 PLAS
<0.65E-15	>5E13	1	$\beta > 0.05$	0	9 BALESTRA	08 PLAS
<1E-18		1	$\gamma > 1E8$	0	8 HOGAN	08 RICE
<1.4E-16		1	$1.1E-4 < \beta < 1$	0	10 AMBROSIO	02B MCRO
<3E-16		Catty	$1.1E-4 < \beta < 5E-3$	0	11 AMBROSIO	02C MCRO
<1.5E-15		1	$5E-3 < \beta < 0.99$	0	12 AMBROSIO	02D MCRO
<1E-15		1	$1.1 \times 10^{-4} - 0.1$	0	13 AMBROSIO	97 MCRO
<5.6E-15		1	(0.18-3.0)E-3	0	14 AHLEN	94 MCRO
<2.7E-15		Catty	$\beta \sim 1 \times 10^{-3}$	0	15 BECKER-SZ.	94 IMB
<8.7E-15		1	$> 2E-3$	0	THRON	92 SOUD
<4.4E-12		1	all β	0	GARDNER	91 INDU
<7.2E-13		1	all β	0	HUBER	91 INDU

Searches Particle Listings

Magnetic Monopole Searches

<3.7E-15	>E12	1	$\beta=1.E-4$	0	16	ORITO	91	PLAS
<3.2E-16	>E10	1	$\beta > 0.05$	0	16	ORITO	91	PLAS
<3.2E-16	>E10-E12	2,3		0	16	ORITO	91	PLAS
<3.8E-13		1	all β	0		BERMON	90	INDU
<5.E-16		Caty	$\beta < 1.E-3$	0	15	BEZRU KOV	90	CHER
<1.8E-14		1	$\beta > 1.1E-4$	0	17	BUCKLAND	90	HEPT
<1E-18		1	$3.E-4 < \beta < 1.5E-3$	0	18	GHOSH	90	MICA
<7.2E-13		1	all β	0		HUBER	90	INDU
<5.E-12	>E7	1	$3.E-4 < \beta < 5.E-3$	0		BARISH	87	CNTR
<1.E-13		Caty	$1.E-5 < \beta < 1$	0	15	BARTELT	87	SOUD
<1.E-10		1	all β	0		EBISU	87	INDU
<2.E-13		1	$1.E-4 < \beta < 6.E-4$	0		MASEK	87	HEPT
<2.E-14		1	$4.E-5 < \beta < 2.E-4$	0		NAKAMURA	87	PLAS
<2.E-14		1	$1.E-3 < \beta < 1$	0		NAKAMURA	87	PLAS
<5.E-14		1	$9.E-4 < \beta < 1.E-2$	0		SHEP KO	87	CNTR
<2.E-13		1	$4.E-4 < \beta < 1$	0		TSUKAMOTO	87	CNTR
<5.E-14		1	all β	1	19	CAPLIN	86	INDU
<5.E-12		1		0		CROMAR	86	INDU
<1.E-13		1	$7.E-4 < \beta$	0		HARA	86	CNTR
<7.E-11		1	all β	0		INCANDELA	86	INDU
<1.E-18		1	$4.E-4 < \beta < 1.E-3$	0	18	PRICE	86	MICA
<5.E-12		1		0		BERMON	85	INDU
<6.E-12		1		0		CAPLIN	85	INDU
<6.E-10		1		0		EBISU	85	INDU
<3.E-15		Caty	$5.E-5 \leq \beta \leq 1.E-3$	0	15	KAJITA	85	KAMI
<2.E-21		Caty	$\beta < 1.E-3$	0	15,20	KAJITA	85	KAMI
<3.E-15		Caty	$1.E-3 < \beta < 1.E-1$	0	15	PARK	85B	CNTR
<5.E-12		1	$1.E-4 < \beta < 1$	0		BATTISTONI	84	NUSX
<7.E-12		1		0		INCANDELA	84	INDU
<7.E-13		1	$3.E-4 < \beta$	0	17	KAJINO	84	CNTR
<2.E-12		1	$3.E-4 < \beta < 1.E-1$	0		KAJINO	84B	CNTR
<6.E-13		1	$5.E-4 < \beta < 1$	0		KAWAGOE	84	CNTR
<2.E-14		1	$1.E-3 < \beta$	0	15	KRISHNA...	84	CNTR
<4.E-13		1	$6.E-4 < \beta < 2.E-3$	0		LISS	84	CNTR
<1.E-16		1	$3.E-4 < \beta < 1.E-3$	0	18	PRICE	84	MICA
<1.E-13		1	$1.E-4 < \beta$	0		PRICE	84B	PLAS
<4.E-13		1	$6.E-4 < \beta < 2.E-3$	0		TARLE	84	CNTR
<4.E-13		1	$1.E-2 < \beta < 1.E-3$	0	21	ANDERSON	83	EMUL
<1.E-12		1	$7.E-3 < \beta < 1$	0		BARTELT	83B	CNTR
<3.E-13		1	$1.E-3 < \beta < 4.E-1$	0		BARWICK	83	PLAS
<3.E-12		Caty	$5.E-4 < \beta < 5.E-2$	0		BONARELLI	83	CNTR
<4.E-11		1		0	15	BOSETTI	83	CNTR
<5.E-15		1	$1.E-2 < \beta < 1$	0		CABRERA	83	INDU
<8.E-15		Caty	$1.E-4 < \beta < 1.E-1$	0		DOKE	83	PLAS
<5.E-12		1	$1.E-4 < \beta < 3.E-2$	0	15	ERREDE	83	IMB
<2.E-12		1	$6.E-4 < \beta < 1$	0		GROOM	83	CNTR
<1.E-13		1	$\beta=3.E-3$	0		MASHIMO	83	CNTR
<2.E-12		1	$7.E-3 < \beta < 6.E-1$	0		ALEXEYEV	82	CNTR
6.E-10		1	all β	1	22	BONARELLI	82	CNTR
<2.E-11		1	$1.E-2 < \beta < 1.E-1$	0		CABRERA	82	INDU
<2.E-15		1	concentrator	0		MASHIMO	82	CNTR
<1.E-13	>1	1	$1.E-3 < \beta$	0		BARTLETT	81	PLAS
<5.E-11	<E17	1	$3.E-4 < \beta < 1.E-3$	0		KINOSHITA	81B	PLAS
<2.E-11		1	concentrator	0		ULLMAN	81	CNTR
1.E-1	>200	2		1	23	BARTLETT	78	PLAS
<2.E-13		>2		0		PRICE	75	PLAS
<1.E-19		>2	obsidian, mica	0		FLEISCHER	71	PLAS
<5.E-15	<15	<3	concentrator	0		FLEISCHER	69C	PLAS
<2.E-11		<1-3	concentrator	0		CARITHERS	66	ELEC
				0		MALKUS	51	EMUL

- ALBERT 17 limits were estimated using a Cherenkov light in an array of optical modules under the Mediterranean Sea. The limits are for MM masses between 10^{10} and 10^{14} GeV. The limits are speed-dependent.
- AAB 16 search was made with a set of telescopes sampling the longitudinal profile of fluorescence light emitted by extensive air showers. Limits are speed dependent.
- AARTSEN 16B was based on a Cherenkov signature in an array of optical modules which were sunk in the Antarctic ice cap. Limits are speed-dependent.
- Beyond the monopole speed, the limits of AARTSEN 14 depend on the catalysis cross section (σ) which corresponds to the monopole radiating \bar{l} times the light per track length compared to the Cherenkov light from a single electrically charged, relativistic particle. The values quoted here correspond to $\sigma = 1$ barn or $\bar{l} = 30$.
- ABBASI 13 and ABBASI 10A were based on a Cherenkov signature in an array of optical modules which were sunk in the Antarctic ice cap. Limits are speed-dependent.
- ADRIAN-MARTINEZ 12A measurements were based on a Cherenkov signature in an underwater telescope in the Western Mediterranean Sea. Limits are speed-dependent.
- The limits from UENO 12 depend on the monopole speed and are also sensitive to assumed values of monopole mass and the catalysis cross section.
- HOGAN 08 and DETRIXHE 11 limits on relativistic monopoles are based on nonobservation of radio Cherenkov signals at the South Pole. Limits are speed-dependent.
- BALESTRA 08 exposed of nuclear track detector modules totaling 400 m^2 for 4 years at the Chacaltaya Laboratory (5230 m) in search for intermediate-mass monopoles with $\beta > 0.05$. The analysis is mainly based on three CR39 modules. For $M > 5 \times 10^{13}$ GeV there can be upward-going monopoles as well, hence the flux limit is half that obtained for less massive monopoles. Previous experiments (e.g. MACRO and OHYA (ORITO 91)) had set limits only for $M > 1 \times 10^9$ GeV.
- AMBROSIO 02B direct search final result for $m \geq 10^{17}$ GeV, based upon 4.2 to 9.5 years of running, depending upon the subsystem. Limit with CR39 track-etch detector extends the limit from $\beta=4 \times 10^{-5}$ ($3.1 \times 10^{-16} \text{ cm}^{-2} \text{ sr}^{-1} \text{ s}^{-1}$) to $\beta=1 \times 10^{-4}$ ($2.1 \times 10^{-16} \text{ cm}^{-2} \text{ sr}^{-1} \text{ s}^{-1}$). Limit curve in paper is piecewise continuous due to different detection techniques for different β ranges.

- AMBROSIO 02C limit for catalysis of nucleon decay with catalysis cross section of ≈ 1 mb. The flux limit increases by ~ 3 at the higher β limit, and increases to $1 \times 10^{-14} \text{ cm}^{-2} \text{ sr}^{-1} \text{ s}^{-1}$ if the catalysis cross section is 0.01 mb. Based upon 71193 hr of data with the streamer detector, with an acceptance of $4250 \text{ m}^2 \text{ sr}$.
- AMBROSIO 02D result for "more than two years of data." Ionization search using several subsystems. Limit curve as a function of β not given. Included in AMBROSIO 02B.
- AMBROSIO 97 global MACRO 90%CL is 0.78×10^{-15} at $\beta=1.1 \times 10^{-4}$, goes through a minimum at 0.61×10^{-15} near $\beta=(1.1-2.7) \times 10^{-3}$, then rises to 0.84×10^{-15} at $\beta=0.1$. The global limit in this region is below the Parker bound at 10^{-15} . Less stringent limits are established for $4 \times 10^{-5} < \beta < 1 \times 10^{-4}$. Limits set by various triggers and different subdetectors are given in the paper. All limits assume a catalysis cross section smaller than a few mb.
- AHLEN 94 limit for dyons extends down to $\beta=0.9E-4$ and a limit of $1.3E-14$ extends to $\beta=0.8E-4$. Also see comment by PRICE 94 and reply of BARISH 94. One loophole in the AHLEN 94 result is that in the case of monopoles catalyzing nucleon decay, relativistic particles could veto the events. See AMBROSIO 97 for additional results.
- Catalysis of nucleon decay; sensitive to assumed catalysis cross section.
- ORITO 91 limits are functions of velocity. Lowest limits are given here.
- Used DKMPR mechanism and Penning effect.
- Assumes monopole attaches fermion nucleus.
- Limit from combining data of CAPLIN 86, BERMON 85, INCANDELA 84, and CABRERA 83. For a discussion of controversy about CAPLIN 86 observed event, see GUY 87. Also see SCHOUTEN 87.
- Based on lack of high-energy solar neutrinos from catalysis in the sun.
- Anomalous long-range α (^4He) tracks.
- CABRERA 82 candidate event has single Dirac charge within $\pm 5\%$.
- ALVAREZ 75, FLEISCHER 75, and FRIEDLANDER 75 explain as fragmenting nucleus. EBERHARD 75 and ROSS 76 discuss conflict with other experiments. HAGSTROM 77 reinterprets as antineutrino. PRICE 78 reassesses.

Monopole Flux — Astrophysics

FLUX ($\text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1}$)	MASS (GeV)	CHG (g)	COMMENTS ($\beta = v/c$)	DOCUMENT ID	TECN
<1.3E-20			faint white dwarf	1	FREESE 99 ASTR
<1.E-16	E17	1	galactic field	2	ADAMS 93 COSM
<1.E-23			Jovian planets	1	ARAFUNE 85 ASTR
<1.E-16	E15		solar trapping	BRACCI 85B	ASTR
<1.E-18		1		1	HARVEY 84 COSM
<3.E-23			neutron stars	KOLB 84	ASTR
<7.E-22			pulsars	1	FREESE 83B ASTR
<1.E-18	<E18	1	intergalactic field	1	REPHAELI 83 COSM
<1.E-23			neutron stars	1	DIMOPOULOS 82 COSM
<5.E-22			neutron stars	1	KOLB 82 COSM
<5.E-15	>E21		galactic halo	1	SALPETER 82 COSM
<1.E-12	E19	1	$\beta=3.E-3$	3	TURNER 82 COSM
<1.E-16		1	galactic field	PARKER 70	COSM

- Catalysis of nucleon decay.
- ADAMS 93 limit based on "survival and growth of a small galactic seed field" is $10^{-16} \text{ (m/10}^{17} \text{ GeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1})$. Above 10^{17} GeV, limit $10^{-16} \text{ (10}^{17} \text{ GeV/m cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1})$ (from requirement that monopole density does not overclose the universe) is more stringent.
- Re-evaluates PARKER 70 limit for GUT monopoles.

Monopole Density — Matter Searches

DENSITY	CHG (g)	MATERIAL	DOCUMENT ID	TECN
<9.8E-5/gram	≥ 1	Polar rock	BENDTZ 13	INDU
<6.9E-6/gram	>1/3	Meteorites and other	JEON 95	INDU
<2.E-7/gram	>0.6	Fe ore	1	EBISU 87 INDU
<4.6E-6/gram	>0.5	deep schist	KOVALIK 86	INDU
<1.6E-6/gram	>0.5	manganese nodules	2	KOVALIK 86 INDU
<1.3E-6/gram	>0.5	seawater	KOVALIK 86	INDU
>1.E+14/gram	>1/3	iron aerosols	MIKHAILOV 83	SPEC
>6.E-4/gram		air, seawater	CARRIGAN 76	CNTR
<5.E-1/gram	>0.04	11 materials	CABRERA 75	INDU
<2.E-4/gram	>0.05	moon rock	ROSS 73	INDU
<6.E-7/gram	<140	seawater	KOLM 71	CNTR
<1.E-2/gram	<120	manganese nodules	FLEISCHER 69	PLAS
<1.E-4/gram	>0	manganese	FLEISCHER 69B	PLAS
<2.E-3/gram	<1-3	magnetite, meteor	GOTO 63	EMUL
<2.E-2/gram		meteorite	PETUKHOV 63	CNTR

- Mass $1 \times 10^{14} - 1 \times 10^{17}$ GeV.
- KOVALIK 86 examined 498 kg of schist from two sites which exhibited clear mineralogical evidence of having been buried at least 20 km deep and held below the Curie temperature.

Monopole Density — Astrophysics

DENSITY	CHG (g)	MATERIAL	DOCUMENT ID	TECN
<1.E-9/gram	1	sun, catalysis	1	ARAFUNE 83 COSM
<6.E-33/nucl	1	moon wake	SCHATTEN 83	ELEC
<2.E-28/nucl		earth heat	CARRIGAN 80	COSM
<2.E-4/prot		42cm absorption	BRODERICK 79	COSM
<2.E-13/m ³		moon wake	SCHATTEN 70	ELEC

- Catalysis of nucleon decay.

See key on page 999

Searches Particle Listings

Magnetic Monopole Searches, Supersymmetric Particle Searches

REFERENCES FOR Magnetic Monopole Searches

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ACHARYA 19B PRL 123 021802
ACHARYA 18A PL B782 510
ACHARYA 17 PRL 118 061801
ALBERT 17 JHEP 1707 054
GOULD 17 PRL 119 241601
AAB 16 PR D94 082002
AAD 16AB PR D93 052009
AARTSEN 16B EPJ C76 133
ACHARYA 16 JHEP 1608 067
AARTSEN 14 EPJ C74 2938
Also EPJ C79 124 (errat.)
ABBASI 13 PR D87 022001
BENDTZ 13 PRL 110 121803
AAD 12CS PRL 109 261803
ADRIAN-MAR... 12A ASP 35 634
UENO 12 ASP 36 131
DETRIXHE 11 PR D83 023513
ABBASI 10A EPJ C69 361
ABBENDI 08 PL B663 37
BALESTRA 08 EPJ C55 57
HOGAN 08 PR D78 075031
ABULENCIA 06K PRL 96 201801
AKTAS 05A EPJ C41 133
KALBFLEISCH 04 PR D69 052002
AMBRÓSIO 02B EPJ C25 511
AMBRÓSIO 02C EPJ C26 163
AMBRÓSIO 02D ASP 18 27
KALBFLEISCH 00 PRL 85 5292
FRESE 99 PR D59 063007
ABBOTT 98K PRL 81 524
AMBRÓSIO 97 PL B406 249
HE 97 PRL 79 3134
ACCIARRI 95C PL B345 609
JEON 95 PRL 75 1443
Also PRL 76 159 (erratum)
AHLEN 94 PRL 72 608
BARISH 94 PRL 73 1306
BECKER-SZ... 94 PR D49 2169
PRICE 94 PRL 73 1305
ADAMS 93 PRL 70 2511
PINFOLD 93 PL B316 407
KINOSHITA 92 PR D46 881
THRON 92 PR D46 4966
GARDNER 91 PR D44 622
HUBER 91 PR D44 636
ORITO 91 PRL 66 1951
BERMON 90 PRL 64 839
BERTANI 90 EPL 12 613
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BUCKLAND 90 PR D41 2726
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HUBER 90 PRL 64 835
PRICE 90 PRL 65 149
KINOSHITA 89 PL B228 543
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BARISH 87 PR D36 2641
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CROMAR 86 PRL 56 2561
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KOVALIK 86 PR A33 1183
PRICE 86 PRL 56 1226
ARAFUNE 85 PR D32 2586
BERMON 85 PRL 55 1850
BRACCI 85B NP B258 726
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CAPLIN 85 NAT 317 234
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PARK 85B NP B252 261
BATTISTONI 84 PL 133B 454
FRYBERGER 84 PR D29 1524
HARVEY 84 NP B236 255
INCANDELA 84 PRL 53 2067
KAJINO 84 PRL 52 1373
KAJINO 84B JP G10 447
KAWAGOE 84 LNC 41 315
KOLB 84 APJ 286 702
KRISHNA... 84 PL 142B 99
LSS 84 PR D30 884
PRICE 84 PR 52 1265
PRICE 84B PL 140B 112
TARLE 84 PRL 52 90
ANDERSON 83 PR D28 2308
ARAFUNE 83 PL 133B 380
AUBERT 83B PL 120B 465
BARTELT 83B PRL 50 655
BARWICK 83 PR D28 2338
BONARELLI 83 PL 126B 137
BOSETTI 83 PL 133B 265
CABRERA 83 PRL 51 1933
DOKE 83 PL 123B 370
ERREDE 83 PRL 51 245
FRESE 83B PRL 51 1625
GROOM 83 PRL 50 573
MASHIMO 83 PL 128B 327
MIKHAILOV 83 PL 130B 331
MUSSET 83 PL 128B 333
REPHAEIL 83 PL 121B 115
SCHATTEN 83 PR D27 1525
ALEXEYEV 82 LNC 35 413
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CARRIGAN 80 NAT 288 348
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HOFFMANN 78 LNC 23 357
PRICE 78 PR D18 1382
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OTHER RELATED PAPERS

GROOM 86 PRPL 140 323
Review D.E. Groom (UTAH)

Supersymmetric Particle Searches

The exclusion of particle masses within a mass range (m_1, m_2) will be denoted with the notation “none $m_1 - m_2$ ” in the VALUE column of the following Listings. The latest unpublished results are described in the “Supersymmetry: Experiment” review.

See the related review(s):

Supersymmetry, Part I (Theory)

Supersymmetry, Part II (Experiment)

CONTENTS:

- $\tilde{\chi}_1^0$ (Lightest Neutralino) mass limit
 - Accelerator limits for stable $\tilde{\chi}_1^0$
 - Bounds on $\tilde{\chi}_1^0$ from dark matter searches
 - $\tilde{\chi}_1^0 - p$ elastic cross section
 - Spin-dependent interactions
 - Spin-independent interactions
 - Other bounds on $\tilde{\chi}_1^0$ from astrophysics and cosmology
- Unstable $\tilde{\chi}_1^0$ (Lightest Neutralino) mass limit
- $\tilde{\chi}_2^0, \tilde{\chi}_3^0, \tilde{\chi}_4^0$ (Neutralinos) mass limits
- $\tilde{\chi}_1^\pm, \tilde{\chi}_2^\pm$ (Charginos) mass limits
- Long-lived $\tilde{\chi}^\pm$ (Chargino) mass limit
- $\tilde{\nu}$ (Sneutrino) mass limit
- Charged sleptons
 - R-parity conserving \tilde{e} (Selectron) mass limit
 - R-parity violating \tilde{e} (Selectron) mass limit
 - R-parity conserving $\tilde{\mu}$ (Smuon) mass limit
 - R-parity violating $\tilde{\mu}$ (Smuon) mass limit
 - R-parity conserving $\tilde{\tau}$ (Stau) mass limit
 - R-parity violating $\tilde{\tau}$ (Stau) mass limit
 - Long-lived $\tilde{\ell}$ (Slepton) mass limit
- \tilde{q} (Squark) mass limit
 - R-parity conserving \tilde{q} (Squark) mass limit
 - R-parity violating \tilde{q} (Squark) mass limit

Searches Particle Listings

Supersymmetric Particle Searches

Long-lived \tilde{q} (Squark) mass limit
 \tilde{b} (Sbottom) mass limit
 – R-parity conserving \tilde{b} (Sbottom) mass limit
 – R-parity violating \tilde{b} (Sbottom) mass limit
 \tilde{t} (Stop) mass limit
 – R-parity conserving \tilde{t} (Stop) mass limit
 – R-parity violating \tilde{t} (Stop) mass limit
 Heavy \tilde{g} (Gluino) mass limit
 – R-parity conserving heavy \tilde{g} (Gluino) mass limit
 – R-parity violating heavy \tilde{g} (Gluino) mass limit
 Long-lived \tilde{g} (Gluino) mass limit
 Light \tilde{G} (Gravitino) mass limits from collider experiments
 Supersymmetry miscellaneous results

Most of the results shown below, unless stated otherwise, are based on the Minimal Supersymmetric Standard Model (MSSM), as described in the Note on Supersymmetry. Unless otherwise indicated, this includes the assumption of common gaugino and scalar masses at the scale of Grand Unification (GUT), and use of the resulting relations in the spectrum and decay branching ratios. Unless otherwise indicated, it is also assumed that R -parity (R) is conserved and that:

- 1) The $\tilde{\chi}_1^0$ is the highest supersymmetric particle (LSP)
- 2) $m_{\tilde{f}_L} = m_{\tilde{f}_R}$, where $\tilde{f}_{L,R}$ refer to the scalar partners of left- and right-handed fermions.

Limits involving different assumptions are identified in the Comments or in the Footnotes. We summarize here the notations used in this Chapter to characterize some of the most common deviations from the MSSM (for further details, see the Note on Supersymmetry).

Theories with R -parity violation (\tilde{R}) are characterized by a superpotential of the form: $\lambda_{ijk} L_i L_j e_k^c + \lambda'_{ijk} L_i Q_j d_k^c + \lambda''_{ijk} u_i^c d_j^c d_k^c$, where i, j, k are generation indices. The presence of any of these couplings is often identified in the following by the symbols $LL\tilde{E}$, $LQ\tilde{D}$, and $U\tilde{D}\tilde{D}$. Mass limits in the presence of \tilde{R} will often refer to “direct” and “indirect” decays. Direct refers to \tilde{R} decays of the particle in consideration. Indirect refers to cases where \tilde{R} appears in the decays of the LSP. The LSP need not be the $\tilde{\chi}_1^0$.

In several models, most notably in theories with so-called Gauge Mediated Supersymmetry Breaking (GMSB), the gravitino (\tilde{G}) is the LSP. It is usually much lighter than any other massive particle in the spectrum, and $m_{\tilde{G}}$ is then neglected in all decay processes involving gravitinos. In these scenarios, particles other than the neutralino are sometimes considered as the next-to-highest supersymmetric particle (NLSP), and are assumed to decay to their even- R partner plus \tilde{G} . If the lifetime is short enough for the decay to take place within the detector, \tilde{G} is assumed to be undetected and to give rise to missing energy (\cancel{E}) or missing transverse energy (\cancel{E}_T) signatures.

When needed, specific assumptions on the eigenstate content of $\tilde{\chi}^0$ and $\tilde{\chi}^\pm$ states are indicated, using the notation $\tilde{\gamma}$ (photino), \tilde{H} (higgsino), \tilde{W} (wino), and \tilde{Z} (zino) to signal that the limit of pure states was used. The terms gaugino is also used, to generically indicate wino-like charginos and zino-like neutralinos.

In the listings we have made use of the following abbreviations for simplified models employed by the experimental collaborations in supersymmetry searches published in the past year.

WARNING: Experimental lower mass limits determined within simplified models are to be treated with extreme care as they might not be directly applicable to realistic models. This is outlined in detail in the publications and we recommend consulting them before using bounds. For example, branching ratios, typically fixed to specific values in simplified models, can vary substantially in more elaborate models.

Simplified Models Table

- Tglu1A:** gluino pair production with $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$.
Tglu1B: gluino pair production with $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$.
Tglu1C: gluino pair production with a 2/3 probability of having a $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$ decay and a 1/3 probability of having a $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \rightarrow Z^\pm\tilde{\chi}_1^0$ decay.
Tglu1D: gluino pair production with one gluino decaying to $q\bar{q}\tilde{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm \rightarrow W^\pm + \tilde{G}$, and the other gluino decaying to $q\bar{q}\tilde{\chi}_1^0$ with $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$.
Tglu1E: gluino pair production with $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_2^0$ and $\tilde{\chi}_2^0 \rightarrow Z^\pm\tilde{\chi}_1^0$ where $m_{\tilde{\chi}_1^\pm} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2$, $m_{\tilde{\chi}_2^0} = (m_{\tilde{\chi}_1^\pm} + m_{\tilde{\chi}_1^0})/2$.
Tglu1F: gluino pair production with $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^\pm$ or $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_2^0$ with equal branching ratios, where $\tilde{\chi}_1^\pm$ decays through an intermediate scalar tau lepton or sneutrino to $\tau\nu\tilde{\chi}_1^0$ and where $\tilde{\chi}_2^0$ decays through an intermediate scalar tau lepton or sneutrino to $\tau^+\tau^-\tilde{\chi}_1^0$ or $\nu\bar{\nu}\tilde{\chi}_1^0$; the mass hierarchy is such that $m_{\tilde{\chi}_1^\pm} \sim m_{\tilde{\chi}_2^0} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2$ and $m_{\tilde{\tau},\tilde{\nu}} = (m_{\tilde{\chi}_1^\pm} + m_{\tilde{\chi}_1^0})/2$.
Tglu1G: gluino pair production with $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_2^0$, and $\tilde{\chi}_2^0$ decaying through an intermediate slepton or sneutrino to $l^+l^-\tilde{\chi}_1^0$ or $\nu\bar{\nu}\tilde{\chi}_1^0$ where $m_{\tilde{\chi}_2^0} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2$ and $m_{\tilde{l},\tilde{\nu}} = (m_{\tilde{\chi}_2^0} + m_{\tilde{\chi}_1^0})/2$.
Tglu1H: gluino pair production with $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_2^0$, and $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 Z^{0(*)}$.
Tglu1I: gluino pair production with $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_2^0$, and $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 H$.
Tglu1J: gluino pair production with $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_2^0$, and $\text{BR}(\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 Z^{0(*)}) = \text{BR}(\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 H) = 0.5$.
Tglu1LL gluino pair production where $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$ happens with 1/3 probability and $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^\pm$ happens with 2/3 probability. The $\tilde{\chi}_1^\pm$ is assumed to be few hundreds of MeV heavier than the $\tilde{\chi}_1^0$, and decays to $\tilde{\chi}_1^0$ via a pion.
Tglu2A: gluino pair production with $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$.
Tglu3A: gluino pair production with $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$.
Tglu3B: gluino pair production with $\tilde{g} \rightarrow t\bar{t}$ where \tilde{t} decays exclusively to $t\tilde{\chi}_1^0$.
Tglu3C: gluino pair production with $\tilde{g} \rightarrow t\bar{t}$ where \tilde{t} decays exclusively to $c\tilde{\chi}_1^0$.
Tglu3D: gluino pair production with $\tilde{g} \rightarrow t\bar{b}\tilde{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$.
Tglu3E: gluino pair production where the gluino decays 25% of the time through $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$, 25% of the time through $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$ and 50% of the time through $\tilde{g} \rightarrow t\bar{b}\tilde{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$.
Tglu4A: gluino pair production with one gluino decaying to $q\bar{q}\tilde{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm \rightarrow W^\pm + \tilde{G}$, and the other gluino decaying to $q\bar{q}\tilde{\chi}_1^0$ with $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$.
Tglu4B: gluino pair production with gluinos decaying to $q\bar{q}\tilde{\chi}_1^0$ and $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$.
Tglu4C: gluino pair production with gluinos decaying to $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$ and $\tilde{\chi}_1^0 \rightarrow Z + \tilde{G}$.
Tglu4D: gluino pair production with $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$ where the $\tilde{\chi}_1^0$ decays with equal probability to $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$ or to $\tilde{\chi}_1^0 \rightarrow H + \tilde{G}$.
Tglu4E: gluino pair production with $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$ where the $\tilde{\chi}_1^0$ decays with equal probability to $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$ or to $\tilde{\chi}_1^0 \rightarrow Z + \tilde{G}$.
Tglu4F: gluino pair production with $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ where the $\tilde{\chi}_1^0$ decays with equal probability to $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$ or to $\tilde{\chi}_1^0 \rightarrow Z + \tilde{G}$.

Tsqk1: squark pair production with $\tilde{q} \rightarrow q\tilde{\chi}_1^0$.

Tsqk1LL squark pair production where $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ and $\tilde{q} \rightarrow q'\tilde{\chi}_1^\pm$ each happen with 50% probability. The $\tilde{\chi}_1^\pm$ is assumed to be few hundreds of MeV heavier than the $\tilde{\chi}_1^0$, and decays to $\tilde{\chi}_1^0$ via a pion.

Tsqk2: squark pair production with $\tilde{q} \rightarrow q\tilde{\chi}_2^0$ and $\tilde{\chi}_2^0 \rightarrow Z + \tilde{\chi}_1^0$.

Tsqk3: squark pair production with $\tilde{q} \rightarrow q'\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$ (like Tglu1B but for squarks)

- Tsqk4:** squark pair production with squarks decaying to $q\tilde{\chi}_1^0$ and $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$.
- Tsqk4A:** squark pair production with one squark decaying to $q\tilde{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm \rightarrow W^\pm + \tilde{G}$, and the other squark decaying to $q\tilde{\chi}_1^0$ with $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$.
- Tsqk4B:** squark pair production with squarks decaying to $q\tilde{\chi}_1^0$ and $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$.
- Tstop1:** stop pair production with $\tilde{t} \rightarrow t\tilde{\chi}_1^0$.
- Tstop1LL:** stop pair production where $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ and $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$ each happen with 50% probability. The $\tilde{\chi}_1^\pm$ is assumed to be few hundreds of MeV heavier than the $\tilde{\chi}_1^0$, and decays to $\tilde{\chi}_1^0$ via a pion.
- Tstop2:** stop pair production with $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$.
- Tstop3:** stop pair production with the subsequent four-body decay $\tilde{t} \rightarrow bff'\tilde{\chi}_1^0$ where f represents a lepton or a quark.
- Tstop4:** stop pair production with $\tilde{t} \rightarrow c\tilde{\chi}_1^0$.
- Tstop5:** stop pair production with $\tilde{t} \rightarrow b\tilde{\nu}\tilde{\tau}$ with $\tilde{\tau} \rightarrow \tau\tilde{G}$.
- Tstop6:** stop pair production with $\tilde{t} \rightarrow t + \tilde{\chi}_2^0$, where $\tilde{\chi}_2^0 \rightarrow Z + \tilde{\chi}_1^0$ or $H + \tilde{\chi}_1^0$ each with Br=50%.
- Tstop7:** stop pair production with $\tilde{t}_2 \rightarrow \tilde{t}_1 + H/Z$, where $\tilde{t}_1 \rightarrow t + \tilde{\chi}_1^0$.
- Tstop8:** stop pair production with equal probability of the stop decaying via $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ or via $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$.
- Tstop9:** stop pair production with equal probability of the stop decaying via $\tilde{t} \rightarrow c\tilde{\chi}_1^0$ or via the four-body decay $\tilde{t} \rightarrow bff'\tilde{\chi}_1^0$ where f represents a lepton or a quark.
- Tstop10:** stop pair production with $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0 \rightarrow (f\bar{f}') + \tilde{\chi}_1^0$ with a virtual W -boson.
- Tstop11:** stop pair production with $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm$ decaying through an intermediate slepton to $l\nu\tilde{\chi}_1^0$.
- Tstop12:** stop pair production with $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ and $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$.
- Tstop13:** stop pair production with $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ where the $\tilde{\chi}_1^0$ can decay with equal probability to $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$ or to $\tilde{\chi}_1^0 \rightarrow Z + \tilde{G}$.
- Tstop1RPV:** stop pair production with $\tilde{t} \rightarrow b\tilde{s}$ via RPV coupling λ_{323} .
- Tstop2RPV:** stop pair production with $\tilde{t} \rightarrow b\tilde{t}$, via RPV coupling λ_{333} .
- Tsbot1:** sbottom pair production with $\tilde{b} \rightarrow b\tilde{\chi}_1^0$.
- Tsbot2:** sbottom pair production with $\tilde{b} \rightarrow t\chi_1^-, \chi_1^- \rightarrow W^-\tilde{\chi}_1^0$.
- Tsbot3:** sbottom pair production with $\tilde{b} \rightarrow b\tilde{\chi}_2^0$, where one of the $\tilde{\chi}_2^0 \rightarrow Z^{(*)}\tilde{\chi}_1^0 \rightarrow f\bar{f}\tilde{\chi}_1^0$ and the other $\tilde{\chi}_2^0 \rightarrow \tilde{\ell}\ell^+ \rightarrow \ell^+\ell^-\tilde{\chi}_1^0$.
- Tsbot4:** sbottom pair production with $\tilde{b} \rightarrow b\tilde{\chi}_2^0$, with $\tilde{\chi}_2^0 \rightarrow H\tilde{\chi}_1^0$.
- Tchi1chi1A:** electroweak pair and associated production of nearly mass-degenerate charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_1^0$, where $\tilde{\chi}_1^\pm$ decays to $\tilde{\chi}_1^0$ plus soft radiation, and where one of the $\tilde{\chi}_1^0$ decays to $\gamma + \tilde{G}$ while the other one decays to $Z/H + \tilde{G}$ (with equal probability).
- Tchi1chi1B:** electroweak pair production of charginos $\tilde{\chi}_1^\pm$, where $\tilde{\chi}_1^\pm$ decays through an intermediate slepton or sneutrino to $l\nu\tilde{\chi}_1^0$ and where the slepton or sneutrino mass is 5%, 25%, 50%, 75% and 95% of the $\tilde{\chi}_1^\pm$ mass.
- Tchi1chi1C:** electroweak pair production of charginos $\tilde{\chi}_1^\pm$, where $\tilde{\chi}_1^\pm$ decays through an intermediate slepton or sneutrino to $l\nu\tilde{\chi}_1^0$ and where $m_{\tilde{\ell},\tilde{\nu}} = (m_{\tilde{\chi}_1^\pm} + m_{\tilde{\chi}_1^0})/2$.
- Tchi1chi1D:** electroweak associated pair production of charginos $\tilde{\chi}_1^\pm$, where $\tilde{\chi}_1^\pm$ decays through an intermediate scalar tau lepton or sneutrino to $\tau\nu\tilde{\chi}_1^0$ and where $m_{\tilde{\tau},\tilde{\nu}} = (m_{\tilde{\chi}_1^\pm} + m_{\tilde{\chi}_1^0})/2$.
- Tchi1chi1F:** electroweak pair and associated production of nearly mass-degenerate charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_1^0$ (i.e. $\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^\pm\tilde{\chi}_1^0$ production) where the $\tilde{\chi}_1^\pm$ decays exclusively to $\tilde{\chi}_1^0$ plus soft radiation and the $\tilde{\chi}_1^0$ decays to $\gamma/Z + \tilde{G}$.
- Tchi1chi1G:** electroweak pair production of charginos $\tilde{\chi}_1^\pm$, which are nearly mass-degenerate with neutralinos $\tilde{\chi}_1^0$. The $\tilde{\chi}_1^\pm$ decays either to $W^\pm + \tilde{G}$, or to $\tilde{\chi}_1^0$ plus soft radiation. The $\tilde{\chi}_1^0$ decays exclusively to $\gamma + \tilde{G}$.
- Tchi1n1A:** electroweak associated production of mass-degenerate charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_1^0$, where $\tilde{\chi}_1^\pm$ decays exclusively to $W^\pm + \tilde{G}$ and $\tilde{\chi}_1^0$ decays exclusively to $\gamma + \tilde{G}$.
- Tchi1n2A:** electroweak associated production of mass-degenerate charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_2^0$, where $\tilde{\chi}_1^\pm$ decays through an intermediate slepton or sneutrino to $l\nu\tilde{\chi}_1^0$ and where $\tilde{\chi}_2^0$ decays through an intermediate slepton or sneutrino to $l^+l^-\tilde{\chi}_1^0$ or $\nu\bar{\nu}\tilde{\chi}_1^0$.
- Tchi1n2B:** electroweak associated production of mass-degenerate charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_2^0$, where $\tilde{\chi}_1^\pm$ decays through an intermediate slepton or sneutrino to $l\nu\tilde{\chi}_1^0$ and where $\tilde{\chi}_2^0$ decays through an intermediate slepton or sneutrino to $l^+l^-\tilde{\chi}_1^0$ or $\nu\bar{\nu}\tilde{\chi}_1^0$ and where the slepton or sneutrino mass is 5%, 25%, 50%, 75% and 95% of the $\tilde{\chi}_1^\pm$ mass.
- Tchi1n2C:** electroweak associated production of mass-degenerate charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_2^0$, where $\tilde{\chi}_1^\pm$ decays through an intermediate slepton or sneutrino to $l\nu\tilde{\chi}_1^0$ and where $\tilde{\chi}_2^0$ decays through an intermediate slepton or sneutrino to $l^+l^-\tilde{\chi}_1^0$ or $\nu\bar{\nu}\tilde{\chi}_1^0$ and where $m_{\tilde{\ell},\tilde{\nu}} = (m_{\tilde{\chi}_1^\pm} + m_{\tilde{\chi}_1^0})/2$.
- Tchi1n2D:** electroweak associated production of mass-degenerate charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_2^0$, where $\tilde{\chi}_1^\pm$ decays through an intermediate scalar tau lepton or sneutrino to $\tau\nu\tilde{\chi}_1^0$ and where $\tilde{\chi}_2^0$ decays through an intermediate scalar tau lepton or sneutrino to $\tau^+\tau^-\tilde{\chi}_1^0$ or $\nu\bar{\nu}\tilde{\chi}_1^0$ and where $m_{\tilde{\tau},\tilde{\nu}} = (m_{\tilde{\chi}_1^\pm} + m_{\tilde{\chi}_1^0})/2$.
- Tchi1n2E:** electroweak associated production of mass-degenerate charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_2^0$, where $\tilde{\chi}_1^\pm \rightarrow W^\pm + \tilde{\chi}_1^0$ and $\tilde{\chi}_2^0 \rightarrow H + \tilde{\chi}_1^0$.
- Tchi1n2F:** electroweak associated production of mass-degenerate wino-like charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_2^0$, where $\tilde{\chi}_1^\pm$ decays through an intermediate W^{**} to $l\nu\tilde{\chi}_1^0$ and where $\tilde{\chi}_2^0$ decays through an intermediate Z^* to $l^+l^-\tilde{\chi}_1^0$ or $\nu\bar{\nu}\tilde{\chi}_1^0$.
- Tchi1n2G:** electroweak associated production of Higgsino-like charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_2^0$, and electroweak associated production of $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^0$, where $m_{\tilde{\chi}_1^\pm} = (m_{\tilde{\chi}_2^0} + m_{\tilde{\chi}_1^0})/2$ and where $\tilde{\chi}_1^\pm$ decays through an intermediate W^{**} to $l\nu\tilde{\chi}_1^0$ and where $\tilde{\chi}_2^0$ decays through an intermediate Z^* to $l^+l^-\tilde{\chi}_1^0$.
- Tchi1n2H:** electroweak associated production of mass-degenerate charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_2^0$, where $\tilde{\chi}_1^\pm$ decays through an intermediate slepton or sneutrino to $l\nu\tilde{\chi}_1^0$ and where $\tilde{\chi}_2^0$ decays through an intermediate scalar tau lepton or sneutrino to $\tau^+\tau^-\tilde{\chi}_1^0$ or $\nu\bar{\nu}\tilde{\chi}_1^0$.
- Tchi1n2I:** electroweak associated production of mass-degenerate charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_2^0$, where $\tilde{\chi}_1^\pm$ decays to $W^\pm + \tilde{\chi}_1^0$ and where $\tilde{\chi}_2^0$ decays 50% of the time to $Z + \tilde{\chi}_1^0$ and 50% of the time to $H + \tilde{\chi}_1^0$.
- Tchi1n12-GGM:** in the framework of General Gauge Mediation (GGM): electroweak pair and associated production of nearly mass-degenerate charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_1^0, \tilde{\chi}_2^0$ (i.e. $\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm\tilde{\chi}_1^0$ and $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production) where the $\tilde{\chi}_1^\pm$ decays exclusively to $W^\pm + \tilde{G}$, the $\tilde{\chi}_2^0$ decays to $Z/H + \tilde{G}$ and the $\tilde{\chi}_1^0$ decays to $\gamma/Z + \tilde{G}$. The branching ratios depend on the composition of the gauge eigenstates of the neutralinos in the GGM scenario.
- Tn1n1A:** electroweak pair and associated production of nearly mass-degenerate Higgsino-like charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$, where $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ decay to $\tilde{\chi}_1^0$ plus soft radiation and where both of the $\tilde{\chi}_1^0$ decay to $H + \tilde{G}$.
- Tn1n1B:** electroweak pair and associated production of nearly mass-degenerate Higgsino-like charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$, where $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ decay to $\tilde{\chi}_1^0$ plus soft radiation and where the $\tilde{\chi}_1^0$ decays 50% of the time to $H + \tilde{G}$ and 50 % of the time to $Z + \tilde{G}$.
- Tn1n1C:** electroweak pair and associated production of nearly mass-degenerate Higgsino-like charginos $\tilde{\chi}_1^\pm$ and neutralinos $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$, where $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ decay to $\tilde{\chi}_1^0$ plus soft radiation and where both of the $\tilde{\chi}_1^0$ decay to $Z + \tilde{G}$.
- Tn2n3A:** electroweak associated production of mass-degenerate neutralinos $\tilde{\chi}_2^0$ and $\tilde{\chi}_3^0$, where $\tilde{\chi}_2^0$ and $\tilde{\chi}_3^0$ decay through intermediate sleptons to $l^+l^-\tilde{\chi}_1^0$ and where the slepton mass is 5%, 25%, 50%, 75% and 95% of the $\tilde{\chi}_2^0$ mass.
- Tn2n3B:** electroweak associated production of mass-degenerate neutralinos $\tilde{\chi}_2^0$ and $\tilde{\chi}_3^0$, where $\tilde{\chi}_2^0$ and $\tilde{\chi}_3^0$ decay through intermediate sleptons to $l^+l^-\tilde{\chi}_1^0$ and where $m_{\tilde{\ell}} = (m_{\tilde{\chi}_2^0} + m_{\tilde{\chi}_1^0})/2$.

Searches Particle Listings

Supersymmetric Particle Searches

$\tilde{\chi}_1^0$ (Lightest Neutralino) mass limit

$\tilde{\chi}_1^0$ is often assumed to be the lightest supersymmetric particle (LSP). See also the $\tilde{\chi}_2^0, \tilde{\chi}_3^0, \tilde{\chi}_4^0$ section below.

We have divided the $\tilde{\chi}_1^0$ listings below into five sections:

- 1) Accelerator limits for stable $\tilde{\chi}_1^0$,
- 2) Bounds on $\tilde{\chi}_1^0$ from dark matter searches,
- 3) $\tilde{\chi}_1^0 - p$ elastic cross section (spin-dependent, spin-independent interactions),
- 4) Other bounds on $\tilde{\chi}_1^0$ from astrophysics and cosmology, and
- 5) Unstable $\tilde{\chi}_1^0$ (Lightest Neutralino) mass limit.

Accelerator limits for stable $\tilde{\chi}_1^0$

Unless otherwise stated, results in this section assume spectra, production rates, decay modes, and branching ratios as evaluated in the MSSM, with gaugino and sfermion mass unification at the GUT scale. These papers generally study production of $\tilde{\chi}_i^0 \tilde{\chi}_j^0$ ($i \geq 1, j \geq 2$), $\tilde{\chi}_1^+ \tilde{\chi}_1^-$, and (in the case of hadronic collisions) $\tilde{\chi}_1^+ \tilde{\chi}_2^0$ pairs. The mass limits on $\tilde{\chi}_1^0$ are either direct, or follow indirectly from the constraints set by the non-observation of $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ states on the gaugino and higgsino MSSM parameters M_2 and μ . In some cases, information is used from the nonobservation of slepton decays.

Obsolete limits obtained from e^+e^- collisions up to $\sqrt{s}=184$ GeV have been removed from this compilation and can be found in the 2000 Edition (The European Physical Journal **C15** 1 (2000)) of this Review.
 $\Delta m = m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
		1 DREINER	09 THEO	
>40	95	2 ABBIENDI	04H OPAL	all $\tan\beta$, $\Delta m > 5$ GeV, $m_0 > 500$ GeV, $A_0 = 0$
>42.4	95	3 HEISTER	04 ALEP	all $\tan\beta$, all Δm , all m_0
>39.2	95	4 ABDALLAH	03M DLPH	all $\tan\beta$, $m_{\tilde{\nu}} > 500$ GeV
>46	95	5 ABDALLAH	03M DLPH	all $\tan\beta$, all Δm , all m_0
>32.5	95	6 ACCIARRI	00D L3	$\tan\beta > 0.7$, $\Delta m > 3$ GeV, all m_0
• • • We do not use the following data for averages, fits, limits, etc. • • •				
		7 AAD	14K ATLS	

- 1 DREINER 09 show that in the general MSSM with non-universal gaugino masses there exists no model-independent laboratory bound on the mass of the lightest neutralino. An essentially massless $\tilde{\chi}_1^0$ is allowed by the experimental and observational data, imposing some constraints on other MSSM parameters, including M_2 , μ and the slepton and squark masses.
- 2 ABBIENDI 04H search for charginos and neutralinos in events with acoplanar leptons+jets and multi-jet final states in the 192–209 GeV data, combined with the results on leptonic final states from ABBIENDI 04. The results hold for a scan over the parameter space covering the region $0 < M_2 < 5000$ GeV, $-1000 < \mu < 1000$ GeV and $\tan\beta$ from 1 to 40. This limit supersedes ABBIENDI 00H.
- 3 HEISTER 04 data collected up to 209 GeV. Updates earlier analysis of selectrons from HEISTER 02E, includes a new analysis of charginos and neutralinos decaying into stau and uses results on charginos with initial state radiation from HEISTER 02J. The limit is based on the direct search for charginos and neutralinos, the constraints from the slepton search and the Higgs mass limits from HEISTER 02 using a top mass of 175 GeV, interpreted in a framework with universal gaugino and sfermion masses. Assuming the mixing in the stau sector to be negligible, the limit improves to 43.1 GeV. Under the assumption of MSUGRA with unification of the Higgs and sfermion masses, the limit improves to 50 GeV, and reaches 53 GeV for $A_0 = 0$. These limits include and update the results of BARATE 01.
- 4 ABDALLAH 03M uses data from $\sqrt{s} = 192$ –208 GeV. A limit on the mass of $\tilde{\chi}_1^0$ is derived from direct searches for neutralinos combined with the chargino search. Neutralinos are searched in the production of $\tilde{\chi}_1^0 \tilde{\chi}_2^0, \tilde{\chi}_1^0 \tilde{\chi}_3^0$, as well as $\tilde{\chi}_2^0 \tilde{\chi}_3^0$ and $\tilde{\chi}_2^0 \tilde{\chi}_4^0$ giving rise to cascade decays, and $\tilde{\chi}_1^0 \tilde{\chi}_2^0$ and $\tilde{\chi}_1^0 \tilde{\chi}_3^0$, followed by the decay $\tilde{\chi}_2^0 \rightarrow \tilde{\tau} \tau$. The results hold for the parameter space defined by values of $M_2 < 1$ TeV, $|\mu| \leq 2$ TeV with the $\tilde{\chi}_1^0$ as LSP. The limit is obtained for $\tan\beta = 1$ and large m_0 , where $\tilde{\chi}_2^0 \tilde{\chi}_4^0$ and chargino pair production are important. If the constraint from Higgs searches is also imposed, the limit improves to 49.0 GeV in the m_h^{max} scenario with $m_t = 174.3$ GeV. These limits update the results of ABREU 00J.
- 5 ABDALLAH 03M uses data from $\sqrt{s} = 192$ –208 GeV. An indirect limit on the mass of $\tilde{\chi}_1^0$ is derived by constraining the MSSM parameter space by the results from direct searches for neutralinos (including cascade decays and $\tilde{\tau} \tau$ final states), for charginos (for all Δm_{\pm}) and for sleptons, stop and sbottom. The results hold for the full parameter space defined by values of $M_2 < 1$ TeV, $|\mu| \leq 2$ TeV with the $\tilde{\chi}_1^0$ as LSP. Constraints from the Higgs search in the m_h^{max} scenario assuming $m_t = 174.3$ GeV are included. The limit is obtained for $\tan\beta \geq 5$ when stau mixing leads to mass degeneracy between $\tilde{\tau}_1$ and $\tilde{\chi}_1^0$ and the limit is based on $\tilde{\chi}_2^0$ production followed by its decay to $\tilde{\tau}_1 \tau$. In the pathological scenario where m_0 and $|\mu|$ are large, so that the $\tilde{\chi}_2^0$ production cross section is negligible, and where there is mixing in the stau sector but not in stop nor sbottom, the limit is based on charginos with soft decay products and an ISR photon. The limit then degrades to 39 GeV. See Figs. 40–42 for the dependence of the limit on $\tan\beta$ and $m_{\tilde{\nu}}$. These limits update the results of ABREU 00W.
- 6 ACCIARRI 00D data collected at $\sqrt{s}=189$ GeV. The results hold over the full parameter space defined by $0.7 \leq \tan\beta \leq 60$, $0 \leq M_2 \leq 2$ TeV, $m_0 \leq 500$ GeV, $|\mu| \leq 2$ TeV. The minimum mass limit is reached for $\tan\beta=1$ and large m_0 . The results of slepton

searches from ACCIARRI 99W are used to help set constraints in the region of small m_0 . The limit improves to 48 GeV for $m_0 \gtrsim 200$ GeV and $\tan\beta \gtrsim 10$. See their Figs. 6–8 for the $\tan\beta$ and m_0 dependence of the limits. Updates ACCIARRI 98F.

7 AAD 14K sets limits on the χ -nucleon spin-dependent and spin-independent cross sections out to $m_\chi = 10$ TeV.

Bounds on $\tilde{\chi}_1^0$ from dark matter searches

These papers generally exclude regions in the $M_2 - \mu$ parameter plane assuming that $\tilde{\chi}_1^0$ is the dominant form of dark matter in the galactic halo. These limits are based on the lack of detection in laboratory experiments, telescopes, or by the absence of a signal in underground neutrino detectors. The latter signal is expected if $\tilde{\chi}_1^0$ accumulates in the Sun or the Earth and annihilates into high-energy ν 's.

VALUE	DOCUMENT ID	TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •		
	1 DI-MAURO	19 FLAT
	2 JOHNSON	19 FLAT
	3 LI	19D FLAT
	4 ABDALLAH	18 HESS
	5 AHNEN	18 MGIC
	6 ALBERT	18B HAWC
	7 ALBERT	18C HAWC
	8 AARTSEN	17 ICCB
	9 AARTSEN	17A ICCB
	10 AARTSEN	17C ICCB
	11 ALBERT	17A ANTR
	12 ARCHAMBAUD	17 VRTS
	13 AARTSEN	16D ICCB
	14 ABDALLAH	16A HESS
	15 ADRIAN-MAR	16 ANTR
	16 AHNEN	16 MGFL
	17 AVORIN	16 BAIK
	18 CIRELLI	16 THEO
	19 LEITE	16 THEO
	20 ABRAMOWSKI	15 HESS
	21 ACKERMANN	15 FLAT
	22 ACKERMANN	15A FLAT
	23 ACKERMANN	15B FLAT
	24 BUCKLEY	15 THEO
	25 CHOI	15 SKAM
	26 ALEKSIC	14 MGIC
	27 AVORIN	14 BAIK
	28 AARTSEN	13C ICCB
	29 ABRAMOWSKI	13 HESS
	30 BERGSTROM	13 COSM
	31 BOLIEV	13 BAKS
	32 JIN	13 ASTR
	33 KOPP	13 COSM
	34 ABBASI	12 ICCB
	35 ABRAMOWSKI	11 HESS
	36 ABDO	10 FLAT
	37 ACKERMANN	10 FLAT
	38 ACHTERBERG	06 AMND
	39 ACKERMANN	06 AMND
	40 DEBOER	06 RVUE
	41 DESAI	04 SKAM
	42 AMBROSIO	99 MCRO
	43 LOSECCO	95 RVUE
	44 MORI	93 KAMI
	45 BOTTINO	92 COSM
	46 BOTTINO	91 RVUE
	47 GELMINI	91 COSM
	48 KAMIONKOW	91 RVUE
	49 MORI	91B KAMI
	50 OLIVE	88 COSM

none 4–15 GeV

- 1 DI-MAURO 19 sets limits on the dark matter annihilation from gamma-ray searches in M31 and M33 galaxies using Fermi LAT data.
- 2 JOHNSON 19 sets limits on p-wave dark matter annihilations in the galactic center using Fermi data.
- 3 LI 19D sets limits on dark matter annihilation cross sections searching for line-like signals in the all-sky Fermi data.
- 4 ABDALLAH 18 places constraints on the dark matter annihilation cross section for annihilations into gamma-rays in the Galactic center for masses between 300 GeV to 70 TeV. This updates ABDALLAH 16.
- 5 AHNEN 18 uses observations of the dwarf satellite galaxy Ursa Major II to obtain upper limits on annihilation cross sections for dark matter in various channels for masses between 0.1–100 TeV.
- 6 ALBERT 18B sets limits on the annihilation cross section of dark matter with mass between 1 and 100 TeV from gamma-ray observations of the Andromeda galaxy.
- 7 ALBERT 18C sets limits on the spin-dependent coupling of dark matter to protons from dark matter annihilation in the Sun.
- 8 AARTSEN 17 is based on data collected during 327 days of detector livetime with IceCube. They looked for interactions of ν 's resulting from neutralino annihilations in the Earth over a background of atmospheric neutrinos and set 90% CL limits on the spin independent neutralino-proton cross section for neutralino masses in the range 10–10000 GeV.
- 9 AARTSEN 17A is based on data collected during 532 days of livetime with the IceCube 86-string detector including the DeepCore sub-array. They looked for interactions of ν 's

- from neutralino annihilations in the Sun over a background of atmospheric neutrinos and set 90% CL limits on the spin dependent neutralino-proton cross section for neutralino masses in the range 10–10000 GeV. This updates AARTSEN 16c.
- 10 AARTSEN 17c is based on 1005 days of running with the IceCube detector. They set a limit on the annihilation cross section for dark matter with masses between 10–1000 GeV annihilating in the Galactic center assuming an NFW profile. The limit is of $1.2 \times 10^{23} \text{ cm}^3 \text{ s}^{-1}$ in the $\tau^+ \tau^-$ channel. Supersedes AARTSEN 15e.
- 11 ALBERT 17a is based on data from the ANTARES neutrino telescope. They looked for interactions of ν 's from neutralino annihilations in the Milky Way galaxy over a background of atmospheric neutrinos and set 90% CL limits on the muon neutrino flux. They also obtain limits on the thermally averaged cross section for neutralino masses in the range 50 to 100,000 GeV. This updates ADRIAN-MARTINEZ 15.
- 12 ARCHAMBAULT 17 performs a joint statistical analysis of four dwarf galaxies with VERITAS looking for gamma-ray emission from neutralino annihilation. They set limits on the neutralino annihilation cross section.
- 13 AARTSEN 16d is based on 329 live days of running with the DeepCore subdetector of the IceCube detector. They set a limit of $10^{-23} \text{ cm}^3 \text{ s}^{-1}$ on the annihilation cross section to $\nu\bar{\nu}$. This updates AARTSEN 15c.
- 14 ABDALLAH 16a place upper limits on the annihilation cross section with final states in the energy range of 0.1 to 2 TeV. This complements ABRAMOWSKI 13.
- 15 ADRIAN-MARTINEZ 16 is based on data from the ANTARES neutrino telescope. They looked for interactions of ν 's from neutralino annihilations in the Sun over a background of atmospheric neutrinos and set 90% CL limits on the muon neutrino flux. They also obtain limits on the spin dependent and spin independent neutralino-proton cross section for neutralino masses in the range 50 to 5,000 GeV. This updates ADRIAN-MARTINEZ 13.
- 16 AHNEN 16 combines 158 hours of Segue 1 observations with MAGIC with 6 year observations of 15 dwarf satellite galaxies by Fermi-LAT to set limits on annihilation cross sections for dark matter masses between 10 GeV and 100 TeV.
- 17 AVORIN 16 is based on 2.76 years with Lake Baikal neutrino telescope. They derive 90% upper limits on the annihilation cross section from dark matter annihilations in the Galactic center.
- 18 CIRELLI 16 and LEITE 16 derive bounds on the annihilation cross section from radio observations.
- 19 ABRAMOWSKI 15 places constraints on the dark matter annihilation cross section for annihilations in the Galactic center for masses between 300 GeV to 10 TeV.
- 20 ACKERMANN 15 is based on 5.8 years of data with Fermi-LAT and search for monochromatic gamma-rays in the energy range of 0.2–500 GeV from dark matter annihilations. This updates ACKERMANN 13a.
- 21 ACKERMANN 15a is based on 50 months of data with Fermi-LAT and search for dark matter annihilation signals in the isotropic gamma-ray background as well as galactic subhalos in the energy range of a few GeV to a few tens of TeV.
- 22 ACKERMANN 15b is based on 6 years of data with Fermi-LAT observations of Milky Way dwarf spheroidal galaxies. Set limits on the annihilation cross section from $m_\chi = 2 \text{ GeV}$ to 10 TeV. This updates ACKERMANN 14.
- 23 BUCKLEY 15 is based on 5 years of Fermi-LAT data searching for dark matter annihilation signals from Large Magellanic Cloud.
- 24 CHOI 15 is based on 3903 days of SuperKamiokande data searching for neutrinos produced from dark matter annihilations in the sun. They place constraints on the dark matter-nucleon scattering cross section for dark matter masses between 4–200 GeV.
- 25 ALEKSIC 14 is based on almost 160 hours of observations of Segue 1 satellite dwarf galaxy using the MAGIC telescopes between 2011 and 2013. Sets limits on the annihilation cross section out to $m_\chi = 10 \text{ TeV}$.
- 26 AVORIN 14 is based on almost 2.76 years with Lake Baikal neutrino telescope. They derive 90% upper limits on the fluxes of muons and muon neutrinos from dark matter annihilations in the Sun.
- 27 AARTSEN 13c is based on data collected during 339.8 effective days with the IceCube 59-string detector. They looked for interactions of ν_μ 's from neutralino annihilations in nearby galaxies and galaxy clusters. They obtain limits on the neutralino annihilation cross section for neutralino masses in the range 30–100,000 GeV.
- 28 ABRAMOWSKI 13 place upper limits on the annihilation cross section with $\gamma\gamma$ final states in the energy range of 0.5–25 TeV.
- 29 BERGSTROM 13, JIN 13, and KOPP 13 derive limits on the mass and annihilation cross section using AMS-02 data. JIN 13 also sets a limit on the lifetime of the dark matter particle.
- 30 BOLIEV 13 is based on data collected during 24.12 years of live time with the Bakson Underground Scintillator Telescope. They looked for interactions of ν_μ 's from neutralino annihilations in the Sun over a background of atmospheric neutrinos and set 90% CL limits on the muon flux. They also obtain limits on the spin dependent and spin independent neutralino-proton cross section for neutralino masses in the range 10–1000 GeV.
- 31 ABBASI 12 is based on data collected during 812 effective days with AMANDA II and 149 days of the IceCube 40-string detector combined with the data of ABBASI 09b. They looked for interactions of ν_μ 's from neutralino annihilations in the Sun over a background of atmospheric neutrinos and set 90% CL limits on the muon flux. No excess is observed. They also obtain limits on the spin dependent neutralino-proton cross section for neutralino masses in the range 50–5000 GeV.
- 32 ABRAMOWSKI 11 place upper limits on the annihilation cross section with $\gamma\gamma$ final states.
- 33 ABDO 10 place upper limits on the annihilation cross section with $\gamma\gamma$ or $\mu^+ \mu^-$ final states.
- 34 ACKERMANN 10 place upper limits on the annihilation cross section with $b\bar{b}$ or $\mu^+ \mu^-$ final states.
- 35 ACHTERBERG 06 is based on data collected during 421.9 effective days with the AMANDA detector. They looked for interactions of ν_μ 's from the centre of the Earth over a background of atmospheric neutrinos and set 90% CL limits on the muon flux. Their limit is compared with the muon flux expected from neutralino annihilations into $W^+ W^-$ and $b\bar{b}$ at the centre of the Earth for MSSM parameters compatible with the relic dark matter density, see their Fig. 7.
- 36 ACKERMANN 06 is based on data collected during 143.7 days with the AMANDA-II detector. They looked for interactions of ν_μ 's from the Sun over a background of atmospheric neutrinos and set 90% CL limits on the muon flux. Their limit is compared with the muon flux expected from neutralino annihilations into $W^+ W^-$ in the Sun for SUSY model parameters compatible with the relic dark matter density, see their Fig. 3.
- 37 DEBOER 06 interpret an excess of diffuse Galactic gamma rays observed with the EGRET satellite as originating from π^0 decays from the annihilation of neutralinos into quark jets. They analyze the corresponding parameter space in a supergravity inspired MSSM model with radiative electroweak symmetry breaking, see their Fig. 3 for the preferred region in the $(m_0, m_{1/2})$ plane of a scenario with large $\tan\beta$.
- 38 AMBROSIO 99 and DESAI 04 set new neutrino flux limits which can be used to limit the parameter space in supersymmetric models based on neutralino annihilation in the Sun and the Earth.
- 39 LOSECCO 95 reanalyzed the IMB data and places lower limit on $m_{\tilde{\chi}_1^0}$ of 18 GeV if the LSP is a photino and 10 GeV if the LSP is a higgsino based on LSP annihilation in the sun producing high-energy neutrinos and the limits on neutrino fluxes from the IMB detector.
- 40 MORI 93 excludes some region in $M_2 - \mu$ parameter space depending on $\tan\beta$ and lightest scalar Higgs mass for neutralino dark matter $m_{\tilde{\chi}_1^0} > m_W$, using limits on upgoing muons produced by energetic neutrinos from neutralino annihilation in the Sun and the Earth.
- 41 BOTTINO 92 excludes some region $M_2 - \mu$ parameter space assuming that the lightest neutralino is the dark matter, using upgoing muons at Kamiokande, direct searches by Ge detectors, and by LEP experiments. The analysis includes top radiative corrections on Higgs parameters and employs two different hypotheses for nucleon-Higgs coupling. Effects of rescaling in the local neutralino density according to the neutralino relic abundance are taken into account.
- 42 BOTTINO 91 excluded a region in $M_2 - \mu$ plane using upgoing muon data from Kamioka experiment, assuming that the dark matter surrounding us is composed of neutralinos and that the Higgs boson is not too heavy.
- 43 GELMINI 91 exclude a region in $M_2 - \mu$ plane using dark matter searches.
- 44 KAMIONKOWSKI 91 excludes a region in the $M_2 - \mu$ plane using IMB limit on upgoing muons originated by energetic neutrinos from neutralino annihilation in the sun, assuming that the dark matter is composed of neutralinos and that $m_{H_1^0} \lesssim 50 \text{ GeV}$. See Fig. 8 in the paper.
- 45 MORI 91b exclude a part of the region in the $M_2 - \mu$ plane with $m_{\tilde{\chi}_1^0} \lesssim 80 \text{ GeV}$ using a limit on upgoing muons originated by energetic neutrinos from neutralino annihilation in the earth, assuming that the dark matter surrounding us is composed of neutralinos and that $m_{H_1^0} \lesssim 80 \text{ GeV}$.
- 46 OLIVE 88 result assumes that photinos make up the dark matter in the galactic halo. Limit is based on annihilations in the sun and is due to an absence of high energy neutrinos detected in underground experiments. The limit is model dependent.

$\tilde{\chi}_1^0 - p$ elastic cross section

Experimental results on the $\tilde{\chi}_1^0 - p$ elastic cross section are evaluated at $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$. The experimental results on the cross section are often mass dependent. Therefore, the mass and cross section results are also given where the limit is strongest, when appropriate. Results are quoted separately for spin-dependent interactions (based on an effective 4-Fermi Lagrangian of the form $\bar{\chi}\gamma^\mu\gamma^5\chi\bar{p}\gamma_\mu\gamma^5q$) and spin-independent interactions ($\bar{\chi}\chi\bar{p}p$). For calculational details see GRIEST 88b, ELLIS 88b, BARBIERI 89c, DREES 93b, ARNOWITT 96, BERGSTROM 96, and BAER 97 in addition to the theory papers listed in the Tables. For a description of the theoretical assumptions and experimental techniques underlying most of the listed papers, see the review on "Dark matter" in this "Review of Particle Physics," and references therein. Most of the following papers use galactic halo and nuclear interaction assumptions from (LEWIN 96).

Spin-dependent interactions

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 4 \times 10^{-5}$	90	1 AMOLE	19 PICO	C ₃ F ₈
$< 5 \times 10^{-4}$	90	2 APRILE	19A XE1T	Xe
$< 7 \times 10^{-4}$	90	3 XIA	19A PNDX	Xe
$< 8 \times 10^{-4}$	90	4 AKERIB	17A LUX	Xe
< 0.28	90	5 BATTAT	17 DRFT	CS ₂ ; CF ₄
< 0.027	90	6 BEHNKE	17 PICA	C ₄ F ₁₀
$< 5 \times 10^{-4}$	90	7 AMOLE	16 PICO	CF ₃ I
$< 6.8 \times 10^{-3}$	90	8 APRILE	16B X100	Xe
$< 6.3 \times 10^{-3}$	90	9 FELIZARDO	14 SMP1	C ₂ ClF ₅
< 0.01	90	10 AKIMOV	12 ZEP3	Xe
$< 7 \times 10^{-3}$	90	11 BEHNKE	12 COUP	CF ₃ I
$< 8.5 \times 10^{-3}$	90	12 FELIZARDO	12 SMP1	C ₂ ClF ₅
< 0.016	90	13 KIM	12 KIMS	Csl
5×10^{-10} to 10^{-5}	95	14 BUCHMUEL...	11B THEO	
< 1	90	15 ANGLE	08A XE10	Xe
< 0.055	90	16 BEDNYAKOV	08 HDMS	Ge
< 0.33	90	17 BEHNKE	08 COUP	CF ₃ I
< 5	90	18 AKERIB	06 CDMS	Ge
< 2	90	19 SHIMIZU	06A CNTR	CaF ₂
< 0.4	90	20 ALNER	05 NAIA	NaI Spin Dep.
< 2	90	21 BARNABE-HE.	05 PICA	C
2×10^{-11} to 1×10^{-4}	90	22 ELLIS	04 THEO	$\mu > 0$
< 0.8	90	23 AHMED	03 NAIA	NaI Spin Dep.
< 40	90	24 TAKEDA	03 BOLO	NaF Spin Dep.
< 10	90	25 ANGLOHER	02 CRES	Saphire
8×10^{-7} to 2×10^{-5}	90	26 ELLIS	01C THEO	$\tan\beta \leq 10$
< 3.8	90	27 BERNABE	00D DAMA	Xe
< 0.8	90	28 SPOONER	00 UKDM	NaI
< 4.8	90	29 BELL	99C DAMA	F
< 100	90	30 OOTANI	99 BOLO	LIF
< 0.6	90	31 BERNABE	98C DAMA	Xe
< 5	90	32 BERNABE	97 DAMA	F

Searches Particle Listings

Supersymmetric Particle Searches

1 The strongest limit is $< 2.5 \times 10^{-5}$ pb at $m_\chi = 25$ GeV. This updates AMOLE 17.

2 The strongest limit is $< 2 \times 10^{-4}$ pb at $m_\chi = 30$ GeV. For scatterings on neutrons, the strongest limit is $< 6.3 \times 10^{-6}$ at $m_\chi = 30$ GeV.

3 The strongest limit is $< 4.4 \times 10^{-4}$ pb at $m_\chi = 40$ GeV. This updates FU 17.

4 The strongest limit is 5×10^{-4} pb at $m_\chi = 35$ GeV. The limit for scattering on neutrons is 3×10^{-5} pb at 100 GeV and is 1.6×10^{-5} pb at 35 GeV. This updates AKERIB 16A.

5 Directional recoil detector. This updates DAW 12.

6 This result updates ARCHAMBAULT 12. The strongest limit is 0.013 pb at $m_\chi = 20$ GeV.

7 The strongest limit is 5×10^{-4} pb at $m_\chi = 80$ GeV.

8 The strongest limit is 5.2×10^{-3} pb at 50 GeV. The limit for scattering on neutrons is 2.8×10^{-4} pb at 100 GeV and the strongest limit is 2.0×10^{-4} pb at 50 GeV. This updates APRILE 13.

9 The strongest limit is 0.0043 pb and occurs at $m_\chi = 35$ GeV. FELIZARDO 14 also presents limits for the scattering on neutrons. At $m_\chi = 100$ GeV, the upper limit is 0.13 pb and the strongest limit is 0.066 pb at $m_\chi = 35$ GeV.

10 This result updates LEBEDENKO 09A. The strongest limit is 8×10^{-3} pb at $m_\chi = 50$ GeV. Limit applies to the neutralino neutron elastic cross section.

11 The strongest limit is 6×10^{-3} at $m_\chi = 60$ GeV.

12 The strongest limit is 5.7×10^{-3} at $m_\chi = 35$ GeV.

13 This result updates LEE 07A. The strongest limit is at $m_\chi = 80$ GeV.

14 Predictions for the spin-dependent elastic cross section based on a frequentist approach to electroweak observables in the framework of $N = 1$ supergravity models with radiative breaking of the electroweak gauge symmetry.

15 The strongest limit is 0.6 pb and occurs at $m_\chi = 30$ GeV. The limit for scattering on neutrons is 0.01 pb at $m_\chi = 100$ GeV, and the strongest limit is 0.0045 pb at $m_\chi = 30$ GeV.

16 Limit applies to neutron elastic cross section.

17 The strongest upper limit is 0.25 pb and occurs at $m_\chi \simeq 40$ GeV.

18 The strongest upper limit is 4 pb and occurs at $m_\chi \simeq 60$ GeV. The limit on the neutron spin-dependent elastic cross section is 0.07 pb. This latter limit is improved in AHMED 09, where a limit of 0.02 pb is obtained at $m_\chi = 100$ GeV. The strongest limit in AHMED 09 is 0.018 pb and occurs at $m_\chi = 60$ GeV.

19 The strongest upper limit is 1.2 pb and occurs at $m_\chi \simeq 40$ GeV. The limit on the neutron spin-dependent cross section is 35 pb.

20 The strongest upper limit is 0.35 pb and occurs at $m_\chi \simeq 60$ GeV.

21 The strongest upper limit is 1.2 pb and occurs $m_\chi \simeq 30$ GeV.

22 ELLIS 04 calculates the χp elastic scattering cross section in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry, but without universal scalar masses. In the case of universal squark and slepton masses, but non-universal Higgs masses, the limit becomes 2×10^{-4} , see ELLIS 03E.

23 The strongest upper limit is 0.75 pb and occurs at $m_\chi \approx 70$ GeV.

24 The strongest upper limit is 30 pb and occurs at $m_\chi \approx 20$ GeV.

25 The strongest upper limit is 8 pb and occurs at $m_\chi \approx 30$ GeV.

26 ELLIS 01c calculates the χp elastic scattering cross section in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry. In models with nonuniversal Higgs masses, the upper limit to the cross section is 6×10^{-4} .

27 The strongest upper limit is 3 pb and occurs at $m_\chi \simeq 60$ GeV. The limits are for inelastic scattering $\chi^0 + {}^{129}\text{Xe} \rightarrow \chi^0 + {}^{129}\text{Xe}^* (39.58 \text{ keV})$.

28 The strongest upper limit is 4.4 pb and occurs at $m_\chi \simeq 60$ GeV.

29 The strongest upper limit is about 35 pb and occurs at $m_\chi \simeq 15$ GeV.

Spin-independent interactions

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 2.5 \times 10^{-8}$	90	1 ABE	19 XMAS	Xe
$< 3.9 \times 10^{-9}$	90	2 AJAJ	19 DEAP	Ar
$< 2 \times 10^{-8}$	90	3 AMOLE	19 PICO	C ₃ F ₈
$< 2.25 \times 10^{-6}$	90	4 ADHIKARI	18 C100	Nal
$< 1.14 \times 10^{-8}$	90	5 AGNES	18A DS50	Ar
$< 1.6 \times 10^{-8}$	90	6 AGNESE	18A CDMS	Ge
$< 9 \times 10^{-11}$	90	7 APRILE	18 XE1T	Xe
$< 1.8 \times 10^{-10}$	90	8 AKERIB	17 LUX	Xe
$< 1.4 \times 10^{-10}$	90	9 CUI	17A PNDX	Xe
$< 1.5 \times 10^{-9}$	90	10 APRILE	16B X100	Xe
$< 1.5 \times 10^{-9}$	90	11 AKERIB	14 LUX	Xe
10^{-11} - 10^{-7}	95	12 BUCHMUEL...	14A THEO	
$< 4.6 \times 10^{-6}$	90	13 FELIZARDO	14 SMPL	C ₂ ClF ₅
10^{-11} - 10^{-8}	95	14 ROSZKOWSKI	14 THEO	
$< 2.2 \times 10^{-6}$	90	15 AGNESE	13 CDMS	Si
$< 5 \times 10^{-8}$	90	16 AKIMOV	12 ZEP3	Xe
1.6×10^{-6} ; 3.7×10^{-5}		17 ANGLOHER	12 CRES	CaWO ₄
3×10^{-12} to 3×10^{-9}	95	18 BECHTLE	12 THEO	
$< 1.6 \times 10^{-7}$		19 BEHNKE	12 COUP	CF ₃ I
$< 2.3 \times 10^{-7}$	90	20 KIM	12 KIMS	Csl
$< 3.3 \times 10^{-8}$	90	21 AHMED	11A	Ge
$< 4.4 \times 10^{-8}$	90	22 ARMENGAUD	11 EDE2	Ge
$< 1 \times 10^{-7}$	90	23 ANGLE	08 XE10	Xe
$< 1 \times 10^{-6}$	90	BENETTI	08 WARP	Ar
$< 7.5 \times 10^{-7}$	90	24 ALNER	07A ZEP2	Xe
$< 2 \times 10^{-7}$		25 AKERIB	06A CDMS	Ge
$< 90 \times 10^{-7}$		ALNER	05 NAlA	Nal Spin Indep.
$< 12 \times 10^{-7}$		26 ALNER	05A ZEPL	

$< 14 \times 10^{-7}$

$< 4 \times 10^{-7}$

2×10^{-11} to 1.5×10^{-7} 95

2×10^{-11} to 8×10^{-6}

$< 5 \times 10^{-8}$

$< 2 \times 10^{-5}$

$< 3 \times 10^{-6}$

2×10^{-13} to 2×10^{-7}

$< 1.4 \times 10^{-5}$

$< 6 \times 10^{-6}$

1×10^{-12} to 7×10^{-6}

$< 3 \times 10^{-5}$

$< 1 \times 10^{-5}$

$< 1 \times 10^{-6}$

$< 3 \times 10^{-5}$

$< 7 \times 10^{-6}$

$< 1 \times 10^{-8}$

5×10^{-10} to 1.5×10^{-8}

$< 4 \times 10^{-6}$

2×10^{-10} to 1×10^{-7}

$< 3 \times 10^{-6}$

$< 6 \times 10^{-7}$

2.5×10^{-9} to 3.5×10^{-8}

$< 1.5 \times 10^{-5}$

$< 4 \times 10^{-5}$

$< 7 \times 10^{-6}$

$< 7 \times 10^{-6}$

SANGLARD 05 EDEL Ge

27 AKERIB 04 CDMS Ge

28 BALTZ 04 THEO

29,30 ELLIS 04 THEO $\mu > 0$

31 PIERCE 04A THEO

32 AHMED 03 NAlA Nal Spin Indep.

33 AKERIB 03 CDMS Ge

34 BAER 03A THEO

35 KLAPDOR-K... 03 HDMS Ge

36 ABRAMS 02 CDMS Ge

29 KIM 02b THEO

37 MORALES 02b CSME Ge

38 MORALES 02c IGEX Ge

BALTZ 01 THEO

39 BAUDIS 01 HDMS Ge

40 BOTTINO 01 THEO

41 CORSETTI 01 THEO $\tan\beta \leq 25$

42 ELLIS 01c IGEX $\tan\beta \leq 10$

41 GOMEZ 01 THEO

41 LAHANAS 01 THEO

ABUSAIDI 00 CDMS Ge, Si

43 ACCOMANDO 00 THEO

44 BERNABEI 00 DAMA Nal

45 FENG 00 THEO $\tan\beta=10$

MORALES 00 IGEX Ge

SPOONER 00 UKDM Nal

BAUDIS 99 HDMO ⁷⁶Ge

BERNABEI 98c DAMA Xe

1 The strongest upper limit is 2.2×10^{-8} pb at 60 GeV.

2 This updates AMAUDRUZ 18.

3 This updates AMOLE 16.

4 The strongest limit is 2.05×10^{-6} at $m = 60$ GeV.

5 The strongest limit is 1.09×10^{-8} pb at $m_\chi = 126$ GeV. This updates AGNES 15.

6 The strongest limit is 1.0×10^{-8} pb at $m_\chi = 46$ GeV. This updates AGNESE 15B.

7 Based on 278.8 days of data collection. The strongest limit is 4.1×10^{-11} pb at $m_\chi = 30$ GeV. This updates APRILE 17G.

8 AKERIB 17. The strongest limit is 1.1×10^{-10} pb at 50 GeV. This updates AKERIB 16.

9 The strongest limit is 8.6×10^{-11} pb at 40 GeV. This updates TAN 16B.

10 The strongest limit is 1.1×10^{-9} pb at 50 GeV. This updates APRILE 12.

11 The strongest upper limit is 7.6×10^{-10} at $m_\chi = 33$ GeV.

12 Predictions for the spin-independent elastic cross section based on a frequentist approach to electroweak observables in the framework of $N = 1$ supergravity models with radiative breaking of the electroweak gauge symmetry using the 20 fb⁻¹ 8 TeV and the 5 fb⁻¹ 7 TeV LHC data and the LUX data.

13 The strongest limit is 3.6×10^{-6} pb and occurs at $m_\chi = 35$ GeV. Felizardo 2014 updates Felizardo 2012.

14 Predictions for the spin-independent elastic cross section based on a Bayesian approach to electroweak observables in the framework of $N = 1$ supergravity models with radiative breaking of the electroweak gauge symmetry using the 20 fb⁻¹ LHC data and LUX.

15 AGNESE 13 presents 90% CL limits on the elastic cross section for masses in the range 7-100 GeV using the Si based detector. The strongest upper limit is 1.8×10^{-6} pb at $m_\chi = 50$ GeV. This limit is improved to 7×10^{-7} pb in AGNESE 13A.

16 This result updates LEBEDENKO 09. The strongest limit is 3.9×10^{-8} pb at $m_\chi = 52$ GeV.

17 ANGLOHER 12 presents results of 730 kg days from the CRESST-II dark matter detector. They find two maxima in the likelihood function corresponding to best fit WIMP masses of 25.3 and 11.6 GeV with elastic cross sections of 1.6×10^{-6} and 3.7×10^{-5} pb respectively, see their Table 4. The statistical significance is more than 4σ . ANGLOHER 12 updates ANGLOHER 09

18 Predictions for the spin-independent elastic cross section based on a frequentist approach to electroweak observables in the framework of $N = 1$ supergravity models with radiative breaking of the electroweak gauge symmetry using the 5 fb⁻¹ LHC data and XENON100.

19 The strongest limit is 1.4×10^{-7} at $m_\chi = 60$ GeV.

20 This result updates LEE 07A. The strongest limit is 2.1×10^{-7} at $m_\chi = 70$ GeV.

21 AHMED 11A gives combined results from CDMS and EDELWEISS. The strongest limit is at $m_\chi = 90$ GeV.

22 ARMENGAUD 11 updates result of ARMENGAUD 10. Strongest limit at $m_\chi = 85$ GeV.

23 The strongest upper limit is 5.1×10^{-8} pb and occurs at $m_\chi \simeq 30$ GeV. The values quoted here are based on the analysis performed in ANGLE 08 with the update from SORENSSEN 09.

24 The strongest upper limit is 6.6×10^{-7} pb and occurs at $m_\chi \simeq 65$ GeV.

25 AKERIB 06A updates the results of AKERIB 05. The strongest upper limit is 1.6×10^{-7} pb and occurs at $m_\chi \approx 60$ GeV.

26 The strongest upper limit is also close to 1.0×10^{-6} pb and occurs at $m_\chi \simeq 70$ GeV. BENOIT 06 claim that the discrimination power of ZEPLIN-I measurement (ALNER 05A) is not reliable enough to obtain a limit better than 1×10^{-3} pb. However, SMITH 06 do not agree with the criticisms of BENOIT 06.

27 AKERIB 04 is incompatible with BERNABEI 00 most likely value, under the assumption of standard WIMP-halo interactions. The strongest upper limit is 4×10^{-7} pb and occurs at $m_\chi \simeq 60$ GeV.

28 Predictions for the spin-independent elastic cross section in the framework of $N = 1$ supergravity models with radiative breaking of the electroweak gauge symmetry.

29 KIM 02 and ELLIS 04 calculate the χp elastic scattering cross section in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry, but without universal scalar masses.

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³⁰ In the case of universal squark and slepton masses, but non-universal Higgs masses, the limit becomes 2×10^{-6} (2×10^{-11} when constraint from the BNL $g-2$ experiment are included), see ELLIS 03E. ELLIS 05 display the sensitivity of the elastic scattering cross section to the π -Nucleon Σ term.

³¹ PIERCE 04A calculates the χp elastic scattering cross section in the framework of models with very heavy scalar masses. See Fig. 2 of the paper.

³² The strongest upper limit is 1.8×10^{-5} pb and occurs at $m_\chi \approx 80$ GeV.

³³ Under the assumption of standard WIMP-halo interactions, Akerib 03 is incompatible with BERNABEI 00 most likely value at the 99.98% CL. See Fig. 4.

³⁴ BAER 03A calculates the χp elastic scattering cross section in several models including the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry.

³⁵ The strongest upper limit is 7×10^{-6} pb and occurs at $m_\chi \approx 30$ GeV.

³⁶ ABRAMS 02 is incompatible with the DAMA most likely value at the 99.9% CL. The strongest upper limit is 3×10^{-6} pb and occurs at $m_\chi \approx 30$ GeV.

³⁷ The strongest upper limit is 2×10^{-5} pb and occurs at $m_\chi \approx 40$ GeV.

³⁸ The strongest upper limit is 7×10^{-6} pb and occurs at $m_\chi \approx 46$ GeV.

³⁹ The strongest upper limit is 1.8×10^{-5} pb and occurs at $m_\chi \approx 32$ GeV.

⁴⁰ BOTTINO 01 calculates the χ - p elastic scattering cross section in the framework of the following supersymmetric models: $N=1$ supergravity with the radiative breaking of the electroweak gauge symmetry, $N=1$ supergravity with nonuniversal scalar masses and an effective MSSM model at the electroweak scale.

⁴¹ Calculates the χ - p elastic scattering cross section in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry.

⁴² ELLIS 01c calculates the χ - p elastic scattering cross section in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry. ELLIS 02B find a range 2×10^{-8} – 1.5×10^{-7} at $\tan\beta=50$. In models with nonuniversal Higgs masses, the upper limit to the cross section is 4×10^{-7} .

⁴³ ACCOMANDO 00 calculate the χ - p elastic scattering cross section in the framework of minimal $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry. The limit is relaxed by at least an order of magnitude when models with nonuniversal scalar masses are considered. A subset of the authors in ARNOWITT 02 updated the limit to $< 9 \times 10^{-8}$ ($\tan\beta < 55$).

⁴⁴ BERNABEI 00 search for annual modulation at 4σ and are consistent, for a particular model framework quoted there, with $m_{\chi_0=44} = 12/9$ GeV and a spin-independent X^0 -proton cross section of $(5.4 \pm 1.0) \times 10^{-6}$ pb. See also BERNABEI 01 and BERNABEI 00c.

⁴⁵ FENG 00 calculate the χ - p elastic scattering cross section in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry with a particular emphasis on focus point models. At $\tan\beta=50$, the range is 8×10^{-8} – 4×10^{-7} .

Other bounds on $\tilde{\chi}_1^0$ from astrophysics and cosmology

Most of these papers generally exclude regions in the M_2 – μ parameter plane by requiring that the $\tilde{\chi}_1^0$ contribution to the overall cosmological density is less than some maximal value to avoid overclosure of the Universe. Those not based on the cosmological density are indicated. Many of these papers also include LEP and/or other bounds.

VALUE	DOCUMENT ID	TECN	COMMENT
>46 GeV	1 ELLIS 00	RVUE	
• • • We do not use the following data for averages, fits, limits, etc. • • •			
	2 BUCHMUEL... 14	COSM	
	3 BUCHMUEL... 14A	COSM	
	4 ROSZKOWSKI 14	COSM	
	5 CABRERA 13	COSM	
	6 ELLIS 13B	COSM	
	5 STREGE 13	COSM	
	2 AKULA 12	COSM	
	2 ARBEY 12A	COSM	
	2 BAER 12	COSM	
	7 BALAZS 12	COSM	
	8 BECHTLE 12	COSM	
	9 BESKIDT 12	COSM	
> 18 GeV	10 BOTTINO 12	COSM	
	2 BUCHMUEL... 12	COSM	
	2 CAO 12A	COSM	
	2 ELLIS 12B	COSM	
	11 FENG 12B	COSM	
	2 KADASTIK 12	COSM	
	7 STREGE 12	COSM	
	12 BUCHMUEL... 11	COSM	
	13 ROSZKOWSKI 11	COSM	
	14 ELLIS 10	COSM	
	15 BUCHMUEL... 09	COSM	
	16 DREINER 09	THEO	
	17 BUCHMUEL... 08	COSM	
	13 ELLIS 08	COSM	
	18 CALIBBI 07	COSM	
	19 ELLIS 07	COSM	
	20 ALLANACH 06	COSM	
	21 DE-AUSTRI 06	COSM	
	13 BAER 05	COSM	
	22 BALTZ 04	COSM	
> 6 GeV	10,23 BELANGER 04	THEO	
	22 ELLIS 04B	COSM	
	25 PIERCE 04A	COSM	
	26 BAER 03	COSM	

> 6 GeV	10 BOTTINO 03	COSM	
	26 CHATTOPAD...03	COSM	
	27 ELLIS 03	COSM	
	13 ELLIS 03B	COSM	
	26 ELLIS 03C	COSM	
	26 LAHANAS 03	COSM	
	28 LAHANAS 02	COSM	
	29 BARGER 01c	COSM	
	30 ELLIS 01B	COSM	
	27 BOEHM 00B	COSM	
	31 FENG 00	COSM	
< 600 GeV	32 ELLIS 98B	COSM	
	33 EDSJO 97	COSM	Co-annihilation
	34 BAER 96	COSM	
	13 BEREZINSKY 95	COSM	
	35 FALK 95	COSM	CP-violating phases
	36 DREES 93	COSM	Minimal supergravity
	37 FALK 93	COSM	Sfermion mixing
	36 KELLEY 93	COSM	Minimal supergravity
	38 MIZUTA 93	COSM	Co-annihilation
	39 LOPEZ 92	COSM	Minimal supergravity, $m_0=A=0$
	40 MCDONALD 92	COSM	
	41 GRIEST 91	COSM	
	42 NOJIRI 91	COSM	Minimal supergravity
	43 OLIVE 91	COSM	
	44 ROSZKOWSKI 91	COSM	
	45 GRIEST 90	COSM	
	43 OLIVE 89	COSM	
none 100 eV – 15 GeV	SREDNICKI 88	COSM	$\tilde{\gamma}$; $m_{\tilde{f}}=100$ GeV
none 100 eV–5 GeV	ELLIS 84	COSM	$\tilde{\gamma}$; for $m_{\tilde{f}}=100$ GeV
	GOLDBERG 83	COSM	$\tilde{\gamma}$
	46 KRAUSS 83	COSM	$\tilde{\gamma}$
	VYSOTSKII 83	COSM	$\tilde{\gamma}$

¹ ELLIS 00 updates ELLIS 98. Uses LEP e^+e^- data at $\sqrt{s}=202$ and 204 GeV to improve bound on neutralino mass to 51 GeV when scalar mass universality is assumed and 46 GeV when Higgs mass universality is relaxed. Limits on $\tan\beta$ improve to > 2.7 ($\mu > 0$), > 2.2 ($\mu < 0$) when scalar mass universality is assumed and > 1.9 (both signs of μ) when Higgs mass universality is relaxed.

² Implications of the LHC result on the Higgs mass and on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry.

³ BUCHMUELLER 14A places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry using indirect experimental searches using the 20 fb $^{-1}$ 8 TeV and the 5 fb $^{-1}$ 7 TeV LHC and the LUX data.

⁴ ROSZKOWSKI 14 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry using Bayesian statistics and indirect experimental searches using the 20 fb $^{-1}$ LHC and the LUX data.

⁵ CABRERA 13 and STREGE 13 place constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry with and without non-universal Higgs masses using the 5.8 fb $^{-1}$, $\sqrt{s}=7$ TeV ATLAS supersymmetry searches and XENON100 results.

⁶ ELLIS 13B places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry with and without Higgs mass universality. Models with universality below the GUT scale are also considered.

⁷ BALAZS 12 and STREGE 12 place constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry using the 1 fb $^{-1}$ LHC supersymmetry searches, the 5 fb $^{-1}$ Higgs mass constraints, both with $\sqrt{s}=7$ TeV, and XENON100 results.

⁸ BECHTLE 12 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry using indirect experimental searches, using the 5 fb $^{-1}$ LHC and XENON100 data.

⁹ BESKIDT 12 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry using indirect experimental searches, the 5 fb $^{-1}$ LHC and the XENON100 data.

¹⁰ BELANGER 04 and BOTTINO 12 (see also BOTTINO 03, BOTTINO 03A and BOTTINO 04) do not assume gaugino or scalar mass unification.

¹¹ FENG 12B places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry and large sfermion masses using the 1 fb $^{-1}$ LHC supersymmetry searches, the 5 fb $^{-1}$ LHC Higgs mass constraints both with $\sqrt{s}=7$ TeV, and XENON100 results.

¹² BUCHMUELLER 11 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry using indirect experimental searches and including supersymmetry breaking relations between A and B parameters.

¹³ Places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry but non-Universal Higgs masses.

¹⁴ ELLIS 10 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry with universality above the GUT scale.

¹⁵ BUCHMUELLER 09 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry using indirect experimental searches.

¹⁶ DREINER 09 show that in the general MSSM with non-universal gaugino masses there exists no model-independent laboratory bound on the mass of the lightest neutralino. An essentially massless $\tilde{\chi}_1^0$ is allowed by the experimental and observational data, imposing some constraints on other MSSM parameters, including M_2 , μ and the slepton and squark masses.

Searches Particle Listings

Supersymmetric Particle Searches

- ¹⁷ BUCHMUELLER 08 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry using indirect experimental searches.
- ¹⁸ CALIBBI 07 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry with universality above the GUT scale including the effects of right-handed neutrinos.
- ¹⁹ ELLIS 07 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry with universality below the GUT scale.
- ²⁰ ALLANACH 06 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry.
- ²¹ DE-AUSTRI 06 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry.
- ²² BALTZ 04 places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry.
- ²³ Limit assumes a pseudo scalar mass < 200 GeV. For larger pseudo scalar masses, $m_{\tilde{\chi}} > 18(29)$ GeV for $\tan\beta = 50(10)$. Bounds from WMAP, $(g-2)_\mu$, $b \rightarrow s\gamma$, LEP.
- ²⁴ ELLIS 04b places constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry including supersymmetry breaking relations between A and B parameters. See also ELLIS 03d.
- ²⁵ PIERCE 04a places constraints on the SUSY parameter space in the framework of models with very heavy scalar masses.
- ²⁶ BAER 03, CHATTOPADHYAY 03, ELLIS 03c and LAHANAS 03 place constraints on the SUSY parameter space in the framework of $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry based on WMAP results for the cold dark matter density.
- ²⁷ BOEHM 00b and ELLIS 03 place constraints on the SUSY parameter space in the framework of minimal $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry. Includes the effect of $\tilde{\chi}-\tilde{t}$ co-annihilations.
- ²⁸ LAHANAS 02 places constraints on the SUSY parameter space in the framework of minimal $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry. Focuses on the role of pseudo-scalar Higgs exchange.
- ²⁹ BARGER 01c use the cosmic relic density inferred from recent CMB measurements to constrain the parameter space in the framework of minimal $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry.
- ³⁰ ELLIS 01b places constraints on the SUSY parameter space in the framework of minimal $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry. Focuses on models with large $\tan\beta$.
- ³¹ FENG 00 explores cosmologically allowed regions of MSSM parameter space with multi-TeV masses.
- ³² ELLIS 98b assumes a universal scalar mass and radiative supersymmetry breaking with universal gaugino masses. The upper limit to the LSP mass is increased due to the inclusion of $\tilde{\chi}-\tilde{\tau}$ coannihilations.
- ³³ EDSJO 97 included all coannihilation processes between neutralinos and charginos for any neutralino mass and composition.
- ³⁴ Notes the location of the neutralino Z resonance and h resonance annihilation corridors in minimal supergravity models with radiative electroweak breaking.
- ³⁵ Mass of the bino ($=\text{LSP}$) is limited to $m_{\tilde{B}} \lesssim 350$ GeV for $m_t = 174$ GeV.
- ³⁶ DREES 93, KELLEY 93 compute the cosmic relic density of the LSP in the framework of minimal $N=1$ supergravity models with radiative breaking of the electroweak gauge symmetry.
- ³⁷ FALK 93 relax the upper limit to the LSP mass by considering stfermion mixing in the MSSM.
- ³⁸ MIZUTA 93 include coannihilations to compute the relic density of Higgsino dark matter.
- ³⁹ LOPEZ 92 calculate the relic LSP density in a minimal SUSY GUT model.
- ⁴⁰ MCDONALD 92 calculate the relic LSP density in the MSSM including exact tree-level annihilation cross sections for all two-body final states.
- ⁴¹ GRIEST 91 improve relic density calculations to account for coannihilations, pole effects, and threshold effects.
- ⁴² NOJIRI 91 uses minimal supergravity mass relations between squarks and sleptons to narrow cosmologically allowed parameter space.
- ⁴³ Mass of the bino ($=\text{LSP}$) is limited to $m_{\tilde{B}} \lesssim 350$ GeV for $m_t \leq 200$ GeV. Mass of the higgsino ($=\text{LSP}$) is limited to $m_{\tilde{H}} \lesssim 1$ TeV for $m_t \leq 200$ GeV.
- ⁴⁴ ROSZKOWSKI 91 calculates LSP relic density in mixed gaugino/higgsino region.
- ⁴⁵ Mass of the bino ($=\text{LSP}$) is limited to $m_{\tilde{B}} \lesssim 550$ GeV. Mass of the higgsino ($=\text{LSP}$) is limited to $m_{\tilde{H}} \lesssim 3.2$ TeV.
- ⁴⁶ KRAUSS 83 finds $m_{\tilde{\gamma}}$ not 30 eV to 2.5 GeV. KRAUSS 83 takes into account the gravitino decay. Find that limits depend strongly on reheated temperature. For example a new allowed region $m_{\tilde{\gamma}} = 4-20$ MeV exists if $m_{\text{gravitino}} < 40$ TeV. See figure 2.

Unstable $\tilde{\chi}_1^0$ (Lightest Neutralino) mass limit

Unless otherwise stated, results in this section assume spectra and production rates as evaluated in the MSSM. Unless otherwise stated, the goldstino or gravitino mass $m_{\tilde{G}}$ is assumed to be negligible relative to all other masses. In the following, \tilde{G} is assumed to be undetected and to give rise to a missing energy (\cancel{E}) signature.

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, et al. (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>525	95	1 SIRUNYAN	19Ca CMS	$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$, GMSB, SPS8, $\sigma_{\text{eff}}=1$ m
>290	95	2 SIRUNYAN	19ci CMS	$\geq 1 H (\rightarrow \gamma\gamma) + \text{jets} + \cancel{E}_T$, Tn1n1A, GMSB
>230	95	2 SIRUNYAN	19ci CMS	$\geq 1 H (\rightarrow \gamma\gamma) + \text{jets} + \cancel{E}_T$, Tn1n1B, GMSB
>930	95	3 SIRUNYAN	19K CMS	$\gamma + \text{lepton} + \cancel{E}_T$, Tchi1n1A
130–230, 290–880	95	4 AABOUD	18ck ATLS	$2H (\rightarrow b\bar{b}) + \cancel{E}_T$, Tn1n1A, GMSB
>295	95	5 AABOUD	18Z ATLS	$\geq 4\ell$, GMSB, Tn1n1C

>180	95	6 SIRUNYAN	18Ao CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tn1n1A
>260	95	6 SIRUNYAN	18Ao CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tn1n1B
>450	95	6 SIRUNYAN	18Ao CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tn1n1C
>750	95	7 SIRUNYAN	18AP CMS	Combination of searches, GMSB, Tn1n1A
>650	95	7 SIRUNYAN	18AP CMS	Combination of searches, GMSB, Tn1n1B
>690	95	7 SIRUNYAN	18AP CMS	Combination of searches, GMSB, Tn1n1C
>500	95	8 SIRUNYAN	18AR CMS	$\ell^\pm \ell^\pm + \text{jets} + \cancel{E}_T$, GMSB, Tn1n1B
>650	95	8 SIRUNYAN	18AR CMS	$\ell^\pm \ell^\pm + \text{jets} + \cancel{E}_T$, GMSB, Tn1n1C
none	95	9 SIRUNYAN	18o CMS	$2 H (\rightarrow b\bar{b}) + \cancel{E}_T$, Tn1n1A, GMSB
$\frac{230-770}{>205}$	95	10 SIRUNYAN	18x CMS	$\geq 1 H (\rightarrow \gamma\gamma) + \text{jets} + \cancel{E}_T$, Tn1n1A, GMSB
>130	95	10 SIRUNYAN	18x CMS	$\geq 1 H (\rightarrow \gamma\gamma) + \text{jets} + \cancel{E}_T$, Tn1n1B, GMSB
>380	95	11 KHACHATRYAN	14L CMS	$\tilde{\chi}_1^0 \rightarrow Z \tilde{G}$ simplified models, GMSB, RPV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
none	95	12 AABOUD	19c ATLS	$\tilde{\chi}_1^0 \rightarrow Z \tilde{G}$ from gluinos as in Tglu1A, GMSB, depending on μ
300–1000		13 AAIJ	17Z	displaced vertex with associated μ
		14 KHACHATRYAN	16bx CMS	$\geq 3\ell^\pm$, RPV, λ or λ' couplings, wino- or higgsino-like neutralinos
		15 AAD	14BH ATLS	$2\gamma + \cancel{E}_T$, GMSB, SPS8
		16 AAD	13AP ATLS	$2\gamma + \cancel{E}_T$, GMSB, SPS8
none	95	17 AAD	13Q ATLS	$\gamma + b + \cancel{E}_T$, higgsino-like neutralino, GMSB
220–380		18 AAD	13R ATLS	$\tilde{\chi}_1^0 \rightarrow \mu j j$, RPV, $\lambda'_{211} \neq 0$
		19 AALTONEN	13i CDF	$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$, \cancel{E}_T , GMSB
>220	95	20 CHATRCHYAN	13AH CMS	$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$, GMSB, SPS8, $\sigma_{\text{eff}} < 500$ mm
		21 AAD	12cp ATLS	$2\gamma + \cancel{E}_T$, GMSB
		22 AAD	12ct ATLS	$\geq 4\ell^\pm$, RPV
		23 AAD	12R ATLS	$\tilde{\chi}_1^0 \rightarrow \mu j j$, RPV, $\lambda'_{211} \neq 0$
		24 ABAZOV	12AD D0	$\tilde{\chi}_1^0 \rightarrow \gamma Z \tilde{G}$, GMSB
		25 CHATRCHYAN	12BK CMS	$2\gamma + \cancel{E}_T$, GMSB
		26 CHATRCHYAN	11B CMS	$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$, $\tilde{W}^\pm \rightarrow \ell^\pm \tilde{G}$, GMSB
>149	95	27 AALTONEN	10 CDF	$p\bar{p} \rightarrow \tilde{\chi}\tilde{\chi}, \tilde{\chi}=\tilde{\chi}_2^0, \tilde{\chi}_1^\pm, \tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$, GMSB
>175	95	28 ABAZOV	10P D0	$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$, GMSB
>125	95	29 ABAZOV	08F D0	$p\bar{p} \rightarrow \tilde{\chi}\tilde{\chi}, \tilde{\chi}=\tilde{\chi}_2^0, \tilde{\chi}_1^\pm, \tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$, GMSB
		30 ABULENCIA	07H CDF	RPV, $LL\bar{E}$
> 96.8	95	31 ABBIENDI	06B OPAL	$e^+e^- \rightarrow \tilde{B}\tilde{B}, (\tilde{B} \rightarrow \tilde{G}\gamma)$
		32 ABDALLAH	05B DLPH	$e^+e^- \rightarrow \tilde{G}\tilde{\chi}_1^0, (\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma)$
> 96	95	33 ABDALLAH	05B DLPH	$e^+e^- \rightarrow \tilde{B}\tilde{B}, (\tilde{B} \rightarrow \tilde{G}\gamma)$

¹ SIRUNYAN 19Ca searched in 77.4 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events containing delayed photons in both single and diphoton plus \cancel{E}_T final states. No excess is observed above the background expected from Standard Model processes. The results are used to set 95% C.L. exclusion limits in the context of GMSB, using the SPS8 benchmark model. For neutralino proper decay lengths of 0.1, 1, 10, and 100 m, masses up to about 320, 525, 360, and 215 GeV are excluded, respectively. See their Fig. 5. The searches involve the simplified models Tglu1D, Tglu4A,B,C, Tsq4A,4B,4E.

² SIRUNYAN 19ci searched in 77.5 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with one or more high-momentum Higgs bosons, decaying to pairs of photons, jets and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the sbottom mass in the Tsb04 simplified model, see Figure 3, and on the wino mass in the Tchi1n2E simplified model, see their Figure 4. Limits are also set on the higgsino mass in the Tn1n1A and Tn1n1B simplified models, see their Figure 5.

³ SIRUNYAN 19K searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with a photon, an electron or muon, and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. In the framework of GMSB, limits are set on the chargino and neutralino mass in the Tchi1n1A simplified model, see their Figure 6. Limits are also set on the gluino mass in the Tglu4A simplified model, and on the squark mass in the Tsq4A simplified model, see their Figure 7.

⁴ AABOUD 18ck searched for events with at least 3 b -jets and large missing transverse energy in two datasets of pp collisions at $\sqrt{s} = 13$ TeV of 36.1 fb^{-1} and 24.3 fb^{-1} depending on the trigger requirements. The analyses aimed to reconstruct two Higgs bosons decaying to pairs of b -quarks. No significant excess above the Standard Model expectations is observed. Limits are set on the Higgsino mass in the Tn1n1A simplified model, see their Figure 15(a). Constraints are also presented as a function of the BR of Higgsino decaying into an higgs boson and a gravitino, see their Figure 15(b).

⁵ AABOUD 18Z searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events containing four or more charged leptons (electrons, muons and up to two hadronically decaying taus). No significant deviation from the expected SM background is observed. Limits are set on the Higgsino mass in simplified models of general gauge mediated supersymmetry Tn1n1A/Tn1n1B/Tn1n1C, see their Figure 9. Limits are also set on the wino, slepton, sneutrino and gluino mass in a simplified model of NLSP pair production with R-parity violating decays of the LSP via λ_{12k} or λ_{j33} to charged leptons, see their Figures 7, 8.

⁶ SIRUNYAN 18Ao searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for direct electroweak production of charginos and neutralinos in events with either two or more leptons (electrons or muons) of the same electric charge, or with three or more leptons, which can include up to two hadronically decaying tau leptons. No significant excess above the Standard Model expectations is observed. Limits are set on the chargino/neutralino mass in the Tchi1n2A, Tchi1n2H, Tchi1n2D, Tchi1n2E and Tchi1n2F simplified models, see their Figures 14, 15, 16, 17 and 18. Limits are also set on the higgsino mass in the Tn1n1A, Tn1n1B and Tn1n1C simplified models, see their Figure 19.

- ⁷ SIRUNYAN 18AP searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos and neutralinos by combining a number of previous and new searches. No significant excess above the Standard Model expectations is observed. Limits are set on the chargino/neutralino mass in the Tchi1n2E, Tchi1n2F and Tchi1n2I simplified models, see their Figures 7, 8, 9 and 10. Limits are also set on the higgsino mass in the Tn1n1A, Tn1n1B and Tn1n1C simplified models, see their Figure 11, 12, 13 and 14.
- ⁸ SIRUNYAN 18AR searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing two opposite-charge, same-flavour leptons (electrons or muons), jets and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu4C simplified model, see their Figure 7. Limits are also set on the chargino/neutralino mass in the Tchi1n2F simplified models, see their Figure 8, and on the higgsino mass in the Tn1n1B and Tn1n1C simplified models, see their Figure 9. Finally, limits are set on the sbottom mass in the Tsb0t3 simplified model, see their Figure 10.
- ⁹ SIRUNYAN 18o searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two Higgs bosons, decaying to pairs of b -quarks, and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the Higgsino mass in the T1n1n1A simplified model, see their Figure 9.
- ¹⁰ SIRUNYAN 18x searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one or more high-momentum Higgs bosons, decaying to pairs of photons, jets and \cancel{E}_T . The razor variables (M_R and R^2) are used to categorise the events. No significant excess above the Standard Model expectations is observed. Limits are set on the sbottom mass in the Tsb0t4 simplified model and on the wino mass in the Tchi1n2E simplified model, see their Figure 5. Limits are also set on the higgsino mass in the Tn1n1A and Tn1n1B simplified models, see their Figure 6.
- ¹¹ KHACHATRYAN 14L searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for evidence of direct pair production of neutralinos with Higgs or Z -bosons in the decay chain, leading to HH , HZ and ZZ final states with missing transverse energy. The decays of 16–20. a Higgs boson to a b -quark pair, to a photon pair, and to final states with leptons are considered in conjunction with hadronic and leptonic decay modes of the Z and W bosons. No significant excesses over the expected SM backgrounds are observed. The results are interpreted in the context of GMSB simplified models where the decays $\tilde{\chi}_1^0 \rightarrow H\tilde{G}$ or $\tilde{\chi}_1^0 \rightarrow Z\tilde{G}$ take place either 100% or 50% of the time, see Figs. 16–20.
- ¹² AABOUD 19g searched in 32.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for evidence of neutralinos decaying into a Z -boson and a gravitino, in events characterized by the presence of dimuon vertices with displacements from the pp interaction point in the range of 1400 cm. Neutralinos are assumed to be produced in the decay chain of gluinos as in Tglu1A models. No significant excess is observed in the number of vertices relative to the predicted background. In GGM with a gluino mass of 1100 GeV, neutralino masses in the range 300–1000 GeV are excluded for certain values of $c\tau$, see their Figure 7.
- ¹³ AIJ 17Z searched in 1 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ and in 2 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing a displaced vertex with one associated high transverse momentum μ . No excess is observed above the background expected from Standard Model processes. The results are used to set 95% C.L. upper limits on the cross section times branching fractions of pair-produced neutralinos decaying non-promptly into a muon and two quarks. Long-lived particles in a mass range 23–198 GeV are considered, see their Fig. 5 and Fig. 6.
- ¹⁴ KHACHATRYAN 16BX searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing 3 or more leptons coming from the electroweak production of wino- or higgsino-like neutralinos, assuming non-zero R -parity-violating leptonic couplings λ_{122} , λ_{123} , and λ_{233} or semileptonic couplings λ'_{131} , λ'_{233} , λ'_{331} , and λ'_{333} . No excess over the expected background is observed and limits are derived on the neutralino mass, see Figs. 24 and 25.
- ¹⁵ AAD 14BH searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing non-pointing photons in a diphoton plus missing transverse energy final state. No excess is observed above the background expected from Standard Model processes. The results are used to set 95% C.L. exclusion limits in the context of gauge-mediated supersymmetric breaking models, with the lightest neutralino being the next-to-lightest supersymmetric particle and decaying with a lifetime in the range from 0.25 ns to about 100 ns into a photon and a gravitino. For limits on the NLSP lifetime versus Λ plane, for the SPS8 model, see their Fig. 7.
- ¹⁶ AAD 13AP searched in 4.8 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing non-pointing photons in a diphoton plus missing transverse energy final state. No excess is observed above the background expected from Standard Model processes. The results are used to set 95% C.L. exclusion limits in the context of gauge-mediated supersymmetric breaking models, with the lightest neutralino being the next-to-lightest supersymmetric particle and decaying with a lifetime in excess of 0.25 ns into a photon and a gravitino. For limits in the NLSP lifetime versus Λ plane, for the SPS8 model, see their Fig. 8.
- ¹⁷ AAD 13Q searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing a high- p_T isolated photon, at least one jet identified as originating from a bottom quark, and high missing transverse momentum. Such signatures may originate from supersymmetric models with gauge-mediated supersymmetry breaking in events in which one of a pair of higgsino-like neutralinos decays into a photon and a gravitino while the other decays into a Higgs boson and a gravitino. No significant excess above the expected background was found and limits were set on the neutralino mass in a generalized GMSB model (GGM) with a higgsino-like neutralino NLSP, see their Fig. 4. Intermediate neutralino masses between 220 and 380 GeV are excluded at 95% C.L. regardless of the squark and gluino masses, purely on the basis of the expected weak production.
- ¹⁸ AAD 13R looked in 4.4 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing new, heavy particles that decay at a significant distance from their production point into a final state containing a high-momentum muon and charged hadrons. No excess over the expected background is observed and limits are placed on the production cross-section of neutralinos via squarks for various $m_{\tilde{q}}, m_{\tilde{\chi}_1^0}$ in an R -parity violating scenario with $\lambda'_{211} \neq 0$, as a function of the neutralino lifetime, see their Fig. 6.
- ¹⁹ AALTONEN 13i searched in 6.3 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for events containing \cancel{E}_T and a delayed photon that arrives late in the detector relative to the time expected from prompt production. No evidence of delayed photon production is observed.
- ²⁰ CHATRCHYAN 13AH searched in 4.9 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing \cancel{E}_T and a delayed photon that arrives late in the detector relative to the time expected from prompt production. No significant excess above the expected background was found and limits were set on the pair production of $\tilde{\chi}_1^0$ depending on the neutralino proper decay length, see Fig. 8. Supersedes CHATRCHYAN 12BK.
- ²¹ AAD 12CP searched in 4.8 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with two photons and large \cancel{E}_T due to $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$ decays in a GMSB framework. No significant excess above the expected background was found and limits were set on the neutralino mass in a generalized GMSB model (GGM) with a bino-like neutralino NLSP, see Figs. 6 and 7. The other sparticle masses were decoupled, $\tan\beta = 2$ and $c\tau_{\text{NLSP}} < 0.1 \text{ mm}$. Also, in the framework of the SPS8 model, limits are presented in Fig. 8.
- ²² AAD 12CT searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing four or more leptons (electrons or muons) and either moderate values of missing transverse momentum or large effective mass. No significant excess is found in the data. Limits are presented in a simplified model of R -parity violating supersymmetry in which charginos are pair-produced and then decay into a W -boson and a $\tilde{\chi}_1^0$, which in turn decays through an RPV coupling into two charged leptons ($e^\pm e^\mp$ or $\mu^\pm \mu^\mp$) and a neutrino. In this model, limits are set on the neutralino mass as a function of the chargino mass, see Fig. 3a. Limits are also set in an R -parity violating mSUGRA model, see Fig. 3b.
- ²³ AAD 12R looked in 33 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing new, heavy particles that decay at a significant distance from their production point into a final state containing a high-momentum muon and charged hadrons. No excess over the expected background is observed and limits are placed on the production cross-section of neutralinos via squarks for various $(m_{\tilde{q}}, m_{\tilde{\chi}_1^0})$ in an R -parity violating scenario with $\lambda'_{211} \neq 0$, as a function of the neutralino lifetime, see their Fig. 8. Superseded by AAD 13R.
- ²⁴ ABZOV 12AD looked in 6.2 fb^{-1} of pp collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for events with a photon, a Z -boson, and large \cancel{E}_T in the final state. This topology corresponds to a GMSB model where pairs of neutralino NLSPs are either pair produced promptly or from decays of other supersymmetric particles and then decay to either $Z\tilde{G}$ or $\gamma\tilde{G}$. No significant excess over the SM expectation is observed and a limit at 95% C.L. on the cross section is derived as a function of the effective SUSY breaking scale Λ , see Fig. 3. Assuming $N_{\text{mes}} = 2$, $M_{\text{mes}} = 3 \text{ A}$, $\tan\beta = 3$, $\mu = 0.75 M_1$, and $C_{\text{grav}} = 1$, the model is excluded at 95% C.L. for values of $\Lambda < 87 \text{ TeV}$.
- ²⁵ CHATRCHYAN 12BK searched in 2.23 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with two photons and large \cancel{E}_T due to $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$ decays in a GMSB framework. No significant excess above the expected background was found and limits were set on the pair production of $\tilde{\chi}_1^0$ depending on the neutralino lifetime, see Fig. 6.
- ²⁶ CHATRCHYAN 11B looked in 35 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with an isolated lepton (e or μ), a photon and \cancel{E}_T which may arise in a generalized gauge mediated model from the decay of Wino-like NLSPs. No evidence for an excess over the expected background is observed. Limits are derived in the plane of squark/gluino mass versus Wino mass (see Fig. 4). Mass degeneracy of the produced squarks and gluinos is assumed.
- ²⁷ AALTONEN 10 searched in 2.6 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for diphoton events with large \cancel{E}_T . They may originate from the production of $\tilde{\chi}^\pm$ in pairs or associated to a $\tilde{\chi}_1^0$, decaying into $\tilde{\chi}_1^0$ which itself decays in GMSB to $\gamma\tilde{G}$. There is no excess of events beyond expectation. An upper limit on the cross section is calculated in the GMSB model as a function of the $\tilde{\chi}_1^0$ mass and lifetime, see their Fig. 2. A limit is derived on the $\tilde{\chi}_1^0$ mass of 149 GeV for $\tau_{\tilde{\chi}_1^0} \ll 1 \text{ ns}$, which improves the results of previous searches.
- ²⁸ ABZOV 10P looked in 6.3 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for events with at least two isolated γ s and large \cancel{E}_T . These could be the signature of $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^\pm$ production, decaying to $\tilde{\chi}_1^0$ and finally $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$ in a GMSB framework. No significant excess over the SM expectation is observed, and a limit at 95% C.L. on the cross section is derived for $N_{\text{mes}} = 1$, $\tan\beta = 15$ and $\mu > 0$, see their Fig. 2. This allows them to set a limit on the effective SUSY breaking scale $\Lambda > 124 \text{ TeV}$, from which the excluded $\tilde{\chi}_1^0$ mass range is obtained.
- ²⁹ ABZOV 08f looked in 1.1 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for diphoton events with large \cancel{E}_T . They may originate from the production of $\tilde{\chi}^\pm$ in pairs or associated to a $\tilde{\chi}_1^0$, decaying to a $\tilde{\chi}_1^0$ which itself decays promptly in GMSB to $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$. No significant excess was found compared to the background expectation. A limit is derived on the masses of SUSY particles in the GMSB framework for $M = 2\Lambda$, $N = 1$, $\tan\beta = 15$ and $\mu > 0$, see Figure 2. It also excludes $\Lambda < 91.5 \text{ TeV}$. Supersedes the results of ABZOV 05A. Superseded by ABZOV 10P.
- ³⁰ ABULENCIA 07H searched in 346 pb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for events with at least three leptons (e or μ) from the decay of $\tilde{\chi}_1^0$ via $LL\tilde{E}$ couplings. The results are consistent with the hypothesis of no signal. Upper limits on the cross-section are extracted and a limit is derived in the framework of mSUGRA on the masses of $\tilde{\chi}_1^0$ and $\tilde{\chi}_1^\pm$, see e.g. their Fig. 3 and Tab. II.
- ³¹ ABBIENDI 06b use 600 pb^{-1} of data from $\sqrt{s} = 189\text{--}209 \text{ GeV}$. They look for events with diphotons + \cancel{E} final states originating from prompt decays of pair-produced neutralinos in a GMSB scenario with $\tilde{\chi}_1^0$ NLSP. Limits on the cross-section are computed as a function of $m(\tilde{\chi}_1^0)$, see their Fig. 14. The limit on the $\tilde{\chi}_1^0$ mass is for a pure Bino state assuming a prompt decay, with lifetimes up to 10^{-9} s . Supersedes the results of ABBIENDI 04N.
- ³² ABDALLAH 05B use data from $\sqrt{s} = 180\text{--}209 \text{ GeV}$. They look for events with single photons + \cancel{E} final states. Limits are computed in the plane $(m(\tilde{G}), m(\tilde{\chi}_1^0))$, shown in their Fig. 9b for a pure Bino state in the GMSB framework and in Fig. 9c for a no-scale supergravity model. Supersedes the results of ABREU 00Z.
- ³³ ABDALLAH 05b use data from $\sqrt{s} = 130\text{--}209 \text{ GeV}$. They look for events with diphotons + \cancel{E} final states and single photons not pointing to the vertex, expected in GMSB when the $\tilde{\chi}_1^0$ is the NLSP. Limits are computed in the plane $(m(\tilde{G}), m(\tilde{\chi}_1^0))$, see their Fig. 10. The lower limit is derived on the $\tilde{\chi}_1^0$ mass for a pure Bino state assuming a prompt decay and $m_{\tilde{e}_R} = m_{\tilde{e}_L} = 2 m_{\tilde{\chi}_1^0}$. It improves to 100 GeV for $m_{\tilde{e}_R} = m_{\tilde{e}_L} = 1.1 m_{\tilde{\chi}_1^0}$, and the limit in the plane $(m(\tilde{\chi}_1^0), m(\tilde{e}_R))$ is shown in Fig. 10b. For long-lived neutralinos, cross-section limits are displayed in their Fig. 11. Supersedes the results of ABREU 00Z.

Searches Particle Listings

Supersymmetric Particle Searches

$\tilde{\chi}_2^0, \tilde{\chi}_3^0, \tilde{\chi}_4^0$ (Neutralinos) mass limits

Neutralinos are unknown mixtures of photinos, z-inos, and neutral higgsinos (the supersymmetric partners of photons and of Z and Higgs bosons). The limits here apply only to $\tilde{\chi}_2^0, \tilde{\chi}_3^0$, and $\tilde{\chi}_4^0$. $\tilde{\chi}_1^0$ is the lightest supersymmetric particle (LSP); see $\tilde{\chi}_1^0$ Mass Limits. It is not possible to quote rigorous mass limits because they are extremely model dependent; i.e. they depend on branching ratios of various $\tilde{\chi}^0$ decay modes, on the masses of decay products ($\tilde{e}, \tilde{\gamma}, \tilde{q}, \tilde{g}$), and on the \tilde{e} mass exchanged in $e^+e^- \rightarrow \tilde{\chi}_i^0 \tilde{\chi}_j^0$. Limits arise either from direct searches, or from the MSSM constraints set on the gaugino and higgsino mass parameters M_2 and μ through searches for lighter charginos and neutralinos. Often limits are given as contour plots in the $m_{\tilde{\chi}^0} - m_{\tilde{e}}$ plane vs other parameters. When specific assumptions are made, e.g., the neutralino is a pure photino ($\tilde{\gamma}$), pure z-ino (\tilde{Z}), or pure neutral higgsino (\tilde{H}^0), the neutralinos will be labelled as such.

Limits obtained from e^+e^- collisions at energies up to 136 GeV, as well as other limits from different techniques, are now superseded and have not been included in this compilation. They can be found in the 1998 Edition (The European Physical Journal **C3** 1 (1998)) of this Review. Some later papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, *et al.* (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
> 680	95	1 AABOUD	19AU ATL	0, 1, 2 or more $\ell, H \rightarrow \gamma\gamma, b\bar{b}, WW^*, ZZ^*, \tau\tau$ (various searches), Tchi1n2E, $m_{\tilde{\chi}_1^0}=0$
> 112	95	2 SIRUNYAN	19BU CMS	GeV $pp \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_2^0 + 2 \text{ jets}, \tilde{\chi}_2^0 \rightarrow \ell^+ \ell^- \tilde{\chi}_1^0$, heavy sleptons, $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 1 \text{ GeV}, m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^0}$
> 215	95	2 SIRUNYAN	19BU CMS	GeV $pp \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_2^0 + 2 \text{ jets}, \tilde{\chi}_2^0 \rightarrow \ell^+ \ell^- \tilde{\chi}_1^0$, heavy sleptons, $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 30 \text{ GeV}, m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^0}$
> 760	95	3 AABOUD	18AY ATLS	$2\tau + \cancel{E}_T$, Tchi1n2D and $\tilde{\tau}_L$ -only, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1125	95	4 AABOUD	18BT ATLS	$2,3\ell + \cancel{E}_T$, Tchi1n2C, $m_{\tilde{\chi}_1^0}=0 \text{ GeV}$
> 580	95	5 AABOUD	18BT ATLS	$2,3\ell + \cancel{E}_T$, Tchi1n2F, $m_{\tilde{\chi}_1^0}=0 \text{ GeV}$
none	95	6 AABOUD	18CK ATLS	$2H \rightarrow b\bar{b} + \cancel{E}_T$, Tn1n1A, GMSB
130–230, 290–880	95	7 AABOUD	18CO ATLS	$2,3\ell + \cancel{E}_T$, recursive jigsaw, Tchi1n2F, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
none	95	8 AABOUD	18R ATLS	2ℓ (soft) + \cancel{E}_T , Tchi1n2G, higgsino, $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$
> 145	95	8 AABOUD	18R ATLS	2ℓ (soft) + \cancel{E}_T , Tchi1n2F, wino, $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$
> 175	95	9 AABOUD	18R ATLS	2ℓ (soft) + \cancel{E}_T , Tchi1n2F, wino, $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$
>1060	95	10 AABOUD	18U ATLS	$2\gamma + \cancel{E}_T$, GGM, Tchi1chi1A, any NLSP mass
> 167	95	11 SIRUNYAN	18AJ CMS	2ℓ (soft) + \cancel{E}_T , Tchi1n2G, higgsino, $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 15 \text{ GeV}$
> 710	95	12 SIRUNYAN	18DP CMS	$2\tau + \cancel{E}_T$, Tchi1n2D, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
none	95	13 SIRUNYAN	17AW CMS	$1\ell + 2 \text{ } b\text{-jets} + \cancel{E}_T$, Tchi1n2E, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 600	95	14 AAD	16AA ATLS	$3,4\ell + \cancel{E}_T$, Tn2n3A, $m_{\tilde{\chi}_1^0}=0\text{GeV}$
> 670	95	14 AAD	16AA ATLS	$3,4\ell + \cancel{E}_T$, Tn2n3B, $m_{\tilde{\chi}_1^0} < 200\text{GeV}$
> 250	95	15 AAD	15BA ATLS	$m_{\tilde{\chi}_1^+} = m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 380	95	16 AAD	14H ATLS	$\tilde{\chi}_1^+ \tilde{\chi}_2^0 \rightarrow \tau^\pm \nu \tilde{\chi}_1^0 \tau^\mp \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^+} = m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 700	95	16 AAD	14H ATLS	$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow \ell^\pm \nu \tilde{\chi}_1^0 \ell^\mp \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 345	95	16 AAD	14H ATLS	$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W_{\tilde{\chi}_1^0}^{\pm} Z \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0} = 0$
> 148	95	16 AAD	14H ATLS	GeV $\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W_{\tilde{\chi}_1^0}^{\pm} H \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0} = 0$
> 620	95	17 AAD	14X ATLS	GeV $\geq 4\ell^\pm, \tilde{\chi}_2^0 \rightarrow \ell^\pm \ell^\mp \tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 62.4	95	18 AAD	13 ATLS	$3\ell^\pm + \cancel{E}_T$, pMSSM, SMS
> 99.9	95	19 CHATARCHYAN12BJ	CMS	$\geq 2 \ell, \text{ jets} + \cancel{E}_T, pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0$
> 116.0	95	20 ABREU	00W DLPH	$\tilde{\chi}_2^0, 1 \leq \tan\beta \leq 40, \text{ all } \Delta m, \text{ all } m_0$
	95	20 ABREU	00W DLPH	$\tilde{\chi}_3^0, 1 \leq \tan\beta \leq 40, \text{ all } \Delta m, \text{ all } m_0$
	95	20 ABREU	00W DLPH	$\tilde{\chi}_4^0, 1 \leq \tan\beta \leq 40, \text{ all } \Delta m, \text{ all } m_0$

• • • We do not use the following data for averages, fits, limits, etc. • • •

none	95	21 AAD	14G ATLS	$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W_{\tilde{\chi}_1^0}^{\pm} Z \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0} = 0$
180–355		22 KHACHATRYAN14	CMS	GeV $\tilde{\chi}_2^0 \rightarrow (Z, H) \tilde{\chi}_1^0 \tilde{\ell} \ell$, simplified model
		23 AAD	12AS ATLS	$3\ell^\pm + \cancel{E}_T$, pMSSM
		24 AAD	12T ATLS	$\ell^\pm \ell^\pm + \cancel{E}_T, pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0$

1 AABOUD 19AU searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos and next-to-lightest neutralinos decaying into lightest neutralinos and a W and a Higgs boson, respectively. Fully hadronic, semileptonic, diphoton, and multilepton (electrons, muons) final states with missing transverse momentum are considered in this search. Observations are consistent with the Standard Model expectations, and 95% confidence-level limits of up to 680 GeV on the chargino/next-to-lightest neutralino masses are set (Tchi1n2E model). See their Figure 14 for an overlay of exclusion contours from all searches.

2 SIRUNYAN 19BU searched for pair production of gauginos via vector boson fusion assuming the gaugino spectrum is compressed, in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$. The final states explored included zero leptons plus two jets, one lepton plus two jets, and one hadronic tau plus two jets. A similar bound is obtained in the light slepton limit.

3 AABOUD 18AY searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos and neutralinos as in Tchi1n2D models, in events characterised by the presence of at least two hadronically decaying tau leptons and large missing transverse energy. No significant deviation from the expected SM background is observed. Assuming decays via intermediate $\tilde{\tau}_L$ and $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$, the observed

limits rule out $\tilde{\chi}_2^0$ masses up to 760 GeV for a massless $\tilde{\chi}_1^0$. See their Fig.7 (right). Interpretations are also provided in Fig 8 (bottom) for different assumptions on the ratio between $m_{\tilde{\tau}}$ and $m_{\tilde{\chi}_2^0} + m_{\tilde{\chi}_1^0}$.

4 AABOUD 18BT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos, chargino and next-to-lightest neutralinos and sleptons in events with two or three leptons (electrons or muons), with or without jets, and large missing transverse energy. No significant excess above the Standard Model expectations is observed. Limits are set on the next-to-lightest neutralino mass up to 580 GeV for massless $\tilde{\chi}_1^0$ in the Tchi1n2C simplified model exploiting the 3ℓ signature, see their Figure 8(c).

5 AABOUD 18BT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos, chargino and next-to-lightest neutralinos and sleptons in events with two or three leptons (electrons or muons), with or without jets, and large missing transverse energy. No significant excess above the Standard Model expectations is observed. Limits are set on the next-to-lightest neutralino mass up to 580 GeV for massless $\tilde{\chi}_1^0$ in the Tchi1n2F simplified model exploiting the $2\ell + 2 \text{ jets}$ and 3ℓ signatures, see their Figure 8(d).

6 AABOUD 18CK searched for events with at least 3 b -jets and large missing transverse energy in two datasets of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ of 36.1 fb^{-1} and 24.3 fb^{-1} depending on the trigger requirements. The analyses aimed to reconstruct two Higgs bosons decaying to pairs of b -quarks. No significant excess above the Standard Model expectations is observed. Limits are set on the Higgsino mass in the Tn1n1A simplified model, see their Figure 15(a). Constraints are also presented as a function of the BR of Higgsino decaying into an higgs boson and a gravitino, see their Figure 15(b).

7 AABOUD 18CO searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of mass-degenerate charginos and next-to-lightest neutralinos in events with two or three leptons (electrons or muons), with or without jets, and large missing transverse energy. The search channels are based on recursive jigsaw reconstruction. Limits are set on the next-to-lightest neutralinos mass up to 600 GeV for massless neutralinos in the Tchi1n2F simplified model exploiting the statistical combination of $2\ell + 2 \text{ jets}$ and 3ℓ channels. Next-to-lightest neutralinos masses below 220 GeV are not excluded due to an excess of events above the SM prediction in the dedicated regions. See their Figure 13(d).

8 AABOUD 18R searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for electroweak production in scenarios with compressed mass spectra in final states with two low-momentum leptons and missing transverse momentum. The data are found to be consistent with the SM prediction. Results are interpreted in Tchi1n2G higgsino models, and $\tilde{\chi}_2^0$ masses are excluded up to 145 GeV for $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$. The exclusion limits extend down to mass splittings of 2.5 GeV, see their Fig. 10 (top). Results are also interpreted in terms of exclusion bounds on the production cross-sections for the NUHM2 scenario as a function of the universal gaugino mass $m_{1/2}$ and $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$, see their Fig. 12.

9 AABOUD 18R searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for electroweak production in scenarios with compressed mass spectra in final states with two low-momentum leptons and missing transverse momentum. The data are found to be consistent with the SM prediction. Results are interpreted in Tchi1n2F wino models, and $\tilde{\chi}_2^0$ masses are excluded up to 175 GeV for $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$. The exclusion limits extend down to mass splittings of 2 GeV, see their Fig. 10 (bottom). Results are also interpreted in terms of exclusion bounds on the production cross-sections for the NUHM2 scenario as a function of the universal gaugino mass $m_{1/2}$ and $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$, see their Fig. 12.

10 AABOUD 18U searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with at least one isolated photon, possibly jets and significant transverse momentum targeting generalised models of gauge-mediated SUSY breaking. No significant excess of events is observed above the SM prediction. Results of the diphoton channel are interpreted in terms of lower limits on the masses of gauginos Tchi1chi1A models, which reach as high as 1.3 TeV. Gaugino masses below 1060 GeV are excluded for any NLSP mass, see their Fig. 10.

11 SIRUNYAN 18AJ searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing two low-momentum, oppositely charged leptons (electrons or muons) and \cancel{E}_T . No excess over the expected background is observed. Limits are derived on the wino mass in the Tchi1n2F simplified model, see their Figure 5. Limits are also set on the stop mass in the Tstop10 simplified model, see their Figure 6. Finally, limits are set on the Higgsino mass in the Tchi1n2G simplified model, see Figure 8 and in the pMSSM, see Figure 7.

- ¹² SIRUNYAN 18DP searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos and neutralinos or of chargino pairs in events with a tau lepton pair and significant missing transverse momentum. Both hadronic and leptonic decay modes are considered for the tau lepton. No significant excess above the Standard Model expectations is observed. Limits are set on the chargino mass in the Tchi1ch1D and Tchi1n2 simplified models, see their Figures 14 and 15. Also, excluded stau pair production cross sections are shown in Figures 11, 12, and 13.
- ¹³ SIRUNYAN 17AW searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with a charged lepton (electron or muon), two jets identified as originating from a b -quark, and large E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the mass of the chargino and the next-to-lightest neutralino in the Tchi1n2E simplified model, see their Figure 6.
- ¹⁴ AAD 16AA summarized and extended ATLAS searches for electroweak supersymmetry in final states containing several charged leptons, E_T , with or without hadronic jets, in 20 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$. The paper reports the results of new interpretations and statistical combinations of previously published analyses, as well as new analyses. Exclusion limits at 95% C.L. are set on mass-degenerate $\tilde{\chi}_2^0$ and $\tilde{\chi}_3^0$ masses in the Tn2n3A and Tn2n3B simplified models. See their Fig. 15.
- ¹⁵ AAD 15BA searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for electroweak production of charginos and neutralinos decaying to a final state containing a W boson and a 125 GeV Higgs boson, plus missing transverse momentum. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in simplified models of direct chargino and next-to-lightest neutralino production, with the decays $\tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$ and $\tilde{\chi}_2^0 \rightarrow H \tilde{\chi}_1^0$ having 100% branching fraction, see Fig. 8. A combination of the multiple final states for the Higgs decay yields the best limits (Fig. 8d).
- ¹⁶ AAD 14H searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for electroweak production of charginos and neutralinos decaying to a final state with three leptons and missing transverse momentum. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in simplified models of direct chargino and next-to-lightest neutralino production, with decays to the lightest neutralino via either all three generations of leptons, staus only, gauge bosons, or Higgs bosons, see Fig. 7. An interpretation in the pMSSM is also given, see Fig. 8.
- ¹⁷ AAD 14X searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least four leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the neutralino mass in an R-parity conserving simplified model where the decay $\tilde{\chi}_{2,3}^0 \rightarrow \ell^\pm \ell^\mp \tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 10.
- ¹⁸ AAD 13 searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for charginos and neutralinos decaying to a final state with three leptons (e and μ) and missing transverse energy. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in the phenomenological MSSM, see Fig. 2 and 3, and in simplified models, see Fig. 4. For the simplified models with intermediate slepton decays, degenerate $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ masses up to 500 GeV are excluded at 95% C.L. for very large mass differences with the $\tilde{\chi}_1^0$. Supersedes AAD 12As.
- ¹⁹ CHATRCHYAN 12BJ searched in 4.98 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for direct electroweak production of charginos and neutralinos in events with at least two leptons, jets and missing transverse momentum. No significant excesses over the expected SM backgrounds are observed and 95% C.L. limits on the production cross section of $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ pair production were set in a number of simplified models, see Figs. 7 to 12. Most limits are for exactly 3 jets.
- ²⁰ ABREU 00w combines data collected at $\sqrt{s}=189 \text{ GeV}$ with results from lower energies. The mass limit is obtained by constraining the MSSM parameter space with gaugino and sfermion mass universality at the GUT scale, using the results of negative direct searches for neutralinos (including cascade decays and $\tilde{\tau}\tau$ final states) from ABREU 01, for charginos from ABREU 00j and ABREU 00t (for all Δm_+), and for charged sleptons from ABREU 01b. The results hold for the full parameter space defined by all values of M_2 and $|\mu| \leq 2 \text{ TeV}$ with the $\tilde{\chi}_1^0$ as LSP.
- ²¹ AAD 14G searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for electroweak production of chargino-neutralino pairs, decaying to a final state with two leptons (e and μ) and missing transverse momentum. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in simplified models of chargino and next-to-lightest neutralino production, with decays to the lightest neutralino via gauge bosons, see Fig. 7. An interpretation in the pMSSM is also given, see Fig. 10.
- ²² KHACHATRYAN 14i searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for electroweak production of charginos and neutralinos decaying to a final state with three leptons (e or μ) and missing transverse momentum, or with a Z -boson, dijets and missing transverse momentum. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in simplified models, see Figs. 12–16.
- ²³ AAD 12As searched in 2.06 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for charginos and neutralinos decaying to a final state with three leptons (e and μ) and missing transverse energy. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in the phenomenological MSSM, see Fig. 2 (top), and in simplified models, see Fig. 2 (bottom).
- ²⁴ AAD 12T looked in 1 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for the production of supersymmetric particles decaying into final states with missing transverse momentum and exactly two isolated leptons (e or μ). Same-sign dilepton events were separately studied. Additionally, in opposite-sign events, a search was made for an excess of same-flavor over different-flavor lepton pairs. No excess over the expected background is observed and limits are placed on the effective production cross section of opposite-sign dilepton events with $E_T > 250 \text{ GeV}$ and on same-sign dilepton events with $E_T > 100 \text{ GeV}$. The latter limit is interpreted in a simplified electroweak gaugino production model.

$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ (Charginos) mass limits

Charginos are unknown mixtures of w -inos and charged higgsinos (the supersymmetric partners of W and Higgs bosons). A lower mass limit for the lightest chargino ($\tilde{\chi}_1^\pm$) of approximately 45 GeV, independent of the field composition and of the decay mode, has been obtained by the LEP experiments from the analysis of the Z width and decays. These results, as well as other now superseded limits from e^+e^- collisions at energies below 136 GeV, and from hadronic collisions, can be found in the 1998 Edition (The European Physical Journal **C3** 1 (1998)) of this Review.

Unless otherwise stated, results in this section assume spectra, production rates, decay modes and branching ratios as evaluated in the MSSM, with gaugino and sfermion mass unification at the GUT scale. These papers generally study production of $\tilde{\chi}_1^0 \tilde{\chi}_2^0$, $\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$ and (in the case of hadronic collisions) $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ pairs, including the effects of cascade decays. The mass limits on $\tilde{\chi}_1^\pm$ are either direct, or follow indirectly from the constraints set by the non-observation of $\tilde{\chi}_2^0$ states on the gaugino and higgsino MSSM parameters M_2 and μ . For generic values of the MSSM parameters, limits from high-energy e^+e^- collisions coincide with the highest value of the mass allowed by phase-space, namely $m_{\tilde{\chi}_1^\pm} \lesssim \sqrt{s}/2$. The still unpublished combination of the results of the four LEP collaborations from the 2000 run of LEP2 at \sqrt{s} up to $\approx 209 \text{ GeV}$ yields a lower mass limit of 103.5 GeV valid for general MSSM models. The limits become however weaker in certain regions of the MSSM parameter space where the detection efficiencies or production cross sections are suppressed. For example, this may happen when: (i) the mass differences $\Delta m_+ = m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0}$ or $\Delta m_- = m_{\tilde{\chi}_1^\pm} - m_{\tilde{\nu}_\tau}$ are very small, and the detection efficiency is reduced; (ii) the electron sneutrino mass is small, and the $\tilde{\chi}_1^\pm$ production rate is suppressed due to a destructive interference between s and t channel exchange diagrams. The regions of MSSM parameter space where the following limits are valid are indicated in the comment lines or in the footnotes.

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, *et al.* (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1050	95	¹ SIRUNYAN	20B CMS	$\geq 1\gamma + \cancel{E}_T$, Tchi1ch1F, $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$
> 825	95	¹ SIRUNYAN	20B CMS	$\geq 1\gamma + \cancel{E}_T$, Tchi1ch1G, $\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0 + \text{soft}$
> 840	95	¹ SIRUNYAN	20B CMS	$\geq 1\gamma + \cancel{E}_T$, Tchi1n2-GGM, 120 GeV < $m_{\tilde{\chi}_1^0}$ < 720 GeV
> 680	95	² AABOUD	19AU ATL	0, 1, 2 or more $\ell, H (\rightarrow \gamma\gamma, b\bar{b}, W W^*, Z Z^*, \tau\tau)$ (various searches), Tchi1n2E, $m_{\tilde{\chi}_1^0}=0$ GeV
> 112	95	³ SIRUNYAN	19BU CMS	$pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0 + 2 \text{ jets}, \tilde{\chi}_1^\pm \rightarrow \ell^\pm \nu_{\tilde{\chi}_1^0}$, heavy sleptons, $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 1 \text{ GeV}, m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$
> 215	95	³ SIRUNYAN	19BU CMS	$pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0 + 2 \text{ jets}, \tilde{\chi}_1^\pm \rightarrow \ell^\pm \nu_{\tilde{\chi}_1^0}$, heavy sleptons, $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 30 \text{ GeV}, m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$
> 235	95	⁴ SIRUNYAN	19CI CMS	$\geq 1 H (\rightarrow \gamma\gamma) + \text{jets} + \cancel{E}_T$, Tchi1n2E, $m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$
> 930	95	⁵ SIRUNYAN	19K CMS	$\gamma + \text{lepton} + \cancel{E}_T$, Tchi1n1A
> 630	95	⁶ AABOUD	18AY ATLS	$2\tau + \cancel{E}_T$, Tchi1ch1D and $\tilde{\tau}_L$ -only, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 760	95	⁷ AABOUD	18AY ATLS	$2\tau + \cancel{E}_T$, Tchi1n2D and $\tilde{\tau}_L$ -only, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 740	95	⁸ AABOUD	18BT ATLS	$2\ell + \cancel{E}_T$, Tchi1ch1C, $m_{\tilde{\chi}_1^0}=0 \text{ GeV}$
>1125	95	⁹ AABOUD	18BT ATLS	$2,3\ell + \cancel{E}_T$, Tchi1n2C, $m_{\tilde{\chi}_1^0}=0 \text{ GeV}$
> 580	95	¹⁰ AABOUD	18BT ATLS	$2,3\ell + \cancel{E}_T$, Tchi1n2F, $m_{\tilde{\chi}_1^0}=0 \text{ GeV}$
none	95	¹¹ AABOUD	18CK ATLS	$2H (\rightarrow b\bar{b}) + \cancel{E}_T$, Tn1n1A, GMSB
130–230, 290–880	95	¹² AABOUD	18Co ATLS	$2,3\ell + \cancel{E}_T$, recursive jigsaw, Tchi1n2F, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
none	95	¹³ AABOUD	18R ATLS	$2\ell (\text{soft}) + \cancel{E}_T$, Tchi1n2F, wino, $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$
> 145	95	¹⁴ AABOUD	18R ATLS	$2\ell (\text{soft}) + \cancel{E}_T$, Tchi1n2G, higgsino, $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$
>1060	95	¹⁵ AABOUD	18U ATLS	$2\gamma + \cancel{E}_T$, GGM, Tchi1ch1A, any NLSP mass
>1400	95	¹⁶ AABOUD	18Z ATLS	$\geq 4\ell$, RPV, $\lambda_{12k} \neq 0, m_{\tilde{\chi}_1^0} > 500 \text{ GeV}$
>1320	95	¹⁶ AABOUD	18Z ATLS	$\geq 4\ell$, RPV, $\lambda_{12k} \neq 0, m_{\tilde{\chi}_1^0} > 500 \text{ GeV}$
> 980	95	¹⁶ AABOUD	18Z ATLS	$\geq 4\ell$, RPV, $\lambda_{133} \neq 0, 400 \text{ GeV} < m_{\tilde{\chi}_1^0} < 700 \text{ GeV}$
> 980	95	¹⁷ SIRUNYAN	18AA CMS	$\geq 1\gamma + \cancel{E}_T$, GGM, wino-like $\tilde{\chi}_2^0 \tilde{\chi}_1^\pm$ pair production, nearly degenerate wino and bino masses
> 780	95	¹⁷ SIRUNYAN	18AA CMS	$\geq 1\gamma + \cancel{E}_T$, Tchi1n1A
> 950	95	¹⁷ SIRUNYAN	18AA CMS	$\geq 1\gamma + \cancel{E}_T$, Tchi1ch1A
> 230	95	¹⁸ SIRUNYAN	18AJ CMS	$2\ell (\text{soft}) + \cancel{E}_T$, Tchi1n2F, wino, $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 20 \text{ GeV}$

Searches Particle Listings

Supersymmetric Particle Searches

>1150	95	19 SIRUNYAN	18AO CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tchl1n2A, $m_{\tilde{\ell}} = m_{\tilde{\nu}} = m_{\tilde{\chi}_1^0} + 0.5 (m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0})$, $m_{\tilde{\chi}_1^\pm} = 0$ GeV	> 380	95	32 AAD	14H ATLS	$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow \tau^\pm \nu \tilde{\chi}_1^0 \tau^\pm \tilde{\chi}_1^\pm$, simplified model, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$, $m_{\tilde{\chi}_1^0} = 0$ GeV
>1120	95	19 SIRUNYAN	18AO CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tchl1n2A, $m_{\tilde{\ell}} = m_{\tilde{\nu}} = m_{\tilde{\chi}_1^0} + 0.05 (m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0})$, $m_{\tilde{\chi}_1^\pm} = 0$ GeV	> 750	95	33 AAD	14x ATLS	RPV, $\geq 4\ell^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^{(*)} \tilde{\chi}_1^0$, $\tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \nu$
>1050	95	19 SIRUNYAN	18AO CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tchl1n2A, $m_{\tilde{\ell}} = m_{\tilde{\nu}} = m_{\tilde{\chi}_1^0} + 0.95 (m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0})$, $m_{\tilde{\chi}_1^\pm} = 0$ GeV	> 210	95	34 KHACHATRY..14L	CMS	$\tilde{\chi}_2^0 \rightarrow H \tilde{\chi}_1^0$ and $\tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$, simplified models, $m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^\pm}$, $m_{\tilde{\chi}_1^0} = 0$ GeV
>1080	95	19 SIRUNYAN	18AO CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tchl1n2H, $m_{\tilde{\ell}} = m_{\tilde{\nu}} = m_{\tilde{\chi}_1^0} + 0.5 (m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0})$, $m_{\tilde{\chi}_1^\pm} = 0$ GeV	> 540	95	35 AAD	13 ATLS	$3\ell^\pm + \cancel{E}_T$, pMSSM, SMS
>1030	95	19 SIRUNYAN	18AO CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tchl1n2H, $m_{\tilde{\ell}} = m_{\tilde{\nu}} = m_{\tilde{\chi}_1^0} + 0.05 (m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0})$, $m_{\tilde{\chi}_1^\pm} = 0$ GeV	> 540	95	36 AAD	13B ATLS	$2\ell^\pm + \cancel{E}_T$, pMSSM, SMS
>1050	95	19 SIRUNYAN	18AO CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tchl1n2H, $m_{\tilde{\ell}} = m_{\tilde{\nu}} = m_{\tilde{\chi}_1^0} + 0.95 (m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0})$, $m_{\tilde{\chi}_1^\pm} = 0$ GeV	> 540	95	37 AAD	12CT ATLS	$\geq 4\ell^\pm$, RPV, $m_{\tilde{\chi}_1^0} > 300$ GeV
> 625	95	19 SIRUNYAN	18AO CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tchl1n2D, $m_{\tilde{\ell}} = m_{\tilde{\nu}} = m_{\tilde{\chi}_1^0} + 0.5 (m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0})$, $m_{\tilde{\chi}_1^\pm} = 0$ GeV	> 94	95	38 CHATRCHYAN12BJ	CMS	$\geq 2\ell$, jets + \cancel{E}_T , $pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0$
> 180	95	19 SIRUNYAN	18AO CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tchl1n2E, $m_{\tilde{\chi}_1^0} = 0$ GeV	> 94	95	39 ABDALLAH	03M DLPH	$\tilde{\chi}_1^\pm$, $\tan\beta \leq 40$, $\Delta m_{\tilde{\chi}_1^\pm} > 3$ GeV, all m_0
> 450	95	19 SIRUNYAN	18AO CMS	$\ell^\pm \ell^\pm$ or $\geq 3\ell$, Tchl1n2F, $m_{\tilde{\chi}_1^0} = 0$ GeV	<p>• • • We do not use the following data for averages, fits, limits, etc. • • •</p> <p>> 570 95 40 KHACHATRY..16AA CMS $\geq 1\gamma + \text{jets} + \cancel{E}_T$, Tchl1chi1A</p> <p>> 680 95 40 KHACHATRY..16AA CMS $\geq 1\gamma + \text{jets} + \cancel{E}_T$, Tchl1n1A</p> <p>> 710 95 40 KHACHATRY..16AA CMS $\geq 1\gamma + \text{jets} + \cancel{E}_T$, GGM, $\tilde{\chi}_2^0 \tilde{\chi}_1^\pm$ pair production, wino-like NLSP</p> <p>>1000 95 41 KHACHATRY..16R CMS $\geq 1\gamma + 1e$ or $\mu + \cancel{E}_T$, Tglu1F, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0} > 200$ GeV</p> <p>> 307 95 42 KHACHATRY..16Y CMS $1,2$ soft $\ell^\pm + \text{jets} + \cancel{E}_T$, Tchl1n2A, $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 20$ GeV</p> <p>> 410 95 43 AAD 14AV ATLS $\geq 2\tau + \cancel{E}_T$, direct $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$, $\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$ production, $m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^\pm}$, $m_{\tilde{\chi}_1^0} = 0$ GeV</p> <p>> 345 95 44 AAD 14AV ATLS $\geq 2\tau + \cancel{E}_T$, direct $\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$ production, $m_{\tilde{\chi}_1^0} = 0$ GeV</p> <p>none 100–105, 120–135, 145–160 95 45 AAD 14G ATLS $\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp \rightarrow W^\pm \tilde{\chi}_1^0 W^\mp \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^0} = 0$ GeV</p> <p>none 140–465 95 45 AAD 14G ATLS $\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp \rightarrow \ell^\pm \nu \tilde{\chi}_1^0 \ell^\mp \nu \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^0} = 0$ GeV</p> <p>none 180–355 95 45 AAD 14G ATLS $\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W \tilde{\chi}_1^0 Z \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$, $m_{\tilde{\chi}_1^0} = 0$ GeV</p> <p>> 168 95 46 AALTONEN 14 CDF $3\ell^\pm + \cancel{E}_T$, $\tilde{\chi}_1^\pm \rightarrow \ell \nu \tilde{\chi}_1^0$, mSUGRA with $m_0=60$ GeV</p> <p>47 KHACHATRY..14I CMS $\tilde{\chi}_1^\pm \rightarrow W \tilde{\chi}_1^0$, $\ell \tilde{\nu}$, $\tilde{\ell} \nu$, simplified model</p> <p>48 AALTONEN 13Q CDF $\tilde{\chi}_1^\pm \rightarrow \tau X$, simplified gravity- and gauge-mediated models</p> <p>49 AAD 12AS ATLS $3\ell^\pm + \cancel{E}_T$, pMSSM</p> <p>50 AAD 12T ATLS $\ell^\pm \ell^\mp + \cancel{E}_T$, $\ell^\pm \ell^\pm + \cancel{E}_T$, $pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0$</p> <p>51 CHATRCHYAN11B CMS $\tilde{W}^0 \rightarrow \gamma \tilde{G}, \tilde{W}^\pm \rightarrow \ell^\pm \tilde{G}$, GMSB</p> <p>> 163 95 52 CHATRCHYAN11V CMS $\tan\beta=3$, $m_0=60$ GeV, $A_0=0$, $\mu > 0$</p>				
> 500	95	27 AAD	16AA ATLS	$2\ell^\pm + \cancel{E}_T$, Tchl1chi1B, $m_{\tilde{\chi}_1^0} = 0$ GeV	<p>1 SIRUNYAN 20b searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with at least one photon and large \cancel{E}_T. No significant excess above the Standard Model expectations is observed. Limits are set on chargino masses in a general gauge-mediated SUSY breaking (GGM) scenario Tchl1n2-GGM, see Figure 4. Limits are also set on the NLSP mass in the Tchl1chi1F and Tchl1chi1G simplified models, see their Figure 5. Finally, limits are set on the gluino mass in the Tglu4A simplified model, see Figure 6.</p> <p>2 AABOUD 19AU searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for direct electroweak production of charginos and next-to-lightest neutralinos decaying into lightest neutralinos and a W, and a Higgs boson, respectively. Fully hadronic, semileptonic, diphoton, and multilepton (electrons, muons) final states with missing transverse momentum are considered in this search. Observations are consistent with the Standard Model expectations, and 95% confidence-level limits of up to 680 GeV on the chargino/next-to-lightest neutralino masses are set (Tchl1n2E model). See their Figure 14 for an overlay of exclusion contours from all searches.</p> <p>3 SIRUNYAN 19Bu searched for pair production of gauginos via vector boson fusion assuming the gaugino spectrum is compressed, in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV. The final states explored included zero leptons plus two jets, one lepton plus two jets, and one hadronic tau plus two jets. A similar bound is obtained in the light slepton limit.</p> <p>4 SIRUNYAN 19Ci searched in 77.5 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with one or more high-momentum Higgs bosons, decaying to pairs of photons, jets and \cancel{E}_T. No significant excess above the Standard Model expectations is observed. Limits are set on the sbottom mass in the Tsb04 simplified model, see Figure 3, and on the wino mass in the Tchl1n2E simplified model, see their Figure 4. Limits are also set on the higgsino mass in the Tn1n1A and Tn1n1B simplified models, see their Figure 5.</p> <p>5 SIRUNYAN 19K searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with a photon, an electron or muon, and large \cancel{E}_T. No significant excess above the Standard Model expectations is observed. In the framework of GMSB, limits are set on the chargino and neutralino mass in the Tchl1n1A simplified model, see their Figure 6. Limits are also set on the gluino mass in the Tglu4A simplified model, and on the squark mass in the Tsqk4A simplified model, see their Figure 7.</p>				
> 220	95	27 AAD	16AA ATLS	$2\ell^\pm + \cancel{E}_T$, Tchl1chi1C, low Δm for $\tilde{\chi}_1^\pm, \tilde{\chi}_1^0$					
> 700	95	28 AAD	16AA ATLS	$3,4\ell + \cancel{E}_T$, Tchl1n2B, $m_{\tilde{\chi}_1^0} = 0$ GeV					
> 700	95	28 AAD	16AA ATLS	$3,4\ell + \cancel{E}_T$, Tchl1n2C, $m_{\tilde{\ell}} = m_{\tilde{\chi}_1^0} + 0.5$ (or 0.95) $(m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0})$					
> 400	95	28 AAD	16AA ATLS	2 hadronic $\tau + \cancel{E}_T$ & $3\ell + \cancel{E}_T$ combination, Tchl1n2D, $m_{\tilde{\chi}_1^0} = 0$ GeV					
> 540	95	29 KHACHATRY..16R	CMS	$\geq 1\gamma + 1e$ or $\mu + \cancel{E}_T$, Tchl1n1A					
> 250	95	30 AAD	15BA ATLS	$m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$, $m_{\tilde{\chi}_1^0} = 0$ GeV					
> 590	95	31 AAD	15CA ATLS	$\geq 2\gamma + \cancel{E}_T$, GGM, bino-like NLSP, any NLSP mass					
none 124–361	95	31 AAD	15CA ATLS	$\geq 1\gamma + e\mu + \cancel{E}_T$, GGM, wino-like NLSP					
> 700	95	32 AAD	14H ATLS	$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow \ell^\pm \nu \tilde{\chi}_1^0 \ell^\mp \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$, $m_{\tilde{\chi}_1^0} = 0$ GeV					
> 345	95	32 AAD	14H ATLS	$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W \tilde{\chi}_1^0 Z \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$, $m_{\tilde{\chi}_1^0} = 0$ GeV					
> 148	95	32 AAD	14H ATLS	$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W \tilde{\chi}_1^0 H \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0}$, $m_{\tilde{\chi}_1^0} = 0$ GeV					

- ⁶ AABOUD 18AY searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos as in Tchl1ch1D models in events characterised by the presence of at least two hadronically decaying tau leptons and large missing transverse energy. No significant deviation from the expected SM background is observed. In the Tchl1ch1D model, assuming decays via intermediate $\tilde{\tau}_L$, the observed limits rule out $\tilde{\chi}_1^\pm$ masses up to 630 GeV for a massless $\tilde{\chi}_1^0$. See their Fig.7 (left). Interpretations are also provided in Fig 8 (top) for different assumptions on the ratio between $m_{\tilde{\tau}}$ and $m_{\tilde{\chi}_1^\pm}$.
- ⁷ AABOUD 18AY searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos and neutralinos as in Tchl1n2D models, in events characterised by the presence of at least two hadronically decaying tau leptons and large missing transverse energy. No significant deviation from the expected SM background is observed. Assuming decays via intermediate $\tilde{\tau}_L$ and $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0}$, the observed limits rule out $\tilde{\chi}_1^\pm$ masses up to 760 GeV for a massless $\tilde{\chi}_1^0$. See their Fig.7 (right). Interpretations are also provided in Fig 8 (bottom) for different assumptions on the ratio between $m_{\tilde{\tau}}$ and $m_{\tilde{\chi}_1^\pm} + m_{\tilde{\chi}_1^0}$.
- ⁸ AABOUD 18BT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos, chargino and next-to-lightest neutralinos and sleptons in events with two or three leptons (electrons or muons), with or without jets and large missing transverse energy. No significant excess above the Standard Model expectations is observed. Limits are set on the chargino mass up to 750 GeV for massless neutralinos in the Tchl1ch1C simplified model exploiting $2\ell + 0$ jets signatures, see their Figure 8(a).
- ⁹ AABOUD 18BT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos, chargino and next-to-lightest neutralinos and sleptons in events with two or three leptons (electrons or muons), with or without jets, and large missing transverse energy. No significant excess above the Standard Model expectations is observed. Limits are set on the chargino mass up to 1100 GeV for massless neutralinos in the Tchl1n2C simplified model exploiting 3ℓ signature, see their Figure 8(c).
- ¹⁰ AABOUD 18BT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos, chargino and next-to-lightest neutralinos and sleptons in events with two or three leptons (electrons or muons), with or without jets, and large missing transverse energy. No significant excess above the Standard Model expectations is observed. Limits are set on the chargino mass up to 580 GeV for massless neutralinos in the Tchl1n2F simplified model exploiting $2\ell + 2$ jets and 3ℓ signatures, see their Figure 8(d).
- ¹¹ AABOUD 18CK searched for events with at least 3 b -jets and large missing transverse energy in two datasets of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ of 36.1 fb^{-1} and 24.3 fb^{-1} depending on the trigger requirements. The analyses aimed to reconstruct two Higgs bosons decaying to pairs of b -quarks. No significant excess above the Standard Model expectations is observed. Limits are set on the Higgsino mass in the Tln1n1A simplified model, see their Figure 15(a). Constraints are also presented as a function of the BR of Higgsino decaying into a higgs boson and a gravitino, see their Figure 15(b).
- ¹² AABOUD 18CO searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of mass-degenerate charginos and next-to-lightest neutralinos in events with two or three leptons (electrons or muons), with or without jets, and large missing transverse energy. The search channels are based on recursive jigsaw reconstruction. Limits are set on the chargino mass up to 600 GeV for massless neutralinos in the Tchl1n2F simplified model exploiting the statistical combination of $2\ell + 2$ jets and 3ℓ channels. Chargino masses below 220 GeV are not excluded due to an excess of events above the SM prediction in the dedicated regions. See their Figure 13(d).
- ¹³ AABOUD 18R searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for electroweak production in scenarios with compressed mass spectra in final states with two low-momentum leptons and missing transverse momentum. The data are found to be consistent with the SM prediction. Results are interpreted in Tchl1n2G wino models and $\tilde{\chi}_1^\pm$ masses are excluded up to 175 GeV for $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$. The exclusion limits extend down to mass splittings of 2 GeV, see their Fig. 10 (bottom).
- ¹⁴ AABOUD 18R searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for electroweak production in scenarios with compressed mass spectra in final states with two low-momentum leptons and missing transverse momentum. The data are found to be consistent with the SM prediction. Results are interpreted in Tchl1n2G higgsino models and $\tilde{\chi}_1^\pm$ masses are excluded up to 145 GeV for $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$. The exclusion limits extend down to mass splittings of 2.5 GeV, see their Fig. 10 (top).
- ¹⁵ AABOUD 18U searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with at least one isolated photon, possibly jets and significant transverse momentum targeting generalised models of gauge-mediated SUSY breaking. No significant excess of events is observed above the SM prediction. Results of the diphoton channel are interpreted in terms of lower limits on the masses of gauginos Tchl1ch1A models, which reach as high as 1.3 TeV. Gaugino masses below 1060 GeV are excluded for any NLSM mass, see their Fig. 10.
- ¹⁶ AABOUD 18Z searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing four or more charged leptons (electrons, muons and up to two hadronically decaying taus). No significant deviation from the expected SM background is observed. Limits are set on the Higgsino mass in simplified models of general gauge mediated supersymmetry Tln1n1A/Tln1n1B/Tln1n1C, see their Figure 9. Limits are also set on the wino, slepton, sneutrino and gluino mass in a simplified model of NLSM pair production with R-parity violating decays of the LSP via $\lambda_{12\ell}$ or λ_{133} to charged leptons, see their Figures 7, 8.
- ¹⁷ SIRUNYAN 18AA searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one photon and large E_T . No significant excess above the Standard Model expectations is observed. Limits are set on wino masses in a general gauge-mediated SUSY breaking (GGM) scenario with bino-like $\tilde{\chi}_1^0$ and wino-like $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$, see Figure 7. Limits are also set on the NLSM mass in the Tchl1n1A and Tchl1ch1A simplified models, see their Figure 8. Finally, limits are set on the gluino mass in the Tglu4A and Tglu4B simplified models, see their Figure 9, and on the squark mass in the Tsq4A and Tsq4B simplified models, see their Figure 10.
- ¹⁸ SIRUNYAN 18AJ searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing two low-momentum, oppositely charged leptons (electrons or muons) and E_T . No excess over the expected background is observed. Limits are derived on the wino mass in the Tchl1n2F simplified model, see their Figure 5. Limits are also set on the stop mass in the Tstop10 simplified model, see their Figure 6. Finally, limits are set on the Higgsino mass in the Tchl1n2G simplified model, see Figure 8 and in the pMSSM, see Figure 7.
- ¹⁹ SIRUNYAN 18AO searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos and neutralinos in events with either two or more leptons (electrons or muons) of the same electric charge, or with three or more leptons, which can include up to two hadronically decaying tau leptons. No significant excess above the Standard Model expectations is observed. Limits are set on the chargino/neutralino mass in the Tchl1n2A, Tchl1n2H, Tchl1n2D, Tchl1n2E and Tchl1n2F simplified models, see their Figures 14, 15, 16, 17 and 18. Limits are also set on the higgsino mass in the Tln1n1A, Tln1n1B and Tln1n1C simplified models, see their Figure 19.
- ²⁰ SIRUNYAN 18AP searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos and neutralinos by combining a number of previous and new searches. No significant excess above the Standard Model expectations is observed. Limits are set on the chargino/neutralino mass in the Tchl1n2E, Tchl1n2F and Tchl1n2I simplified models, see their Figures 7, 8, 9 and 10. Limits are also set on the higgsino mass in the Tln1n1A, Tln1n1B and Tln1n1C simplified models, see their Figure 11, 12, 13 and 14.
- ²¹ SIRUNYAN 18AR searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing two opposite-charge, same-flavour leptons (electrons or muons), jets and E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu4C simplified model, see their Figure 7. Limits are also set on the chargino/neutralino mass in the Tchl1n2F simplified models, see their Figure 8, and on the higgsino mass in the Tln1n1B and Tln1n1C simplified models, see their Figure 9. Finally, limits are set on the sbottom mass in the Tstop3 simplified model, see their Figure 10.
- ²² SIRUNYAN 18DN searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos and for pair production of top squarks in events with two leptons (electrons or muons) of the opposite electric charge. No significant excess above the Standard Model expectations is observed. Limits are set on the chargino mass in the Tchl1ch1C and Tchl1ch1E simplified models, see their Figure 8. Limits are also set on the stop mass in the Tstop1 and Tstop2 simplified models, see their Figure 9.
- ²³ SIRUNYAN 18DP searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos and neutralinos or of chargino pairs in events with a tau lepton pair and significant missing transverse momentum. Both hadronic and leptonic decay modes are considered for the tau lepton. No significant excess above the Standard Model expectations is observed. Limits are set on the chargino mass in the Tchl1ch1D and Tchl1n2 simplified models, see their Figures 14 and 15. Also, excluded stau pair production cross sections are shown in Figures 11, 12, and 13.
- ²⁴ SIRUNYAN 18X searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one or more high-momentum Higgs bosons, decaying to pairs of photons, jets and E_T . The razor variables (M_R and R^2) are used to categorise the events. No significant excess above the Standard Model expectations is observed. Limits are set on the sbottom mass in the Tstop4 simplified model and on the wino mass in the Tchl1n2E simplified model, see their Figure 5. Limits are also set on the higgsino mass in the Tln1n1A and Tln1n1B simplified models, see their Figure 6.
- ²⁵ KHACHATRYAN 17L searched in about 19 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with two τ (at least one decaying hadronically) and E_T . In the Tchl1ch1C model, assuming decays via intermediate $\tilde{\tau}$ or $\tilde{\nu}_\tau$ with equivalent mass, the observed limits rule out $\tilde{\chi}_1^\pm$ masses up to 420 GeV for a massless $\tilde{\chi}_1^0$. See their Fig.5.
- ²⁶ SIRUNYAN 17AW searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with a charged lepton (electron or muon), two jets identified as originating from a b -quark, and large E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the mass of the chargino and the next-to-lightest neutralino in the Tchl1n2E simplified model, see their Figure 6.
- ²⁷ AAD 16AA summarized and extended ATLAS searches for electroweak supersymmetry in final states containing several charged leptons, E_T , with or without hadronic jets, in 20 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$. The paper reports the results of new interpretations and statistical combinations of previously published analyses, as well as new analyses. Exclusion limits at 95% C.L. are set on the $\tilde{\chi}_1^\pm$ mass in the Tchl1ch1B and Tchl1ch1C simplified models. See their Fig. 13.
- ²⁸ AAD 16AA summarized and extended ATLAS searches for electroweak supersymmetry in final states containing several charged leptons, E_T , with or without hadronic jets, in 20 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$. The paper reports the results of new interpretations and statistical combinations of previously published analyses, as well as new analyses. Exclusion limits at 95% C.L. are set on mass-degenerate $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ masses in the Tchl1n2B, Tchl1n2C, and Tchl1n2D simplified models. See their Figs. 16, 17, and 18. Interpretations in phenomenological-MSSM, two-parameter Non Universal Higgs Masses (NUHM2), and gauge-mediated symmetry breaking (GMSB) models are also given in their Figs. 20, 21 and 22.
- ²⁹ KHACHATRYAN 16R searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with one or more photons, one electron or muon, and E_T . No significant excess above the Standard Model expectations is observed. Limits are set on wino masses in a general gauge-mediated SUSY breaking model (GGM), for a wino-like neutralino NLSM scenario, see Fig. 5. Limits are also set in the Tglu1D and Tchl1n1A simplified models, see Fig. 6. The Tchl1n1A limit is reduced to 340 GeV for a branching ratio reduced by the weak mixing angle.
- ³⁰ AAD 15BA searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for electroweak production of charginos and neutralinos decaying to a final state containing a W boson and a 125 GeV Higgs boson, plus missing transverse momentum. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in simplified models of direct chargino and next-to-lightest neutralino production, with the decays $\tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$ and $\tilde{\chi}_2^0 \rightarrow H \tilde{\chi}_1^0$ having 100% branching fraction, see Fig. 8. A combination of the multiple final states for the Higgs decay yields the best limits (Fig. 8d).
- ³¹ AAD 15CA searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with one or more photons and E_T , with or without leptons (e, μ). No significant excess above the Standard Model expectations is observed. Limits are set on wino masses in the general gauge-mediated SUSY breaking model (GGM), for wino-like NLSM, see Fig. 9, 12.
- ³² AAD 14H searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for electroweak production of charginos and neutralinos decaying to a final state with three leptons and missing transverse momentum. No excess beyond the Standard Model expectation is observed.

Searches Particle Listings

Supersymmetric Particle Searches

- Exclusion limits are derived in simplified models of direct chargino and next-to-lightest neutralino production, with decays to the lightest neutralino via either all three generations of leptons, staus only, gauge bosons, or Higgs bosons, see Fig. 7. An interpretation in the pMSSM is also given, see Fig. 8.
- ³³ AAD 14X searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least four leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the wino-like chargino mass in an R-parity violating simplified model where the decay $\tilde{\chi}_1^\pm \rightarrow W^{(*)\pm} \tilde{\chi}_1^0$, with $\tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \nu$, takes place with a branching ratio of 100%, see Fig. 8.
- ³⁴ KHACHATRYAN 14L searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for evidence of chargino-neutralino $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ pair production with Higgs or W -bosons in the decay chain, leading to HW final states with missing transverse energy. The decays of a Higgs boson to a photon pair are considered in conjunction with hadronic and leptonic decay modes of the W bosons. No significant excesses over the expected SM backgrounds are observed. The results are interpreted in the context of simplified models where the decays $\tilde{\chi}_2^0 \rightarrow H \tilde{\chi}_1^0$ and $\tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$ take place 100% of the time, see Figs. 22–23.
- ³⁵ AAD 13 searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for charginos and neutralinos decaying to a final state with three leptons (e and μ) and missing transverse energy. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in the phenomenological MSSM, see Fig. 2 and 3, and in simplified models, see Fig. 4. For the simplified models with intermediate slepton decays, degenerate $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ masses up to 500 GeV are excluded at 95% C.L. for very large mass differences with the $\tilde{\chi}_1^0$. Supersedes AAD 12As.
- ³⁶ AAD 13b searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for gauginos decaying to a final state with two leptons (e and μ) and missing transverse energy. No excess beyond the Standard Model expectation is observed. Limits are derived in a simplified model of wino-like chargino pair production, where the chargino always decays to the lightest neutralino via an intermediate on-shell charged slepton, see Fig. 2(b). Chargino masses between 110 and 340 GeV are excluded at 95% C.L. for $m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$. Exclusion limits are also derived in the phenomenological MSSM, see Fig. 3.
- ³⁷ AAD 12CT searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing four or more leptons (electrons or muons) and either moderate values of missing transverse momentum or large effective mass. No significant excess is found in the data. Limits are presented in a simplified model of R-parity violating supersymmetry in which charginos are pair-produced and then decay into a W -boson and a $\tilde{\chi}_1^0$, which in turn decays through an RPV coupling into two charged leptons ($e^\pm e^\mp$ or $e^\pm \mu^\mp$) and a neutrino. In this model, chargino masses up to 540 GeV are excluded at 95% C.L. for $m_{\tilde{\chi}_1^0}$ above 300 GeV, see Fig. 3a. The limit deteriorates for lighter $\tilde{\chi}_1^0$. Limits are also set in an R-parity violating mSUGRA model, see Fig. 3b.
- ³⁸ CHATRCHYAN 12BJ searched in 4.98 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for direct electroweak production of charginos and neutralinos in events with at least two leptons, jets and missing transverse momentum. No significant excesses over the expected SM backgrounds are observed and 95% C.L. limits on the production cross section of $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ pair production were set in a number of simplified models, see Figs. 7 to 12.
- ³⁹ ABDALLAH 03M uses data from $\sqrt{s} = 192\text{--}208 \text{ GeV}$ to obtain limits in the framework of the MSSM with gaugino and stfermion mass universality at the GUT scale. An indirect limit on the mass of charginos is derived by constraining the MSSM parameter space by the results from direct searches for neutralinos (including cascade decays), for charginos and for sleptons. These limits are valid for values of $M_2 < 1 \text{ TeV}$, $|\mu| \leq 2 \text{ TeV}$ with the $\tilde{\chi}_1^0$ as LSP. Constraints from the Higgs search in the m_h^{max} scenario assuming $m_t = 174.3 \text{ GeV}$ are included. The quoted limit applies if there is no mixing in the third family or when $m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0} > 6 \text{ GeV}$. If mixing is included the limit degrades to 90 GeV. See Fig. 43 for the mass limits as a function of $\tan\beta$. These limits update the results of ABREU 00W.
- ⁴⁰ KHACHATRYAN 16AA searched in 7.4 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with one or more photons, hadronic jets and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on wino masses in the general gauge-mediated SUSY breaking model (GGM), for a wino-like neutralino NLSP scenario and with the wino mass fixed at 10 GeV above the bino mass, see Fig. 4. Limits are also set in the Tchl1n1A and Tchl1n1A simplified models, see Fig. 3.
- ⁴¹ KHACHATRYAN 16R searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with one or more photons, one electron or muon, and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are also set in the Tglu1F simplified model, see Fig. 6.
- ⁴² KHACHATRYAN 16V searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with one or two soft isolated leptons, hadronic jets, and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the $\tilde{\chi}_1^\pm$ mass (which is degenerate with the $\tilde{\chi}_2^0$) in the Tchl1n2A simplified model, see Fig. 4.
- ⁴³ AAD 14AV searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for the direct production of charginos, neutralinos and staus in events containing at last two hadronically decaying τ -leptons, large missing transverse momentum and low jet activity. The quoted limit was derived for direct $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ and $\tilde{\chi}_1^\pm \tilde{\chi}_1^0$ production with $\tilde{\chi}_2^0 \rightarrow \tilde{\tau} \tau \rightarrow \tau \tau \tilde{\chi}_1^0$ and $\tilde{\chi}_1^\pm \rightarrow \tilde{\tau} \nu(\bar{\nu} \tau) \rightarrow \tau \nu \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = m_{\tilde{\chi}_1^\pm}$, $m_{\tilde{\tau}} = 0.5 (m_{\tilde{\chi}_1^\pm} + m_{\tilde{\chi}_1^0})$, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$. No excess over the expected SM background is observed. Exclusion limits are set in simplified models of $\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$ and $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ pair production, see their Figure 7. Upper limits on the cross section and signal strength for direct di-stau production are derived, see Figures 8 and 9. Also, limits are derived in a pMSSM model where the only light slepton is the $\tilde{\tau}_R$, see Figure 10.
- ⁴⁴ AAD 14AV searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for the direct production of charginos, neutralinos and staus in events containing at last two hadronically decaying τ -leptons, large missing transverse momentum and low jet activity. The quoted limit was derived for direct $\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$ production with $\tilde{\chi}_1^\pm \rightarrow \tilde{\tau} \nu(\bar{\nu} \tau) \rightarrow \tau \nu \tilde{\chi}_1^0$, $m_{\tilde{\tau}} = 0.5 (m_{\tilde{\chi}_1^\pm} + m_{\tilde{\chi}_1^0})$, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$. No excess over the expected SM background is observed. Exclusion limits are set in simplified models of $\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$ and $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ pair production, see their Figure 7. Upper limits on the cross section and signal strength for direct di-stau production are derived, see Figures 8 and 9. Also, limits are derived in a pMSSM model where the only light slepton is the $\tilde{\tau}_R$, see Figure 10.

- ⁴⁵ AAD 14G searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for electroweak production of chargino pairs, or chargino-neutralino pairs, decaying to a final state with two leptons (e and μ) and missing transverse momentum. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in simplified models of chargino pair production, with chargino decays to the lightest neutralino via either sleptons or gauge bosons, see Fig. 5; or in simplified models of chargino and next-to-lightest neutralino production, with decays to the lightest neutralino via gauge bosons, see Fig. 7. An interpretation in the pMSSM is also given, see Fig. 10.
- ⁴⁶ AALTONEN 14 searched in 5.8 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for evidence of chargino and next-to-lightest neutralino associated production in final states consisting of three leptons (electrons, muons or taus) and large missing transverse momentum. The results are consistent with the Standard Model predictions within 1.85σ . Limits on the chargino mass are derived in an mSUGRA model with $m_0 = 60 \text{ GeV}$, $\tan\beta = 3$, $A_0 = 0$ and $\mu > 0$, see their Fig. 2.
- ⁴⁷ KHACHATRYAN 14I searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for electroweak production of chargino pairs decaying to a final state with opposite-sign lepton pairs (e or μ) and missing transverse momentum. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in simplified models, see Fig. 18.
- ⁴⁸ AALTONEN 13Q searched in 6.0 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for evidence of chargino-neutralino associated production in like-sign dilepton final states. One lepton is identified as the hadronic decay of a tau lepton, while the other is an electron or muon. Good agreement with the Standard Model predictions is observed and limits are set on the chargino-neutralino cross section for simplified gravity- and gauge-mediated models, see their Figs. 2 and 3.
- ⁴⁹ AAD 12As searched in 2.06 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for charginos and neutralinos decaying to a final state with three leptons (e and μ) and missing transverse energy. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in the phenomenological MSSM, see Fig. 2 (top), and in simplified models, see Fig. 2 (bottom).
- ⁵⁰ AAD 12T looked in 1 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for the production of supersymmetric particles decaying into final states with missing transverse momentum and exactly two isolated leptons (e or μ). Opposite-sign and same-sign dilepton events were separately studied. Additionally, in opposite-sign events, a search was made for an excess of same-flavor over different-flavor lepton pairs. No excess over the expected background is observed and limits are placed on the effective production cross section of opposite-sign dilepton events with $\cancel{E}_T > 250 \text{ GeV}$ and on same-sign dilepton events with $\cancel{E}_T > 100 \text{ GeV}$. The latter limit is interpreted in a simplified electroweak gaugino production model as a lower chargino mass limit.
- ⁵¹ CHATRCHYAN 11B looked in 35 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with an isolated lepton (e or μ), a photon and \cancel{E}_T which may arise in a generalized gauge mediated model from the decay of Wino-like NLSPs. No evidence for an excess over the expected background is observed. Limits are derived in the plane of squark/gluino mass versus Wino mass (see Fig. 4). Mass degeneracy of the produced squarks and gluinos is assumed.
- ⁵² CHATRCHYAN 11V looked in 35 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with ≥ 3 isolated leptons (e , μ or τ), with or without jets and \cancel{E}_T . No evidence for an excess over the expected background is observed. Limits are derived in the CMSSM ($m_0, m_{1/2}$) plane for $\tan\beta = 3$ (see Fig. 5).

Long-lived $\tilde{\chi}^\pm$ (Chargino) mass limit

Limits on charginos which leave the detector before decaying.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1090	95	¹ AABOUD	19AT ATLS	long-lived $\tilde{\chi}_1^\pm$ mAMSB
> 460	95	² AABOUD	18AS ATLS	$\tilde{\chi}^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm$, lifetime 0.2 ns, $m_{\tilde{\chi}^\pm} - m_{\tilde{\chi}_1^0} = 160 \text{ MeV}$
> 715	95	³ SIRUNYAN	18BR CMS	$\tilde{\chi}^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm$, AMSB, $\tan\beta = 5$ and $\mu > 0$, $\tau = 3 \text{ ns}$
> 695	95	³ SIRUNYAN	18BR CMS	$\tilde{\chi}^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm$, AMSB, $\tan\beta = 5$ and $\mu > 0$, $\tau = 7 \text{ ns}$
> 505	95	³ SIRUNYAN	18BR CMS	$\tilde{\chi}^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm$, AMSB, $\tan\beta = 5$, $\mu > 0$, $0.5 \text{ ns} > \tau > 60 \text{ ns}$
> 620	95	⁴ AAD	15AE ATLS	stable $\tilde{\chi}^\pm$
> 534	95	⁵ AAD	15BM ATLS	stable $\tilde{\chi}^\pm$
> 239	95	⁵ AAD	15BM ATLS	$\tilde{\chi}^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm$, lifetime 1 ns, $m_{\tilde{\chi}^\pm} - m_{\tilde{\chi}_1^0} = 0.14 \text{ GeV}$
> 482	95	⁵ AAD	15BM ATLS	$\tilde{\chi}^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm$, lifetime 15 ns, $m_{\tilde{\chi}^\pm} - m_{\tilde{\chi}_1^0} = 0.14 \text{ GeV}$
> 103	95	⁶ AAD	13H ATLS	long-lived $\tilde{\chi}^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm$, mAMSB, $\Delta m_{\tilde{\chi}_1^\pm} = 160 \text{ MeV}$
> 92	95	⁷ AAD	12BJ ATLS	long-lived $\tilde{\chi}^\pm \rightarrow \pi^\pm \tilde{\chi}_1^0$, mAMSB
> 171	95	⁸ ABAZOV	09M D0	\tilde{H}
> 102	95	⁹ ABBIENDI	03L OPAL	$m_{\tilde{\nu}} > 500 \text{ GeV}$
none 2–93.0	95	¹⁰ ABREU	00T DLPH	\tilde{H}^\pm or $m_{\tilde{\nu}} > m_{\tilde{\chi}^\pm}$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
> 260	95	¹¹ KHACHATRY...15AB	CMS	$\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm, \tau_{\tilde{\chi}_1^\pm} = 0.2 \text{ ns}$, AMSB
> 800	95	¹² KHACHATRY...15A0	CMS	long-lived $\tilde{\chi}_1^\pm$, mAMSB, $\tau > 100 \text{ ns}$
> 100	95	¹² KHACHATRY...15A0	CMS	long-lived $\tilde{\chi}_1^\pm$, mAMSB, $\tau > 3 \text{ ns}$
> 100	95	¹³ KHACHATRY...15W	CMS	long-lived $\tilde{\chi}^0, \tilde{q} \rightarrow q \tilde{\chi}^0, \tilde{\chi}^0 \rightarrow \ell^\pm \ell^\mp \nu$, RPV disappearing-track signature, AMSB
> 270	95	¹⁴ AAD	13BD ATLS	long-lived $\tilde{\chi}^\pm$, gaugino-like
> 278	95	¹⁵ ABAZOV	13B D0	long-lived $\tilde{\chi}^\pm$, higgsino-like
> 244	95	¹⁵ ABAZOV	13B D0	long-lived $\tilde{\chi}^\pm$, higgsino-like

- ¹ AABOUD 19AT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for metastable R -hadrons. Multiple search strategies for a wide range of lifetimes, corresponding to path lengths of a few meters, are defined. No significant deviations from the expected Standard Model background are observed. Results are interpreted in terms of direct electroweak production of long-lived charginos in the context of mAMSB scenarios. Chargino masses are excluded at 95% C.L. below 1090 GeV. See their Figure 10 (right).
- ² AABOUD 18AS searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of long-lived charginos in the context of AMSB or phenomenological MSSM scenarios with wino-like LSP. Events with a disappearing track due to a low-momentum pion accompanied by at least one jet with high transverse momentum from initial-state radiation are considered. No significant excess above the Standard Model expectations is observed. Exclusion limits are set at 95% confidence level on the mass of charginos for different chargino lifetimes. For a pure wino with a lifetime of about 0.2 ns, corresponding to a mass-splitting between the charged and neutral wino of around 160 MeV, chargino masses up to 460 GeV are excluded, see their Fig. 8.
- ³ SIRUNYAN 18BR searched in 38.4 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of long-lived charginos in events containing isolated tracks with missing hits in the outer layer of the silicon tracker and little or no associated calorimetric energy deposits (disappearing tracks). No significant excess above the Standard Model expectations is observed. In an AMSB context, limits are set on the cross section of direct chargino production through $pp \rightarrow \tilde{\chi}^{\pm} \tilde{\chi}^{\mp}$ and $pp \rightarrow \tilde{\chi}^{\pm} \tilde{\chi}_1^0$, assuming $\text{BR}(\tilde{\chi}^{\pm} \rightarrow \tilde{\chi}_1^0 \pi^{\pm}) = 100\%$, as a function of the chargino mass and mean proper lifetime, see Figures 3, 4 and 5.
- ⁴ AAD 15AE searched in 19.1 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for heavy long-lived charged particles, measured through their specific ionization energy loss in the ATLAS pixel detector or their time-of-flight in the ATLAS muon system. In the absence of an excess of events above the expected backgrounds, limits are set on stable charginos, see Fig. 10.
- ⁵ AAD 15BM searched in 18.4 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for stable and metastable non-relativistic charged particles through their anomalous specific ionization energy loss in the ATLAS pixel detector. In absence of an excess of events above the expected backgrounds, limits are set on stable charginos (see Table 5) and on metastable charginos decaying to $\tilde{\chi}_1^0 \pi^{\pm}$, see Fig. 11.
- ⁶ AAD 13H searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for direct electroweak production of long-lived charginos in the context of AMSB scenarios. The search is based on the signature of a high-momentum isolated track with few associated hits in the outer part of the tracking system, arising from a chargino decay into a neutralino and a low-momentum pion. The p_T spectrum of the tracks was found to be consistent with the SM expectations. Constraints on the lifetime and the production cross section were obtained, see Fig. 6. In the minimal AMSB framework with $\tan\beta = 5$, and $\mu > 0$, a chargino having a mass below 103 (85) GeV for a chargino-neutralino mass splitting $\Delta m_{\tilde{\chi}_1^0}$ of 160 (170) MeV is excluded at the 95% C.L. See Fig. 7 for more precise bounds.
- ⁷ AAD 12BJ looked in 1.02 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for signatures of decaying charginos resulting in isolated tracks with few associated hits in the outer region of the tracking system. The p_T spectrum of the tracks was found to be consistent with the SM expectations. Constraints on the lifetime and the production cross section were obtained. In the minimal AMSB framework with $m_{3/2} < 32 \text{ TeV}$, $m_0 < 1.5 \text{ TeV}$, $\tan\beta = 5$, and $\mu > 0$, a chargino having a mass below 92 GeV and a lifetime between 0.5 ns and 2 ns is excluded at the 95% C.L. See their Fig. 8 for more precise bounds.
- ⁸ ABAZOV 09M searched in 1.1 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for events with direct production of a pair of charged massive stable particles identified by their TOF. The number of the observed events is consistent with the predicted background. The data are used to constrain the production cross section as a function of the $\tilde{\chi}_1^{\pm}$ mass, see their Fig. 2. The quoted limit improves to 206 GeV for gaugino-like charginos.
- ⁹ ABBENDI 03L used e^+e^- data at $\sqrt{s} = 130\text{--}209 \text{ GeV}$ to select events with two high momentum tracks with anomalous dE/dx . The excluded cross section is compared to the theoretical expectation as a function of the heavy particle mass in their Fig. 3. The bounds are valid for colorless fermions with lifetime longer than 10^{-6} s . Supersedes the results from ACKERSTAFF 98P.
- ¹⁰ ABREU 00T searches for the production of heavy stable charged particles, identified by their ionization or Cherenkov radiation, using data from $\sqrt{s} = 130$ to 189 GeV. These limits include and update the results of ABREU 98P.
- ¹¹ KHACHATRYAN 15AB searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing tracks with little or no associated calorimetric energy deposits and with missing hits in the outer layers of the tracking system (disappearing-track signature). Such disappearing tracks can result from the decay of charginos that are nearly mass degenerate with the lightest neutralino. The number of observed events is in agreement with the background expectation. Limits are set on the cross section of electroweak chargino production in terms of the chargino mass and mean proper lifetime, see Fig. 4. In the minimal AMSB model, a chargino mass below 260 GeV is excluded at 95% C.L., see their Fig. 5.
- ¹² KHACHATRYAN 15O searched in 18.8 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for evidence of long-lived charginos in the context of AMSB and pMSSM scenarios. The results are based on a previously published search for heavy stable charged particles at 7 and 8 TeV. In the minimal AMSB framework with $\tan\beta = 5$ and $\mu \geq 0$, constraints on the chargino mass and lifetime were placed, see Fig. 5. Charginos with a mass below 800 (100) GeV are excluded at the 95% C.L. for lifetimes above 100 ns (3 ns). Constraints are also placed on the pMSSM parameter space, see Fig. 3.
- ¹³ KHACHATRYAN 15W searched in up to 20.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for evidence of long-lived neutralinos produced through $\tilde{q}\text{-pair}$ production, with $\tilde{q} \rightarrow q\tilde{\chi}^0$ and $\tilde{\chi}^0 \rightarrow \ell^+ \ell^- \nu$ (RPV: $\lambda_{121}, \lambda_{122} \neq 0$). 95% C.L. exclusion limits on cross section times branching ratio are set as a function of mean proper decay length of the neutralino, see Figs. 6 and 9.
- ¹⁴ AAD 13BD searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing tracks with no associated hits in the outer region of the tracking system resulting from the decay of charginos that are nearly mass degenerate with the lightest neutralino, as is often the case in AMSB scenarios. No significant excess above the background expectation is observed for candidate tracks with large transverse momentum. Constraints on chargino properties are obtained and in the minimal AMSB model, a chargino mass below 270 GeV is excluded at 95% C.L., see their Fig. 7.
- ¹⁵ ABAZOV 13B looked in 6.3 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for charged massive long-lived particles in events with muon-like particles that have both speed and ionization energy loss inconsistent with muons produced in beam collisions. In the absence of an excess, limits are set at 95% C.L. on gaugino- and higgsino-like charginos, see their Table 20 and Fig. 23.

 $\tilde{\nu}$ (Sneutrino) mass limit

The limits may depend on the number, $M(\tilde{\nu})$, of sneutrinos assumed to be degenerate in mass. Only $\tilde{\nu}_L$ (not $\tilde{\nu}_R$) is assumed to exist. It is possible that $\tilde{\nu}$ could be the lightest supersymmetric particle (LSP).

We report here, but do not include in the Listings, the limits obtained from the fit of the final results obtained by the LEP Collaborations on the invisible width of the Z boson ($\Delta\Gamma_{\text{inv.}} < 2.0 \text{ MeV}$, LEP-SLC 06): $m_{\tilde{\nu}} > 43.7 \text{ GeV}$ ($M(\tilde{\nu})=1$) and $m_{\tilde{\nu}} > 44.7 \text{ GeV}$ ($M(\tilde{\nu})=3$).

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, et al. (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>3400	95	¹ AABOUD	18CM ATLS	RPV, $\tilde{\nu}_\tau \rightarrow e\mu$, $\lambda_{312} = \lambda_{321} = 0.07$, $\lambda'_{311} = 0.11$
>2900	95	² AABOUD	18CM ATLS	RPV, $\tilde{\nu}_\tau \rightarrow e\tau$, $\lambda_{313} = \lambda_{331} = 0.07$, $\lambda'_{311} = 0.11$
>2600	95	³ AABOUD	18CM ATLS	RPV, $\tilde{\nu}_\tau \rightarrow \mu\tau$, $\lambda_{323} = \lambda_{332} = 0.07$, $\lambda'_{311} = 0.11$
>1060	95	⁴ AABOUD	18Z ATLS	RPV, $\geq 4\ell$, $\lambda_{12k} \neq 0$, $m_{\tilde{\chi}_1^0} = 600 \text{ GeV}$ (mass-degenerate left-handed sleptons and sneutrinos of all 3 generations)
> 780	95	⁴ AABOUD	18Z ATLS	RPV, $\geq 4\ell$, $\lambda_{333} \neq 0$, $m_{\tilde{\chi}_1^0} = 300 \text{ GeV}$ (mass-degenerate left-handed sleptons and sneutrinos of all 3 generations)
>1700	95	⁵ SIRUNYAN	18AT CMS	RPV, $\tilde{\nu}_\tau \rightarrow e\mu$, $\lambda_{132} = \lambda_{231} = \lambda'_{311} = 0.01$
>3800	95	⁵ SIRUNYAN	18AT CMS	RPV, $\tilde{\nu}_\tau \rightarrow e\mu$, $\lambda_{132} = \lambda_{231} = \lambda'_{311} = 0.1$
>2300	95	⁶ AABOUD	16P ATLS	RPV, $\tilde{\nu}_\tau \rightarrow e\mu$, $\lambda'_{311} = 0.11$
>2200	95	⁶ AABOUD	16P ATLS	RPV, $\tilde{\nu}_\tau \rightarrow e\tau$, $\lambda'_{311} = 0.11$
>1900	95	⁶ AABOUD	16P ATLS	RPV, $\tilde{\nu}_\tau \rightarrow \mu\tau$, $\lambda'_{311} = 0.11$
> 400	95	⁷ AAD	14X ATLS	RPV, $\geq 4\ell^{\pm}$, $\tilde{\nu} \rightarrow \nu\tilde{\chi}_1^0$, $\tilde{\chi}_1^0 \rightarrow \ell^{\pm} \ell^{\mp} \nu$
> 94	95	⁸ AAD	11Z ATLS	RPV, $\tilde{\nu}_\tau \rightarrow e\mu$
> 84	95	⁹ ABDALLAH	03M DLPH	$1 \leq \tan\beta \leq 40$, $m_{\tilde{e}_R} - m_{\tilde{\chi}_1^0} > 10 \text{ GeV}$
> 41	95	¹⁰ HEISTER	02N ALEP	$\tilde{\nu}_e$, any Δm
> 41	95	¹¹ DECAMP	92 ALEP	$\Gamma(Z \rightarrow \text{invisible})$; $M(\tilde{\nu})=3$, model independent
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>1280	95	¹² SIRUNYAN	19AO	RPV, $\mu^{\pm}\mu^{\pm} + \geq 2\text{jets}$, $\lambda'_{211} \neq 0$, $\tilde{\nu}_\mu \rightarrow \mu\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_1^{\pm} \rightarrow \mu q\bar{q}q\bar{q}$
>2300	95	¹³ KHACHATRYAN...16BE	CMS	RPV, $\tilde{\nu}_\tau \rightarrow e\mu$, $\lambda_{132} = \lambda_{231} = \lambda_{311} = 0.01$
>2000	95	¹³ KHACHATRYAN...16BE	CMS	RPV, $\tilde{\nu}_\tau \rightarrow e\mu$, $\lambda_{132} = \lambda_{231} = 0.07$, $\lambda'_{311} = 0.11$
>1700	95	¹⁴ AAD	15O ATLS	RPV ($e\mu$), $\tilde{\nu}_\tau$, $\lambda'_{311} = 0.11$, $\lambda_{33k} = 0.07$
> 95	95	¹⁴ AAD	15O ATLS	RPV ($\tau\mu$, $e\tau$), $\tilde{\nu}_\tau$, $\lambda'_{311} = 0.11$, $\lambda_{33k} = 0.07$
> 37.1	95	¹⁵ AAD	13AI ATLS	RPV, $\tilde{\nu}_\tau \rightarrow e\mu$, $e\tau$, $\mu\tau$
> 36	95	¹⁶ AAD	11H ATLS	RPV, $\tilde{\nu}_\tau \rightarrow e\mu$
> 31.2	95	¹⁷ AALTONEN	10Z CDF	RPV, $\tilde{\nu}_\tau \rightarrow e\mu$, $e\tau$, $\mu\tau$
> 31.2	95	¹⁸ ABAZOV	10M D0	RPV, $\tilde{\nu}_\tau \rightarrow e\mu$
> 31.2	95	¹⁹ ABDALLAH	04H DLPH	AMSB, $\mu > 0$
> 31.2	95	²⁰ ADRIANI	93M L3	$\Gamma(Z \rightarrow \text{invisible})$; $M(\tilde{\nu})=1$
> 31.2	95	²¹ ABREU	91F DLPH	$\Gamma(Z \rightarrow \text{invisible})$; $M(\tilde{\nu})=1$
> 31.2	95	²¹ ALEXANDER	91F OPAL	$\Gamma(Z \rightarrow \text{invisible})$; $M(\tilde{\nu})=1$

¹ AABOUD 18CM searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for heavy particles decaying into an $e\mu$, $e\tau$, $\mu\tau$ final state. No significant deviation from the expected SM background is observed. Limits are set on the mass of a stau neutrino with R-parity-violating couplings. For $\tilde{\nu}_\tau \rightarrow e\mu$, masses below 3.4 TeV are excluded at 95% CL, see their Figure 4(b). Upper limits on the RPV couplings $|\lambda_{312}|$ versus $|\lambda'_{311}|$ are also performed, see their Figure 8(a-b).

² AABOUD 18CM searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for heavy particles decaying into an $e\mu$, $e\tau$, $\mu\tau$ final state. No significant deviation from the expected SM background is observed. Limits are set on the mass of a stau neutrino with R-parity-violating couplings. For $\tilde{\nu}_\tau \rightarrow e\tau$, masses below 2.9 TeV are excluded at 95% CL, see their Figure 5(b). Upper limits on the RPV couplings $|\lambda_{313}|$ versus $|\lambda'_{311}|$ are also performed, see their Figure 8(c).

³ AABOUD 18CM searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for heavy particles decaying into an $e\mu$, $e\tau$, $\mu\tau$ final state. No significant deviation from the expected SM background is observed. Limits are set on the mass of a stau neutrino with R-parity-violating couplings. For $\tilde{\nu}_\tau \rightarrow \mu\tau$, masses below 2.6 TeV are excluded at 95% CL, see their Figure 6(b). Upper limits on the RPV couplings $|\lambda_{323}|$ versus $|\lambda'_{311}|$ are also performed, see their Figure 8(d).

Searches Particle Listings

Supersymmetric Particle Searches

- ⁴ AABOUD 18Z searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing four or more charged leptons (electrons, muons and up to two hadronically decaying taus). No significant deviation from the expected SM background is observed. Limits are set on the Higgsino mass in simplified models of general gauge mediated supersymmetry Tn1A/Tn1B/Tn1C , see their Figure 9. Limits are also set on the wino, slepton, sneutrino and gluino mass in a simplified model of NLSP pair production with R-parity violating decays of the LSP via λ_{12k} or λ_{133} to charged leptons, see their Figures 7, 8.
- ⁵ SIRUNYAN 18AT searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for heavy resonances decaying into $e\mu$ final states. No significant excess above the Standard Model expectation is observed and 95% C.L. exclusions are placed on the cross section times branching ratio for the R-parity-violating production and decay of a supersymmetric tau sneutrino, see their Fig. 3.
- ⁶ AABOUD 16P searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with different flavour dilepton pairs ($e\mu, e\tau, \mu\tau$) from the production of $\tilde{\nu}_\tau$ via an RPV λ'_{311} coupling and followed by a decay via $\lambda_{312} = \lambda_{321} = 0.07$ for $e + \mu$, via $\lambda_{313} = \lambda_{331} = 0.07$ for $e + \tau$ and via $\lambda_{323} = \lambda_{332} = 0.07$ for $\mu + \tau$. No evidence for a dilepton resonance over the SM expectation is observed, and limits are derived on $m_{\tilde{\nu}}$ at 95% CL, see their Figs. 2(b), 3(b), 4(b), and Table 3.
- ⁷ AAD 14X searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least four leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the sneutrino mass in an R-parity violating simplified model where the decay $\tilde{\nu} \rightarrow \nu \tilde{\chi}_1^0$, with $\tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \nu$, takes place with a branching ratio of 100%, see Fig. 9.
- ⁸ AAD 11Z looked in 1.07 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with one electron and one muon of opposite charge from the production of $\tilde{\nu}_\tau$ via an RPV λ'_{311} coupling and followed by a decay via λ_{312} into $e + \mu$. No evidence for an (e, μ) resonance over the SM expectation is observed, and a limit is derived in the plane of λ'_{311} versus $m_{\tilde{\nu}}$ for three values of λ_{312} , see their Fig. 2. Masses $m_{\tilde{\nu}} < 1.32 \text{ (1.45) TeV}$ are excluded for $\lambda'_{311} = 0.10$ and $\lambda_{312} = 0.05$ ($\lambda'_{311} = 0.11$ and $\lambda_{312} = 0.07$).
- ⁹ ABDALLAH 03M uses data from $\sqrt{s} = 192\text{--}208 \text{ GeV}$ to obtain limits in the framework of the MSSM with gaugino and sfermion mass universality at the GUT scale. An indirect limit on the mass is derived by constraining the MSSM parameter space by the results from direct searches for neutralinos (including cascade decays) and for sleptons. These limits are valid for values of $M_2 < 1 \text{ TeV}$, $|\mu| \leq 1 \text{ TeV}$ with the $\tilde{\chi}_1^0$ as LSP. The quoted limit is obtained when there is no mixing in the third family. See Fig. 43 for the mass limits as a function of $\tan\beta$. These limits update the results of ABREU 00W.
- ¹⁰ HEISTER 02N derives a bound on $m_{\tilde{\nu}_e}$ by exploiting the mass relation between the $\tilde{\nu}_e$ and \tilde{e} , based on the assumption of universal GUT scale gaugino and scalar masses $m_{1/2}$ and m_0 and the search described in the \tilde{e} section. In the MSUGRA framework with radiative electroweak symmetry breaking, the limit improves to $m_{\tilde{\nu}_e} > 130 \text{ GeV}$, assuming a trilinear coupling $A_0=0$ at the GUT scale. See Figs. 5 and 7 for the dependence of the limits on $\tan\beta$.
- ¹¹ DECAMP 92 limit is from $\Gamma(\text{invisible})/\Gamma(\ell\ell) = 5.91 \pm 0.15$ ($N_\nu = 2.97 \pm 0.07$).
- ¹² SIRUNYAN 19AO searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing two same-sign muons and at last two jets, originating from resonant production of second-generation sleptons ($\tilde{\mu}_L, \tilde{\nu}_\mu$) via the R-parity violating coupling λ'_{211} to quarks. No significant excess above the Standard Model expectations is observed. Upper limits on cross sections are derived in the context of two simplified models, see their Figure 4. The cross section limits are translated into limits on λ'_{211} for a modified CMSSM, see their Figure 5.
- ¹³ KHACHATRYAN 16BE searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for evidence of narrow resonances decaying into $e\mu$ final states. No significant excess above the Standard Model expectation is observed and 95% C.L. exclusions are placed on the cross section times branching ratio for the production of an R-parity-violating supersymmetric tau sneutrino, see their Fig. 3.
- ¹⁴ AAD 15O searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for evidence of heavy particles decaying into $e\mu, e\tau$ or $\mu\tau$ final states. No significant excess above the Standard Model expectation is observed, and 95% C.L. exclusions are placed on the cross section times branching ratio for the production of an R-parity-violating supersymmetric tau sneutrino, applicable to any sneutrino flavour, see their Fig. 2.
- ¹⁵ AAD 13AI searched in 4.6 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for evidence of heavy particles decaying into $e\mu, e\tau$ or $\mu\tau$ final states. No significant excess above the Standard Model expectation is observed, and 95% C.L. exclusions are placed on the cross section times branching ratio for the production of an R-parity-violating supersymmetric tau sneutrino, see their Fig. 2. For couplings $\lambda'_{311} = 0.10$ and $\lambda_{33k} = 0.05$, the lower limits on the $\tilde{\nu}_\tau$ mass are 1610, 1110, 1100 GeV in the $e\mu, e\tau$, and $\mu\tau$ channels, respectively.
- ¹⁶ AAD 11H looked in 35 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with one electron and one muon of opposite charge from the production of $\tilde{\nu}_\tau$ via an RPV λ'_{311} coupling and followed by a decay via λ_{312} into $e + \mu$. No evidence for an excess over the SM expectation is observed, and a limit is derived in the plane of λ'_{311} versus $m_{\tilde{\nu}}$ for several values of λ_{312} , see their Fig. 2. Superseded by AAD 11Z.
- ¹⁷ AALTONEN 10Z searched in 1 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for events from the production $d\bar{d} \rightarrow \tilde{\nu}_\tau$ with the subsequent decays $\tilde{\nu}_\tau \rightarrow e\mu, \mu\tau, e\tau$ in the MSSM framework with RPV. Two isolated leptons of different flavor and opposite charges are required, with τ s identified by their hadronic decay. No statistically significant excesses are observed over the SM background. Upper limits on λ'_{311} times the branching ratio are listed in their Table III for various $\tilde{\nu}_\tau$ masses. Limits on the cross section times branching ratio for $\lambda'_{311} = 0.10$ and $\lambda_{33k} = 0.05$, displayed in Fig. 2, are used to set limits on the $\tilde{\nu}_\tau$ mass of 558 GeV for the $e\mu$, 441 GeV for the $\mu\tau$ and 442 GeV for the $e\tau$ channels.
- ¹⁸ ABAZOV 10M looked in 5.3 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for events with exactly one pair of high p_T isolated $e\mu$ and a veto against hard jets. No evidence for an excess over the SM expectation is observed, and a limit at 95% C.L. on the cross section times branching ratio is derived, see their Fig. 3. These limits are translated into limits on couplings as a function of $m_{\tilde{\nu}_\tau}$ as shown on their Fig. 4. As an example, for $m_{\tilde{\nu}_\tau} = 100 \text{ GeV}$ and $\lambda_{312} \leq 0.07$, couplings $\lambda'_{311} > 7.7 \times 10^{-4}$ are excluded.
- ¹⁹ ABDALLAH 04H use data from LEP 1 and $\sqrt{s} = 192\text{--}208 \text{ GeV}$. They re-use results or re-analyze the data from ABDALLAH 03M to put limits on the parameter space of anomaly-mediated supersymmetry breaking (AMSB), which is scanned in the region $1 < m_{3/2} < 50 \text{ TeV}$, $0 < m_0 < 1000 \text{ GeV}$, $1.5 < \tan\beta < 35$, both signs of μ . The constraints

are obtained from the searches for mass degenerate chargino and neutralino, for SM-like and invisible Higgs, for leptonically decaying charginos and from the limit on non-SM Z width of 3.2 MeV. The limit is for $m_t = 174.3 \text{ GeV}$ (see Table 2 for other m_t values). The limit improves to 114 GeV for $\mu < 0$.

²⁰ ADRIANI 93M limit from $\Delta\Gamma(Z)(\text{invisible}) < 16.2 \text{ MeV}$.

²¹ ALEXANDER 91F limit is for one species of $\tilde{\nu}$ and is derived from $\Gamma(\text{invisible, new})/\Gamma(\ell\ell) < 0.38$.

Charged sleptons

This section contains limits on charged scalar leptons ($\tilde{\ell}$, with $\ell=e, \mu, \tau$). Studies of width and decays of the Z boson (use is made here of $\Delta\Gamma_{\text{inv}} < 2.0 \text{ MeV}$, LEP 00) conclusively rule out $m_{\tilde{\ell}_R} < 40 \text{ GeV}$ (41 GeV for $\tilde{\ell}_L$), independently of decay modes, for each individual slepton. The limits improve to 43 GeV (43.5 GeV for $\tilde{\ell}_L$) assuming all 3 flavors to be degenerate. Limits on higher mass sleptons depend on model assumptions and on the mass splitting $\Delta m = m_{\tilde{\ell}} - m_{\tilde{\chi}_1^0}$. The mass and composition

of $\tilde{\chi}_1^0$ may affect the selectron production rate in e^+e^- collisions through t -channel exchange diagrams. Production rates are also affected by the potentially large mixing angle of the lightest mass eigenstate $\tilde{\ell}_1 = \tilde{\ell}_R \sin\theta_{\tilde{\ell}} + \tilde{\ell}_L \cos\theta_{\tilde{\ell}}$. It is generally assumed that only $\tilde{\tau}$ may have significant mixing. The coupling to the Z vanishes for $\theta_{\tilde{\ell}}=0.82$. In the high-energy limit of e^+e^- collisions the interference between γ and Z exchange leads to a minimal cross section for $\theta_{\tilde{\ell}}=0.91$, a value which is sometimes used in the following entries relative to data taken at LEP2. When limits on $m_{\tilde{\ell}_R}$ are quoted, it is understood that limits on $m_{\tilde{\ell}_L}$ are usually at least as strong.

Possibly open decays involving gauginos other than $\tilde{\chi}_1^0$ will affect the detection efficiencies. Unless otherwise stated, the limits presented here result from the study of $\tilde{\ell}^+\tilde{\ell}^-$ production, with production rates and decay properties derived from the MSSM. Limits made obsolete by the recent analyses of e^+e^- collisions at high energies can be found in previous Editions of this Review.

For decays with final state gravitinos (\tilde{G}), $m_{\tilde{G}}$ is assumed to be negligible relative to all other masses.

R-parity conserving \tilde{e} (Selectron) mass limit

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, et al. (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>250	95	¹ SIRUNYAN	19AW CMS	$\ell^\pm \ell^\mp + \not{E}_T, \tilde{e}_R, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>310	95	¹ SIRUNYAN	19AW CMS	$\ell^\pm \ell^\mp + \not{E}_T, \tilde{e}_L, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>350	95	¹ SIRUNYAN	19AW CMS	$\ell^\pm \ell^\mp + \not{E}_T, m_{\tilde{e}_R} = m_{\tilde{e}_L}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>290	95	¹ SIRUNYAN	19AW CMS	$\ell^\pm \ell^\mp + \not{E}_T, \tilde{e}_R \text{ and } \tilde{e}_L, \tilde{\mu}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>400	95	¹ SIRUNYAN	19AW CMS	$\ell^\pm \ell^\mp + \not{E}_T, \tilde{e}_L \text{ and } \tilde{e}_R, \tilde{\mu}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>450	95	¹ SIRUNYAN	19AW CMS	$\ell^\pm \ell^\mp + \not{E}_T, m_{\tilde{e}_R} = m_{\tilde{e}_L} \text{ and } \tilde{e} = \tilde{e}, \tilde{\mu}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>500	95	² AABOUD	18BT ATLS	$2\ell + \not{E}_T, m_{\tilde{e}_R} = m_{\tilde{e}_L} \text{ and } \tilde{e} = \tilde{e}, \tilde{\mu}, \tilde{\tau}, \text{ with } m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>190	95	³ AABOUD	18R ATLS	$2\ell(\text{soft}) + \not{E}_T, m_{\tilde{e}} = m_{\tilde{\mu}}, m_{\tilde{e}} - m_{\tilde{\mu}} = 5 \text{ GeV}$
		⁴ CHATRCHYAN14R	CMS	$\geq 3\ell^\pm, \tilde{e} \rightarrow \ell^\pm \tau^\mp \tau^\mp \tilde{G}$ simplified model, GMSB, stau (N)NLSP scenario
> 97.5		⁵ AAD	13B ATLS	$2\ell^\pm + \not{E}_T, \text{SMS, pMSSM}$
> 94.4		⁶ ABBIENDI	04 OPAL	$\tilde{e}_R, \Delta m > 11 \text{ GeV}, \mu > 100 \text{ GeV}, \tan\beta=1.5$
> 71.3		⁷ ACHARD	04 L3	$\tilde{e}_R, \Delta m > 10 \text{ GeV}, \mu > 200 \text{ GeV}, \tan\beta \geq 2$
none 30–94	95	⁸ ACHARD	04 L3	$\tilde{e}_R, \text{all } \Delta m$
> 94	95	⁹ ABDALLAH	03M DLPH	$\Delta m > 15 \text{ GeV}, \tilde{e}_R^+ \tilde{e}_R^-$
> 95	95	¹⁰ ABDALLAH	03M DLPH	$\tilde{e}_R, 1 \leq \tan\beta \leq 40, \Delta m > 10 \text{ GeV}$
> 73	95	¹¹ HEISTER	02E ALEP	$\Delta m > 15 \text{ GeV}, \tilde{e}_R^+ \tilde{e}_R^-$
>107	95	¹¹ HEISTER	02N ALEP	$\tilde{e}_R, \text{any } \Delta m$
		¹¹ HEISTER	02N ALEP	$\tilde{e}_L, \text{any } \Delta m$
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
none 90–325	95	¹² AAD	14G ATLS	$\tilde{e}\tilde{e} \rightarrow \ell^+ \tilde{\chi}_1^0 \ell^- \tilde{\chi}_1^0$, simplified model, $m_{\tilde{e}} = m_{\tilde{\tau}}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
		¹³ KHACHATRYAN14I	CMS	$\tilde{e} \rightarrow \ell \tilde{\chi}_1^0$, simplified model

¹ SIRUNYAN 19AW searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak pair production of selectrons or smuons in events with two leptons (electrons or muons) of the opposite electric charge and same flavour, no jets and large \not{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the selectron mass assuming left-handed, right-handed or both left- and right-handed (mass degenerate) production, see their Figure 6. Similarly, limits are set on the smuon mass, see their Figure 7. Limits are also set on slepton masses under the assumption that the selectron and smuon are mass degenerate, see their Figure 5.

See key on page 999

Searches Particle Listings

Supersymmetric Particle Searches

- ² AABOUD 18BT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos, chargino and next-to-lightest neutralinos and sleptons in events with two or three leptons (electrons or muons), with or without jets, and large missing transverse energy. No significant excess above the Standard Model expectations is observed. Limits are set on the slepton mass up to 500 GeV for massless $\tilde{\chi}_1^0$, assuming degeneracy of \tilde{e} , $\tilde{\mu}$, and $\tilde{\tau}$ and exploiting the 2ℓ signature, see their Figure 8(b).
- ³ AABOUD 18R searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for electroweak production in scenarios with compressed mass spectra in final states with two low-momentum leptons and missing transverse momentum. The data are found to be consistent with the SM prediction. Results are interpreted in slepton pair production models with a fourfold degeneracy assumed in selectron and smuon masses. The \tilde{e} masses are excluded up to 190 GeV for $m_{\tilde{e}} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$. The exclusion limits extend down to mass splittings of 1 GeV, see their Fig. 11.
- ⁴ CHATRCHYAN 14R searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least three leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the slepton mass in a stau (N)NLSM simplified model (GMSB) where the decay $\tilde{e} \rightarrow e^\pm \tau^\pm \tau^\mp \tilde{G}$ takes place with a branching ratio of 100%, see Fig. 8.
- ⁵ AAD 13B searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for sleptons decaying to a final state with two leptons (e and μ) and missing transverse energy. No excess beyond the Standard Model expectation is observed. Limits are derived in a simplified model of direct left-handed slepton pair production, where left-handed slepton masses between 85 and 195 GeV are excluded at 95% C.L. for $m_{\tilde{\chi}_1^0} = 20 \text{ GeV}$. See also Fig. 2(a). Exclusion limits are also derived in the phenomenological MSSM, see Fig. 3.
- ⁶ ABBIENDI 04 search for $\tilde{e}_R \tilde{e}_R$ production in acoplanar di-electron final states in the 183–208 GeV data. See Fig. 13 for the dependence of the limits on $m_{\tilde{\chi}_1^0}$ and for the limit at $\tan\beta=35$. This limit supersedes ABBIENDI 00G.
- ⁷ ACHARD 04 search for $\tilde{e}_R \tilde{e}_L$ and $\tilde{e}_R \tilde{e}_R$ production in single- and acoplanar di-electron final states in the 192–209 GeV data. Absolute limits on $m_{\tilde{e}_R}$ are derived from a scan over the MSSM parameter space with universal GUT scale gaugino and scalar masses $m_{1/2}$ and m_0 , $1 \leq \tan\beta \leq 60$ and $-2 \leq \mu \leq 2 \text{ TeV}$. See Fig. 4 for the dependence of the limits on $m_{\tilde{\chi}_1^0}$. This limit supersedes ACCIARRI 99w.
- ⁸ ABDALLAH 03M looked for acoplanar dilepton + \cancel{E}_T final states at $\sqrt{s} = 189\text{--}208 \text{ GeV}$. The limit assumes $\mu = -200 \text{ GeV}$ and $\tan\beta=1.5$ in the calculation of the production cross section and $B(\tilde{e} \rightarrow e \tilde{\chi}_1^0)$. See Fig. 15 for limits in the $(m_{\tilde{e}_R}, m_{\tilde{\chi}_1^0})$ plane. These limits include and update the results of ABREU 01.
- ⁹ ABDALLAH 03M uses data from $\sqrt{s} = 192\text{--}208 \text{ GeV}$ to obtain limits in the framework of the MSSM with gaugino and sfermion mass universality at the GUT scale. An indirect limit on the mass is derived by constraining the MSSM parameter space by the results from direct searches for neutralinos (including cascade decays) and for sleptons. These limits are valid for values of $M_2 < 1 \text{ TeV}$, $|\mu| \leq 1 \text{ TeV}$ with the $\tilde{\chi}_1^0$ as LSP. The quoted limit is obtained when there is no mixing in the third family. See Fig. 43 for the mass limits as a function of $\tan\beta$. These limits update the results of ABREU 00w.
- ¹⁰ HEISTER 02E looked for acoplanar dilepton + \cancel{E}_T final states from e^+e^- interactions between 183 and 209 GeV. The mass limit assumes $\mu < -200 \text{ GeV}$ and $\tan\beta=2$ for the production cross section and $B(\tilde{e} \rightarrow e \tilde{\chi}_1^0)=1$. See their Fig. 4 for the dependence of the limit on Δm . These limits include and update the results of BARATE 01.
- ¹¹ HEISTER 02N search for $\tilde{e}_R \tilde{e}_L$ and $\tilde{e}_R \tilde{e}_R$ production in single- and acoplanar di-electron final states in the 183–208 GeV data. Absolute limits on $m_{\tilde{e}_R}$ are derived from a scan over the MSSM parameter space with universal GUT scale gaugino and scalar masses $m_{1/2}$ and m_0 , $1 \leq \tan\beta \leq 50$ and $-10 \leq \mu \leq 10 \text{ TeV}$. The region of small $|\mu|$, where cascade decays are important, is covered by a search for $\tilde{\chi}_1^0 \tilde{\chi}_3^0$ in final states with leptons and possibly photons. Limits on $m_{\tilde{e}_L}$ are derived by exploiting the mass relation between the \tilde{e}_L and \tilde{e}_R , based on universal m_0 and $m_{1/2}$. When the constraint from the mass limit of the lightest Higgs from HEISTER 02 is included, the bounds improve to $m_{\tilde{e}_R} > 77(75) \text{ GeV}$ and $m_{\tilde{e}_L} > 115(115) \text{ GeV}$ for a top mass of 175(180) GeV. In the MSUGRA framework with radiative electroweak symmetry breaking, the limits improve further to $m_{\tilde{e}_R} > 95 \text{ GeV}$ and $m_{\tilde{e}_L} > 152 \text{ GeV}$, assuming a trilinear coupling $A_0=0$ at the GUT scale. See Figs. 4, 5, 7 for the dependence of the limits on $\tan\beta$.
- ¹² AAD 14G searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for electroweak production of slepton pairs, decaying to a final state with two leptons (e and μ) and missing transverse momentum. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in simplified models of slepton pair production, see Fig. 8. An interpretation in the pMSSM is also given, see Fig. 10.
- ¹³ KHACHATRYAN 14I searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for electroweak production of slepton pairs decaying to a final state with opposite-sign lepton pairs (e or μ) and missing transverse momentum. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in simplified models, see Fig. 18.

R-parity violating \tilde{e} (Selectron) mass limit

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, et al. (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1065	95	¹ AABOUD 18Z ATLS		$\geq 4\ell, \lambda_{12k} \neq 0, m_{\tilde{\chi}_1^0} = 600 \text{ GeV}$ (mass-degenerate left-handed sleptons and sneutrinos of all 3 generations)
> 780	95	¹ AABOUD 18Z ATLS		$\geq 4\ell, \lambda_{133} \neq 0, m_{\tilde{\chi}_1^0} = 300 \text{ GeV}$ (mass-degenerate left-handed sleptons and sneutrinos of all 3 generations)
> 410	95	² AAD 14X ATLS		RPV, $\geq 4\ell^\pm, \tilde{e} \rightarrow \ell^\pm \tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \nu$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
> 89	95	³ ABBIENDI 04F OPAL	RPV, \tilde{e}_L	
> 92	95	⁴ ABDALLAH 04M DPH	RPV, \tilde{e}_R , indirect, $\Delta m > 5 \text{ GeV}$	

- ¹ AABOUD 18Z searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing four or more charged leptons (electrons, muons and up to two hadronically decaying taus). No significant deviation from the expected SM background is observed. Limits are set on the Higgsino mass in simplified models of general gauge mediated supersymmetry Tn1nA/Tn1nB/Tn1nC, see their Figure 9. Limits are also set on the wino, slepton, sneutrino and gluino mass in a simplified model of NLSM pair production with R-parity violating decays of the LSP via λ_{12k} or λ_{133} to charged leptons, see their Figures 7, 8.
- ² AAD 14X searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least four leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the slepton mass in an R-parity violating simplified model where the decay $\tilde{e} \rightarrow \ell \tilde{\chi}_1^0$, with $\tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \nu$, takes place with a branching ratio of 100%, see Fig. 9.
- ³ ABBIENDI 04F use data from $\sqrt{s} = 189\text{--}209 \text{ GeV}$. They derive limits on sparticle masses under the assumption of RPV with $LL\tilde{E}$ or $LQ\tilde{D}$ couplings. The results are valid for $\tan\beta = 1.5$, $\mu = -200 \text{ GeV}$, with, in addition, $\Delta m > 5 \text{ GeV}$ for indirect decays via $LQ\tilde{D}$. The limit quoted applies to direct decays via $LL\tilde{E}$ or $LQ\tilde{D}$ couplings. For indirect decays, the limits on the \tilde{e}_R mass are respectively 99 and 92 GeV for $LL\tilde{E}$ and $LQ\tilde{D}$ couplings and $m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$ and degrade slightly for larger $\tilde{\chi}_1^0$ mass. Supersedes the results of ABBIENDI 00.
- ⁴ ABDALLAH 04M use data from $\sqrt{s} = 192\text{--}208 \text{ GeV}$ to derive limits on sparticle masses under the assumption of RPV with $LL\tilde{E}$ or $UD\tilde{D}$ couplings. The results are valid for $\mu = -200 \text{ GeV}$, $\tan\beta = 1.5$, $\Delta m > 5 \text{ GeV}$ and assuming a BR of 1 for the given decay. The limit quoted is for indirect $UD\tilde{D}$ decays using the neutralino constraint of 39.5 GeV for $LL\tilde{E}$ and of 38.0 GeV for $UD\tilde{D}$ couplings, also derived in ABDALLAH 04M. For indirect decays via $LL\tilde{E}$ the limit improves to 95 GeV if the constraint from the neutralino is used and to 94 GeV if it is not used. For indirect decays via $UD\tilde{D}$ couplings it remains unchanged when the neutralino constraint is not used. Supersedes the result of ABREU 00U.

R-parity conserving $\tilde{\mu}$ (Smuon) mass limit

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>210	95	¹ SIRUNYAN 19AW CMS		$\ell^\pm \ell^\mp + \cancel{E}_T, \tilde{\mu}_R, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>280	95	¹ SIRUNYAN 19AW CMS		$\ell^\pm \ell^\mp + \cancel{E}_T, \tilde{\mu}_L, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>290	95	¹ SIRUNYAN 19AW CMS		$\ell^\pm \ell^\mp + \cancel{E}_T, \tilde{e}_R$ and $\tilde{e} = \tilde{e}, \tilde{\mu}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>400	95	¹ SIRUNYAN 19AW CMS		$\ell^\pm \ell^\mp + \cancel{E}_T, \tilde{e}_L$ and $\tilde{e} = \tilde{e}, \tilde{\mu}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>450	95	¹ SIRUNYAN 19AW CMS		$\ell^\pm \ell^\mp + \cancel{E}_T, m_{\tilde{e}_R} = m_{\tilde{e}_L}$ and $\tilde{e} = \tilde{e}, \tilde{\mu}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>310	95	¹ SIRUNYAN 19AW CMS		$\ell^\pm \ell^\mp + \cancel{E}_T, m_{\tilde{\mu}_R} = m_{\tilde{\mu}_L}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>190	95	² AABOUD 18R ATLS		$2\ell + \cancel{E}_T, m_{\tilde{e}} = m_{\tilde{\mu}}, m_{\tilde{\mu}} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$
		³ CHATRCHYAN 14R CMS		$\geq 3\ell^\pm, \tilde{e} \rightarrow \ell^\pm \tau^\pm \tau^\mp \tilde{G}$ simplified model, GMSB, stau (N)NLSM scenario
		⁴ AAD 13B ATLS		$2\ell^\pm + \cancel{E}_T, \text{SMS, pMSSM}$
> 91.0		⁵ ABBIENDI 04 OPAL		$\Delta m > 3 \text{ GeV}, \tilde{\mu}_R^\pm \tilde{\mu}_R^\mp, \mu > 100 \text{ GeV}, \tan\beta=1.5$
> 86.7		⁶ ACHARD 04 L3		$\Delta m > 10 \text{ GeV}, \tilde{\mu}_R^\pm \tilde{\mu}_R^\mp, \mu > 200 \text{ GeV}, \tan\beta \geq 2$
none 30–88	95	⁷ ABDALLAH 03M DPH		$\Delta m > 5 \text{ GeV}, \tilde{\mu}_R^\pm \tilde{\mu}_R^\mp$
> 94	95	⁸ ABDALLAH 03M DPH		$\tilde{\mu}_R, 1 \leq \tan\beta \leq 40, \Delta m > 10 \text{ GeV}$
> 88	95	⁹ HEISTER 02E ALEP		$\Delta m > 15 \text{ GeV}, \tilde{\mu}_R^\pm \tilde{\mu}_R^\mp$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>500	95	¹⁰ AABOUD 18BT ATLS		$2\ell + \cancel{E}_T, m_{\tilde{e}_R} = m_{\tilde{e}_L}$ and $\tilde{e} = \tilde{e}, \tilde{\mu}, \tilde{\tau}$, with $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
none 90–325	95	¹¹ AAD 14G ATLS		$\tilde{e}\tilde{e} \rightarrow \ell^\pm \tilde{\chi}_1^0 \ell^\mp \tilde{\chi}_1^0$, simplified model, $m_{\tilde{e}_L} = m_{\tilde{e}_R}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
		¹² KHACHATRYAN 14I CMS		$\tilde{e} \rightarrow \ell \tilde{\chi}_1^0$, simplified model
> 80	95	¹³ ABREU 00V DPH		$\tilde{\mu}_R \tilde{\mu}_R \rightarrow \mu \tilde{G}, m_{\tilde{G}} > 8 \text{ eV}$

- ¹ SIRUNYAN 19AW searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak pair production of selectrons or smuons in events with two leptons (electrons or muons) of the opposite electric charge and same flavour, no jets and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the selectron mass assuming left-handed, right-handed or both left- and right-handed (mass degenerate) production, see their Figure 6. Similarly, limits are set on the smuon mass, see their Figure 7. Limits are also set on slepton masses under the assumption that the selectron and smuon are mass degenerate, see their Figure 5.
- ² AABOUD 18R searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for electroweak production in scenarios with compressed mass spectra in final states with two low-momentum leptons and missing transverse momentum. The data are found to be consistent with the SM prediction. Results are interpreted in slepton pair production models with a fourfold degeneracy assumed in selectron and smuon masses. The $\tilde{\mu}$ masses are excluded up to 190 GeV for $m_{\tilde{\mu}} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$. The exclusion limits extend down to mass splittings of 1 GeV, see their Fig. 11.
- ³ CHATRCHYAN 14R searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least three leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the slepton mass in a stau (N)NLSM simplified model (GMSB) where the decay $\tilde{e} \rightarrow \ell^\pm \tau^\pm \tau^\mp \tilde{G}$ takes place with a branching ratio of 100%, see Fig. 8.
- ⁴ AAD 13B searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for sleptons decaying to a final state with two leptons (e and μ) and missing transverse energy. No excess beyond

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the Standard Model expectation is observed. Limits are derived in a simplified model of direct left-handed slepton pair production, where left-handed slepton masses between 85 and 195 GeV are excluded at 95% C.L. for $m_{\tilde{\chi}_1^0} = 20$ GeV. See also Fig. 2(a). Exclusion limits are also derived in the phenomenological MSSM, see Fig. 3.

⁵ ABBIENDI 04 search for $\tilde{\mu}_R \tilde{\mu}_R$ production in acoplanar di-muon final states in the 183–208 GeV data. See Fig. 14 for the dependence of the limits on $m_{\tilde{\chi}_1^0}$ and for the

limit at $\tan\beta=35$. Under the assumption of 100% branching ratio for $\tilde{\mu}_R \rightarrow \mu \tilde{\chi}_1^0$, the limit improves to 94.0 GeV for $\Delta m > 4$ GeV. See Fig. 11 for the dependence of the limits on $m_{\tilde{\chi}_1^0}$ at several values of the branching ratio. This limit supersedes ABBIENDI 00G.

⁶ ACHARD 04 search for $\tilde{\mu}_R \tilde{\mu}_R$ production in acoplanar di-muon final states in the 192–209 GeV data. Limits on $m_{\tilde{\mu}_R}$ are derived from a scan over the MSSM parameter space with universal GUT scale gaugino and scalar masses $m_{1/2}$ and m_0 , $1 \leq \tan\beta \leq 60$ and $-2 \leq \mu \leq 2$ TeV. See Fig. 4 for the dependence of the limits on $m_{\tilde{\chi}_1^0}$. This limit supersedes ACCIARRI 99W.

⁷ ABDALLAH 03M looked for acoplanar dimuon + \cancel{E} final states at $\sqrt{s} = 189$ –208 GeV. The limit assumes $B(\tilde{\mu} \rightarrow \mu \tilde{\chi}_1^0) = 100\%$. See Fig. 16 for limits on the $(m_{\tilde{\mu}_R}, m_{\tilde{\chi}_1^0})$ plane. These limits include and update the results of ABREU 01.

⁸ ABDALLAH 03M uses data from $\sqrt{s} = 192$ –208 GeV to obtain limits in the framework of the MSSM with gaugino and sfermion mass universality at the GUT scale. An indirect limit on the mass is derived by constraining the MSSM parameter space by the results from direct searches for neutralinos (including cascade decays) and for sleptons. These limits are valid for values of $M_2 < 1$ TeV, $|\mu| \leq 1$ TeV with the $\tilde{\chi}_1^0$ as LSP. The quoted limit is obtained when there is no mixing in the third family. See Fig. 43 for the mass limits as a function of $\tan\beta$. These limits update the results of ABREU 00W.

⁹ HEISTER 02E looked for acoplanar dimuon + \cancel{E}_T final states from e^+e^- interactions between 183 and 209 GeV. The mass limit assumes $B(\tilde{\mu} \rightarrow \mu \tilde{\chi}_1^0) = 1$. See their Fig. 4 for the dependence of the limit on Δm . These limits include and update the results of BARATE 01.

¹⁰ AABOUD 18BT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for direct electroweak production of charginos, chargino and next-to-lightest neutralinos and sleptons in events with two or three leptons (electrons or muons), with or without jets, and large missing transverse energy. No significant excess above the Standard Model expectations is observed. Limits are set on the slepton mass up to 500 GeV for massless $\tilde{\chi}_1^0$, assuming degeneracy of \tilde{e} , $\tilde{\mu}$, and $\tilde{\tau}$ and exploiting the 2ℓ signature, see their Figure 8(b).

¹¹ AAD 14G searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV for electroweak production of slepton pairs, decaying to a final state with two leptons (e and μ) and missing transverse momentum. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in simplified models of slepton pair production, see Fig. 8. An interpretation in the pMSSM is also given, see Fig. 10.

¹² KHACHATRYAN 14I searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV for electroweak production of slepton pairs decaying to a final state with opposite-sign lepton pairs (e or μ) and missing transverse momentum. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in simplified models, see Fig. 18.

¹³ ABREU 00V use data from $\sqrt{s} = 130$ –189 GeV to search for tracks with large impact parameter or visible decay vertices. Limits are obtained as function of $m_{\tilde{G}}$, after combining these results with the search for slepton pair production in the SUGRA framework from ABREU 01 to cover prompt decays and on stable particle searches from ABREU 00Q. For limits at different $m_{\tilde{G}}$, see their Fig. 12.

R-parity violating $\tilde{\mu}$ (Smuon) mass limit

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
> 780	95	¹ AABOUD 18Z ATLS	18Z	$\geq 4\ell, \lambda_{133} \neq 0, m_{\tilde{\chi}_1^0} = 300 \text{ GeV}$ (mass-degenerate left-handed sleptons and sneutrinos of all 3 generations)
>1060	95	¹ AABOUD 18Z ATLS	18Z	$\geq 4\ell, \lambda_{12k} \neq 0, m_{\tilde{\chi}_1^0} = 600 \text{ GeV}$ (mass-degenerate left-handed sleptons and sneutrinos of all 3 generations)
> 410	95	² AAD 14X ATLS	14X	RPV, $\geq 4\ell^\pm, \tilde{\ell} \rightarrow \ell \tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \ell^\pm \tilde{\ell}^\mp \nu$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
		³ SIRUNYAN 19A0	19A0	$\mu^\pm \mu^\pm + \geq 2\text{jets}, \lambda'_{211} \neq 0, \tilde{\mu}_L \rightarrow \mu \tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \mu q \bar{q}$
> 87	95	⁴ ABDALLAH 04M DLP	04M	RPV, $\tilde{\mu}_R$, indirect, $\Delta m > 5 \text{ GeV}$
> 81	95	⁵ HEISTER 03G ALEP	03G	RPV, $\tilde{\mu}_L$

¹ AABOUD 18Z searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events containing four or more charged leptons (electrons, muons and up to two hadronically decaying taus). No significant deviation from the expected SM background is observed. Limits are set on the Higgsino mass in simplified models of general gauge mediated supersymmetry Tn1n1A/Tn1n1B/Tn1n1C, see their Figure 9. Limits are also set on the wino, slepton, sneutrino and gluino mass in a simplified model of NLSP pair production with R-parity violating decays of the LSP via λ_{12k} or λ_{133} to charged leptons, see their Figures 7, 8.

² AAD 14X searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV for events with at least four leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the slepton mass in an R-parity violating simplified model where the decay $\tilde{\ell} \rightarrow \ell \tilde{\chi}_1^0$, with $\tilde{\chi}_1^0 \rightarrow \ell^\pm \tilde{\ell}^\mp \nu$, takes place with a branching ratio of 100%, see Fig. 9.

³ SIRUNYAN 19A0 searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events containing two same-sign muons and at least two jets, originating from resonant production of second-generation sleptons ($\tilde{\mu}_L, \tilde{\nu}_\mu$) via the R-parity violating coupling λ'_{211} to quarks. No significant excess above the Standard Model expectations is observed. Upper limits on cross sections are derived in the context of two simplified models, see their Figure 4. The cross section limits are translated into limits on λ'_{211} for a modified CMSSM, see their Figure 5.

⁴ ABDALLAH 04M use data from $\sqrt{s} = 192$ –208 GeV to derive limits on sparticle masses under the assumption of RPV with $LL\bar{E}$ or $U\bar{D}\bar{D}$ couplings. The results are valid for μ

$= -200 \text{ GeV}, \tan\beta = 1.5, \Delta m > 5 \text{ GeV}$ and assuming a BR of 1 for the given decay. The limit quoted is for indirect $U\bar{D}\bar{D}$ decays using the neutralino constraint of 39.5 GeV for $LL\bar{E}$ and of 38.0 GeV for $U\bar{D}\bar{D}$ couplings, also derived in ABDALLAH 04M. For indirect decays via $LL\bar{E}$ the limit improves to 90 GeV if the constraint from the neutralino is used and remains at 87 GeV if it is not used. For indirect decays via $U\bar{D}\bar{D}$ couplings it degrades to 85 GeV when the neutralino constraint is not used. Supersedes the result of ABREU 00U.

⁵ HEISTER 03G searches for the production of smuons in the case of RPV prompt decays with $LL\bar{E}, LQ\bar{D}$ or $U\bar{D}\bar{D}$ couplings at $\sqrt{s} = 189$ –209 GeV. The search is performed for direct and indirect decays, assuming one coupling at a time to be non-zero. The limit holds for direct decays mediated by RPV $LQ\bar{D}$ couplings and improves to 90 GeV for indirect decays (for $\Delta m > 10 \text{ GeV}$). Limits are also given for $LL\bar{E}$ direct ($m_{\tilde{\mu}_R} > 87 \text{ GeV}$) and indirect decays ($m_{\tilde{\mu}_R} > 96 \text{ GeV}$ for $m(\tilde{\chi}_1^0) > 23 \text{ GeV}$ from BARATE 98S) and for $U\bar{D}\bar{D}$ indirect decays ($m_{\tilde{\mu}_R} > 85 \text{ GeV}$ for $\Delta m > 10 \text{ GeV}$). Supersedes the results from BARATE 01B.

R-parity conserving $\tilde{\tau}$ (Stau) mass limit

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, *et al.* (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
> 85.2		¹ ABBIENDI 04 OPAL	04	$\Delta m > 6 \text{ GeV}, \theta_\tau = \pi/2, \mu > 100 \text{ GeV}, \tan\beta = 1.5$
> 78.3		² ACHARD 04 L3	L3	$\Delta m > 15 \text{ GeV}, \theta_\tau = \pi/2, \mu > 200 \text{ GeV}, \tan\beta \geq 2$
> 81.9	95	³ ABDALLAH 03M DLP	03M	$\Delta m > 15 \text{ GeV}, \text{all } \theta_\tau$
> 79	95	⁴ HEISTER 02E ALEP	02E	$\Delta m > 15 \text{ GeV}, \theta_\tau = \pi/2$
> 76	95	⁴ HEISTER 02E ALEP	02E	$\Delta m > 15 \text{ GeV}, \theta_\tau = 0.91$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>500	95	⁵ AABOUD 18BT ATLS	18BT	$2\ell + \cancel{E}_T, m_{\tilde{e}} = m_{\tilde{\mu}} = m_{\tilde{\tau}} = m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
	95	⁶ KHACHATRYAN 17L CMS	17L	$2\tau + \cancel{E}_T, \tilde{\tau}_L \rightarrow \tau \tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
none 109	95	⁷ AAD 16AA ATLS	16AA	2 hadronic $\tau + \cancel{E}_T, \tilde{\tau}_{R/L} \rightarrow \tau \tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
		⁸ AAD 12AF ATLS	12AF	$2\tau + \text{jets} + \cancel{E}_T, \text{GMSB}$
		⁹ AAD 12AG ATLS	12AG	$\geq 1\tau_h + \text{jets} + \cancel{E}_T, \text{GMSB}$
		¹⁰ AAD 12CM ATLS	12CM	$\geq 1\tau + \text{jets} + \cancel{E}_T, \text{GMSB}$
> 87.4	95	¹¹ ABBIENDI 06B OPAL	06B	$\tilde{\tau}_R \rightarrow \tau \tilde{G}, \text{all } \tau(\tilde{\tau}_R)$
> 68	95	¹² ABDALLAH 04H DLP	04H	AMSB, $\mu > 0$
none $m_{\tilde{\tau}} = 26.3$	95	³ ABDALLAH 03M DLP	03M	$\Delta m > m_{\tilde{\tau}}, \text{all } \theta_\tau$

¹ ABBIENDI 04 search for $\tilde{\tau}\tilde{\tau}$ production in acoplanar di-tau final states in the 183–208 GeV data. See Fig. 15 for the dependence of the limits on $m_{\tilde{\chi}_1^0}$ and for the limit

at $\tan\beta=35$. Under the assumption of 100% branching ratio for $\tilde{\tau}_R \rightarrow \tau \tilde{\chi}_1^0$, the limit improves to 89.8 GeV for $\Delta m > 8 \text{ GeV}$. See Fig. 12 for the dependence of the limits on $m_{\tilde{\chi}_1^0}$ at several values of the branching ratio and for their dependence on θ_τ . This limit supersedes ABBIENDI 00G.

² ACHARD 04 search for $\tilde{\tau}\tilde{\tau}$ production in acoplanar di-tau final states in the 192–209 GeV data. Limits on $m_{\tilde{\tau}_R}$ are derived from a scan over the MSSM parameter space with universal GUT scale gaugino and scalar masses $m_{1/2}$ and m_0 , $1 \leq \tan\beta \leq 60$ and $-2 \leq \mu \leq 2$ TeV. See Fig. 4 for the dependence of the limits on $m_{\tilde{\chi}_1^0}$.

³ ABDALLAH 03M looked for acoplanar ditau + \cancel{E} final states at $\sqrt{s} = 130$ –208 GeV. A dedicated search was made for low mass $\tilde{\tau}$ s decoupling from the Z^0 . The limit assumes $B(\tilde{\tau} \rightarrow \tau \tilde{\chi}_1^0) = 100\%$. See Fig. 20 for limits on the $(m_{\tilde{\tau}}, m_{\tilde{\chi}_1^0})$ plane and as function

of the $\tilde{\chi}_1^0$ mass and of the branching ratio. The limit in the low-mass region improves to 29.6 and 31.1 GeV for $\tilde{\tau}_R$ and $\tilde{\tau}_L$, respectively, at $\Delta m > m_{\tilde{\tau}}$. The limit in the high-mass region improves to 84.7 GeV for $\tilde{\tau}_R$ and $\Delta m > 15 \text{ GeV}$. These limits include and update the results of ABREU 01.

⁴ HEISTER 02E looked for acoplanar ditau + \cancel{E}_T final states from e^+e^- interactions between 183 and 209 GeV. The mass limit assumes $B(\tilde{\tau} \rightarrow \tau \tilde{\chi}_1^0) = 1$. See their Fig. 4 for the dependence of the limit on Δm . These limits include and update the results of BARATE 01.

⁵ AABOUD 18BT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for direct electroweak production of charginos, chargino and next-to-lightest neutralinos and sleptons in events with two or three leptons (electrons or muons), with or without jets, and large missing transverse energy. No significant excess above the Standard Model expectations is observed. Limits are set on the slepton mass up to 500 GeV for massless $\tilde{\chi}_1^0$, assuming degeneracy of \tilde{e} , $\tilde{\mu}$, and $\tilde{\tau}$ and exploiting the 2ℓ signature, see their Figure 8(b).

⁶ KHACHATRYAN 17L searched in about 19 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV for events with two τ (at least one decaying hadronically) and \cancel{E}_T . Results were interpreted to set constraints on the cross section for production of $\tilde{\tau}_L$ pairs for $m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$. No mass constraints are set, see their Fig. 7.

⁷ AAD 16AA summarized and extended ATLAS searches for electroweak supersymmetry in final states containing several charged leptons, \cancel{E}_T , with or without hadronic jets, in 20 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$. The paper reports 95% C.L. exclusion limits on the cross-section for production of $\tilde{\tau}_R$ and $\tilde{\tau}_L$ pairs for various $m_{\tilde{\chi}_1^0}$, using the 2 hadronic $\tau + \cancel{E}_T$ analysis. The $m_{\tilde{\tau}_{R/L}} = 109 \text{ GeV}$ is excluded for $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$, with the constraints being stronger for $\tilde{\tau}_R$. See their Fig. 12.

⁸ AAD 12AF searched in 2 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with two tau leptons, jets and large \cancel{E}_T in a GMSB framework. No significant excess above the expected background was found and an upper limit on the visible cross section for new phenomena is set. A 95% C.L. lower limit of 32 TeV on the mGMSB breaking scale Λ is set for $M_{\text{mess}} = 250 \text{ TeV}, N_S = 3, \mu > 0$ and $C_{\text{grav}} = 1$, independent of $\tan\beta$.

- ⁹ AAD 12AG searched in 2.05 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with at least one hadronically decaying tau lepton, jets, and large E_T in a GMSB framework. No significant excess above the expected background was found and an upper limit on the visible cross section for new phenomena is set. A 95% C.L. lower limit of 30 TeV on the mGMSB breaking scale Λ is set for $M_{\text{mess}} = 250 \text{ TeV}$, $N_5 = 3$, $\mu > 0$ and $C_{\text{grav}} = 1$, independent of $\tan\beta$. For large values of $\tan\beta$, the limit on Λ increases to 43 TeV.
- ¹⁰ AAD 12CM searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with at least one tau lepton, zero or one additional light lepton (e/μ) jets, and large E_T in a GMSB framework. No significant excess above the expected background was found and an upper limit on the visible cross section for new phenomena is set. A 95% C.L. lower limit of 54 TeV on the mGMSB breaking scale Λ is set for $M_{\text{mess}} = 250 \text{ TeV}$, $N_5 = 3$, $\mu > 0$ and $C_{\text{grav}} = 1$, for $\tan\beta > 20$. Here the $\tilde{\tau}_1$ is the NLSP.
- ¹¹ ABBIENDI 06B use 600 pb^{-1} of data from $\sqrt{s} = 189\text{--}209 \text{ GeV}$. They look for events from pair-produced staus in a GMSB scenario with $\tilde{\tau}$ NLSP including prompt $\tilde{\tau}$ decays to ditau + E final states, large impact parameters, kinked tracks and heavy stable charged particles. Limits on the cross-section are computed as a function of $m(\tilde{\tau})$ and the lifetime, see their Fig. 7. The limit is compared to the $\sigma \cdot BR^2$ from a scan over the GMSB parameter space.
- ¹² ABDALLAH 04H use data from LEP 1 and $\sqrt{s} = 192\text{--}208 \text{ GeV}$. They re-use results or re-analyze the data from ABDALLAH 03M to put limits on the parameter space of anomaly-mediated supersymmetry breaking (AMSB), which is scanned in the region $1 < m_{3/2} < 50 \text{ TeV}$, $0 < m_0 < 1000 \text{ GeV}$, $1.5 < \tan\beta < 35$, both signs of μ . The constraints are obtained from the searches for mass degenerate chargino and neutralino, for SM-like and invisible Higgs, for leptonically decaying charginos and from the limit on non-SM Z width of 3.2 MeV. The limit is for $m_t = 174.3 \text{ GeV}$ (see Table 2 for other m_t values). The limit improves to 75 GeV for $\mu < 0$.

R-parity violating $\tilde{\tau}$ (Stau) mass limit

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VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1060	95	¹ AABOUD	18z ATLS	$\geq 4\ell$, RPV, $\lambda_{12k} \neq 0$, $m_{\tilde{\chi}_1^0} = 600 \text{ GeV}$ (mass-degenerate left-handed sleptons and sneutrinos of all 3 generations)
> 780	95	¹ AABOUD	18z ATLS	$\geq 4\ell$, RPV, $\lambda_{133} \neq 0$, $m_{\tilde{\chi}_1^0} = 300 \text{ GeV}$ (mass-degenerate left-handed sleptons and sneutrinos of all 3 generations)

• • • We do not use the following data for averages, fits, limits, etc. • • •

> 74	95	² ABBIENDI	04f OPAL	RPV, $\tilde{\tau}_L$
> 90	95	³ ABDALLAH	04M DLFH	RPV, $\tilde{\tau}_R$, indirect, $\Delta m > 5 \text{ GeV}$
¹ AABOUD 18z searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing four or more charged leptons (electrons, muons and up to two hadronically decaying taus). No significant deviation from the expected SM background is observed. Limits are set on the Higgsino mass in simplified models of general gauge mediated supersymmetry Tn1n1A/Tn1n1B/Tn1n1C, see their Figure 9. Limits are also set on the wino, slepton, sneutrino and gluino mass in a simplified model of NLSP pair production with R-parity violating decays of the LSP via λ_{12k} or λ_{133} to charged leptons, see their Figures 7, 8.				
² ABBIENDI 04f use data from $\sqrt{s} = 189\text{--}209 \text{ GeV}$. They derive limits on sparticle masses under the assumption of RPV with $LL\tilde{E}$ or $LQ\tilde{D}$ couplings. The results are valid for $\tan\beta = 1.5$, $\mu = -200 \text{ GeV}$, with, in addition, $\Delta m > 5 \text{ GeV}$ for indirect decays via $LQ\tilde{D}$. The limit quoted applies to direct decays with $LL\tilde{E}$ couplings and improves to 75 GeV for $LQ\tilde{D}$ couplings. The limit on the $\tilde{\tau}_R$ mass for indirect decays is 92 GeV for $LL\tilde{E}$ couplings at $m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$ and no exclusion is obtained for $LQ\tilde{D}$ couplings. Supersedes the results of ABBIENDI 00.				
³ ABDALLAH 04M use data from $\sqrt{s} = 192\text{--}208 \text{ GeV}$ to derive limits on sparticle masses under the assumption of RPV with $LL\tilde{E}$ couplings. The results are valid for $\mu = -200 \text{ GeV}$, $\tan\beta = 1.5$, $\Delta m > 5 \text{ GeV}$ and assuming a BR of 1 for the given decay. The limit quoted is for indirect decays using the neutralino constraint of 39.5 GeV, also derived in ABDALLAH 04M. For indirect decays via $LL\tilde{E}$ the limit decreases to 86 GeV if the constraint from the neutralino is not used. Supersedes the result of ABREU 00U.				

Long-lived $\tilde{\ell}$ (Slepton) mass limit

Limits on scalar leptons which leave detector before decaying. Limits from Z decays are independent of lepton flavor. Limits from continuum e^+e^- annihilation are also independent of flavor for smuons and staus. Selection limits from e^+e^- collisions in the continuum depend on MSSM parameters because of the additional neutralino exchange contribution.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>430	95	¹ AABOUD	19AT ATLS	long-lived $\tilde{\tau}$, GMSB
>490	95	² KHACHATRYAN	16BW CMS	long-lived $\tilde{\tau}$ from inclusive production, mGMSB SPS line 7 scenario
>240	95	² KHACHATRYAN	16BW CMS	long-lived $\tilde{\tau}$ from direct pair production, mGMSB SPS line 7 scenario
>440	95	³ AAD	15AE ATLS	mGMSB, $M_{\text{mess}} = 250 \text{ TeV}$, $N_5 = 3$, $\mu > 0$, $C_{\text{grav}} = 5000$, $\tan\beta = 10$
>385	95	³ AAD	15AE ATLS	mGMSB, $M_{\text{mess}} = 250 \text{ TeV}$, $N_5 = 3$, $\mu > 0$, $C_{\text{grav}} = 5000$, $\tan\beta = 50$
>286	95	³ AAD	15AE ATLS	direct $\tilde{\tau}$ production
none 124–309	95	⁴ AAIJ	15BD LHCb	long-lived $\tilde{\tau}$, mGMSB, SPS7
> 98	95	⁵ ABBIENDI	03L OPAL	$\tilde{\mu}_R, \tilde{\tau}_R$
none 2–87.5	95	⁶ ABREU	00Q DLFH	$\tilde{\mu}_R, \tilde{\tau}_R$
> 81.2	95	⁷ ACCIARRI	99H L3	$\tilde{\mu}_R, \tilde{\tau}_R$
> 81	95	⁸ BARATE	98K ALEP	$\tilde{\mu}_R, \tilde{\tau}_R$

• • • We do not use the following data for averages, fits, limits, etc. • • •

>300	95	⁹ AAD	13AA ATLS	long-lived $\tilde{\tau}$, GMSB, $\tan\beta = 5\text{--}20$
		¹⁰ ABAZOV	13B D0	long-lived $\tilde{\tau}$, $100 < m_{\tilde{\tau}} < 300 \text{ GeV}$
>339	95	^{11,12} CHATRCHYAN	13AB CMS	long-lived $\tilde{\tau}$, direct $\tilde{\tau}_1$ pair prod., minimal GMSB, SPS line 7
>500	95	^{11,13} CHATRCHYAN	13AB CMS	long-lived $\tilde{\tau}$, $\tilde{\tau}_1$ from direct pair prod. and from decay of heavier SUSY particles, minimal GMSB, SPS line 7
>314	95	¹⁴ CHATRCHYAN	12L CMS	long-lived $\tilde{\tau}$, $\tilde{\tau}_1$ from decay of heavier SUSY particles, minimal GMSB, SPS line 7
>136	95	¹⁵ AAD	11P ATLS	stable $\tilde{\tau}$, GMSB scenario, $\tan\beta=5$
¹ AABOUD 19AT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for metastable and stable R -hadrons. Multiple search strategies for a wide range of lifetimes, corresponding to path lengths of a few meters, are defined. No significant deviations from the expected Standard Model background are observed. Results are interpreted in terms of exclusion limits on long-lived stau in the context of GMSB models. Lower limits on the mass for direct production of staus are set at 430 GeV, see their Fig. 10 (left).				
² KHACHATRYAN 16BW searched in 2.5 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with heavy stable charged particles, identified by their anomalously high energy deposits in the silicon tracker and/or long time-of-flight measurements by the muon system. No evidence for an excess over the expected background is observed. Limits are derived for pair production of tau sleptons as a function of mass, depending on their direct or inclusive production in a minimal GMSB scenario along the Snowmass Points and Slopes (SPS) line 7, see Fig. 4 and Table 7.				
³ AAD 15AE searched in 19.1 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for heavy long-lived charged particles, measured through their specific ionization energy loss in the ATLAS pixel detector or their time-of-flight in the ATLAS muon system. In the absence of an excess of events above the expected backgrounds, limits are set on stable $\tilde{\tau}$ sleptons in various scenarios, see Figs. 5–7.				
⁴ AAIJ 15BD searched in 3.0 fb^{-1} of pp collisions at $\sqrt{s} = 7$ and 8 TeV for evidence of Drell-Yan pair production of long-lived $\tilde{\tau}$ particles. No evidence for such particles is observed and 95% C.L. upper limits on the cross section of $\tilde{\tau}$ pair production are derived, see Fig. 7. In the mGMSB, assuming the SPS7 benchmark scenario $\tilde{\tau}$ masses between 124 and 309 GeV are excluded at 95% C.L.				
⁵ ABBIENDI 03L used e^+e^- data at $\sqrt{s} = 130\text{--}209 \text{ GeV}$ to select events with two high momentum tracks with anomalous dE/dx . The excluded cross section is compared to the theoretical expectation as a function of the heavy particle mass in their Fig. 3. The limit improves to 98.5 GeV for $\tilde{\mu}_L$ and $\tilde{\tau}_L$. The bounds are valid for colorless spin 0 particles with lifetimes longer than 10^{-6} s . Supersedes the results from ACKERSTAFF 98P.				
⁶ ABREU 00Q searches for the production of pairs of heavy, charged stable particles in e^+e^- annihilation at $\sqrt{s} = 130\text{--}189 \text{ GeV}$. The upper bound improves to 88 GeV for $\tilde{\mu}_L, \tilde{\tau}_L$. These limits include and update the results of ABREU 98P.				
⁷ ACCIARRI 99H searched for production of pairs of back-to-back heavy charged particles at $\sqrt{s} = 130\text{--}183 \text{ GeV}$. The upper bound improves to 82.2 GeV for $\tilde{\mu}_L, \tilde{\tau}_L$.				
⁸ The BARATE 98K mass limit improves to 82 GeV for $\tilde{\mu}_L, \tilde{\tau}_L$. Data collected at $\sqrt{s} = 161\text{--}184 \text{ GeV}$.				
⁹ AAD 13AA searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing long-lived massive particles in a GMSB framework. No significant excess above the expected background was found. A 95% C.L. lower limit of 300 GeV is placed on long-lived $\tilde{\tau}$'s in the GMSB model with $M_{\text{mess}} = 250 \text{ TeV}$, $N_5 = 3$, $\mu > 0$, for $\tan\beta = 5\text{--}20$. The lower limit on the GMSB breaking scale Λ was found to be 99–110 TeV, for $\tan\beta$ values between 5 and 40, see Fig. 4 (top). Also, directly produced long-lived sleptons, or sleptons decaying to long-lived ones, are excluded at 95% C.L. up to a $\tilde{\tau}$ mass of 278 GeV for models with slepton splittings smaller than 50 GeV.				
¹⁰ ABAZOV 13b looked in 6.3 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for charged massive long-lived particles in events with muon-like particles that have both speed and ionization energy loss inconsistent with muons produced in beam collisions. In the absence of an excess, limits are set at 95% C.L. on the production cross section of stau leptons in the mass range 100–300 GeV, see their Table 20 and Fig. 23.				
¹¹ CHATRCHYAN 13AB looked in 5.0 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ and in 18.8 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with heavy stable particles, identified by their anomalous dE/dx in the tracker or additionally requiring that it be identified as muon in the muon chambers, from pair production of $\tilde{\tau}_1$'s. No evidence for an excess over the expected background is observed. Supersedes CHATRCHYAN 12L.				
¹² CHATRCHYAN 13AB limits are derived for pair production of $\tilde{\tau}_1$ as a function of mass in minimal GMSB scenarios along the Snowmass Points and Slopes (SPS) line 7 (see Fig. 8 and Table 7). The limit given here is valid for direct pair $\tilde{\tau}_1$ production.				
¹³ CHATRCHYAN 13AB limits are derived for the production of $\tilde{\tau}_1$ as a function of mass in minimal GMSB scenarios along the Snowmass Points and Slopes (SPS) line 7 (see Fig. 8 and Table 7). The limit given here is valid for the production of $\tilde{\tau}_1$ from both direct pair production and from the decay of heavier supersymmetric particles.				
¹⁴ CHATRCHYAN 12L looked in 5.0 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with heavy stable particles, identified by their anomalous dE/dx in the tracker or additionally requiring that it be identified as muon in the muon chambers, from pair production of $\tilde{\tau}_1$'s. No evidence for an excess over the expected background is observed. Limits are derived for the production of $\tilde{\tau}_1$ as a function of mass in minimal GMSB scenarios along the Snowmass Points and Slopes (SPS) line 7 (see Fig. 3). The limit given here is valid for the production of $\tilde{\tau}_1$ in the decay of heavier supersymmetric particles.				
¹⁵ AAD 11P looked in 37 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with two heavy stable particles, reconstructed in the Inner tracker and the Muon System and identified by their time of flight in the Muon System. No evidence for an excess over the SM expectation is observed. Limits on the mass are derived, see Fig. 3, for $\tilde{\tau}$ in a GMSB scenario and for sleptons produced by electroweak processes only, in which case the limit degrades to 110 GeV.				

Searches Particle Listings

Supersymmetric Particle Searches

\tilde{q} (Squark) mass limit

For $m_{\tilde{q}} > 60\text{--}70\text{ GeV}$, it is expected that squarks would undergo a cascade decay via a number of neutralinos and/or charginos rather than undergo a direct decay to photinos as assumed by some papers. Limits obtained when direct decay is assumed are usually higher than limits when cascade decays are included.

Limits from e^+e^- collisions depend on the mixing angle of the lightest mass eigenstate $\tilde{q}_1 = \tilde{q}_R \sin\theta_q + \tilde{q}_L \cos\theta_q$. It is usually assumed that only the sbottom and stop squarks have non-trivial mixing angles (see the stop and sbottom sections). Here, unless otherwise noted, squarks are always taken to be either left/right degenerate, or purely of left or right type. Data from Z decays have set squark mass limits above 40 GeV, in the case of $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ decays if $\Delta m = m_{\tilde{q}} - m_{\tilde{\chi}_1^0} \gtrsim 5\text{ GeV}$. For smaller values of Δm , current constraints on the invisible width of the Z ($\Delta\Gamma_{\text{inv}} < 2.0\text{ MeV}$, LEP 00) exclude $m_{\tilde{u}_{L,R}} < 44\text{ GeV}$, $m_{\tilde{d}_{L,R}} < 33\text{ GeV}$, $m_{\tilde{t}} < 44\text{ GeV}$ and, assuming all squarks degenerate, $m_{\tilde{q}} < 45\text{ GeV}$.

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, *et al.* (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

R-parity conserving \tilde{q} (Squark) mass limit

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1590	95	1	SIRUNYAN 19AG CMS	$2\gamma + \cancel{E}_T$, Tsqk4B, 500 GeV $< m_{\tilde{\chi}_1^0} < 1500\text{ GeV}$
>1130	95	2	SIRUNYAN 19CH CMS	$\text{jets} + \cancel{E}_T$, Tsqk1, 1 light flavour, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
>1630	95	2	SIRUNYAN 19CH CMS	$\text{jets} + \cancel{E}_T$, Tsqk1, 8 degenerate light flavours, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
>1430	95	3	SIRUNYAN 19K CMS	$\gamma + \ell + \cancel{E}_T$, Tsqk4A, $m_{\tilde{\chi}_1^0} =$ 1200 GeV
>1200	95	4	AABOUD 18BJ ATLS	$\ell^\pm \ell^\mp + \text{jets} + \cancel{E}_T$, Tsqk2, $m_{\tilde{\chi}_1^0}$ $= 1\text{ GeV}$, any $m_{\tilde{\chi}_2^0}$
> 850	95	5	AABOUD 18BV ATLS	$c\text{-jets} + \cancel{E}_T$, Tsqk1 (charm only), $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
> 710	95	6	AABOUD 18I ATLS	$\geq 1\text{ jets} + \cancel{E}_T$, Tsqk1, $m_{\tilde{q}} \sim$ $m_{\tilde{\chi}_1^0}$
>1820	95	7	AABOUD 18U ATLS	$2\gamma + \cancel{E}_T$, GGM, Tsqk4B, any NLSP mass
>1550	95	8	AABOUD 18V ATLS	$\text{jets} + \cancel{E}_T$, Tsqk1, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
>1150	95	9	AABOUD 18V ATLS	$\text{jets} + \cancel{E}_T$, Tsqk3, $m_{\tilde{\chi}_1^\pm} = 0.5$ ($m_{\tilde{q}} + m_{\tilde{\chi}_1^0}$), $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
>1650	95	10	SIRUNYAN 18AA CMS	$\geq 1\gamma + \cancel{E}_T$, Tsqk4A
>1750	95	10	SIRUNYAN 18AA CMS	$\geq 1\gamma + \cancel{E}_T$, Tsqk4B
> 675	95	11	SIRUNYAN 18AY CMS	$\text{jets} + \cancel{E}_T$, Tsqk1, 1 light flavor state, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
>1320	95	11	SIRUNYAN 18AY CMS	$\text{jets} + \cancel{E}_T$, Tsqk1, 8 degenerate light flavor states, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
>1220	95	12	AABOUD 17AR ATLS	$1\ell + \text{jets} + \cancel{E}_T$, Tsqk3, $m_{\tilde{\chi}_1^0} = 0$ GeV
>1000	95	13	AABOUD 17N ATLS	2 same-flavour, opposite-sign $\ell +$ $\text{jets} + \cancel{E}_T$, Tsqk2, $m_{\tilde{\chi}_1^0} = 0$ GeV
>1150	95	14	KHACHATRY...17P CMS	1 or more $\text{jets} + \cancel{E}_T$, Tsqk1, 4(flavor) $\times 2(\text{isospin}) = 8$ mass degenerate states, $m_{\tilde{\chi}_1^0} = 0$ GeV
> 575	95	14	KHACHATRY...17P CMS	1 or more $\text{jets} + \cancel{E}_T$, Tsqk1, one light flavor state, $m_{\tilde{\chi}_1^0} = 0$ GeV
>1370	95	15	KHACHATRY...17v CMS	$2\gamma + \cancel{E}_T$, GGM, Tsqk4, any NLSP mass
>1600	95	16	SIRUNYAN 17AY CMS	$\gamma + \text{jets} + \cancel{E}_T$, Tsqk4B, $m_{\tilde{\chi}_1^0} = 0$ GeV
>1370	95	16	SIRUNYAN 17AY CMS	$\gamma + \text{jets} + \cancel{E}_T$, Tsqk4A, $m_{\tilde{\chi}_1^0} = 0$ GeV
>1050	95	17	SIRUNYAN 17AZ CMS	$\geq 1\text{ jets} + \cancel{E}_T$, Tsqk1, single light flavor state, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
>1550	95	17	SIRUNYAN 17AZ CMS	$\geq 1\text{ jets} + \cancel{E}_T$, Tsqk1, 4(flavor) $\times 2(\text{isospin}) = 8$ degenerate mass states, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
>1390	95	18	SIRUNYAN 17P CMS	$\text{jets} + \cancel{E}_T$, Tsqk1, 4(flavor) \times $2(\text{isospin}) = 8$ degenerate mass states, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
> 950	95	18	SIRUNYAN 17P CMS	$\text{jets} + \cancel{E}_T$, Tsqk1, one light flavor state, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
> 608	95	19	AABOUD 16D ATLS	$\geq 1\text{ jet} + \cancel{E}_T$, Tsqk1, $m_{\tilde{q}} - m_{\tilde{\chi}_1^0}$ $= 5\text{ GeV}$

>1030	95	20	AABOUD 16N ATLS	$\geq 2\text{ jets} + \cancel{E}_T$, Tsqk1, $m_{\tilde{\chi}_1^0} = 0$ GeV
> 600	95	21	KHACHATRY...16Bs CMS	$\text{jets} + \cancel{E}_T$, Tsqk1, single light squark, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
>1260	95	21	KHACHATRY...16Bs CMS	$\text{jets} + \cancel{E}_T$, Tsqk1, 8 degenerate light squarks, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
> 850	95	22	AAD 15BV ATLS	$\text{jets} + \cancel{E}_T$, $\tilde{q} \rightarrow q\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} =$ 100 GeV
> 250	95	23	AAD 15Cs ATLS	photon + \cancel{E}_T , $p\bar{p} \rightarrow \tilde{q}\tilde{q}^*\gamma$, $\tilde{q} \rightarrow q\tilde{\chi}_1^0$, $m_{\tilde{q}} - m_{\tilde{\chi}_1^0} = m_c$
> 490	95	24	AAD 15K ATLS	$\tilde{c} \rightarrow c\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} < 200\text{ GeV}$
> 875	95	25	KHACHATRY...15AF CMS	$\tilde{q} \rightarrow q\tilde{\chi}_1^0$, simplified model, 8 degenerate light \tilde{q} , $m_{\tilde{\chi}_1^0} = 0$
> 520	95	25	KHACHATRY...15AF CMS	$\tilde{q} \rightarrow q\tilde{\chi}_1^0$, simplified model, single light squark, $m_{\tilde{\chi}_1^0} = 0$
>1450	95	25	KHACHATRY...15AF CMS	CMSSM, $\tan\beta = 30$, $A_0 =$ $-2\max(m_0, m_{1/2})$, $\mu > 0$
> 850	95	26	AAD 14AE ATLS	$\text{jets} + \cancel{E}_T$, $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ simplified model, mass degenerate first and second generation squarks, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
> 440	95	26	AAD 14AE ATLS	$\text{jets} + \cancel{E}_T$, $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ simpli- fied model, single light-flavour squark, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
>1700	95	26	AAD 14AE ATLS	$\text{jets} + \cancel{E}_T$, mSUGRA/CMSSM, $m_{\tilde{q}} = m_{\tilde{g}}$
> 800	95	27	CHATRCHYAN14AH CMS	$\text{jets} + \cancel{E}_T$, $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 50\text{ GeV}$
> 780	95	28	CHATRCHYAN14I CMS	multijets + \cancel{E}_T , $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ sim- plified model, $m_{\tilde{\chi}_1^0} < 200$ GeV
>1360	95	29	AAD 13L ATLS	$\text{jets} + \cancel{E}_T$, CMSSM, $m_{\tilde{g}} = m_{\tilde{q}}$
>1200	95	30	AAD 13Q ATLS	$\gamma + b + \cancel{E}_T$, higgsino-like neutralino, $m_{\tilde{\chi}_1^0} > 220\text{ GeV}$, GMSB
>1250	95	31	CHATRCHYAN13 CMS	$\ell^\pm \ell^\mp + \text{jets} + \cancel{E}_T$, CMSSM
	95	32	CHATRCHYAN13G CMS	0,1,2, $\geq 3\text{ }b\text{-jets} + \cancel{E}_T$, CMSSM, $m_{\tilde{q}} = m_{\tilde{g}}$
>1430	95	33	CHATRCHYAN13H CMS	$2\gamma + \geq 4\text{ jets} + \text{low } \cancel{E}_T$, stealth SUSY model
> 750	95	34	CHATRCHYAN13T CMS	$\text{jets} + \cancel{E}_T$, $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 0\text{ GeV}$
> 820	95	35	AAD 12AX ATLS	$\ell + \text{jets} + \cancel{E}_T$, CMSSM, $m_{\tilde{q}} = m_{\tilde{g}}$
>1200	95	36	AAD 12CJ ATLS	$\ell^\pm + \text{jets} + \cancel{E}_T$, CMSSM, $m_{\tilde{q}} = m_{\tilde{g}}$
> 870	95	37	AAD 12CP ATLS	$2\gamma + \cancel{E}_T$, GMSB, bino NLSP, $m_{\tilde{\chi}_1^0} > 50\text{ GeV}$
> 950	95	38	AAD 12W ATLS	$\text{jets} + \cancel{E}_T$, CMSSM, $m_{\tilde{q}} = m_{\tilde{g}}$
> 760	95	39	CHATRCHYAN12 CMS	$e, \mu, \text{jets, razor, CMSSM}$
	95	40	CHATRCHYAN12AE CMS	$\text{jets} + \cancel{E}_T$, $\tilde{q} \rightarrow q\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} <$ 200 GeV
>1110	95	41	CHATRCHYAN12AT CMS	$\text{jets} + \cancel{E}_T$, CMSSM
>1180	95	41	CHATRCHYAN12AT CMS	$\text{jets} + \cancel{E}_T$, CMSSM, $m_{\tilde{q}} = m_{\tilde{g}}$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>1080	95	42	AABOUD 18v ATLS	$\text{jets} + \cancel{E}_T$, Tsqk5, $(m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}) /$ $(m_{\tilde{q}} - m_{\tilde{\chi}_1^0}) < 0.95$, $m_{\tilde{\chi}_1^0} =$ 60 GeV
> 300	95	43	KHACHATRY...16BT CMS	19-parameter pMSSM model, global Bayesian analysis, flat prior
	95	44	AAD 15AI ATLS	$\ell^\pm + \text{jets} + \cancel{E}_T$
>1650	95	22	AAD 15BV ATLS	$\text{jets} + \cancel{E}_T$, $m_{\tilde{g}} = m_{\tilde{q}}$, $m_{\tilde{\chi}_1^0} = 1$ GeV
> 790	95	22	AAD 15BV ATLS	$\text{jets} + \cancel{E}_T$, $\tilde{q} \rightarrow qW\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} =$ 100 GeV
> 820	95	22	AAD 15BV ATLS	2 or 3 leptons + jets, \tilde{q} decays via sleptons, $m_{\tilde{\chi}_1^0} = 100\text{ GeV}$
> 850	95	22	AAD 15BV ATLS	τ, \tilde{q} decays via staus, $m_{\tilde{\chi}_1^0} = 50$ GeV
> 700	95	45	KHACHATRY...15AR CMS	$\tilde{q} \rightarrow q\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \tilde{3}g, \tilde{3} \rightarrow$ $S\tilde{G}, S \rightarrow g\tilde{g}, m_{\tilde{S}} = 100$ GeV, $m_{\tilde{S}} = 90\text{ GeV}$
> 550	95	45	KHACHATRY...15AR CMS	$\ell^\pm, \tilde{q} \rightarrow q\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow \tilde{3}W^\pm,$ $\tilde{3} \rightarrow S\tilde{G}, S \rightarrow g\tilde{g}, m_{\tilde{S}} =$ 100 GeV, $m_{\tilde{S}} = 90\text{ GeV}$
>1500	95	46	KHACHATRY...15AZ CMS	$\geq 2\gamma, \geq 1\text{ jet, (Razor), bino-}$ like NLSP, $m_{\tilde{\chi}_1^0} = 375\text{ GeV}$
>1000	95	46	KHACHATRY...15AZ CMS	$\geq 1\gamma, \geq 2\text{ jet, wino-like NLSP,}$ $m_{\tilde{\chi}_1^0} = 375\text{ GeV}$

> 670	95	47 AAD	14E ATLS	$\ell^\pm \ell^\pm (\ell^\mp) + \text{jets}, \tilde{q} \rightarrow q' \tilde{\chi}_1^\pm,$ $\tilde{\chi}_1^\pm \rightarrow W(*) \tilde{\chi}_2^0, \tilde{\chi}_2^0 \rightarrow$ $Z(*) \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} < 300 \text{ GeV}$
> 780	95	47 AAD	14E ATLS	$\ell^\pm \ell^\pm (\ell^\mp) + \text{jets}, \tilde{q} \rightarrow$ $q' \tilde{\chi}_1^\pm / \tilde{\chi}_2^0, \tilde{\chi}_1^\pm \rightarrow \ell^\pm \nu \tilde{\chi}_1^0,$ $\tilde{\chi}_2^0 \rightarrow \ell^\pm \ell^\pm (\nu \nu) \tilde{\chi}_1^0$ simpli- fied model
> 700	95	48 CHATRCHYAN13ao CMS		$\ell^\pm \ell^\mp + \text{jets} + \cancel{E}_T$, CMSSM, $m_0 < 700 \text{ GeV}$
>1350	95	49 CHATRCHYAN13av CMS		jets (+ leptons) + \cancel{E}_T , CMSSM, $m_{\tilde{g}} = m_{\tilde{q}}$
> 800	95	50 CHATRCHYAN13w CMS		≥ 1 photons + jets + \cancel{E}_T , GGM, wino-like NLSP, $m_{\tilde{\chi}_1^0}$ $= 375 \text{ GeV}$
>1000	95	50 CHATRCHYAN13w CMS		≥ 2 photons + jets + \cancel{E}_T , GGM, bino-like NLSP, $m_{\tilde{\chi}_1^0}$ $= 375 \text{ GeV}$
> 340	95	51 DREINER	12A THEO	$m_{\tilde{q}} \sim m_{\tilde{\chi}_1^0}$
> 650	95	52 DREINER	12A THEO	$m_{\tilde{q}} = m_{\tilde{g}} \sim m_{\tilde{\chi}_1^0}$

1 SIRUNYAN 19AG searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two photons and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu4B simplified model and on the squark mass in the Tsqk4B simplified model, see their Figure 3.

2 SIRUNYAN 19CH searched in 137 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing multiple jets and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu1C, Tglu2A and Tglu3A simplified models, see their Figure 13. Limits are also set on squark, sbottom and stop masses in the Tsqk1, Tsb0t1, Tstop1 simplified models, see their Figure 14.

3 SIRUNYAN 19K searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with a photon, an electron or muon, and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. In the framework of GMSB, limits are set on the chargino and neutralino mass in the Tch1n1A simplified model, see their Figure 6. Limits are also set on the gluino mass in the Tglu4A simplified model, and on the squark mass in the Tsqk4A simplified model, see their Figure 7.

4 AABOUD 18BJ searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with two opposite-sign charged leptons (electrons and muons), jets and missing transverse momentum, with various requirements to be sensitive to signals with different kinematic endpoint values in the dilepton invariant mass distribution. The data are found to be consistent with the SM expectation. Results are interpreted in the Tsqk2 model in case of $m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$: for any $m_{\tilde{\chi}_2^0}$, squark masses below 1200 GeV are excluded, see their Fig. 14(b).

5 AABOUD 18BV searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one jet identified as c -jet, large missing transverse energy and no leptons. Good agreement is observed between the number of events in data and Standard Model predictions. The results are translated into exclusion limits in Tsqk1 models considering only \tilde{c}_1 . In scenarios with massless neutralinos, scharm masses below 850 GeV are excluded. If the differences of the \tilde{c}_1 and $\tilde{\chi}_1^0$ masses is below 100 GeV, scharm masses below 500 GeV are excluded. See their Fig. 6 and Fig. 7.

6 AABOUD 18I searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one jet with a transverse momentum above 250 GeV and no leptons. Good agreement is observed between the number of events in data and Standard Model predictions. The results are translated into exclusion limits in Tsqk1 models. In the compressed scenario with similar squark and neutralino masses, squark masses below 710 GeV are excluded. See their Fig. 10(b).

7 AABOUD 18U searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with at least one isolated photon, possibly jets and significant transverse momentum targeting generalised models of gauge-mediated SUSY breaking. No significant excess of events is observed above the SM prediction. Results are interpreted in terms of lower limits on the masses of squark in Tsqk4B models. Masses below 1820 GeV are excluded for any NLSP mass, see their Fig. 9.

8 AABOUD 18V searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with no charged leptons, jets and missing transverse momentum. The data are found to be consistent with the SM expectation. Results are interpreted in the Tsqk1 model: squark masses below 1550 GeV are excluded for massless LSP, see their Fig. 13(a).

9 AABOUD 18V searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with no charged leptons, jets and missing transverse momentum. The data are found to be consistent with the SM expectation. Results are interpreted in the Tsqk3 model. Assuming that $m_{\tilde{\chi}_1^\pm} = 0.5 (m_{\tilde{q}} + m_{\tilde{\chi}_1^0})$, squark masses below 1150 GeV are excluded for massless LSP, see their Fig. 14(a). Exclusions are also shown assuming $m_{\tilde{\chi}_1^0} = 60 \text{ GeV}$, see their Fig. 14(b).

10 SIRUNYAN 18AA searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one photon and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on wino masses in a general gauge-mediated SUSY breaking (GGM) scenario with bino-like $\tilde{\chi}_1^\pm$ and wino-like $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$, see Figure 7. Limits are also set on the NLSP mass in the Tch1n1A and Tch1ch1A simplified models, see their Figure 8. Finally, limits are set on the gluino mass in the Tglu4A and Tglu4B simplified models, see their Figure 9, and on the squark mass in the Tsqk4A and Tsqk4B simplified models, see their Figure 10.

11 SIRUNYAN 18AV searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing one or more jets and significant \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A and Tglu3A simplified models, see their Figure 3. Limits are also set on squark, sbottom and stop masses in the Tsqk1, Tsb0t1, Tstop1 and Tstop4 simplified models, see their Figure 3. Finally, limits are set on long-lived gluino masses in a Tglu1A simplified model where the gluino is metastable or long-lived with proper decay lengths in the range $10^{-3} \text{ mm} < c\tau < 10^5 \text{ mm}$, see their Figure 4.

- 12 AABOUD 17AR searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one isolated lepton, at least two jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 1.25 TeV are set on the 1st and 2nd generation squark masses in Tsqk3 simplified models, with $x = (m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0}) / (m_{\tilde{q}} - m_{\tilde{\chi}_1^0}) = 1/2$. Similar limits are obtained for variable x and fixed neutralino mass, $m_{\tilde{\chi}_1^0} = 60 \text{ GeV}$. See their Figure 13.
- 13 AABOUD 17N searched in 14.7 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with 2 same-flavour, opposite-sign leptons (electrons or muons), jets and large missing transverse momentum. The results are interpreted as 95% C.L. limits in Tsqk2 models, assuming $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$ and $m_{\tilde{\chi}_2^0} = 600 \text{ GeV}$. See their Fig. 12 for exclusion limits as a function of $m_{\tilde{\chi}_2^0}$.
- 14 KHACHATRYAN 17P searched in 2.3 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one or more jets and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A, Tglu3A, Tglu3B, Tglu3C and Tglu3D simplified models, see their Figures 7 and 8. Limits are also set on the squark mass in the Tsqk1 simplified model, see their Fig. 7, and on the sbottom mass in the Tsb0t1 simplified model, see Fig. 8. Finally, limits are set on the stop mass in the Tstop1, Tstop3, Tstop4, Tstop6 and Tstop7 simplified models, see Fig. 8.
- 15 KHACHATRYAN 17V searched in 2.3 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two photons and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino and squark mass in the context of general gauge mediation models Tglu4B and Tsqk4, see their Fig. 4.
- 16 SIRUNYAN 17AV searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one photon, jets and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu4A and Tglu4B simplified models, and on the squark mass in the Tsqk4A and Tsqk4B simplified models, see their Figure 6.
- 17 SIRUNYAN 17AZ searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one or more jets and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A, Tglu3A simplified models, see their Figures 6. Limits are also set on the squark mass in the Tsqk1 simplified model (for single light squark and for 8 degenerate light squarks), on the sbottom mass in the Tsb0t1 simplified model and on the stop mass in the Tstop1 simplified model, see their Fig. 7. Finally, limits are set on the stop mass in the Tstop2, Tstop4 and Tstop8 simplified models, see Fig. 8.
- 18 SIRUNYAN 17P searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with multiple jets and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu1C, Tglu2A, Tglu3A and Tglu3D simplified models, see their Fig. 12. Limits are also set on the squark mass in the Tsqk1 simplified model, on the stop mass in the Tstop1 simplified model, and on the sbottom mass in the Tsb0t1 simplified model, see Fig. 13.
- 19 AABOUD 16D searched in 3.2 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with an energetic jet and large missing transverse momentum. The results are interpreted as 95% C.L. limits on masses of first and second generation squarks decaying into a quark and the lightest neutralino in scenarios with $m_{\tilde{q}} - m_{\tilde{\chi}_1^0} < 25 \text{ GeV}$. See their Fig. 6.
- 20 AABOUD 16N searched in 3.2 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing hadronic jets, large \cancel{E}_T , and no electrons or muons. No significant excess above the Standard Model expectations is observed. First- and second-generation squark masses below 1030 GeV are excluded at the 95% C.L. decaying to quarks and a massless lightest neutralino. See their Fig. 7a.
- 21 KHACHATRYAN 16BS searched in 2.3 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one energetic jet, no isolated leptons, and significant \cancel{E}_T , using the transverse mass variable M_{T2} to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on the squark mass in the Tsqk1 simplified model, both in the assumption of a single light squark and of 8 degenerate squarks, see Fig. 11 and Table 3.
- 22 AAD 15BV summarized and extended ATLAS searches for gluinos and first- and second-generation squarks in final states containing jets and missing transverse momentum, with or without leptons or b -jets in the $\sqrt{s} = 8 \text{ TeV}$ data set collected in 2012. The paper reports the results of new interpretations and statistical combinations of previously published analyses, as well as new analyses. Exclusion limits at 95% C.L. are set on the squark mass in several R-parity conserving models. See their Figs. 9, 11, 18, 22, 24, 27, 28.
- 23 AAD 15CS searched in 20.3 fb⁻¹ of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for evidence of pair production of squarks, decaying into a quark and a neutralino, where a photon was radiated either from an initial-state quark, from an intermediate squark, or from a final-state quark. No evidence was found for an excess above the expected level of Standard Model background and a 95% C.L. exclusion limit was set on the squark mass as a function of the squark-neutralino mass difference, see Fig. 19.
- 24 AAD 15K searched in 20.3 fb⁻¹ of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing at least two jets, where the two leading jets are each identified as originating from c -quarks, and large missing transverse momentum. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the mass of superpartners of charm quarks (\tilde{c}). Assuming that the decay $\tilde{c} \rightarrow c \tilde{\chi}_1^0$ takes place 100% of the time, a scalar charm mass below 490 GeV is excluded for $m_{\tilde{\chi}_1^0} < 200 \text{ GeV}$. For more details, see their Fig. 2.
- 25 KHACHATRYAN 15AF searched in 19.5 fb⁻¹ of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least two energetic jets and significant \cancel{E}_T , using the transverse mass variable M_{T2} to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on the squark mass in simplified models where the decay $\tilde{q} \rightarrow q \tilde{\chi}_1^0$ takes place with a branching ratio of 100%, both for the case of a single light squark or 8 degenerate squarks, see Fig. 12. See also Table 5. Exclusions in the CMSSM, assuming $\tan\beta = 30$, $A_0 = -2 \max(m_0, m_{1/2})$ and $\mu > 0$, are also presented, see Fig. 15.
- 26 AAD 14AE searched in 20.3 fb⁻¹ of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for strongly produced supersymmetric particles in events containing jets and large missing transverse momentum, and no electrons or muons. No excess over the expected SM background is observed. Exclusion limits are derived in simplified models containing squarks that decay via $\tilde{q} \rightarrow q \tilde{\chi}_1^0$, where either a single light state or two degenerate generations of squarks are assumed, see Fig. 10.
- 27 CHATRCHYAN 14AH searched in 4.7 fb⁻¹ of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with at least two energetic jets and significant \cancel{E}_T , using the razor variables (M_R and

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- R^2) to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on squark masses in simplified models where the decay $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 28. Exclusions in the CMSSM, assuming $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, are also presented, see Fig. 26.
- 28 CHATRCHYAN 14i searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing multijets and large \cancel{E}_T . No excess over the expected SM background is observed. Exclusion limits are derived in simplified models containing squarks that decay via $\tilde{q} \rightarrow q\tilde{\chi}_1^0$, where either a single light state or two degenerate generations of squarks are assumed, see Fig. 7a.
- 29 AAD 13i searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for the production of squarks and gluinos in events containing jets, missing transverse momentum and no high- p_T electrons or muons. No excess over the expected SM background is observed. In mSUGRA/CMSSM models with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, squarks and gluinos of equal mass are excluded for masses below 1360 GeV at 95% C.L. In a simplified model containing only squarks of the first two generations, a gluino octet and a massless neutralino, squark masses below 1320 GeV are excluded at 95% C.L. for gluino masses below 2 TeV. See Figures 10–15 for more precise bounds.
- 30 AAD 13q searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing a high- p_T isolated photon, at least one jet identified as originating from a bottom quark, and high missing transverse momentum. Such signatures may originate from supersymmetric models with gauge-mediated supersymmetry breaking in events in which one of a pair of higgsino-like neutralinos decays into a photon and a gravitino while the other decays into a Higgs boson and a gravitino. No significant excess above the expected background was found and limits were set on the squark mass as a function of the neutralino mass in a generalized GMSB model (GGM) with a higgsino-like neutralino NLSP, see their Fig. 4. For neutralino masses greater than 220 GeV, squark masses below 1020 GeV are excluded at 95% C.L.
- 31 CHATRCHYAN 13 looked in 4.98 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with two opposite-sign leptons (e, μ, τ), jets and missing transverse energy. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in the mSUGRA/CMSSM model with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, see Fig. 6.
- 32 CHATRCHYAN 13c searched in 4.98 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for the production of squarks and gluinos in events containing 0, 1, 2, ≥ 3 b-jets, missing transverse momentum and no electrons or muons. No excess over the expected SM background is observed. In mSUGRA/CMSSM models with $\tan\beta = 10$, $A_0 = 0$, and $\mu > 0$, squarks and gluinos of equal mass are excluded for masses below 1250 GeV at 95% C.L. Exclusions are also derived in various simplified models, see Fig. 7.
- 33 CHATRCHYAN 13h searched in 4.96 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with two photons, ≥ 4 jets and low \cancel{E}_T due to $\tilde{q} \rightarrow \gamma\tilde{\chi}_1^0$ decays in a stealth SUSY framework, where the $\tilde{\chi}_1^0$ decays through a singlino (\tilde{S}) intermediate state to $\gamma S\tilde{G}$, with the singlet state S decaying to two jets. No significant excess above the expected background was found and limits were set in a particular R-parity conserving stealth SUSY model. The model assumes $m_{\tilde{\chi}_1^0} = 0.5 m_{\tilde{q}}$, $m_{\tilde{S}} = 100 \text{ GeV}$ and $m_S = 90 \text{ GeV}$. Under these assumptions, squark masses less than 1430 GeV were excluded at the 95% C.L.
- 34 CHATRCHYAN 13t searched in 11.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least two energetic jets and significant \cancel{E}_T , using the α_T variable to discriminate between processes with genuine and misreconstructed \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on squark masses in simplified models where the decay $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, assuming an eightfold degeneracy of the masses of the first two generation squarks, see Fig. 8 and Table 9. Also limits in the case of a single light squark are given.
- 35 AAD 12Ax searched in 1.04 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for supersymmetry in events containing jets, missing transverse momentum and one isolated electron or muon. No excess over the expected SM background is observed and model-independent limits are set on the cross section of new physics contributions to the signal regions. In mSUGRA/CMSSM models with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, squarks and gluinos of equal mass are excluded for masses below 820 GeV at 95% C.L. Limits are also set on simplified models for squark production and decay via an intermediate chargino and on supersymmetric models with bilinear R-parity violation. Supersedes AAD 11g.
- 36 AAD 12c searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing one or more isolated leptons (electrons or muons), jets and \cancel{E}_T . The observations are in good agreement with the SM expectations and exclusion limits have been set in number of SUSY models. In the mSUGRA/CMSSM model with $\tan\beta = 10$, $A_0 = 0$, and $\mu > 0$, 95% C.L. exclusion limits have been derived for $m_{\tilde{q}} < 1200 \text{ GeV}$, assuming equal squark and gluino masses. In minimal GMSB, values of the effective SUSY breaking scale $\Lambda < 50 \text{ TeV}$ are excluded at 95% C.L. for $\tan\beta < 45$. Also exclusion limits in a number of simplified models have been presented, see Figs. 10 and 12.
- 37 AAD 12cp searched in 4.8 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with two photons and large \cancel{E}_T due to $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$ decays in a GMSB framework. No significant excess above the expected background was found and limits were set on the squark mass as a function of the neutralino mass in a generalized GMSB model (GGM) with a bino-like neutralino NLSP. The other sparticle masses were decoupled, $\tan\beta = 2$ and $c\tau_{NLSP} < 0.1 \text{ mm}$. Also, in the framework of the SPS8 model, a 95% C.L. lower limit was set on the breaking scale Λ of 196 TeV.
- 38 AAD 12w searched in 1.04 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for the production of squarks and gluinos in events containing jets, missing transverse momentum and no electrons or muons. No excess over the expected SM background is observed. In mSUGRA/CMSSM models with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, squarks and gluinos of equal mass are excluded for masses below 950 GeV at 95% C.L. In a simplified model containing only squarks of the first two generations, a gluino octet and a massless neutralino, squark masses below 875 GeV are excluded at 95% C.L.
- 39 CHATRCHYAN 12 looked in 35 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with e and/or μ and/or jets, a large total transverse energy, and \cancel{E}_T . The event selection is based on the dimensionless razor variable R , related to the \cancel{E}_T and $M_{\cancel{E}_T}$, an indicator of the heavy particle mass scale. No evidence for an excess over the expected background is observed. Limits are derived in the CMSSM ($m_0, m_{1/2}$) plane for $\tan\beta = 3, 10$ and 50 (see Fig. 7 and 8). Limits are also obtained for Simplified Model Spectra.
- 40 CHATRCHYAN 12aE searched in 4.98 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with at least three jets and large missing transverse momentum. No significant excesses over the expected SM backgrounds are observed and 95% C.L. limits on the production cross section of squarks in a scenario where $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ with a 100% branching ratio, see Fig. 3. For $m_{\tilde{\chi}_1^0} < 200 \text{ GeV}$, values of $m_{\tilde{q}}$ below 760 GeV are excluded at 95% C.L. Also limits in the CMSSM are presented, see Fig. 2.
- 41 CHATRCHYAN 12AT searched in 4.73 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for the production of squarks and gluinos in events containing jets, missing transverse momentum and no electrons or muons. No excess over the expected SM background is observed. In mSUGRA/CMSSM models with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, squarks with masses below 1110 GeV are excluded at 95% C.L. Squarks and gluinos of equal mass are excluded for masses below 1180 GeV at 95% C.L. Exclusions are also derived in various simplified models, see Fig. 6.
- 42 AABOUD 18v searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with no charged leptons, jets and missing transverse momentum. The data are found to be consistent with the SM expectation. Results are interpreted in the Tsqk5 model. Squark masses below 1100 GeV are excluded if $(m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})/(m_{\tilde{q}} - m_{\tilde{\chi}_1^0}) < 0.95$ and $m_{\tilde{\chi}_1^0} = 60 \text{ GeV}$, see their Fig. 16(a).
- 43 KHACHATRYAN 16BT performed a global Bayesian analysis of a wide range of CMS results obtained with data samples corresponding to 5.0 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ and in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$. The set of searches considered, both individually and in combination, includes those with all-hadronic final states, same-sign and opposite-sign dileptons, and multi-lepton final states. An interpretation was given in a scan of the 19-parameter pMSSM. No scan points with a gluino mass less than 500 GeV survived and 98% of models with a squark mass less than 300 GeV were excluded.
- 44 AAD 15AI searched in 20 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing at least one isolated lepton (electron or muon), jets, and large missing transverse momentum. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the squark masses in the CMSSM/mSUGRA, see Fig. 15, in the NUHM2, see Fig. 16, and in various simplified models, see Figs. 19–21.
- 45 KHACHATRYAN 15AR searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing jets, either a charged lepton or a photon, and low missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits are set on the squark mass in a stealth SUSY model where the decays $\tilde{q} \rightarrow q\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow \tilde{S} W^\pm$, $\tilde{S} \rightarrow S\tilde{G}$ and $S \rightarrow g\tilde{g}$, with $m_{\tilde{S}} = 100 \text{ GeV}$ and $m_S = 90 \text{ GeV}$, take place with a branching ratio of 100%. See Fig. 6 for γ or Fig. 7 for ℓ^\pm analyses.
- 46 KHACHATRYAN 15AZ searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with either at least one photon, hadronic jets and \cancel{E}_T (single photon channel) or with at least two photons and at least one jet and using the razor variables. No significant excess above the Standard Model expectations is observed. Limits are set on gluino masses in the general gauge-mediated SUSY breaking model (GGM), for both a bino-like and wino-like neutralino NLSP scenario, see Fig. 8 and 9.
- 47 AAD 14e searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for strongly produced supersymmetric particles in events containing jets and two same-sign leptons or three leptons. The search also utilises jets originating from b -quarks, missing transverse momentum and other variables. No excess over the expected SM background is observed. Exclusion limits are derived in simplified models containing gluinos and squarks, see Figs. 5 and 6. In the $\tilde{q} \rightarrow q'\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^{(*)}\tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \rightarrow Z^{(*)}\tilde{\chi}_1^0$ simplified model, the following assumptions have been made: $m_{\tilde{\chi}_1^\pm} = 0.5 m_{\tilde{\chi}_2^0} + m_{\tilde{g}}$, $m_{\tilde{\chi}_2^0} = 0.5 (m_{\tilde{\chi}_1^0} + m_{\tilde{\chi}_1^\pm})$. In the $\tilde{q} \rightarrow q'\tilde{\chi}_1^\pm$ or $\tilde{q} \rightarrow q'\tilde{\chi}_2^0$, $\tilde{\chi}_1^\pm \rightarrow \ell^\pm \nu_{\chi_1^0}$ or $\tilde{\chi}_2^0 \rightarrow \ell^\pm \ell^\mp (\nu\nu)\tilde{\chi}_1^0$ simplified model, the following assumptions have been made: $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0} = 0.5 (m_{\tilde{\chi}_1^0} + m_{\tilde{q}})$, $m_{\tilde{\chi}_1^0} < 460 \text{ GeV}$. Limits are also derived in the mSUGRA/CMSSM, bRPV and GMSB models, see their Fig. 8.
- 48 CHATRCHYAN 13AO searched in 4.98 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with two opposite-sign isolated leptons accompanied by hadronic jets and \cancel{E}_T . No significant excesses over the expected SM backgrounds are observed and 95% C.L. exclusion limits are derived in the mSUGRA/CMSSM model with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, see Fig. 8.
- 49 CHATRCHYAN 13AV searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for new heavy particle pairs decaying into jets (possibly b -tagged), leptons and \cancel{E}_T using the Razor variables. No significant excesses over the expected SM backgrounds are observed and 95% C.L. exclusion limits are derived in the mSUGRA/CMSSM model with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, see Fig. 3. The results are also interpreted in various simplified models, see Fig. 4.
- 50 CHATRCHYAN 13W searched in 4.93 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with one or more photons, hadronic jets and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on squark masses in the general gauge-mediated SUSY breaking model (GGM), for both a wino-like and bino-like neutralino NLSP scenario, see Fig. 5.
- 51 DREINER 12A reassesses constraints from CMS (at 7 TeV, $\sim 4.4 \text{ fb}^{-1}$) under the assumption that the first and second generation squarks and the lightest SUSY particle are quasi-degenerate in mass (compressed spectrum).
- 52 DREINER 12A reassesses constraints from CMS (at 7 TeV, $\sim 4.4 \text{ fb}^{-1}$) under the assumption that the first and second generation squarks, the gluino, and the lightest SUSY particle are quasi-degenerate in mass (compressed spectrum).

R-parity violating \tilde{q} (Squark) mass limit

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
none 100–720	95	1 SIRUNYAN	18EA CMS	2 large jets with four-parton substructure, $\tilde{q} \rightarrow 4q$
>1600	95	2 KHACHATRYAN 16BX	CMS	$\tilde{q} \rightarrow q\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \ell\ell\nu, \lambda_{121}$ or $\lambda_{122} \neq 0, m_{\tilde{g}} = 2400 \text{ GeV}$
>1000	95	3 AAD	15CB ATLAS	jets, $\tilde{q} \rightarrow q\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \ell q q$, $m_{\tilde{\chi}_1^0} = 108 \text{ GeV}$ and $2.5 < c\tau_{\tilde{\chi}_1^0} < 200 \text{ mm}$
		4 AAD	12AX ATLAS	$\ell + \text{jets} + \cancel{E}_T$, CMSSM, $m_{\tilde{q}} = m_{\tilde{g}}$
		5 CHATRCHYAN 12AL	CMS	$\geq 3\ell^\pm$

1 SIRUNYAN 18EA searched in 38.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for the pair production of resonances, each decaying to at least four quarks. Reconstructed particles are clustered into two large jets of similar mass, each consistent with four-parton substructure. No statistically significant excess over the Standard Model expectation is observed. Limits are set on the squark and gluino mass in RPV supersymmetry models where squarks (gluinos) decay, through intermediate higgsinos, to four (five) quarks, see their Figure 4.

- ² KHACHATRYAN 16BX searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing 4 leptons coming from R-parity-violating decays of $\tilde{\chi}_1^0 \rightarrow \ell\ell\nu$ with $\lambda_{121} \neq 0$ or $\lambda_{122} \neq 0$. No excess over the expected background is observed. Limits are derived on the gluino, squark and stop masses, see Fig. 23.
- ³ AAD 15CB searched for events containing at least one long-lived particle that decays at a significant distance from its production point (displaced vertex, DV) into two leptons or into five or more charged particles in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$. The dilepton signature is characterised by DV formed from at least two lepton candidates. Four different final states were considered for the multitrack signature, in which the DV must be accompanied by a high-transverse momentum muon or electron candidate that originates from the DV, jets or missing transverse momentum. No events were observed in any of the signal regions. Results were interpreted in SUSY scenarios involving R-parity violation, split supersymmetry, and gauge mediation. See their Fig. 14–20.
- ⁴ AAD 12AX searched in 1.04 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for supersymmetry in events containing jets, missing transverse momentum and one isolated electron or muon. No excess over the expected SM background is observed and model-independent limits are set on the cross section of new physics contributions to the signal regions. In mSUGRA/CMSSM models with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, squarks and gluinos of equal mass are excluded for masses below 820 GeV at 95% C.L. Limits are also set on simplified models for squark production and decay via an intermediate chargino and on supersymmetric models with bilinear R-parity violation. Supersedes AAD 11G.
- ⁵ CHATRCHYAN 12AL looked in 4.98 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for anomalous production of events with three or more isolated leptons. Limits on squark and gluino masses are set in RPV SUSY models with leptonic $LL\bar{E}$ couplings, $\lambda_{123} > 0.05$, and hadronic $U\bar{D}\bar{D}$ couplings, $\lambda_{112}^H > 0.05$, see their Fig. 5. In the $U\bar{D}\bar{D}$ case the leptons arise from supersymmetric cascade decays. A very specific supersymmetric spectrum is assumed. All decays are prompt.

Long-lived \tilde{q} (Squark) mass limit

The following are bounds on long-lived scalar quarks, assumed to hadronise into hadrons with lifetime long enough to escape the detector prior to a possible decay. Limits may depend on the mixing angle of mass eigenstates: $\tilde{q}_1 = \tilde{q}_L \cos\theta_q + \tilde{q}_R \sin\theta_q$.

The coupling to the Z^0 boson vanishes for up-type squarks when $\theta_u = 0.98$, and for down type squarks when $\theta_d = 1.17$.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1250	95	¹ AABOUD	19AT ATLS	\tilde{b} R-hadrons
>1340	95	² AABOUD	19AT ATLS	\tilde{t} R-hadrons
>1600	95	³ SIRUNYAN	19BH CMS	long-lived \tilde{t} , RPV, $\tilde{t} \rightarrow \bar{d}\bar{d}$, $10 \text{ mm} < c\tau < 110 \text{ mm}$
>1350	95	³ SIRUNYAN	19BH CMS	long-lived \tilde{t} , RPV, $\tilde{t} \rightarrow b\bar{\ell}$, $7 \text{ mm} < c\tau < 110 \text{ mm}$
> 805	95	⁴ AABOUD	16B ATLS	\tilde{b} R-hadrons
> 890	95	⁵ AABOUD	16B ATLS	\tilde{t} R-hadrons
>1040	95	⁶ KHACHATRY..16BW	CMS	\tilde{t} R-hadrons, cloud interaction model
>1000	95	⁶ KHACHATRY..16BW	CMS	\tilde{t} R-hadrons, charge-suppressed interaction model
> 845	95	⁷ AAD	15AE ATLS	\tilde{b} R-hadron, stable, Regge model
> 900	95	⁷ AAD	15AE ATLS	\tilde{t} R-hadron, stable, Regge model
>1500	95	⁷ AAD	15AE ATLS	\tilde{g} decaying to 300 GeV stable sleptons, LeptoSUSY model
> 751	95	⁸ AAD	15BM ATLS	\tilde{b} R-hadron, stable, Regge model
> 766	95	⁸ AAD	15BM ATLS	\tilde{t} R-hadron, stable, Regge model
> 525	95	⁹ KHACHATRY..15AK	CMS	\tilde{t} R-hadrons, $10 \mu\text{s} < \tau < 1000 \text{ s}$
> 470	95	⁹ KHACHATRY..15AK	CMS	\tilde{t} R-hadrons, $1 \mu\text{s} < \tau < 1000 \text{ s}$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
> 683	95	¹⁰ AAD	13AA ATLS	\tilde{t} , R-hadrons, generic interaction model
> 612	95	¹¹ AAD	13AA ATLS	\tilde{b} , R-hadrons, generic interaction model
> 344	95	¹² AAD	13BC ATLS	R-hadrons, $\tilde{t} \rightarrow b\tilde{\chi}_1^0$, Regge model, lifetime between 10^{-5} and 10^3 s , $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
> 379	95	¹³ AAD	13BC ATLS	R-hadrons, $\tilde{t} \rightarrow t\tilde{\chi}_1^0$, Regge model, lifetime between 10^{-5} and 10^3 s , $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
> 935	95	¹⁴ CHATRCHYAN	13AB CMS	long-lived \tilde{t} forming R-hadrons, cloud interaction model

¹ AABOUD 19AT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for metastable and stable R-hadrons. Multiple search strategies for a wide range of lifetimes, corresponding to path lengths of a few meters, are defined. No significant deviations from the expected Standard Model background are observed. Sbottom R-hadrons are excluded at 95% C.L. for masses below 1250 GeV . Less stringent constraints are achieved with the muon-spectrometer agnostic analysis. See their Figure 9 (bottom-left).

² AABOUD 19AT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for metastable and stable R-hadrons. Multiple search strategies for a wide range of lifetimes, corresponding to path lengths of a few meters, are defined. No significant deviations from the expected Standard Model background are observed. Stop R-hadrons are excluded at 95% C.L. for masses below 1340 GeV . Similar constraints are achieved with the muon-spectrometer agnostic analysis. See their Figure 9 (bottom-right).

³ SIRUNYAN 19BH searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for long-lived particles decaying into jets, with each long-lived particle having a decay vertex well displaced from the production vertex. The selected events are found to be consistent with standard model predictions. Limits are set on the gluino mass in a GMSB model where the gluino is decaying via $\tilde{g} \rightarrow g\tilde{G}$, see their Figure 4 and in an RPV model of supersymmetry where the gluino is decaying via $\tilde{g} \rightarrow \tilde{t}\bar{b}s$, see their Figures 5. Limits are also set on the stop mass in two RPV models, see their Figure 6 (for $\tilde{t} \rightarrow b\bar{\ell}$ decays) and Figure 7 (for $\tilde{t} \rightarrow \bar{d}\bar{d}$ decays).

⁴ AABOUD 16B searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for long-lived R-hadrons using observables related to large ionization losses and slow propagation velocities, which are signatures of heavy charged particles traveling significantly slower than

the speed of light. Exclusion limits at 95% C.L. are set on the long-lived sbottom masses exceeding 805 GeV . See their Fig. 5.

⁵ AABOUD 16B searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for long-lived R-hadrons using observables related to large ionization losses and slow propagation velocities, which are signatures of heavy charged particles traveling significantly slower than the speed of light. Exclusion limits at 95% C.L. are set on the long-lived stop masses exceeding 890 GeV . See their Fig. 5.

⁶ KHACHATRYAN 16BW searched in 2.5 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with heavy stable charged particles, identified by their anomalously high energy deposits in the silicon tracker and/or long time-of-flight measurements by the muon system. No evidence for an excess over the expected background is observed. Limits are derived for pair production of top squarks as a function of mass, depending on the interaction model, see Fig. 4 and Table 7.

⁷ AAD 15AE searched in 19.1 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for heavy long-lived charged particles, measured through their specific ionization energy loss in the ATLAS pixel detector or their time-of-flight in the ATLAS muon system. In the absence of an excess of events above the expected backgrounds, limits are set on R-hadrons in various scenarios, see Fig. 11. Limits are also set in LeptoSUSY models where the gluino decays to stable 300 GeV leptons, see Fig. 9.

⁸ AAD 15BM searched in 18.4 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for stable and metastable non-relativistic charged particles through their anomalously specific ionization energy loss in the ATLAS pixel detector. In absence of an excess of events above the expected backgrounds, limits are set on stable bottom and top squark R-hadrons, see Table 5.

⁹ KHACHATRYAN 15AK looked in a data set corresponding to fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$, and a search interval corresponding to 281 h of trigger lifetime, for long-lived particles that have stopped in the CMS detector. No evidence for an excess over the expected background in a cloud interaction model is observed. Assuming the decay $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ and lifetimes between $1 \mu\text{s}$ and 1000 s , limits are derived on \tilde{t} production as a function of $m_{\tilde{\chi}_1^0}$, see Figs. 4 and 7. The exclusions require that $m_{\tilde{\chi}_1^0}$ is kinematically consistent with the minimum values of the jet energy thresholds used.

¹⁰ AAD 13AA searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing colored long-lived particles that hadronize forming R-hadrons. No significant excess above the expected background was found. Long-lived R-hadrons containing a \tilde{t} are excluded for masses up to 683 GeV at 95% C.L. in a general interaction model. Also, limits independent of the fraction of R-hadrons that arrive charged in the muon system were derived, see Fig. 6.

¹¹ AAD 13AA searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing colored long-lived particles that hadronize forming R-hadrons. No significant excess above the expected background was found. Long-lived R-hadrons containing a \tilde{b} are excluded for masses up to 612 GeV at 95% C.L. in a general interaction model. Also, limits independent of the fraction of R-hadrons that arrive charged in the muon system were derived, see Fig. 6.

¹² AAD 13BC searched in 5.0 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ and in 22.9 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for bottom squark R-hadrons that have come to rest within the ATLAS calorimeter and decay at some later time to hadronic jets and a neutralino. In absence of an excess of events above the expected backgrounds, limits are set on sbottom masses for the decay $\tilde{b} \rightarrow b\tilde{\chi}_1^0$, for different lifetimes, and for a neutralino mass of 100 GeV , see their Table 6 and Fig. 10.

¹³ AAD 13BC searched in 5.0 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ and in 22.9 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for bottom squark R-hadrons that have come to rest within the ATLAS calorimeter and decay at some later time to hadronic jets and a neutralino. In absence of an excess of events above the expected backgrounds, limits are set on stop masses for the decay $\tilde{t} \rightarrow t\tilde{\chi}_1^0$, for different lifetimes, and for a neutralino mass of 100 GeV , see their Table 6 and Fig. 10.

¹⁴ CHATRCHYAN 13AB looked in 5.0 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ and in 18.8 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with heavy stable particles, identified by their anomalous dE/dx in the tracker or additionally requiring that it be identified as muon in the muon chambers, from pair production of \tilde{t}_1 's. No evidence for an excess over the expected background is observed. Limits are derived for pair production of stops as a function of mass in the cloud interaction model (see Fig. 8 and Table 6). In the charge-suppressed model, the limit decreases to 818 GeV .

\tilde{b} (Sbottom) mass limit

Limits in e^+e^- depend on the mixing angle of the mass eigenstate $\tilde{b}_1 = \tilde{b}_L \cos\theta_b + \tilde{b}_R \sin\theta_b$. Coupling to the Z vanishes for $\theta_b \sim 1.17$. As a consequence, no absolute constraint in the mass region $\lesssim 40 \text{ GeV}$ is available in the literature at this time from e^+e^- collisions. In the Listings below, we use $\Delta m = m_{\tilde{b}_1} - m_{\tilde{\chi}_1^0}$.

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, *et al.* (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

R-parity conserving \tilde{b} (Sbottom) mass limit

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1500	95	¹ AAD	19H ATLS	$\geq 3 \text{ b-jets} + \cancel{E}_T$, Tsbot4, $\geq 1 \text{ h}(\rightarrow b\bar{b})$, $m_{\tilde{\chi}_1^0} = 60 \text{ GeV}$
>1300	95	² AAD	19H ATLS	$\geq 3 \text{ b-jets} + \cancel{E}_T$, Tsbot4, $\geq 1 \text{ h}(\rightarrow b\bar{b})$, $m_{\tilde{\chi}_1^0} = m_{\tilde{\chi}_2^0} + 130 \text{ GeV}$
>1220	95	³ SIRUNYAN	19CH CMS	$\text{jets} + \cancel{E}_T$, Tsbot1, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 530	95	⁴ SIRUNYAN	19CI CMS	$\geq 1 \text{ H}(\rightarrow \gamma\gamma) + \text{jets} + \cancel{E}_T$, Tsbot4, $m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^0} + 130 \text{ GeV}$, $m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$
> 430	95	⁵ AABOUD	18I ATLS	$\geq 1 \text{ jets} + \cancel{E}_T$, Tsbot1, $m_{\tilde{b}} - m_{\tilde{\chi}_1^0} \sim m_b$

Searches Particle Listings

Supersymmetric Particle Searches

> 840	95	6	SIRUNYAN	18AL CMS	$\geq 3\ell^\pm + \text{jets} + \cancel{E}_T$, Tsb2, $m_{\tilde{\chi}_1^0} \geq 50$ GeV	> 500	95	36	CHATRCHYAN14H CMS	same-sign $\ell^\pm \ell^\pm$, $\tilde{b} \rightarrow t \tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^\pm} = 2$ GeV, $m_{\tilde{\chi}_1^0} = 100$ GeV
> 975	95	7	SIRUNYAN	18AR CMS	$\ell^\pm \ell^\mp + \text{jets} + \cancel{E}_T$, Tsb3, $m_{\tilde{\chi}_1^0} = (m_{\tilde{\chi}_2^0} + m_{\tilde{\chi}_1^0})/2$, $m_{\tilde{\chi}_1^0} = 100$ GeV	> 620	95	37	AAD 13AU ATLS	2 b -jets + \cancel{E}_T , $\tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} < 120$ GeV
>1060	95	8	SIRUNYAN	18AY CMS	jets + \cancel{E}_T , Tsb1, $m_{\tilde{\chi}_1^0} = 0$ GeV	> 550	95	38	CHATRCHYAN13AT CMS	jets + \cancel{E}_T , $\tilde{b} \rightarrow b \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 50$ GeV
>1230	95	9	SIRUNYAN	18B CMS	jets + \cancel{E}_T , Tsb1, $m_{\tilde{\chi}_1^0} = 0$ GeV	> 600	95	39	CHATRCHYAN13T CMS	jets + \cancel{E}_T , $\tilde{b} \rightarrow b \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 0$ GeV
> 420	95	10	SIRUNYAN	18X CMS	$\geq 1 H (\rightarrow \gamma\gamma) + \text{jets} + \cancel{E}_T$, Tsb4, $m_{\tilde{\chi}_1^0} = m_{\tilde{\chi}_2^0} + 130$ GeV, $m_{\tilde{\chi}_1^0} < 225$ GeV	> 450	95	40	CHATRCHYAN13v CMS	same-sign $\ell^\pm \ell^\pm + \geq 2$ b -jets, $\tilde{b} \rightarrow t \tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 50$ GeV
> 700	95	11	AABOUD	17AJ ATLS	same-sign $\ell^\pm \ell^\pm + 3 \ell + \text{jets} + \cancel{E}_T$, Tsb2, $m_{\tilde{\chi}_1^0} = 0$ GeV	> 390		41	AAD 12AN ATLS	$\tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^0} < 60$ GeV
> 950	95	12	AABOUD	17AX ATLS	2 b -jets + \cancel{E}_T , Tsb1, $m_{\tilde{\chi}_1^0} = 0$ GeV	> 410	95	42	CHATRCHYAN12AI CMS	$\ell^\pm \ell^\pm + b$ -jets + \cancel{E}_T
> 880	95	13	AABOUD	17AX ATLS	2 b -jets + \cancel{E}_T , mixture Tsb1 and Tsb2 BR=50%, $m_{\tilde{\chi}_1^0} = 0$ GeV, $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 1$ GeV	> 294	95	43	CHATRCHYAN12Bo CMS	$\tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^0} = 50$ GeV
> 315	95	14	KHACHATRY...17A	CMS	2 VBF jets + \cancel{E}_T , Tsb1, $m_{\tilde{b}} - m_{\tilde{\chi}_1^0} = 5$ GeV	> 230	95	44	AAD 11K ATLS	stable \tilde{b}
> 450	95	15	KHACHATRY...17AW	CMS	$\geq 3\ell^\pm$, 2 jets, Tsb2, $m_{\tilde{\chi}_1^0} = 50$ GeV, $m_{\tilde{\chi}_1^\pm} = 200$ GeV	> 247	95	45	AAD 11o ATLS	$\tilde{g} \rightarrow \tilde{b}_1 b, \tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 60$ GeV
> 800	95	16	KHACHATRY...17P	CMS	1 or more jets + \cancel{E}_T , Tsb1, $m_{\tilde{\chi}_1^0} = 0$ GeV	> 230	95	46	CHATRCHYAN11D CMS	$\tilde{b}, \tilde{t} \rightarrow b$
>1175	95	17	SIRUNYAN	17AZ CMS	≥ 1 jets + \cancel{E}_T , Tsb1, $m_{\tilde{\chi}_1^0} = 0$ GeV	> 230	95	47	AALTONEN 10R CDF	$\tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} < 70$ GeV
> 890	95	18	SIRUNYAN	17K CMS	jets + \cancel{E}_T , Tsb1, $m_{\tilde{\chi}_1^0} = 0$ GeV	> 247	95	48	ABAZOV 10L D0	$\tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 0$ GeV
> 810	95	19	SIRUNYAN	17s CMS	same-sign $\ell^\pm \ell^\pm + \text{jets} + \cancel{E}_T$, Tsb2, $m_{\tilde{\chi}_1^0} = 50$ GeV, $m_{\tilde{\chi}_1^\pm} = 100$ GeV					
> 323	95	20	AABOUD	16D ATLS	≥ 1 jet + \cancel{E}_T , Tsb1, $m_{\tilde{b}} - m_{\tilde{\chi}_1^0} = 5$ GeV					
> 840	95	21	AABOUD	16Q ATLS	2 b -jets + \cancel{E}_T , Tsb1, $m_{\tilde{\chi}_1^0} = 100$ GeV					
> 540	95	22	AAD	16BB ATLS	2 same-sign $\ell^\pm \ell^\pm + \text{jets} + \cancel{E}_T$, Tsb2, $m_{\tilde{\chi}_1^0} < 55$ GeV					
> 680	95	23	KHACHATRY...16Bj	CMS	same-sign $\ell^\pm \ell^\pm$, Tsb2, $m_{\tilde{\chi}_1^\pm} < 550$ GeV, $m_{\tilde{\chi}_1^0} = 50$ GeV					
> 500	95	23	KHACHATRY...16Bj	CMS	same-sign $\ell^\pm \ell^\pm$, Tsb2, $m_{\tilde{b}} - m_{\tilde{\chi}_1^0} < 100$ GeV, $m_{\tilde{\chi}_1^0} = 50$ GeV					
> 880	95	24	KHACHATRY...16Bs	CMS	jets + \cancel{E}_T , Tsb1, $m_{\tilde{\chi}_1^0} = 0$ GeV					
> 550	95	25	KHACHATRY...16By	CMS	opposite-sign $\ell^\pm \ell^\pm$, Tsb3, $m_{\tilde{\chi}_1^0} = 100$ GeV					
> 600	95	26	AAD	15Cj ATLS	$\tilde{b} \rightarrow b \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} < 250$ GeV					
> 440	95	26	AAD	15Cj ATLS	$\tilde{b} \rightarrow t \tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow W^{(*)} \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 60$ GeV, $m_{\tilde{b}} - m_{\tilde{\chi}_1^\pm} < m_t$					
none 300–650	95	26	AAD	15Cj ATLS	$\tilde{b} \rightarrow \tilde{b} b \tilde{\chi}_2^0, \tilde{\chi}_2^0 \rightarrow h \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 60$ GeV, $m_{\tilde{\chi}_2^0} > 250$ GeV					
> 640	95	27	KHACHATRY...15AF	CMS	$\tilde{b} \rightarrow b \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 0$					
> 650	95	28	KHACHATRY...15AH	CMS	$\tilde{b} \rightarrow b \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 0$					
> 250	95	28	KHACHATRY...15AH	CMS	$\tilde{b} \rightarrow b \tilde{\chi}_1^0$, $m_{\tilde{b}} - m_{\tilde{\chi}_1^0} < 10$ GeV					
> 570	95	29	KHACHATRY...15i	CMS	$\tilde{b} \rightarrow t \tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 50$ GeV, $150 < m_{\tilde{\chi}_1^\pm} < 300$ GeV					
> 255	95	30	AAD	14T ATLS	$\tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$, $m_{\tilde{b}_1} - m_{\tilde{\chi}_1^0} \approx m_b$					
> 400	95	31	CHATRCHYAN14AH	CMS	jets + \cancel{E}_T , $\tilde{b} \rightarrow b \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 50$ GeV					
		32	CHATRCHYAN14R	CMS	$\geq 3\ell^\pm$, $\tilde{b} \rightarrow t \tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 50$ GeV					
• • • We do not use the following data for averages, fits, limits, etc. • • •		33	KHACHATRY...15AD	CMS	$\ell^\pm \ell^\mp + \text{jets} + \cancel{E}_T$, $\tilde{b} \rightarrow b \ell^\pm \ell^\mp \tilde{\chi}_1^0$					
none 340–600	95	34	AAD	14AX ATLS	≥ 3 b -jets + \cancel{E}_T , $\tilde{b} \rightarrow b \tilde{\chi}_2^0$ simplified model with $\tilde{\chi}_2^0 \rightarrow h \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 60$ GeV, $m_{\tilde{\chi}_2^0} = 300$ GeV					
> 440	95	35	AAD	14E ATLS	$\ell^\pm \ell^\pm (\ell^\mp) + \text{jets}$, $\tilde{b}_1 \rightarrow t \tilde{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm \rightarrow W^{(*)} \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^\pm} \geq 2$ GeV, $m_{\tilde{\chi}_1^0} = 0$ GeV					

- 11 AABOUD 17AJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two same-sign or three leptons, jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 700 GeV are set on the bottom squark mass in Tsb02 simplified models assuming $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$. See their Figure 4(d).
- 12 AABOUD 17AX searched in 36 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing two jets identified as originating from b -quarks and large missing transverse momentum. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the masses of bottom squarks. In the Tsb01 simplified model, a \tilde{b}_1 mass below 950 GeV is excluded for $m_{\tilde{\chi}_1^0} = 0$ (<420) GeV . See their Fig. 7(a).
- 13 AABOUD 17AX searched in 36 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing two jets identified as originating from b -quarks and large missing transverse momentum, with or without leptons. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the masses of bottom squarks. Assuming 50% BR for Tsb01 and Tsb02 simplified models, a \tilde{b}_1 mass below 880 (860) GeV is excluded for $m_{\tilde{\chi}_1^0} = 0$ (<250) GeV . See their Fig. 7(b).
- 14 KHACHATRYAN 17A searched in 18.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with two forward jets, produced through vector boson fusion, and missing transverse momentum. No significant excess above the Standard Model expectations is observed. A limit is set on sbottom masses in the Tsb01 simplified model, see Fig. 3.
- 15 KHACHATRYAN 17AW searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least three charged leptons, in any combination of electrons and muons, and significant E_{miss} . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu3A and Tglu1C simplified models, and on the sbottom mass in the Tsb02 simplified model, see their Figure 4.
- 16 KHACHATRYAN 17P searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one or more jets and large E_{miss} . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A, Tglu3A, Tglu3B, Tglu3C and Tglu3D simplified models, see their Figures 7 and 8. Limits are also set on the squark mass in the Tsqk1 simplified model, see their Fig. 7, and on the sbottom mass in the Tsb01 simplified model, see Fig. 8. Finally, limits are set on the stop mass in the Tstop1, Tstop3, Tstop4, Tstop6 and Tstop7 simplified models, see Fig. 8.
- 17 SIRUNYAN 17AZ searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one or more jets and large E_{miss} . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A, Tglu3A simplified models, see their Figures 6. Limits are also set on the squark mass in the Tsqk1 simplified model (for single light squark and for 8 degenerate light squarks), on the sbottom mass in the Tsb01 simplified model and on the stop mass in the Tstop1 simplified model, see their Fig. 7. Finally, limits are set on the stop mass in the Tstop2, Tstop4 and Tstop8 simplified models, see Fig. 8.
- 18 SIRUNYAN 17K searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct production of stop or sbottom pairs in events with multiple jets and significant E_{miss} . A second search also requires an isolated lepton and is combined with the all-hadronic search. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1, Tstop8 and Tstop4 simplified models, see their Figures 7, 8 and 9 (for the Tstop4 limits, only the results of the all-hadronic search are used). Limits are also set on the sbottom mass in the Tsb01 simplified model, see Fig. 10 (also here, only the results of the all-hadronic search are used).
- 19 SIRUNYAN 17S searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two isolated same-sign leptons, jets, and large E_{miss} . No significant excess above the Standard Model expectations is observed. Limits are set on the mass of the gluino mass in the Tglu3A, Tglu3B, Tglu3C, Tglu3D and Tglu1B simplified models, see their Figures 5 and 6, and on the sbottom mass in the Tsb02 simplified model, see their Figure 6.
- 20 AABOUD 16D searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with an energetic jet and large missing transverse momentum. The results are interpreted as 95% C.L. limits on mass of sbottom decaying into a b -quark and the lightest neutralino in scenarios with $m_{\tilde{b}_1} - m_{\tilde{\chi}_1^0}$ between 5 and 20 GeV . See their Fig. 6.
- 21 AABOUD 16Q searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing two jets identified as originating from b -quarks and large missing transverse momentum. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the masses of third-generation squarks. Assuming that the decay $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$ (Tsb01) takes place 100% of the time, a \tilde{b}_1 mass below 840 (800) GeV is excluded for $m_{\tilde{\chi}_1^0} < 100$ (360) GeV . Differences in mass above 100 GeV between the \tilde{b}_1 and the $\tilde{\chi}_1^0$ are excluded up to a \tilde{b}_1 mass of 500 GeV . For more details, see their Fig. 4.
- 22 AAD 16BB searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with exactly two same-sign leptons or at least three leptons, multiple hadronic jets, b -jets, and E_{miss} . No significant excess over the Standard Model expectation is found. Exclusion limits at 95% C.L. are set on the sbottom mass for the Tsb02 model, assuming $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0} + 100 \text{ GeV}$. See their Fig. 4c.
- 23 KHACHATRYAN 16BJ searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two isolated same-sign dileptons and jets in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the sbottom mass in the Tsb02 simplified model, see Fig. 6.
- 24 KHACHATRYAN 16BS searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one energetic jet, no isolated leptons, and significant E_{miss} , using the transverse mass variable M_{T2} to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on the sbottom mass in the Tsb01 simplified model, see Fig. 11 and Table 3.
- 25 KHACHATRYAN 16BY searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two opposite-sign, same-flavour leptons, jets, and missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu4C simplified model, see Fig. 4, and on sbottom masses in the Tsb03 simplified model, see Fig. 5.
- 26 AAD 15CU searched in 20 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for evidence of third generation squarks by combining a large number of searches covering various final states. Limits on the sbottom mass are shown, either assuming the $\tilde{b} \rightarrow b\tilde{\chi}_1^0$ decay, see Fig. 11, or assuming the $\tilde{b} \rightarrow t\tilde{\chi}_1^\pm$ decay, with $\tilde{\chi}_1^\pm \rightarrow W^{(*)}\tilde{\chi}_1^0$, see Fig. 12a, or assuming the $\tilde{b} \rightarrow b\tilde{\chi}_1^0$ decay, with $\tilde{\chi}_1^0 \rightarrow h\tilde{\chi}_1^0$, see Fig. 12b. Interpretations in the pMSSM are also discussed, see Figures 13–15.
- 27 KHACHATRYAN 15AF searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least two energetic jets and significant E_{miss} , using the transverse mass variable M_{T2} to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on the sbottom mass in simplified models where the decay $\tilde{b} \rightarrow b\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 12. See also Table 5. Exclusions in the CMSSM, assuming $\tan\beta = 30$, $A_0 = -2 \max(m_0, m_{1/2})$ and $\mu > 0$, are also presented, see Fig. 15.
- 28 KHACHATRYAN 15AH searched in 19.4 or 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing either a fully reconstructed top quark, or events containing dijets requiring one or both jets to originate from b -quarks, or events containing a mono-jet. No significant excess above the Standard Model expectations is observed. Limits are set on the sbottom mass in simplified models where the decay $\tilde{b} \rightarrow b\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 12. Limits are also set in a simplified model where the decay $\tilde{b} \rightarrow c\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 12.
- 29 KHACHATRYAN 15I searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events in which b -jets and four W -bosons are produced. Five individual search channels are combined (fully hadronic, single lepton, same-sign dilepton, opposite-sign dilepton, multi-lepton). No significant excess above the Standard Model expectations is observed. Limits are set on the sbottom mass in a simplified model where the decay $\tilde{b} \rightarrow t\tilde{\chi}_1^\pm$, with $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$, takes place with a branching ratio of 100%, see Fig. 7.
- 30 AAD 14T searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for monojet-like events. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the masses of third-generation squarks in simplified models which assume that the decay $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$ takes place 100% of the time, see Fig. 12.
- 31 CHATRCHYAN 14AH searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with at least two energetic jets and significant E_{miss} , using the razor variables (M_R and R^2) to discriminate between signal and background processes. A second analysis requires at least one of the jets to be originating from a b -quark. No significant excess above the Standard Model expectations is observed. Limits are set on sbottom masses in simplified models where the decay $\tilde{b} \rightarrow b\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Figs. 28 and 29. Exclusions in the CMSSM, assuming $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, are also presented, see Fig. 26.
- 32 CHATRCHYAN 14R searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least three leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in a simplified model where the decay $\tilde{b} \rightarrow t\tilde{\chi}_1^\pm$, with $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$, takes place with a branching ratio of 100%, see Fig. 11.
- 33 KHACHATRYAN 15AD searched in 19.4 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with two opposite-sign same flavor isolated leptons featuring either a kinematic edge, or a peak at the Z -boson mass, in the invariant mass spectrum. No evidence for a statistically significant excess over the expected SM backgrounds is observed and 95% C.L. exclusion limits are derived in a simplified model of sbottom pair production where the sbottom decays into a b -quark, two opposite-sign dileptons and a neutralino LSP, through an intermediate state containing either an off-shell Z -boson or a slepton, see Fig. 8.
- 34 AAD 14AX searched in 20.1 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for the strong production of supersymmetric particles in events containing either zero or at least one high p_T lepton, large missing transverse momentum, high jet multiplicity and at least three jets identified as originating from b -quarks. No excess over the expected SM background is observed. Limits are derived in mSUGRA/CMSSM models with $\tan\beta = 30$, $A_0 = -2m_0$ and $\mu > 0$, see their Fig. 14. Also, exclusion limits are set in simplified models containing scalar bottom quarks, where the decay $\tilde{b} \rightarrow b\tilde{\chi}_2^0$ and $\tilde{\chi}_2^0 \rightarrow h\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see their Figures 11.
- 35 AAD 14E searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for strongly produced supersymmetric particles in events containing jets and two same-sign leptons or three leptons. The search also utilizes jets originating from b -quarks, missing transverse momentum and other variables. No excess over the expected SM background is observed. Exclusion limits are derived in simplified models containing bottom, see Fig. 7. Limits are also derived in the mSUGRA/CMSSM, bRPV and GMSB models, see their Fig. 8.
- 36 CHATRCHYAN 14H searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with two isolated same-sign dileptons and jets in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the sbottom mass in a simplified models where the decay $\tilde{b} \rightarrow t\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, with varying mass of the $\tilde{\chi}_1^\pm$, for $m_{\tilde{\chi}_1^0} = 50 \text{ GeV}$, see Fig. 6.
- 37 AAD 13AU searched in 20.1 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing two jets identified as originating from b -quarks and large missing transverse momentum. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the masses of third-generation squarks. Assuming that the decay $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$ takes place 100% of the time, a \tilde{b}_1 mass below 620 GeV is excluded for $m_{\tilde{\chi}_1^0} < 120 \text{ GeV}$. For more details, see their Fig. 5.
- 38 CHATRCHYAN 13AT provides interpretations of various searches for supersymmetry by the CMS experiment based on $4.73\text{--}4.98 \text{ fb}^{-1}$ of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ in the framework of simplified models. Limits are set on the sbottom mass in a simplified models where sbottom quarks are pair-produced and the decay $\tilde{b} \rightarrow b\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 4.
- 39 CHATRCHYAN 13T searched in 11.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least two energetic jets and significant E_{miss} , using the α_T variable to discriminate between processes with genuine and misreconstructed E_{miss} . No significant excess above the Standard Model expectations is observed. Limits are set on sbottom masses in simplified models where the decay $\tilde{b} \rightarrow b\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 8 and Table 9.
- 40 CHATRCHYAN 13V searched in 10.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with two isolated same-sign dileptons and at least two b -jets in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the bottom mass in a simplified models where the decay $\tilde{b} \rightarrow t\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, with varying mass of the $\tilde{\chi}_1^\pm$, for $m_{\tilde{\chi}_1^0} = 50 \text{ GeV}$, see Fig. 4.

Searches Particle Listings

Supersymmetric Particle Searches

- ⁴¹ AAD 12AN searched in 2.05 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for scalar bottom quarks in events with large missing transverse momentum and two b -jets in the final state. The data are found to be consistent with the Standard Model expectations. Limits are set in an R-parity conserving minimal supersymmetric scenario, assuming $B(\bar{b}_1 \rightarrow b\bar{\chi}_1^0) = 100\%$, see their Fig. 2.
- ⁴² CHATRCHYAN 12AI looked in 4.98 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with two same-sign leptons (e, μ), but not necessarily same flavor, at least 2 b -jets and missing transverse energy. No excess beyond the Standard Model expectation is observed. Exclusion limits are derived in a simplified model for sbottom pair production, where the sbottom decays through $\bar{b}_1 \rightarrow t\bar{\chi}_1 W$, see Fig. 8.
- ⁴³ CHATRCHYAN 12BO searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for scalar bottom quarks in events with large missing transverse momentum and two b -jets in the final state. The data are found to be consistent with the Standard Model expectations. Limits are set in an R-parity conserving minimal supersymmetric scenario, assuming $B(\bar{b}_1 \rightarrow b\bar{\chi}_1^0) = 100\%$, see their Fig. 2.
- ⁴⁴ AAD 11K looked in 34 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with heavy stable particles, identified by their anomalous dE/dx in the tracker or time of flight in the tile calorimeter, from pair production of \tilde{b} . No evidence for an excess over the SM expectation is observed and limits on the mass are derived for pair production of sbottom, see Fig. 4.
- ⁴⁵ AAD 11O looked in 35 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with jets, of which at least one is a b -jet, and \cancel{E}_T . No excess above the Standard Model was found. Limits are derived in the $(m_{\tilde{g}}, m_{\tilde{b}_1})$ plane (see Fig. 2) under the assumption of 100% branching ratios and \tilde{b}_1 being the lightest squark. The quoted limit is valid for $m_{\tilde{b}_1} < 500 \text{ GeV}$. A similar approach for \tilde{t}_1 as the lightest squark with $\tilde{g} \rightarrow \tilde{t}_1 t$ and $\tilde{t}_1 \rightarrow b\bar{\chi}_1^\pm$ with 100% branching ratios leads to a gluino mass limit of 520 GeV for $130 < m_{\tilde{t}_1} < 300 \text{ GeV}$. Limits are also derived in the CMSSM $(m_0, m_{1/2})$ plane for $\tan\beta = 40$, see Fig. 4, and in scenarios based on the gauge group $SO(10)$.
- ⁴⁶ CHATRCHYAN 11D looked in 35 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with ≥ 2 jets, at least one of which is b -tagged, and \cancel{E}_T , where the b -jets are decay products of \tilde{t} or \tilde{b} . No evidence for an excess over the expected background is observed. Limits are derived in the CMSSM $(m_0, m_{1/2})$ plane for $\tan\beta = 50$ (see Fig. 2).
- ⁴⁷ AALTONEN 10R searched in 2.65 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for events with \cancel{E}_T and exactly two jets, at least one of which is b -tagged. The results are in agreement with the SM prediction, and a limit on the cross section of 0.1 pb is obtained for the range of masses $80 < m_{\tilde{b}_1} < 280 \text{ GeV}$ assuming that the sbottom decays exclusively to $b\bar{\chi}_1^0$. The excluded mass region in the framework of conserved R_p is shown in a plane of $(m_{\tilde{b}_1}, m_{\tilde{\chi}_1^0})$, see their Fig. 2.
- ⁴⁸ ABAZOV 10L looked in 5.2 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ for events with at least 2 b -jets and \cancel{E}_T from the production of $\tilde{b}_1 \tilde{b}_1$. No evidence for an excess over the SM expectation is observed, and a limit on the cross section is derived under the assumption of 100% branching ratio. The excluded mass region in the framework of conserved R_p is shown in a plane of $(m_{\tilde{b}_1}, m_{\tilde{\chi}_1^0})$, see their Fig. 3b. The exclusion also extends to $m_{\tilde{\chi}_1^0} = 110 \text{ GeV}$ for $160 < m_{\tilde{b}_1} < 200 \text{ GeV}$.

R-parity violating \tilde{b} (Sbottm) mass limit

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>307	95	¹ KHACHATRYAN 16BX CMS	RPV, $\tilde{b} \rightarrow t d$ or ts , λ''_{332} or λ''_{331} coupling	

• • • We do not use the following data for averages, fits, limits, etc. • • •

		² AAD	14E ATLS	$\ell^\pm \ell^\mp (\ell^\mp) + \text{jets}, \tilde{b}_1 \rightarrow t\bar{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm \rightarrow W^{(*)} \pm \chi_1^0$ simplified model, $m_{\tilde{\chi}_1^\pm} = 2 m_{\tilde{\chi}_1^0}$
¹ KHACHATRYAN 16BX	searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing 2 leptons coming from R-parity-violating decays of supersymmetric particles. No excess over the expected background is observed. Limits are derived on the sbottom mass, assuming the RPV $\tilde{b} \rightarrow t d$ or $\tilde{b} \rightarrow ts$ decay, see Fig. 15.			
² AAD 14E	searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for strongly produced supersymmetric particles in events containing jets and two same-sign leptons or three leptons. The search also utilises jets originating from b -quarks, missing transverse momentum and other variables. No excess over the expected SM background is observed. Exclusion limits are derived in simplified models containing bottom, see Fig. 7. Limits are also derived in the mSUGRA/CMSSM, bRPV and GMSB models, see their Fig. 8.			

\tilde{t} (Stop) mass limit

Limits depend on the decay mode. In e^+e^- collisions they also depend on the mixing angle of the mass eigenstate $\tilde{t}_1 = \tilde{t}_L \cos\theta_t + \tilde{t}_R \sin\theta_t$. The coupling to the Z vanishes when $\theta_t = 0.98$. In the Listings below, we use $\Delta m \equiv m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0}$ or $\Delta m \equiv m_{\tilde{t}_1} - m_{\tilde{\nu}_\tau}$, depending on relevant decay mode. See also bounds in "q (Squark) MASS LIMIT."

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, *et al.* (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

R-parity conserving \tilde{t} (Stop) mass limit

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1110	95	¹ SIRUNYAN	19AU CMS	$\gamma + \text{jets} + b\text{-jets} + \cancel{E}_T$, Tstop13, $m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$
>1230	95	¹ SIRUNYAN	19AU CMS	$\gamma + \text{jets} + b\text{-jets} + \cancel{E}_T$, Tstop13, $m_{\tilde{\chi}_1^0} = 800 \text{ GeV}$

>1190	95	² SIRUNYAN	19CH CMS	jets + \cancel{E}_T , Tstop1, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1140	95	³ SIRUNYAN	19S CMS	1 or 2 $\ell + \text{jets} + \cancel{E}_T$, Tstop1, $m_{\tilde{\chi}_1^0} < 200 \text{ GeV}$
> 208	95	⁴ SIRUNYAN	19U CMS	$e^\pm \mu^\mp + \geq 1b\text{-jet}$, Tstop1, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 175 \text{ GeV}$
> 235	95	⁴ SIRUNYAN	19U CMS	$e^\pm \mu^\mp + \geq 1b\text{-jet}$, Tstop1, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 182.5 \text{ GeV}$
> 242	95	⁴ SIRUNYAN	19U CMS	$e^\pm \mu^\mp + \geq 1b\text{-jet}$, Tstop1, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 167.5 \text{ GeV}$
> 940	95	⁵ AABOUD	18AQ ATLS	$1\ell + \text{jets} + \cancel{E}_T$, Tstop1, $m_{\tilde{\chi}_1^0} = 0$
> 270	95	⁶ AABOUD	18AQ ATLS	$1\ell + \text{jets} + \cancel{E}_T$, Tstop3, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 20 \text{ GeV}$
> 840	95	⁷ AABOUD	18AQ ATLS	$1\ell + \text{jets} + \cancel{E}_T$, Tstop2, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^\pm} = 10 \text{ GeV}$
> 500	95	⁸ AABOUD	18BV ATLS	$c\text{-jets} + \cancel{E}_T$, Tstop4, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < 100 \text{ GeV}$
> 850	95	⁹ AABOUD	18BV ATLS	$c\text{-jets} + \cancel{E}_T$, Tstop4, $m_{\tilde{\chi}_1^0} = 0$
> 390	95	¹⁰ AABOUD	18I ATLS	$\geq 1 \text{ jets} + \cancel{E}_T$, Tstop3, $m_{\tilde{t}_1} \sim m_{\tilde{\chi}_1^0}$
> 430	95	¹¹ AABOUD	18I ATLS	$\geq 1 \text{ jets} + \cancel{E}_T$, Tstop4, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$
>1160	95	¹² AABOUD	18Y ATLS	$2\ell (\geq 1 \text{ hadronic } \tau) + b\text{-jets} + \cancel{E}_T$, Tstop5, $m_{\tilde{\tau}} \sim 800 \text{ GeV}$
> 450	95	¹³ SIRUNYAN	18AJ CMS	$2\ell (\text{soft}) + \cancel{E}_T$, Tstop10, $m_{\tilde{\chi}_1^\pm} = (m_{\tilde{t}_1} + m_{\tilde{\chi}_1^0})/2$, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 40 \text{ GeV}$
> 720	95	¹⁴ SIRUNYAN	18AL CMS	$\geq 3\ell^\pm + \text{jets} + \cancel{E}_T$, Tstop7, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 175 \text{ GeV}$, $m_{\tilde{t}_1} = 200 \text{ GeV}$, $\text{BR}(\tilde{t}_2 \rightarrow \tilde{t}_1 H) = 100\%$
> 780	95	¹⁴ SIRUNYAN	18AL CMS	$\geq 3\ell^\pm + \text{jets} + \cancel{E}_T$, Tstop7, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 175 \text{ GeV}$, $m_{\tilde{t}_1} = 200 \text{ GeV}$, $\text{BR}(\tilde{t}_2 \rightarrow \tilde{t}_1 Z) = 100\%$
> 710	95	¹⁴ SIRUNYAN	18AL CMS	$\geq 3\ell^\pm + \text{jets} + \cancel{E}_T$, Tstop7, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 175 \text{ GeV}$, $m_{\tilde{t}_1} = 200 \text{ GeV}$, $\text{BR}(\tilde{t}_2 \rightarrow \tilde{t}_1 Z) = 100\%$
> 730	95	¹⁵ SIRUNYAN	18AN CMS	1 or 2 $\gamma + \ell + \text{jets}$, GGM, Tstop12, $m_{\tilde{\chi}_1^0} = 150 \text{ GeV}$
> 650	95	¹⁵ SIRUNYAN	18AN CMS	1 or 2 $\gamma + \ell + \text{jets}$, GGM, Tstop12, $m_{\tilde{\chi}_1^0} = 500 \text{ GeV}$
>1000	95	¹⁶ SIRUNYAN	18AY CMS	jets + \cancel{E}_T , Tstop1, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 500	95	¹⁶ SIRUNYAN	18AY CMS	jets + \cancel{E}_T , Tstop4, $m_{\tilde{\chi}_1^0} = 420 \text{ GeV}$
> 510	95	¹⁷ SIRUNYAN	18B CMS	jets + \cancel{E}_T , Tstop4, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$
> 800	95	¹⁸ SIRUNYAN	18C CMS	$\ell^\pm \ell^\mp + b\text{-jets} + \cancel{E}_T$, Tstop1, $m_{\tilde{\chi}_1^0} = 0$
> 750	95	¹⁸ SIRUNYAN	18C CMS	$\ell^\pm \ell^\mp + b\text{-jets} + \cancel{E}_T$, Tstop2, $m_{\tilde{\chi}_1^\pm} = (m_{\tilde{t}_1} + m_{\tilde{\chi}_1^0})/2$, $m_{\tilde{\chi}_1^0} = 0$
>1050	95	¹⁸ SIRUNYAN	18C CMS	Combination of all-hadronic, 1 ℓ^\pm and $\ell^\pm \ell^\mp$ searches, Tstop1, $m_{\tilde{\chi}_1^0} = 0$
>1000	95	¹⁸ SIRUNYAN	18C CMS	Combination of all-hadronic, 1 ℓ^\pm and $\ell^\pm \ell^\mp$ searches, Tstop2, $m_{\tilde{\chi}_1^\pm} = (m_{\tilde{t}_1} + m_{\tilde{\chi}_1^0})/2$, $m_{\tilde{\chi}_1^0} = 0$
>1200	95	¹⁸ SIRUNYAN	18C CMS	$\ell^\pm \ell^\mp + b\text{-jets} + \cancel{E}_T$, Tstop11, $m_{\tilde{\chi}_1^\pm} = 0.5 (m_{\tilde{t}_1} + m_{\tilde{\chi}_1^0})$, $m_{\tilde{\ell}} = 0.5 m_{\tilde{\chi}_1^\pm}$, $m_{\tilde{\chi}_1^0} = 0$
>1300	95	¹⁸ SIRUNYAN	18C CMS	$\ell^\pm \ell^\mp + b\text{-jets} + \cancel{E}_T$, Tstop11, $m_{\tilde{\chi}_1^\pm} = 0.5 (m_{\tilde{t}_1} + m_{\tilde{\chi}_1^0})$, $m_{\tilde{\ell}} = 0.95 m_{\tilde{\chi}_1^\pm}$, $m_{\tilde{\chi}_1^0} = 0$
none 460–1060	95	¹⁸ SIRUNYAN	18C CMS	$\ell^\pm \ell^\mp + b\text{-jets} + \cancel{E}_T$, Tstop11, $m_{\tilde{\chi}_1^\pm} = 0.5 (m_{\tilde{t}_1} + m_{\tilde{\chi}_1^0})$, $m_{\tilde{\ell}} = 0.05 m_{\tilde{\chi}_1^\pm}$, $m_{\tilde{\chi}_1^0} = 0$
>1020	95	¹⁹ SIRUNYAN	18D CMS	top quark (hadronically decaying) + jets + \cancel{E}_T , Tstop1, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$

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Searches Particle Listings

Supersymmetric Particle Searches

> 420	95	20	SIRUNYAN	18DI CMS	$\ell^\pm + \text{jet} + \cancel{E}_T, T_{\text{stop}}3, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$	>1000	95	39	SIRUNYAN	17AS CMS	$1\ell + \text{jets} + \cancel{E}_T, T_{\text{stop}}2, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{t}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} = 0$
> 560	95	20	SIRUNYAN	18DI CMS	$\ell^\pm + \text{jet} + \cancel{E}_T, T_{\text{stop}}3, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 80 \text{ GeV}$	> 980	95	39	SIRUNYAN	17AS CMS	$1\ell + \text{jets} + \cancel{E}_T, T_{\text{stop}}8, m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 540	95	20	SIRUNYAN	18DI CMS	$\ell^\pm, T_{\text{stop}}10, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{t}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 40 \text{ GeV}$	>1040	95	40	SIRUNYAN	17AT CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 590	95	20	SIRUNYAN	18DI CMS	Combination of all-hadronic and $1\ell^\pm$ searches, $T_{\text{stop}}3, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 30 \text{ GeV}$	> 750	95	40	SIRUNYAN	17AT CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}2, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{t}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 670	95	20	SIRUNYAN	18DI CMS	Combination of all-hadronic and $1\ell^\pm$ searches, $T_{\text{stop}}10, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{t}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 60 \text{ GeV}$	> 940	95	40	SIRUNYAN	17AT CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}8, m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
> 450	95	21	SIRUNYAN	18DN CMS	$\ell^\pm \ell^\mp, T_{\text{stop}}1, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = m_W$	> 480	95	40	SIRUNYAN	17AT CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}4, 10 \text{ GeV} < m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < 80 \text{ GeV}$
none 225–325	95	21	SIRUNYAN	18DN CMS	$\ell^\pm \ell^\mp, T_{\text{stop}}2, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{t}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 2 m_W$	> 530	95	40	SIRUNYAN	17AT CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}10, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{t}} + m_{\tilde{\chi}_1^0})/2, 10 \text{ GeV} < m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < 80 \text{ GeV}$
none 210–690	95	21	SIRUNYAN	18DN CMS	$\ell^\pm \ell^\mp, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1070	95	41	SIRUNYAN	17AZ CMS	$\geq 1 \text{ jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
none 250–600	95	21	SIRUNYAN	18DN CMS	$\ell^\pm \ell^\mp, T_{\text{stop}}2, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{t}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	> 900	95	41	SIRUNYAN	17AZ CMS	$\geq 1 \text{ jets} + \cancel{E}_T, T_{\text{stop}}2, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{t}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 700	95	22	AABOUD	17AJ ATLS	same-sign $\ell^\pm \ell^\pm / 3 \ell + \text{jets} + \cancel{E}_T, T_{\text{stop}}11, m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^0} + 100 \text{ GeV}$	>1020	95	41	SIRUNYAN	17AZ CMS	$\geq 1 \text{ jets} + \cancel{E}_T, T_{\text{stop}}8, m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
> 880	95	23	AABOUD	17AX ATLS	$b\text{-jets} + \cancel{E}_T$, mixture $T_{\text{stop}}1$ and $T_{\text{stop}}2$ with $\text{BR}=50\%$, $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}, m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$	> 540	95	41	SIRUNYAN	17AZ CMS	$\geq 1 \text{ jets} + \cancel{E}_T, T_{\text{stop}}4, 10 \text{ GeV} < m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < 80 \text{ GeV}$
none 250–1000	95	24	AABOUD	17AY ATLS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	none 280–830	95	42	SIRUNYAN	17K CMS	$0, 1 \ell^\pm + \text{jets} + \cancel{E}_T$ (combination), $T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
none 450–850	95	25	AABOUD	17AY ATLS	$\text{jets} + \cancel{E}_T$, mixture of $T_{\text{stop}}1$ and $T_{\text{stop}}2$ with $\text{BR}=50\%$, $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$	> 700	95	42	SIRUNYAN	17K CMS	$0, 1 \ell^\pm + \text{jets} + \cancel{E}_T$ (combination), $T_{\text{stop}}8, m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
> 720	95	26	AABOUD	17BE ATLS	$\ell^\pm \ell^\mp + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	> 160	95	42	SIRUNYAN	17K CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}4, 10 < m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < 80 \text{ GeV}$
> 400	95	27	AABOUD	17BE ATLS	$\ell^\pm \ell^\mp + \cancel{E}_T, T_{\text{stop}}3, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 40 \text{ GeV}$	none 230–960	95	43	SIRUNYAN	17P CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 430	95	28	AABOUD	17BE ATLS	$\ell^\pm \ell^\mp + \cancel{E}_T, T_{\text{stop}}1$ (offshell t), $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} \sim m_W$	> 990	95	43	SIRUNYAN	17P CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 700	95	29	AABOUD	17BE ATLS	$\ell^\pm \ell^\mp + \cancel{E}_T, T_{\text{stop}}2, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^\pm} = 10 \text{ GeV}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	> 323	95	44	AABOUD	16D ATLS	$\geq 1 \text{ jet} + \cancel{E}_T, T_{\text{stop}}4, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$
> 750	95	30	KHACHATRY...17	CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$	none, 745–780	95	45	AABOUD	16J ATLS	$1 \ell^\pm + \geq 4 \text{ jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
none 250–740	95	31	KHACHATRY...17AD	CMS	$\text{jets} + b\text{-jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	> 490–650	95	46	AAD	16AY ATLS	2ℓ (including hadronic τ) + $\cancel{E}_T, T_{\text{stop}}5, 87 \text{ GeV} < m_{\tilde{\tau}} < m_{\tilde{t}_1}$
> 610	95	32	KHACHATRY...17AD	CMS	$\text{jets} + b\text{-jets} + \cancel{E}_T$, mixture $T_{\text{stop}}1$ and $T_{\text{stop}}2$ with $\text{BR}=50\%$, $m_{\tilde{\chi}_1^0} = 60 \text{ GeV}$	> 700	95	47	KHACHATRY...16AV	CMS	$1 \text{ or } 2 \ell^\pm + \text{jets} + b\text{-jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} < 250 \text{ GeV}$
> 590	95	33	KHACHATRY...17P	CMS	$1 \text{ or more jets} + \cancel{E}_T, T_{\text{stop}}8, m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$	> 700	95	47	KHACHATRY...16AV	CMS	$1 \text{ or } 2 \ell^\pm + \text{jets} + b\text{-jets} + \cancel{E}_T, T_{\text{stop}}2, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}, m_{\tilde{\chi}_1^\pm} = 0.75 m_{\tilde{t}_1} + 0.25 m_{\tilde{\chi}_1^0}$
none 280–640	95	33	KHACHATRY...17P	CMS	$1 \text{ or more jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	> 775	95	48	KHACHATRY...16BK	CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} < 200 \text{ GeV}$
> 350	95	33	KHACHATRY...17P	CMS	$1 \text{ or more jets} + \cancel{E}_T, T_{\text{stop}}4, 10 \text{ GeV} < m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < 80 \text{ GeV}$	> 620	95	48	KHACHATRY...16BK	CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}2, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 280	95	33	KHACHATRY...17P	CMS	$1 \text{ or more jets} + \cancel{E}_T, T_{\text{stop}}3, 10 \text{ GeV} < m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < 80 \text{ GeV}$	> 316	95	49	KHACHATRY...16BS	CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 320	95	33	KHACHATRY...17P	CMS	$1 \text{ or more jets} + \cancel{E}_T, T_{\text{stop}}9, 10 \text{ GeV} < m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < 80 \text{ GeV}$	> 250	95	50	KHACHATRY...16Y	CMS	$1 \text{ or } 2 \text{ soft } \ell^\pm + \text{jets} + \cancel{E}_T, T_{\text{stop}}3, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 25 \text{ GeV}$
> 240	95	34	KHACHATRY...17s	CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}4, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$	> 270	95	51	AAD	15CJ ATLS	$B(\tilde{t} \rightarrow c\tilde{\chi}_1^0) + B(\tilde{t} \rightarrow b f' \tilde{\chi}_1^0) = 1, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$
> 225	95	35	KHACHATRY...17s	CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}3, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$	none, 200–700	95	51	AAD	15CJ ATLS	$\tilde{t} \rightarrow t\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 0$
> 325	95	36	KHACHATRY...17s	CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}2, m_{\tilde{\chi}_1^\pm} = 0.25 m_{\tilde{t}_1} + 0.75 m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_1^0} = 225 \text{ GeV}$	> 500	95	51	AAD	15CJ ATLS	$B(\tilde{t} \rightarrow t\tilde{\chi}_1^0) + B(\tilde{t} \rightarrow b\tilde{\chi}_1^\pm) = 1, \tilde{\chi}_1^\pm \rightarrow W^{(*)}\tilde{\chi}_1^0, m_{\tilde{\chi}_1^\pm} = 2m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_1^0} < 160 \text{ GeV}$
> 400	95	37	KHACHATRY...17s	CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}2, m_{\tilde{\chi}_1^\pm} = 0.75 m_{\tilde{t}_1} + 0.25 m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	> 600	95	51	AAD	15CJ ATLS	$\tilde{t}_2 \rightarrow Z\tilde{t}_1, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 180 \text{ GeV}, m_{\tilde{\chi}_1^0} = 0$
> 500	95	38	KHACHATRY...17s	CMS	$\text{jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	> 600	95	51	AAD	15CJ ATLS	$\tilde{t}_2 \rightarrow h\tilde{t}_1, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 180 \text{ GeV}, m_{\tilde{\chi}_1^0} = 0$
>1120	95	39	SIRUNYAN	17AS CMS	$1\ell + \text{jets} + \cancel{E}_T, T_{\text{stop}}1, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	none, 172.5–191	95	52	AAD	15J ATLS	$\tilde{t} \rightarrow t\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$

Searches Particle Listings

Supersymmetric Particle Searches

> 450	95	53	KHACHATRY...15AF CMS	$\tilde{t} \rightarrow t\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 0, m_{\tilde{t}} > m_t + m_{\tilde{\chi}_1^0}$
> 560	95	54	KHACHATRY...15AH CMS	$\tilde{t} \rightarrow t\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 0, m_{\tilde{t}} > m_t + m_{\tilde{\chi}_1^0}$
> 250	95	55	KHACHATRY...15AH CMS	$\tilde{t} \rightarrow c\tilde{\chi}_1^0, m_{\tilde{t}} - m_{\tilde{\chi}_1^0} < 10 \text{ GeV}$
none, 200–350	95	56	KHACHATRY...15L CMS	$\tilde{t} \rightarrow qq, \text{RPV}, \lambda_{312}'' \neq 0$
none, 200–385	95	56	KHACHATRY...15L CMS	$\tilde{t} \rightarrow qb, \text{RPV}, \lambda_{323}'' \neq 0$
> 730	95	57	KHACHATRY...15x CMS	$\tilde{t} \rightarrow t\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}, m_{\tilde{t}} > m_t + m_{\tilde{\chi}_1^0}$
none 400–645	95	57	KHACHATRY...15x CMS	$\tilde{t} \rightarrow t\tilde{\chi}_1^0 \text{ or } \tilde{t} \rightarrow b\tilde{\chi}_1^\pm, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}, m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$
none 270–645	95	58	AAD 14AJ ATLS	$\geq 4 \text{ jets} + \cancel{E}_T, \tilde{t}_1 \rightarrow t\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} < 30 \text{ GeV}$
none 250–550	95	58	AAD 14AJ ATLS	$\geq 4 \text{ jets} + \cancel{E}_T, B(\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm) = 50\%, m_{\tilde{\chi}_1^\pm} = 2 m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_1^0} < 60 \text{ GeV}$
none 210–640	95	59	AAD 14BD ATLS	$\ell^\pm + \text{jets} + \cancel{E}_T, \tilde{t}_1 \rightarrow t\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
> 500	95	59	AAD 14BD ATLS	$\ell^\pm + \text{jets} + \cancel{E}_T, \tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm, m_{\tilde{\chi}_1^\pm} = 2 m_{\tilde{\chi}_1^0}, 100 \text{ GeV} < m_{\tilde{\chi}_1^0} < 150 \text{ GeV}$
none 150–445	95	60	AAD 14F ATLS	$\ell^\pm \ell^\mp \text{ final state}, \tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm, m_{\tilde{t}} - m_{\tilde{\chi}_1^\pm} = 10 \text{ GeV}, m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$
none 215–530	95	60	AAD 14F ATLS	$\ell^\pm \ell^\mp \text{ final state}, \tilde{t}_1 \rightarrow t\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$
> 270	95	61	AAD 14T ATLS	$\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 200 \text{ GeV}$
> 240	95	61	AAD 14T ATLS	$\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0, m_{\tilde{t}} - m_{\tilde{\chi}_1^0} < 85 \text{ GeV}$
> 255	95	61	AAD 14T ATLS	$\tilde{t}_1 \rightarrow bf\ell'\tilde{\chi}_1^0, m_{\tilde{t}} - m_{\tilde{\chi}_1^0} \approx m_b$
> 400	95	62	CHATRCHYAN14AH CMS	$\text{jets} + \cancel{E}_T, \tilde{t} \rightarrow t\tilde{\chi}_1^0 \text{ simplified model}, m_{\tilde{\chi}_1^0} = 50 \text{ GeV}$
> 740	95	63	CHATRCHYAN14R CMS	$\geq 3\ell^\pm, \tilde{t} \rightarrow (b\tilde{\chi}_1^\pm / t\tilde{\chi}_1^0), \tilde{\chi}_1^\pm \rightarrow (q\ell' / \ell\nu)\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow (H/Z)\tilde{G}, \text{GMSB, natural higgsino NLSP scenario}$
> 580	95	64	KHACHATRY...14T CMS	$\tau + b\text{-jets, RPV, } LQ\tilde{D}, \lambda_{333}' \neq 0, \tilde{t} \rightarrow \tau b \text{ simplified model}$
	95	64	KHACHATRY...14T CMS	$\tau + b\text{-jets, RPV, } LQ\tilde{D}, \lambda_{3jk}' \neq 0 (j \neq 3), \tilde{t} \rightarrow \tilde{\chi}^\pm b, \tilde{\chi}^\pm \rightarrow qq\tau^\pm \text{ simplified model}$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
> 850	95	65	AABOUD 17AF ATLS	$2\ell + \text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tstop6}, m_{\tilde{\chi}_1^0} = 0$
> 800	95	66	AABOUD 17AF ATLS	$2\ell + \text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tstop7 with 100\% decays via } Z, m_{\tilde{\chi}_1^0} = 50 \text{ GeV}$
> 880	95	67	AABOUD 17AF ATLS	$2\ell + \text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tstop7 with 100\% decays via higgs}, m_{\tilde{\chi}_1^0} = 50 \text{ GeV}$
> 230	95	68	AABOUD 17AY ATLS ROLBIECKI 15 THEO	$\text{jets} + \cancel{E}_T, \text{pMSSM-inspired } W\bar{W} \text{ xsection}, \tilde{t}_1 \rightarrow bW\tilde{\chi}_1^0, m_{\tilde{t}} \simeq m_b + m_W + m_{\tilde{\chi}_1^0}$
> 600	95	69	AAD 14B ATLS	$Z + b\cancel{E}_T, \tilde{t}_2 \rightarrow Z\tilde{\ell}_1, \tilde{t}_1 \rightarrow t\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} < 200 \text{ GeV}$
> 540	95	69	AAD 14B ATLS	$Z + b\cancel{E}_T, \tilde{t}_1 \rightarrow t\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow Z\tilde{G}, \text{natural GMSB, } 100 \text{ GeV} < m_{\tilde{\chi}_1^0} < m_{\tilde{t}} - 10 \text{ GeV}$
> 360	95	70	CHATRCHYAN14U CMS	$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow f\ell'\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow H\tilde{G} \text{ simplified model}, m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV, GMSB}$
> 215	95		CZAKON 14	$\tilde{t} \rightarrow t\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} < 10 \text{ GeV}$
	95	71	KHACHATRY...14c CMS	$\tilde{t}_2 \rightarrow H\tilde{t}_1 \text{ or } \tilde{t}_2 \rightarrow Z\tilde{t}_1 \text{ simplified model}$

¹ SIRUNYAN 19AU searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one photon, jets, some of which are identified as originating from b -quarks, and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. In the framework of GMSB, limits are set on the gluino mass in the Tglu4C, Tglu4D and Tglu4E simplified models, and on the top squark mass in the Tstop13 simplified model, see their Figure 5.

- ² SIRUNYAN 19CH searched in 137 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing multiple jets and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu1C, Tglu2A and Tglu3A simplified models, see their Figure 13. Limits are also set on squark, sbottom and stop masses in the Tsqk1, Tsb0t1, Tstop1 simplified models, see their Figure 14.
- ³ SIRUNYAN 19s searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with zero or one charged leptons, jets and \cancel{E}_T . The razor variables (M_R and R^2) are used to categorize the events. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu3A and Tglu3C simplified models, see Figures 22 and 23, and on the stop mass in the Tstop1 simplified model, see their Figure 24.
- ⁴ SIRUNYAN 19u searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing one electron-muon pair with opposite charge. The search targets a region of parameter space where the kinematics of top squark pair production and top quark pair production is very similar, due to the mass difference between the top squark and the neutralino being close to the top quark mass. No excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1 model, with $m_{\tilde{t}} - m_{\tilde{\chi}_1^0}$ close to m_t , see Figure 5.
- ⁵ AABOUD 18AQ searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for top squark pair production in final states with one isolated electron or muon, several energetic jets, and missing transverse momentum. No significant excess over the Standard Model prediction is observed. In case of Tstop1 models, top squark masses up to 940 GeV are excluded assuming $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$, see their Fig. 20. If the top quark is not on-shell (3-body) decay, exclusions up to 500 GeV are obtained for $m_{\tilde{\chi}_1^0} = 300 \text{ GeV}$. Exclusions as a function of $m_{\tilde{t}} - m_{\tilde{\chi}_1^0}$ are given in their Fig. 21.
- ⁶ AABOUD 18AQ searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for top squark pair production in final states with one isolated electron or muon, several energetic jets, and missing transverse momentum. No significant excess over the Standard Model prediction is observed. In case of Tstop3 models (4-body), top squark masses up to 370 GeV are excluded for $m_{\tilde{t}} - m_{\tilde{\chi}_1^0}$ as low as 20 GeV. Top squark masses below 195 GeV are excluded for all $m_{\tilde{\chi}_1^0}$, see their Fig. 20 and Fig. 21.
- ⁷ AABOUD 18AQ searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for top squark pair production in final states with one isolated electron or muon, several energetic jets, and missing transverse momentum. No significant excess over the Standard Model prediction is observed. In case of Tstop2 models, top squark masses up to 840 GeV are excluded for $m_{\tilde{t}} - m_{\tilde{\chi}_1^\pm} = 10 \text{ GeV}$. See their Fig. 23. Exclusion limits for this decay mode are presented also in the context of Higgsino-LSP phenomenological MSSM models, where $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$, see their Fig 26.
- ⁸ AABOUD 18BV searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one jet identified as c -jet, large missing transverse energy and no leptons. Good agreement is observed between the number of events in data and Standard Model predictions. The results are translated into exclusion limits in Tstop4 models. In scenarios with differences of the stop and neutralino masses below 100 GeV, stop masses below 500 GeV are excluded. See their Fig.6 and Fig.7.
- ⁹ AABOUD 18BV searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one jet identified as c -jet, large missing transverse energy and no leptons. Good agreement is observed between the number of events in data and Standard Model predictions. The results are translated into exclusion limits in Tstop1 models. In scenarios with massless neutralinos, top squark masses below 850 GeV are excluded. See their Fig.6.
- ¹⁰ AABOUD 18i searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one jet with a transverse momentum above 250 GeV and no leptons. Good agreement is observed between the number of events in data and Standard Model predictions. The results are translated into exclusion limits in Tstop3 models. Stop masses below 390 GeV are excluded for $m_{\tilde{t}} - m_{\tilde{\chi}_1^0} = m_b$. See their Fig.9(b).
- ¹¹ AABOUD 18i searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one jet with a transverse momentum above 250 GeV and no leptons. Good agreement is observed between the number of events in data and Standard Model predictions. The results are translated into exclusion limits in Tstop4 models. In scenarios with differences of the stop and neutralino masses around 5 GeV, stop masses below 430 GeV are excluded. See their Fig.9(a).
- ¹² AABOUD 18Y searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct pair production of top squarks in final states with two tau leptons, b -jets, and missing transverse momentum. At least one hadronic τ is required. No significant deviation from the SM predictions is observed in the data. The analysis results are interpreted in Tstop5 models with a nearly massless gravitino. Top squark masses up to 1.16 TeV and tau slepton masses up to 1 TeV are excluded, see their Fig 7.
- ¹³ SIRUNYAN 18AJ searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing two low-momentum, oppositely charged leptons (electrons or muons) and \cancel{E}_T . No excess over the expected background is observed. Limits are derived on the wino mass in the Tchi1n2F simplified model, see their Figure 5. Limits are also set on the stop mass in the Tstop10 simplified model, see their Figure 6. Finally, limits are set on the Higgsino mass in the Tchi1n2G simplified model, see Figure 8 and in the pMSSM, see Figure 7.
- ¹⁴ SIRUNYAN 18AL searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least three charged leptons, in any combination of electrons and muons, jets and significant \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu3A and Tglu1C simplified models, see their Figure 5. Limits are also set on the sbottom mass in the Tsb0t2 simplified model, see their Figure 6, and on the stop mass in the Tstop7 simplified model, see their Figure 7.
- ¹⁵ SIRUNYAN 18AN searched in 19.7 fb⁻¹ of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing one or two photons and a pair of top quarks from the decay of a pair of top squark in a natural gauge-mediated scenario. The final state consists of a lepton (electron or muon), jets and one or two photons. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop12 simplified model, see their Figure 6.

- ¹⁶ SIRUNYAN 18AY searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing one or more jets and significant E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A and Tglu3A simplified models, see their Figure 3. Limits are also set on squark, sbottom and stop masses in the Tsqk1, Tsbott1, Tstop1 and Tstop4 simplified models, see their Figure 3. Finally, limits are set on long-lived gluino masses in a Tglu1A simplified model where the gluino is metastable or long-lived with proper decay lengths in the range $10^{-3} \text{ mm} < c\tau < 10^5 \text{ mm}$, see their Figure 4.
- ¹⁷ SIRUNYAN 18B searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for the pair production of third-generation squarks in events with jets and large E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the sbottom mass in the Tsbott1 simplified model, see their Figure 5, and on the stop mass in the Tstop4 simplified model, see their Figure 6.
- ¹⁸ SIRUNYAN 18C searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for the pair production of top squarks in events with two oppositely charged leptons (electrons or muons), jets identified as originating from a b -quark and large E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1, Tstop2 and Tstop11 simplified models, see their Figures 11 and 12. The Tstop1 and Tstop2 results are combined with complementary searches in the all-hadronic and single lepton channels, see their Figures 13 and 14.
- ¹⁹ SIRUNYAN 18D searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing identified hadronically decaying top quarks, no leptons, and E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1 simplified model, see their Figure 8, and on the gluino mass in the Tglu3A, Tglu3B, Tglu3C and Tglu3E simplified models, see their Figure 9.
- ²⁰ SIRUNYAN 18Di searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for pair production of top squarks in events with a low transverse momentum lepton (electron or muon), a high-momentum jet and significant missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop3 and Tstop10 simplified models, see their Figures 7 and 8. A combination of this search with the all-hadronic search is presented in Figure 9.
- ²¹ SIRUNYAN 18DN searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct electroweak production of charginos and for pair production of top squarks in events with two leptons (electrons or muons) of the opposite electric charge. No significant excess above the Standard Model expectations is observed. Limits are set on the chargino mass in the Tch1ch1C and Tch1ch1E simplified models, see their Figure 8. Limits are also set on the stop mass in the Tstop1 and Tstop2 simplified models, see their Figure 9.
- ²² AABOUD 17AJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two same-sign or three leptons, jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 700 GeV are set on the top squark mass in Tstop11 simplified models, assuming $m_{\tilde{\chi}_1^0} = m_{\tilde{t}} - 275 \text{ GeV}$ and $m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^0} + 100 \text{ GeV}$. See their Figure 4(e).
- ²³ AABOUD 17AX searched in 36 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing two jets identified as originating from b -quarks and large missing transverse momentum, with or without leptons. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the masses of top squarks. Assuming 50% BR for Tstop1 and Tstop2 simplified models, a \tilde{t}_1 mass below 880 (860) GeV is excluded for $m_{\tilde{\chi}_1^0} = 0$ (<250) GeV. See their Fig. 7(b).
- ²⁴ AABOUD 17AY searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least four jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits in the range 250–1000 GeV are set on the top squark mass in Tstop1 simplified models. For the first time, additional constraints are set for the region $m_{\tilde{t}_1} \sim m_{\tilde{t}} + m_{\tilde{\chi}_1^0}$, with exclusion of the \tilde{t}_1 mass range 235–590 GeV. See their Figure 8.
- ²⁵ AABOUD 17AY searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least four jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits in the range 450–850 GeV are set on the top squark mass in a mixture of Tstop1 and Tstop2 simplified models with BR=50% and assuming $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$ and $m_{\tilde{\chi}_1^0} < 240 \text{ GeV}$. Constraints are given for various values of the BR. See their Figure 9.
- ²⁶ AABOUD 17BE searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two opposite-charge leptons (electrons and muons) and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 720 GeV are set on the top squark mass in Tstop1 simplified models, assuming massless neutralinos. See their Figure 9 (2-body area).
- ²⁷ AABOUD 17BE searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two opposite-charge leptons (electrons and muons) and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 400 GeV are set on the top squark mass in Tstop3 simplified models, assuming $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 40 \text{ GeV}$. See their Figure 9 (4-body area).
- ²⁸ AABOUD 17BE searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two opposite-charge leptons (electrons and muons) and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 430 GeV are set on the top squark mass in Tstop1 simplified models where top quarks are offshell, assuming $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0}$ close to the W mass. See their Figure 9 (3-body area).
- ²⁹ AABOUD 17BE searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two opposite-charge leptons (electrons and muons) and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 700 GeV are set on the top squark mass in Tstop2 simplified models, assuming $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^\pm} = 10 \text{ GeV}$ and massless neutralinos. See their Figure 10.
- ³⁰ KHACHATRYAN 17 searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing four or more jets, no more than one lepton, and missing transverse momentum, using the razor variables (M_{R} and R^2) to discriminate between signal and background processes. No evidence for an excess over the expected background is observed. Limits are derived on the stop mass in the Tstop1 simplified model, see Fig. 17.
- ³¹ KHACHATRYAN 17AD searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing at least four jets (including b -jets), missing transverse momentum and tagged top quarks. No evidence for an excess over the expected background is observed. Top squark masses in the range 250–740 GeV and neutralino masses up to 240 GeV are excluded at 95% C.L. See Fig. 12.
- ³² KHACHATRYAN 17AD searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing at least four jets (including b -jets), missing transverse momentum and tagged top quarks. No evidence for an excess over the expected background is observed. Limits are derived on the \tilde{t} mass in simplified models that are a mixture of Tstop1 and Tstop2 with branching fractions 50% for each of the two decay modes: top squark masses of up to 610 GeV and neutralino masses up to 190 GeV are excluded at 95% C.L. The $\tilde{\chi}_1^\pm$ and the $\tilde{\chi}_1^0$ are assumed to be nearly degenerate in mass, with a 5 GeV difference between their masses. See Fig. 12.
- ³³ KHACHATRYAN 17P searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one or more jets and large E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A, Tglu3A, Tglu3B, Tglu3C and Tglu3D simplified models, see their Figures 7 and 8. Limits are also set on the squark mass in the Tsqk1 simplified model, see their Fig. 7, and on the sbottom mass in the Tsbott1 simplified model, see Fig. 8. Finally, limits are set on the stop mass in the Tstop1, Tstop3, Tstop4, Tstop6 and Tstop7 simplified models, see Fig. 8.
- ³⁴ KHACHATRYAN 17s searched in 18.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing multiple jets and missing transverse momentum, using the α_T variable to discriminate between signal and background processes. No evidence for an excess over the expected background is observed. Limits are derived on the stop mass in the Tstop4 model: for $\Delta m = m_{\tilde{t}} - m_{\tilde{\chi}_1^0}$ equal to 10 and 80 GeV, masses of stop below 240 and 260 GeV are excluded, respectively. See their Fig. 3.
- ³⁵ KHACHATRYAN 17s searched in 18.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing multiple jets and missing transverse momentum, using the α_T variable to discriminate between signal and background processes. No evidence for an excess over the expected background is observed. Limits are derived on the stop mass in the Tstop3 model: for $\Delta m = m_{\tilde{t}} - m_{\tilde{\chi}_1^0}$ equal to 10 and 80 GeV, masses of stop below 225 and 130 GeV are excluded, respectively. See their Fig. 3.
- ³⁶ KHACHATRYAN 17s searched in 18.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing multiple jets and missing transverse momentum, using the α_T variable to discriminate between signal and background processes. No evidence for an excess over the expected background is observed. Limits are derived on the stop mass in the Tstop2 model: assuming $m_{\tilde{\chi}_1^\pm} = 0.25 m_{\tilde{t}} + 0.75 m_{\tilde{\chi}_1^0}$, masses of stop up to 325 GeV and masses of the neutralino up to 225 GeV are excluded. See their Fig. 3.
- ³⁷ KHACHATRYAN 17s searched in 18.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing multiple jets and missing transverse momentum, using the α_T variable to discriminate between signal and background processes. No evidence for an excess over the expected background is observed. Limits are derived on the stop mass in the Tstop2 model: assuming $m_{\tilde{\chi}_1^\pm} = 0.75 m_{\tilde{t}} + 0.25 m_{\tilde{\chi}_1^0}$, masses of stop up to 400 GeV are excluded for low neutralino masses. See their Fig. 3.
- ³⁸ KHACHATRYAN 17s searched in 18.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing multiple jets and missing transverse momentum, using the α_T variable to discriminate between signal and background processes. No evidence for an excess over the expected background is observed. Limits are derived on the stop mass in the Tstop1 model: assuming masses of stop up to 500 GeV and masses of the neutralino up to 105 GeV are excluded. See their Fig. 3.
- ³⁹ SIRUNYAN 17As searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with a single lepton (electron or muon), jets, and large E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1, Tstop2 and Tstop8 simplified models, see their Figures 5, 6 and 7.
- ⁴⁰ SIRUNYAN 17AT searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct production of top squarks in events with jets and large E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1, Tstop2, Tstop3, Tstop4, Tstop8 and Tstop10 simplified models, see their Figures 9 to 14.
- ⁴¹ SIRUNYAN 17AZ searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one or more jets and large E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A, Tglu3A simplified models, see their Figures 6. Limits are also set on the squark mass in the Tsqk1 simplified model (for single light squark and for 8 degenerate light squarks), on the sbottom mass in the Tsbott1 simplified model and on the stop mass in the Tstop1 simplified model, see their Fig. 7. Finally, limits are set on the stop mass in the Tstop2, Tstop4 and Tstop8 simplified models, see Fig. 8.
- ⁴² SIRUNYAN 17k searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for direct production of stop or sbottom pairs in events with multiple jets and significant E_T . A second search also requires an isolated lepton and is combined with the all-hadronic search. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1, Tstop8 and Tstop4 simplified models, see their Figures 7, 8 and 9 (for the Tstop4 limits, only the results of the all-hadronic search are used). Limits are also set on the sbottom mass in the Tsbott1 simplified model, see Fig. 10 (also here, only the results of the all-hadronic search are used).
- ⁴³ SIRUNYAN 17P searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with multiple jets and large E_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu1C, Tglu2A, Tglu3A and Tglu3D simplified models, see their Fig. 12. Limits are also set on the squark mass in the Tsqk1 simplified model, on the stop mass in the Tstop1 simplified model, and on the sbottom mass in the Tsbott1 simplified model, see Fig. 13.
- ⁴⁴ AABOUD 16D searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with an energetic jet and large missing transverse momentum. The results are interpreted as 95% C.L. limits on mass of stop decaying into a charm-quark and the lightest neutralino in scenarios with $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0}$ between 5 and 20 GeV. See their Fig. 5.
- ⁴⁵ AABOUD 16J searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in final states with one isolated electron or muon, jets, and missing transverse momentum. For the direct stop pair production model where the stop decays via top and lightest neutralino, the results exclude at 95% C.L. stop masses between 745 GeV and 780 GeV for a massless $\tilde{\chi}_1^0$. See their Fig. 8.
- ⁴⁶ AAD 16AY searched in 20 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with either two hadronically decaying tau leptons, one hadronically decaying tau and one light lepton, or two light leptons. No significant excess over the Standard Model expectation is found. Exclusion limits at 95% C.L. on the mass of top squarks decaying via $\tilde{\tau}$ to a nearly massless gravitino are placed depending on $m_{\tilde{\tau}}$ which is ranging from the 87 GeV LEP limit to $m_{\tilde{t}_1}$. See their Figs. 9 and 10.

Searches Particle Listings

Supersymmetric Particle Searches

- 47 KHACHATRYAN 16AV searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with one or two isolated leptons, hadronic jets, b -jets and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1 and Tstop2 simplified models, see Fig. 11.
- 48 KHACHATRYAN 16BK searched in 18.9 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with hadronic jets and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1 and Tstop2 simplified models, see Fig. 16.
- 49 KHACHATRYAN 16BS searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one energetic jet, no isolated leptons, and significant \cancel{E}_T , using the transverse mass variable M_{T2} to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1 simplified model, see Fig. 11 and Table 3.
- 50 KHACHATRYAN 16V searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with one or two soft isolated leptons, hadronic jets, and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop3 simplified model, see Fig. 3.
- 51 AAD 15CJ searched in 20 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for evidence of third generation squarks by combining a large number of searches covering various final states. Stop decays with and without charginos in the decay chain are considered and summaries of all ATLAS Run 1 searches for direct stop production can be found in Fig. 4 (no intermediate charginos) and Fig. 7 (intermediate charginos). Limits are set on stop masses in compressed mass regions regions, with $B(\tilde{t} \rightarrow c\tilde{\chi}_1^0) + B(\tilde{t} \rightarrow b\tilde{f}\tilde{f}'\tilde{\chi}_1^0) = 1$, see Fig. 5. Limits are also set on stop masses assuming that both the decay $\tilde{t} \rightarrow \tilde{\chi}_1^0$ and $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$ are possible, with both their branching ratios summing up to 1, assuming $\tilde{\chi}_1^\pm \rightarrow W^{(*)}\tilde{\chi}_1^0$ and $m_{\tilde{\chi}_1^\pm} = 2 m_{\tilde{\chi}_1^0}$, see Fig. 6. Limits on the mass of the next-to-lightest stop \tilde{t}_2 , decaying either to $Z\tilde{t}_1$, $h\tilde{t}_1$ or $t\tilde{\chi}_1^0$, are also presented, see Figs. 9 and 10. Interpretations in the pMSSM are also discussed, see Figs 13–15.
- 52 AAD 15J interpreted the measurement of spin correlations in $t\bar{t}$ production using 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ in exclusion limits on the pair production of light \tilde{t}_1 squarks with masses similar to the top quark mass. The \tilde{t}_1 is assumed to decay through $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ with predominantly right-handed top and a 100% branching ratio. The data are found to be consistent with the Standard Model expectations and masses between the top quark mass and 191 GeV are excluded, see their Fig. 2.
- 53 KHACHATRYAN 15AF searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least two energetic jets and significant \cancel{E}_T , using the transverse mass variable M_{T2} to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in simplified models where the decay $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 12. See also Table 5. Exclusions in the CMSSM, assuming $\tan\beta = 30$, $A_0 = -2 \max(m_0, m_{1/2})$ and $\mu > 0$, are also presented, see Fig. 15.
- 54 KHACHATRYAN 15AH searched in 19.4 or 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing either a fully reconstructed top quark, or events containing dijets requiring one or both jets to originate from b -quarks, or events containing a mono-jet. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in simplified models where the decay $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 9. Limits are also set in simplified models where the decays $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ and $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$, with $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$, each take place with a branching ratio of 50%, see Fig. 10, or with other fractions, see Fig. 11. Finally, limits are set in a simplified model where the decay $\tilde{t} \rightarrow c\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Figs. 9, 10 and 11.
- 55 KHACHATRYAN 15AH searched in 19.4 or 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing either a fully reconstructed top quark, or events containing dijets requiring one or both jets to originate from b -quarks, or events containing a mono-jet. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in simplified models where the decay $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 9. Limits are also set in simplified models where the decays $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ and $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$, with $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$, each take place with a branching ratio of 50%, see Fig. 10, or with other fractions, see Fig. 11. Finally, limits are set in a simplified model where the decay $\tilde{t} \rightarrow c\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Figs. 9, 10, and 11.
- 56 KHACHATRYAN 15L searched in 19.4 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for pair production of heavy resonances decaying to pairs of jets in four jet events. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in R -parity-violating supersymmetry models where $\tilde{t} \rightarrow q\bar{q} (\lambda_{312} \neq 0)$, see Fig. 6 (top) and $\tilde{t} \rightarrow q\bar{b} (\lambda_{323} \neq 0)$, see Fig. 6 (bottom).
- 57 KHACHATRYAN 15x searched in 19.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least two energetic jets, at least one of which is required to originate from a b quark, possibly a lepton, and significant \cancel{E}_T , using the razor variables (M_R and R_2) to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in simplified models where the decay $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ and the decay $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$, with $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$, take place with branching ratios varying between 0 and 100%, see Figs. 15, 16 and 17.
- 58 AAD 14AJ searched in 20.1 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing four or more jets and large missing transverse momentum. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the masses of third-generation squarks in simplified models which either assume that the decay $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ takes place 100% of the time, see Fig. 8, or that this decay takes place 50% of the time, while the decay $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$ takes place the other 50% of the time, see Fig. 9.
- 59 AAD 14BD searched in 20 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing one isolated lepton, jets and large missing transverse momentum. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the masses of third-generation squarks in simplified models which either assume that the decay $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ takes place 100% of the time, see Fig. 15, or the decay $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$ takes place 100% of the time, see Fig. 16–22. For the mixed decay scenario, see Fig. 23.
- 60 AAD 14F searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing two leptons (e or μ), and possibly jets and missing transverse momentum. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the masses of third-generation squarks in simplified models which either assume that the decay $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$ takes place 100% of the time, see Figs. 14–17 and 20, or that the decay $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ takes place 100% of the time, see Figs. 18 and 19.
- 61 AAD 14T searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for monojet-like and c -tagged events. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the masses of third-generation squarks in simplified models which assume that the decay $\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$ takes place 100% of the time, see Fig. 9 and 10. The results of the monojet-like analysis are also interpreted in terms of stop pair production in the four-body decay $\tilde{t}_1 \rightarrow b\tilde{f}\tilde{f}'\tilde{\chi}_1^0$, see Fig. 11.
- 62 CHATRCHYAN 14AH searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with at least two energetic jets and significant \cancel{E}_T , using the razor variables (M_R and R_2) to discriminate between signal and background processes. A second analysis requires at least one of the jets to be originating from a b -quark. No significant excess above the Standard Model expectations is observed. Limits are set on sbottom masses in simplified models where the decay $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Figs. 28 and 29. Exclusions in the CMSSM, assuming $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, are also presented, see Fig. 26.
- 63 CHATRCHYAN 14R searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least three leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in a natural higgsino NLSP simplified model (GMSB) where the decay $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$, with $\tilde{\chi}_1^\pm \rightarrow (q\bar{q}'/\ell\nu)H$, $Z\tilde{G}$, takes place with a branching ratio of 100% (the particles between brackets have a soft p_T spectrum), see Figs. 4–6.
- 64 KHACHATRYAN 14T searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with τ -leptons and b -quark jets, possibly with extra light-flavour jets. No excess above the Standard Model expectations is observed. Limits are set on stop masses in RPV SUSY models with $LQ\bar{D}$ couplings, in two simplified models. In the first model, the decay $\tilde{t} \rightarrow \tau b$ is considered, with $\lambda_{333}^t \neq 0$, see Fig. 3. In the second model, the decay $\tilde{t} \rightarrow \tilde{\chi}^\pm b$, with the subsequent decay $\tilde{\chi}^\pm \rightarrow q\bar{q}\tau^\pm$ is considered, with $\lambda_{3jk}^t \neq 0$ and the mass splitting between the top squark and the chargin chosen to be 100 GeV, see Fig. 4.
- 65 AABOUD 17AF searched in 36 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for evidence of top squarks in events containing 2 leptons, jets, b -jets and \cancel{E}_T . In Tstop6 model, assuming $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$, \tilde{t}_1 masses up to 850 GeV are excluded for $m_{\tilde{\chi}_2^0} > 200 \text{ GeV}$.
- 66 AABOUD 17AF searched in 36 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for evidence of \tilde{t}_2 in events containing 2 leptons, jets, b -jets and \cancel{E}_T . In Tstop7 model, assuming $m_{\tilde{\chi}_1^0} = 50 \text{ GeV}$ and 100% decays via Z boson, \tilde{t}_2 masses up to 800 GeV are excluded. Exclusion limits are also shown as a function of the \tilde{t}_2 branching ratios in their Figure 7.
- 67 AABOUD 17AF searched in 36 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for evidence of \tilde{t}_2 in events containing 2 leptons, jets, b -jets and \cancel{E}_T . In Tstop7 model, assuming $m_{\tilde{\chi}_1^0} = 50 \text{ GeV}$ and 100% decays via higgs boson, \tilde{t}_2 masses up to 880 GeV are excluded. Exclusion limits are also shown as a function of the \tilde{t}_2 branching ratios in their Figure 7.
- 68 AABOUD 17AY searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least four jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits are set on the top squark mass assuming three pMSSM-inspired models. The first one, referred to as Higgsino LSP model, assumes $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$ and $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 10 \text{ GeV}$, with a mixture of decay modes as in Tstop1, Tstop2 and Tstop6. See their Figure 10. The second and third models are referred to as Wino NLSP and well-tempered pMSSM models, respectively. See their Figure 11 and Figure 12, and text for details on assumptions.
- 69 AAD 14B searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing a Z boson, with or without additional leptons, plus jets originating from b -quarks and significant missing transverse momentum. No excess over the expected SM background is observed. Limits are derived in simplified models featuring \tilde{t}_2 production, with $\tilde{t}_2 \rightarrow Z\tilde{t}_1$, $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ with a 100% branching ratio, see Fig. 4, and in the framework of natural GMSB, see Fig. 6.
- 70 CHATRCHYAN 14U searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for evidence of direct pair production of top squarks, with Higgs bosons in the decay chain. The search is performed using a selection of events containing two Higgs bosons, each decaying to a photon pair, missing transverse energy and possibly b -quark jets. No significant excesses over the expected SM backgrounds are observed. The results are interpreted in the context of a “natural SUSY” simplified model where the decays $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$, with $\tilde{\chi}_1^\pm \rightarrow \tau\tilde{f}\tilde{\chi}_1^0$ and $\tilde{\chi}_1^0 \rightarrow H\tilde{G}$, all happen with 100% branching ratio, see Fig. 4.
- 71 KHACHATRYAN 14C searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for evidence of direct pair production of top squarks, with Higgs or Z -bosons in the decay chain. The search is performed using a selection of events containing leptons and b -quark jets. No significant excesses over the expected SM backgrounds are observed. The results are interpreted in the context of a simplified model with pair production of a heavier top-squark mass eigenstate \tilde{t}_2 decaying to a lighter top-squark eigenstate \tilde{t}_1 via either $\tilde{t}_2 \rightarrow H\tilde{t}_1$ or $\tilde{t}_2 \rightarrow Z\tilde{t}_1$, followed in both cases by $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$. The interpretation is performed in the region where the mass difference between the \tilde{t}_1 and $\tilde{\chi}_1^0$ is approximately equal to the top-quark mass, which is not probed by searches for direct \tilde{t}_1 pair production, see Figs. 5 and 6. The analysis excludes top squarks with masses $m_{\tilde{t}_2} < 575 \text{ GeV}$ and $m_{\tilde{t}_1} < 400 \text{ GeV}$ at 95% C.L.

R-parity violating \tilde{t} (Stop) mass limit

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1150	95	¹ SIRUNYAN	19BI ATLS	$\tilde{t} \rightarrow b\mu$, long-lived, Tstop2RPV, $c\tau = 0.1$ cm
>1100	95	² SIRUNYAN	19BJ CMS	$\tilde{t} \rightarrow be$, Tstop2RPV, prompt
none 100–410	95	³ AABOUD	18BB ATLS	4 jets, Tstop1RPV with $\tilde{t} \rightarrow ds, \lambda''_{312}$ coupling
none 100–470, 480–610	95	⁴ AABOUD	18BB ATLS	4 jets, Tstop1RPV, λ''_{323} coupling
≥ 600 –1500	95	⁵ AABOUD	18P ATLS	$2\ell + b$ -jets, Tstop2RPV, depending on λ'_{33} coupling ($i = 1, 2, 3$)
>1130	95	⁶ SIRUNYAN	18AD CMS	$\tilde{t} \rightarrow b\ell$, long-lived, $c\tau = 70$ –100 mm
> 550	95	⁶ SIRUNYAN	18AD CMS	$\tilde{t} \rightarrow b\ell$, long-lived, $c\tau = 1$ –1000 mm
>1400	95	⁷ SIRUNYAN	18DV CMS	long-lived \tilde{t} , RPV, $\tilde{t} \rightarrow \bar{d}\bar{d}$, 0.6 mm < $c\tau$ < 80 mm
none 80–520	95	⁸ SIRUNYAN	18DY CMS	2, 4 jets, Tstop3RPV, λ''_{312} coupling
none 80–270, 285–340, 400–525	95	⁸ SIRUNYAN	18DY CMS	2, 4 jets, Tstop1RPV, λ''_{323} coupling
>1200	95	⁹ AABOUD	17AI ATLS	$\geq 1\ell + \geq 8$ jets, Tstop1 with $\tilde{\chi}_1^0 \rightarrow tbs, \lambda''_{323}$ coupling, $m_{\tilde{\chi}_1^0} = 500$ GeV

none, 100–315 95 ¹⁰ AAD 16AMATLS 2 large-radius jets, Tstop1RPV
 • • • We do not use the following data for averages, fits, limits, etc. • • •

> 890	95	¹¹ KHACHATRYAN	16AC CMS	$e^+e^- + \geq 5$ jets; $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$; $\tilde{\chi}_1^\pm \rightarrow \ell^\pm jj, \lambda'_{ijk}$
>1000	95	¹¹ KHACHATRYAN	16AC CMS	$\mu^+\mu^- + \geq 5$ jets; $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$; $\tilde{\chi}_1^\pm \rightarrow \ell^\pm jj, \lambda'_{ijk}$
> 950	95	¹² KHACHATRYAN	16BX CMS	$\tilde{t} \rightarrow t\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \ell\ell\nu, \lambda_{121} \neq 0$
> 790	95	¹³ KHACHATRYAN	15E CMS	$\tilde{t}_1 \rightarrow b\ell, c\tau = 2$ cm

¹ SIRUNYAN 19BI searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV in final states with two muons and two jets, or with one muon, two jets, and missing transverse momentum. Limits are set in a model of pair-produced, prompt or long-lived top squarks with R-parity violating decays to a b -quark and a lepton (Tstop2RPV), branching fraction of $\tilde{t} \rightarrow b\mu$ equal to 1/3 and $c\tau$ between 0.1 cm and 10 cm in the case of long-lived top squarks. See their Fig. 10.

² SIRUNYAN 19BJ searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV in final states with two electrons and two jets, or with one electron, two jets, and missing transverse momentum. Limits are set in a model of pair-produced, prompt top squarks with R-parity violating decays to a b -quark and a lepton (Tstop2RPV), assuming branching fraction of $\tilde{t} \rightarrow be$ equal to 1/3 and $c\tau = 0$ cm. See their Fig. 10.

³ AABOUD 18BB searched in 36.7 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for massive colored resonances which are pair-produced and decay into two jets. No significant deviation from the background prediction is observed. Results are interpreted in a SUSY simplified model as Tstop1RPV with $\tilde{t} \rightarrow ds$. Top squarks with masses in the range 100–410 GeV are excluded, see their Figure 9(a). The λ''_{312} coupling is assumed to be sufficiently large for the decays to be prompt, but small enough to neglect the single-top-squark resonant production through RPV couplings.

⁴ AABOUD 18BB searched in 36.7 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for massive coloured resonances which are pair-produced and decay into two jets. No significant deviation from the background prediction is observed. Results are interpreted in Tstop1RPV. Top squarks with masses in the range 100–470 GeV or 480–610 GeV are excluded, see their Figure 9(b). The λ''_{323} coupling is assumed to be sufficiently large for the decays to be prompt, but small enough to neglect the single-top-squark resonant production through RPV couplings.

⁵ AABOUD 18P searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for pair-produced top squarks that decay through RPV λ'_{33} ($i = 1, 2, 3$) couplings to a final state with two leptons and two jets, at least one of which is identified as a b -jet. No significant excess is observed over the SM background. In the Tstop2RPV model, lower limits on the top squark masses between 600 and 1500 GeV are set depending on the branching fraction to be , $b\mu$, and $b\tau$ final states. See their Figs 6 and 7.

⁶ SIRUNYAN 18AD searched in 2.6 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for long-lived particles by exploiting the multiplicity of displaced jets to search for the presence of signal decays occurring at distances between 1 and 1000 mm. Limits are set in a model of pair-produced, long-lived top squarks with R-parity violating decays to a b -quark and a lepton, see their Figure 3.

⁷ SIRUNYAN 18DV searched in 38.5 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for long-lived particles in events with multiple jets and two displaced vertices composed of many tracks. No events with two well-separated high-track-multiplicity vertices were observed. Limits are set on the stop and the gluino mass in RPV models of supersymmetry where the stop (gluino) is decaying solely into dijet (multi-jet) final states, see their Figures 6 and 7.

⁸ SIRUNYAN 18DY searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for the pair production of resonances, each decaying to two quarks. The search is conducted separately in a boosted (two-jet) and resolved (four-jet) jet topology. The mass spectra are found to be consistent with the Standard Model expectations. Limits are set on the stop mass in the Tstop3RPV and Tstop1RPV simplified models, see their Figure 11.

⁹ AABOUD 17AI searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with one or more isolated lepton, at least eight jets, either zero or many b -jets, for evidence of R-parity violating decays of the top squark. No significant excess above the Standard Model expectations is observed. Limits up to 1.25 (1.10) TeV are set on the top squark mass in R-parity-violating supersymmetry models where \tilde{t}_1 decays for a bino LSP as: $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ and for a higgsino LSP as $\tilde{t} \rightarrow t\tilde{\chi}_{1,2}^0/b\tilde{\chi}_1^\pm$. These are followed by the decays through the non-zero λ''_{323} coupling $\tilde{\chi}_{1,2}^0 \rightarrow tbs, \tilde{\chi}_1^\pm \rightarrow bbs$. See their Figure 10 and text for details on model assumptions.

¹⁰ AAD 16AM searched in 17.4 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV for events containing two large-radius hadronic jets. No deviation from the background prediction is observed. Top squarks with masses between 100 and 315 GeV are excluded at 95% C.L. in the hypothesis that they both decay via R-parity violating coupling λ''_{323} to b - and s -quarks. See their Fig. 10.

¹¹ KHACHATRYAN 16AC searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV for events with low missing transverse momentum, two oppositely charged electrons or muons, and at least five jets, at least one of which is a b -jet, for evidence of R-parity violating, charging-mediated decays of the top squark. No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in R-parity-violating supersymmetry models where $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm \rightarrow \ell^\pm jj, \lambda'_{ijk} \neq 0$ ($i, j, k \leq 2$), and with $m_{\tilde{t}} - m_{\tilde{\chi}_1^\pm} = 100$ GeV, see Fig. 3.

¹² KHACHATRYAN 16BX searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV for events containing 4 leptons coming from R-parity-violating decays of $\tilde{\chi}_1^0 \rightarrow \ell\ell\nu$ with $\lambda_{121} \neq 0$ or $\lambda_{122} \neq 0$. No excess over the expected background is observed. Limits are derived on the gluino, squark and stop masses, see Fig. 23.

¹³ KHACHATRYAN 15E searched for long-lived particles decaying to leptons in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV. Events were selected with an electron and muon with opposite charges and each with transverse impact parameter values between 0.02 and 2 cm. Limits are set on SUSY benchmark models with pair production of top squarks decaying into an $e\mu$ final state via RPV interactions. See their Fig. 2

Heavy \tilde{g} (Gluino) mass limit

For $m_{\tilde{g}} > 60$ –70 GeV, it is expected that gluinos would undergo a cascade decay via a number of neutralinos and/or charginos rather than undergo a direct decay to photinos as assumed by some papers. Limits obtained when direct decay is assumed are usually higher than limits when cascade decays are included.

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, et al. (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

R-parity conserving heavy \tilde{g} (Gluino) mass limit

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1975	95	¹ SIRUNYAN	20B CMS	$\geq 1\gamma + \cancel{E}_T, \text{Tglu4A}, \text{BR}(\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^\pm) = 0.5, m_{\tilde{\chi}_1^\pm} \simeq m_{\tilde{g}}$
>2000	95	² AABOUD	19I ATL	≥ 2 jets + 1 or 2 $\tau + \cancel{E}_T, \text{Tglu1F}, m_{\tilde{\chi}_1^0} = 100$ GeV
>1860	95	³ SIRUNYAN	19AG CMS	$2\gamma + \cancel{E}_T, \text{Tglu4B}, 500 \text{ GeV} < m_{\tilde{\chi}_1^0} < 1500 \text{ GeV}$
>1920	95	⁴ SIRUNYAN	19AU CMS	$\gamma + \text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tglu4D}, m_{\tilde{\chi}_1^0} = 127 \text{ GeV}$
>1950	95	⁴ SIRUNYAN	19AU CMS	$\gamma + \text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tglu4E}, m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$
>1800	95	⁴ SIRUNYAN	19AU CMS	$\gamma + \text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tglu4F}, m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$
>2090	95	⁴ SIRUNYAN	19AU CMS	$\gamma + \text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tglu4D}, m_{\tilde{\chi}_1^0} = 1200 \text{ GeV}$
>2120	95	⁴ SIRUNYAN	19AU CMS	$\gamma + \text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tglu4E}, m_{\tilde{\chi}_1^0} = 1200 \text{ GeV}$
>1970	95	⁴ SIRUNYAN	19AU CMS	$\gamma + \text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tglu4F}, m_{\tilde{\chi}_1^0} = 1200 \text{ GeV}$
>1700	95	⁵ SIRUNYAN	19CE CMS	2 jets, Stealth SUSY, Tglu1A and $\tilde{\chi}_1^0 \rightarrow \tilde{S}\gamma (\tilde{S} \rightarrow S\tilde{G}), m_{\tilde{\chi}_1^0} = 200 \text{ GeV}$
>2000	95	⁶ SIRUNYAN	19CH CMS	$\text{jets} + \cancel{E}_T, \text{Tglu1A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>2030	95	⁶ SIRUNYAN	19CH CMS	$\text{jets} + \cancel{E}_T, \text{Tglu1C}, m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0} = 0.5(m_{\tilde{g}} + m_{\tilde{\chi}_1^0}), m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>2270	95	⁶ SIRUNYAN	19CH CMS	$\text{jets} + \cancel{E}_T, \text{Tglu2A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>2180	95	⁶ SIRUNYAN	19CH CMS	$\text{jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1750	95	⁷ SIRUNYAN	19K CMS	$\gamma + \ell + \cancel{E}_T, \text{Tglu4A}, m_{\tilde{\chi}_1^0} = 1500 \text{ GeV}$
>2000	95	⁸ SIRUNYAN	19S CMS	1 or 2 $\ell + \text{jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} < 700 \text{ GeV}$
>1900	95	⁸ SIRUNYAN	19S CMS	1 or 2 $\ell + \text{jets} + \cancel{E}_T, \text{Tglu3C}, 150 \text{ GeV} < m_{\tilde{\chi}_1^0} < 950 \text{ GeV}$
>1970	95	⁹ AABOUD	18AR ATLS	$\text{jets} + \geq 3b\text{-jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} < 300 \text{ GeV}$
>1920	95	¹⁰ AABOUD	18AR ATLS	$\text{jets} + \geq 3b\text{-jets} + \cancel{E}_T, \text{Tglu2A}, m_{\tilde{\chi}_1^0} < 600 \text{ GeV}$
>1650	95	¹¹ AABOUD	18AS ATLS	≥ 4 jets and disappearing tracks from $\tilde{\chi}^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm$, modified Tglu1A or $\text{Tglu1B}, \tilde{\chi}^\pm$ lifetime 0.2 ns, $m_{\tilde{\chi}^\pm} = 460 \text{ GeV}$
>1850	95	¹² AABOUD	18BJ ATLS	$\ell^\pm \cancel{E}_T + \text{jets} + \cancel{E}_T, \text{Tglu1G}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$

Searches Particle Listings

Supersymmetric Particle Searches

>1650	95	13	AABOUD	18BJ ATLS	$\ell^\pm \ell^\mp + \text{jets} + \cancel{E}_T, \text{Tglu1H}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$	>1700	95	36	AABOUD	17N ATLS	2 same-flavor, opposite-sign $\ell + \text{jets} + \cancel{E}_T, \text{Tglu1G}, m_{\tilde{\chi}_1^0} \sim 1 \text{ GeV}$
>2150	95	14	AABOUD	18U ATLS	$2 \gamma + \cancel{E}_T, \text{GGM}, \text{Tglu4B}, \text{any NLSF mass}$	>1400	95	37	KHACHATRY...17	CMS	$\text{jets} + \cancel{E}_T, \text{Tglu1A}, m_{\tilde{\chi}_1^0} = 200 \text{ GeV}$
>1600	95	15	AABOUD	18U ATLS	$\gamma + \text{jets} + \cancel{E}_T, \text{GGM higgsino-bino, mix of Tglu4B and Tglu4C, any NLSF mass}$	>1650	95	37	KHACHATRY...17	CMS	$\text{jets} + \cancel{E}_T, \text{Tglu2A}, m_{\tilde{\chi}_1^0} = 200 \text{ GeV}$
>2030	95	16	AABOUD	18V ATLS	$\text{jets} + \cancel{E}_T, \text{Tglu1A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1600	95	37	KHACHATRY...17	CMS	$\text{jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 200 \text{ GeV}$
>1980	95	17	AABOUD	18V ATLS	$\text{jets} + \cancel{E}_T, \text{Tglu1B}, m_{\tilde{\chi}_1^\pm} = 0.5(m_{\tilde{g}} + m_{\tilde{\chi}_1^0}), m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1550	95	38	KHACHATRY...17AD	CMS	$\text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1750	95	18	AABOUD	18V ATLS	$\text{jets} + \cancel{E}_T, \text{Tglu1C}, m_{\tilde{\chi}_1^0} = 1 \text{ GeV}, \text{any } m_{\tilde{\chi}_2^0} > 100 \text{ GeV}$	>1450	95	39	KHACHATRY...17AD	CMS	$\text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tglu3C}, 200 < m_{\tilde{\chi}_1^0} < 400 \text{ GeV}$
>2000	95	19	SIRUNYAN	18AA CMS	$\geq 1 \gamma + \cancel{E}_T, \text{Tglu4A}$	>1570	95	40	KHACHATRY...17As	CMS	$1 \ell, \text{Tglu3A}, m_{\tilde{\chi}_1^0} < 600 \text{ GeV}$
>2100	95	19	SIRUNYAN	18AA CMS	$\geq 1 \gamma + \cancel{E}_T, \text{Tglu4B}$	>1500	95	40	KHACHATRY...17As	CMS	$1 \ell, \text{Tglu3A}, m_{\tilde{\chi}_1^0} < 775 \text{ GeV}$
>1800	95	20	SIRUNYAN	18AC CMS	$1 \ell + \text{jets}, \text{Tglu3A}, m_{\tilde{\chi}_1^0} < 650 \text{ GeV}$	>1400	95	40	KHACHATRY...17As	CMS	$1 \ell, \text{Tglu1B}, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} < 725 \text{ GeV}$
>1700	95	20	SIRUNYAN	18AC CMS	$1 \ell + \text{jets}, \text{Tglu3A}, m_{\tilde{\chi}_1^0} < 1040 \text{ GeV}$	none	95	40	KHACHATRY...17As	CMS	$1 \ell, \text{Tglu1B}, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} < 850 \text{ GeV}$
>1900	95	20	SIRUNYAN	18AC CMS	$1 \ell + \text{jets}, \text{Tglu1B}, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} < 300 \text{ GeV}$	1050–1350	95	41	KHACHATRY...17AW	CMS	$\geq 3 \ell^\pm, 2 \text{ jets}, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1250	95	20	SIRUNYAN	18AC CMS	$1 \ell + \text{jets}, \text{Tglu1B}, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} < 950 \text{ GeV}$	>1175	95	41	KHACHATRY...17AW	CMS	$\geq 3 \ell^\pm, 2 \text{ jets}, \text{Tglu1C}, m_{\tilde{\chi}_1^\pm} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1610	95	21	SIRUNYAN	18AL CMS	$\geq 3 \ell^\pm + \text{jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1350	95	42	KHACHATRY...17P	CMS	$1 \text{ or more jets} + \cancel{E}_T, \text{Tglu1A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1160	95	21	SIRUNYAN	18AL CMS	$\geq 3 \ell^\pm + \text{jets} + \cancel{E}_T, \text{Tglu1C}, m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^\pm} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1545	95	42	KHACHATRY...17P	CMS	$1 \text{ or more jets} + \cancel{E}_T, \text{Tglu2A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1500	95	22	SIRUNYAN	18AR CMS	$\ell^\pm \ell^\mp + \text{jets} + \cancel{E}_T, \text{GMSB}, \text{Tglu4C}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$	>1120	95	42	KHACHATRY...17P	CMS	$1 \text{ or more jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1770	95	22	SIRUNYAN	18AR CMS	$\ell^\pm \ell^\mp + \text{jets} + \cancel{E}_T, \text{GMSB}, \text{Tglu4C}, m_{\tilde{\chi}_1^0} = 1400 \text{ GeV}$	>1300	95	42	KHACHATRY...17P	CMS	$1 \text{ or more jets} + \cancel{E}_T, \text{Tglu3D}, m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0} + 5 \text{ GeV}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>1625	95	23	SIRUNYAN	18AY CMS	$\text{jets} + \cancel{E}_T, \text{Tglu1A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>780	95	42	KHACHATRY...17P	CMS	$1 \text{ or more jets} + \cancel{E}_T, \text{Tglu3B}, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 175 \text{ GeV}, m_{\tilde{\chi}_1^0} = 50 \text{ GeV}$
>1825	95	23	SIRUNYAN	18AY CMS	$\text{jets} + \cancel{E}_T, \text{Tglu2A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>790	95	42	KHACHATRY...17P	CMS	$1 \text{ or more jets} + \cancel{E}_T, \text{Tglu3C}, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 20 \text{ GeV}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1625	95	23	SIRUNYAN	18AY CMS	$\text{jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1650	95	43	KHACHATRY...17V	CMS	$2 \gamma + \cancel{E}_T, \text{GGM}, \text{Tglu4B}, \text{any NLSF mass}$
>2040	95	24	SIRUNYAN	18D CMS	top quark (hadronically decaying) + jets + $\cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1900	95	44	SIRUNYAN	17AF CMS	$1 \ell + \text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1930	95	24	SIRUNYAN	18D CMS	top quark (hadronically decaying) + jets + $\cancel{E}_T, \text{Tglu3B}, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 175 \text{ GeV}, m_{\tilde{\chi}_1^0} = 200 \text{ GeV}$	>1600	95	44	SIRUNYAN	17AF CMS	$1 \ell + \text{jets} + b\text{-jets} + \cancel{E}_T, \text{Tglu3B}, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 175 \text{ GeV}, m_{\tilde{\chi}_1^0} = 50 \text{ GeV}$
>1690	95	24	SIRUNYAN	18D CMS	top quark (hadronically decaying) + jets + $\cancel{E}_T, \text{Tglu3C}, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 20 \text{ GeV}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1800	95	45	SIRUNYAN	17AY CMS	$\gamma + \text{jets} + \cancel{E}_T, \text{Tglu4B}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1990	95	24	SIRUNYAN	18D CMS	top quark (hadronically decaying) + jets + $\cancel{E}_T, \text{Tglu3E}, m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0} + 5 \text{ GeV}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$	>1600	95	45	SIRUNYAN	17AY CMS	$\gamma + \text{jets} + \cancel{E}_T, \text{Tglu4A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>2010	95	25	SIRUNYAN	18M CMS	$\geq 1 H (\rightarrow b\bar{b}) + \cancel{E}_T, \text{Tglu1I}$	>1860	95	46	SIRUNYAN	17AZ CMS	$\geq 1 \text{ jets} + \cancel{E}_T, \text{Tglu1A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1825	95	25	SIRUNYAN	18M CMS	$\geq 1 H (\rightarrow b\bar{b}) + \cancel{E}_T, \text{Tglu1J}$	>2025	95	46	SIRUNYAN	17AZ CMS	$\geq 1 \text{ jets} + \cancel{E}_T, \text{Tglu2A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1750	95	26	AABOUD	17AJ ATLS	same-sign $\ell^\pm \ell^\pm / 3 \ell + \text{jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$	>1900	95	46	SIRUNYAN	17AZ CMS	$\geq 1 \text{ jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1570	95	27	AABOUD	17AJ ATLS	same-sign $\ell^\pm \ell^\pm / 3 \ell + \text{jets} + \cancel{E}_T, \text{Tglu1E}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$	>1825	95	47	SIRUNYAN	17P CMS	$\text{jets} + \cancel{E}_T, \text{Tglu1A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1860	95	28	AABOUD	17AJ ATLS	same-sign $\ell^\pm \ell^\pm / 3 \ell + \text{jets} + \cancel{E}_T, \text{Tglu1G}, m_{\tilde{\chi}_1^0} = 200 \text{ GeV}$	>1950	95	47	SIRUNYAN	17P CMS	$\text{jets} + \cancel{E}_T, \text{Tglu2A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>2100	95	29	AABOUD	17AR ATLS	$1 \ell + \text{jets} + \cancel{E}_T, \text{Tglu1B}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1960	95	47	SIRUNYAN	17P CMS	$\text{jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1740	95	30	AABOUD	17AR ATLS	$1 \ell + \text{jets} + \cancel{E}_T, \text{Tglu1E}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1800	95	47	SIRUNYAN	17P CMS	$\text{jets} + \cancel{E}_T, \text{Tglu1C}, m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1800	95	31	AABOUD	17AY ATLS	$\text{jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$	>1870	95	47	SIRUNYAN	17P CMS	$\text{jets} + \cancel{E}_T, \text{Tglu3D}, m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0} + 5 \text{ GeV}, m_{\tilde{\chi}_1^0} = 1000 \text{ GeV}$
>1800	95	32	AABOUD	17AZ ATLS	$\geq 7 \text{ jets} + \cancel{E}_T, \text{large R-jets and/or } b\text{-jets}, \text{Tglu1E}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$	>1520	95	48	SIRUNYAN	17s CMS	same-sign $\ell^\pm \ell^\pm + \text{jets} + \cancel{E}_T, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$
>1540	95	33	AABOUD	17AZ ATLS	$\geq 7 \text{ jets} + \cancel{E}_T, \text{large R-jets and/or } b\text{-jets}, \text{Tglu3A}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1200	95	48	SIRUNYAN	17s CMS	same-sign $\ell^\pm \ell^\pm + \text{jets} + \cancel{E}_T, \text{Tglu3D}, m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0} + 5 \text{ GeV}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>1340	95	34	AABOUD	17N ATLS	2 same-flavor, opposite-sign $\ell + \text{jets} + \cancel{E}_T, \text{Tglu1H}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$	>1370	95	48	SIRUNYAN	17s CMS	same-sign $\ell^\pm \ell^\pm + \text{jets} + \cancel{E}_T, \text{Tglu3B}, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 175 \text{ GeV}, m_{\tilde{\chi}_1^0} = 50 \text{ GeV}$
>1310	95	35	AABOUD	17N ATLS	2 same-flavor, opposite-sign $\ell + \text{jets} + \cancel{E}_T, \text{Tglu1H}, m_{\tilde{\chi}_2^0} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2, m_{\tilde{\chi}_1^0} < 400 \text{ GeV}$	>1180	95	48	SIRUNYAN	17s CMS	same-sign $\ell^\pm \ell^\pm + \text{jets} + \cancel{E}_T, \text{Tglu3C}, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 20 \text{ GeV}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$

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Searches Particle Listings

Supersymmetric Particle Searches

>1280	95	48	SIRUNYAN	17s	CMS	same-sign $\ell^\pm \ell^\pm + \text{jets} + \cancel{E}_T$, Tglu1B, $m_{\tilde{\chi}_1^\pm} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2$, $m_{\tilde{\chi}_1^0} = 0$ GeV	> 850	95	64	AAD	15BG ATLS	GGM, $\tilde{g} \rightarrow q\bar{q}Z\tilde{G}$, $\tan\beta = 1.5$, $\mu > 450$ GeV
>1300	95	48	SIRUNYAN	17s	CMS	same-sign $\ell^\pm \ell^\pm + \text{jets} + \cancel{E}_T$, Tglu1B, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 20$ GeV, $m_{\tilde{\chi}_1^0} = 100$ GeV	>1150	95	65	AAD	15BV ATLS	general RPC \tilde{g} decays, $m_{\tilde{\chi}_1^0} < 100$ GeV
>1570	95	49	AABOUD	16AC	ATLS	≥ 2 jets + 1 or 2 $\tau + \cancel{E}_T$, Tglu1F, $m_{\tilde{\chi}_1^0} = 100$ GeV	> 700	95	66	AAD	15BX ATLS	$\tilde{g} \rightarrow X\tilde{\chi}_1^0$, independent of $m_{\tilde{\chi}_1^0}$
>1460	95	50	AABOUD	16J	ATLS	1 $\ell^\pm + \geq 4$ jets + \cancel{E}_T , Tglu3C, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 5$ GeV	>1290	95	67	AAD	15CA ATLS	$\geq 2 \gamma + \cancel{E}_T$, GGM, bino-like NLSP, any NLSP mass
>1650	95	51	AABOUD	16M	ATLS	2 $\gamma + \cancel{E}_T$, Tglu1D, any NLSP mass	>1260	95	67	AAD	15CA ATLS	$\geq 1 \gamma + b$ -jets + \cancel{E}_T , GGM, higgsino-bino admix. NLSP and $\mu < 0$, $m(\text{NLSP}) > 450$ GeV
>1510	95	52	AABOUD	16N	ATLS	≥ 4 jets + \cancel{E}_T , Tglu1A, $m_{\tilde{\chi}_1^0} = 0$ GeV	>1140	95	67	AAD	15CA ATLS	$\geq 1 \gamma + \text{jets} + \cancel{E}_T$, GGM, higgsino-bino admixture NLSP, all $\mu > 0$
>1500	95	53	AABOUD	16N	ATLS	≥ 4 jets + \cancel{E}_T , Tglu1B, $m_{\tilde{\chi}_1^\pm} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2$, $m_{\tilde{\chi}_1^0} = 200$ GeV	>1225	95	68	KHACHATRY...15AF	CMS	$\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 0$
>1780	95	54	AAD	16AD	ATLS	0 ℓ , ≥ 3 b -jets + \cancel{E}_T , Tglu2A, $m_{\tilde{\chi}_1^0} < 800$ GeV	>1300	95	68	KHACHATRY...15AF	CMS	$\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 0$
>1760	95	55	AAD	16AD	ATLS	1 ℓ , ≥ 3 b -jets + \cancel{E}_T , Tglu3A, $m_{\tilde{\chi}_1^0} < 700$ GeV	>1225	95	68	KHACHATRY...15AF	CMS	$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 0$
>1300	95	56	AAD	16BB	ATLS	2 same-sign/ $3\ell + \text{jets} + \cancel{E}_T$, Tglu1D, $m_{\tilde{\chi}_1^0} < 600$ GeV	>1550	95	68	KHACHATRY...15AF	CMS	CMSSM, $\tan\beta=30$, $m_{\tilde{g}}=m_{\tilde{q}}$, $A_0=-2\max(m_0, m_{1/2})$, $\mu > 0$
>1100	95	56	AAD	16BB	ATLS	2 same-sign/ $3\ell + \text{jets} + \cancel{E}_T$, Tglu1E, $m_{\tilde{\chi}_1^0} < 300$ GeV	>1150	95	68	KHACHATRY...15AF	CMS	CMSSM, $\tan\beta=30$, $A_0=-2\max(m_0, m_{1/2})$, $\mu > 0$
>1200	95	56	AAD	16BB	ATLS	2 same-sign/ $3\ell + \text{jets} + \cancel{E}_T$, Tglu3A, $m_{\tilde{\chi}_1^0} < 600$ GeV	>1280	95	69	KHACHATRY...15I	CMS	$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 0$
>1600	95	57	AAD	16Bg	ATLS	1 ℓ , ≥ 4 jets, \cancel{E}_T , Tglu1B, $m_{\tilde{\chi}_1^\pm} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2$, $m_{\tilde{\chi}_1^0} = 100$ GeV	>1310	95	70	KHACHATRY...15X	CMS	$\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 100$ GeV
>1400	95	58	AAD	16V	ATLS	≥ 7 to ≥ 10 jets + \cancel{E}_T , Tglu1E, $m_{\tilde{\chi}_1^0} < 200$ GeV	>1175	95	70	KHACHATRY...15X	CMS	$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 100$ GeV
>1400	95	58	AAD	16V	ATLS	≥ 7 to ≥ 10 jets + \cancel{E}_T , pMSSM $M_1 = 60$ GeV, $M_2 = 3$ TeV, $\tan\beta=10$, $\mu < 0$	>1330	95	71	AAD	14AE ATLS	jets + \cancel{E}_T , $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 0$ GeV
>1100	95	59	KHACHATRY...16AM	CMS	boosted $W+b$, Tglu3C, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < 80$ GeV, $m_{\tilde{\chi}_1^0} < 400$ GeV	>1700	95	71	AAD	14AE ATLS	jets + \cancel{E}_T , mSUGRA/CMSSM, $m_{\tilde{q}} = m_{\tilde{g}}$	
> 700	95	59	KHACHATRY...16AM	CMS	boosted $W+b$, Tglu3B, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 175$ GeV, $m_{\tilde{\chi}_1^0} = 0$ GeV	>1090	95	72	AAD	14AG ATLS	$\tau + \text{jets} + \cancel{E}_T$, natural Gauge Mediation	
>1050	95	60	KHACHATRY...16BJ	CMS	same-sign $\ell^\pm \ell^\pm$, Tglu3A, $m_{\tilde{\chi}_1^0} < 800$ GeV	>1600	95	72	AAD	14AG ATLS	$\tau + \text{jets} + \cancel{E}_T$, mGMSB, $M_{\text{mess}} = 250$ GeV, $N_5 = 3$, $\mu > 0$, $C_{\text{grav}} = 1$	
>1300	95	60	KHACHATRY...16BJ	CMS	same-sign $\ell^\pm \ell^\pm$, Tglu3A, $m_{\tilde{\chi}_1^0} = 0$	> 640	95	73	AAD	14X ATLS	$\geq 4\ell^\pm$, $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$, $\tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \tilde{G}$, $\tan\beta = 30$, GGM	
>1140	95	60	KHACHATRY...16BJ	CMS	same-sign $\ell^\pm \ell^\pm$, Tglu3B, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 20$ GeV, $m_{\tilde{\chi}_1^0} = 0$	>1000	95	74	CHATRCHYAN14AH	CMS	jets + \cancel{E}_T , $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 50$ GeV	
> 850	95	60	KHACHATRY...16BJ	CMS	same-sign $\ell^\pm \ell^\pm$, Tglu3B, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 20$ GeV, $m_{\tilde{\chi}_1^0} < 700$ GeV	>1350	95	74	CHATRCHYAN14AH	CMS	jets + \cancel{E}_T , CMSSM, $m_{\tilde{g}} = m_{\tilde{q}}$	
> 950	95	60	KHACHATRY...16BJ	CMS	same-sign $\ell^\pm \ell^\pm$, Tglu3D, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0} + 5$ GeV	>1000	95	75	CHATRCHYAN14AH	CMS	jets + \cancel{E}_T , $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 50$ GeV	
>1100	95	60	KHACHATRY...16BJ	CMS	same-sign $\ell^\pm \ell^\pm$, Tglu1B, $m_{\tilde{\chi}_1^\pm} = 0.5(m_{\tilde{g}} + m_{\tilde{\chi}_1^0})$, $m_{\tilde{\chi}_1^0} < 400$ GeV	>1000	95	76	CHATRCHYAN14AH	CMS	jets + \cancel{E}_T , $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 50$ GeV	
> 830	95	60	KHACHATRY...16BJ	CMS	same-sign $\ell^\pm \ell^\pm$, Tglu1B, $m_{\tilde{\chi}_1^\pm} = 0.5(m_{\tilde{g}} + m_{\tilde{\chi}_1^0})$, $m_{\tilde{\chi}_1^0} < 700$ GeV	>1160	95	77	CHATRCHYAN14I	CMS	jets + \cancel{E}_T , $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} < 100$ GeV	
>1300	95	60	KHACHATRY...16BJ	CMS	same-sign $\ell^\pm \ell^\pm$, Tglu3B, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = m_{\tilde{t}_1}$, $m_{\tilde{\chi}_1^0} = 0$	>1130	95	77	CHATRCHYAN14I	CMS	multijets + \cancel{E}_T , $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} < 100$ GeV	
>1050	95	60	KHACHATRY...16BJ	CMS	same-sign $\ell^\pm \ell^\pm$, Tglu3B, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = m_{\tilde{t}_1}$, $m_{\tilde{\chi}_1^0} < 800$ GeV	>1210	95	77	CHATRCHYAN14I	CMS	multijets + \cancel{E}_T , $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} < 100$ GeV	
>1725	95	61	KHACHATRY...16BS	CMS	jets + \cancel{E}_T , Tglu1A, $m_{\tilde{\chi}_1^0} = 0$	>1260	95	78	CHATRCHYAN14N	CMS	1 $\ell^\pm + \text{jets} + \geq 2b$ -jets, $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} = 0$ GeV, $m_{\tilde{\tau}} > m_{\tilde{g}}$	
>1750	95	61	KHACHATRY...16BS	CMS	jets + \cancel{E}_T , Tglu2A, $m_{\tilde{\chi}_1^0} = 0$	>1500	95	79	CHATRCHYAN14R	CMS	$\geq 3\ell^\pm$, $(\tilde{g}/\tilde{q}) \rightarrow q\ell^\pm \ell^\mp \tilde{G}$ simplified model, GMSB, slepton co-NLSP scenario	
>1550	95	61	KHACHATRY...16BS	CMS	jets + \cancel{E}_T , Tglu3A, $m_{\tilde{\chi}_1^0} = 0$	>1770	95	80	CHATRCHYAN14R	CMS	$\geq 3\ell^\pm$, $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ simplified model	
>1280	95	62	KHACHATRY...16BY	CMS	opposite-sign $\ell^\pm \ell^\pm$, Tglu4C, $m_{\tilde{\chi}_1^0} = 1000$ GeV	>1600	95	● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
>1030	95	62	KHACHATRY...16BY	CMS	opposite-sign $\ell^\pm \ell^\pm$, Tglu4C, $m_{\tilde{\chi}_1^0} = 0$ GeV	> 500	95	81	AABOUD	18BJ ATLS	$\ell^\pm \ell^\mp + \text{jets} + \cancel{E}_T$, Tglu1H, $m_{\tilde{\chi}_1^0} = 1$ GeV, any $m_{\tilde{\chi}_2^0}$	
>1440	95	63	KHACHATRY...16v	CMS	jets + \cancel{E}_T , Tglu1A, $m_{\tilde{\chi}_1^0} = 0$	>1500	95	82	AABOUD	18v ATLS	jets + \cancel{E}_T , Tglu1C-like, 1/2 BR per decay mode, any $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$, $m_{\tilde{\chi}_1^0} = 60$ GeV	
>1600	95	63	KHACHATRY...16v	CMS	jets + \cancel{E}_T , Tglu2A, $m_{\tilde{\chi}_1^0} = 0$	>1700	95	83	AABOUD	17AZ ATLS	≥ 7 jets + \cancel{E}_T , large R-jets and/or b -jets, pMSSM, $m_{\tilde{\chi}_1^\pm} = 200$ GeV	
>1550	95	63	KHACHATRY...16v	CMS	jets + \cancel{E}_T , Tglu3A, $m_{\tilde{\chi}_1^0} = 0$	>1600	95	84	KHACHATRY...16AY	CMS	1 $\ell^\pm + \text{jets} + b$ -jets + \cancel{E}_T , Tglu3A, $m_{\tilde{\chi}_1^0} = 0$ GeV	
>1450	95	63	KHACHATRY...16v	CMS	jets + \cancel{E}_T , Tglu1C, $m_{\tilde{\chi}_1^0} = 0$	>1600	95	85	KHACHATRY...16BT	CMS	19-parameter pMSSM model, global Bayesian analysis, flat prior	
> 820	95	64	AAD	15Bg	ATLS	GGM, $\tilde{g} \rightarrow q\bar{q}Z\tilde{G}$, $\tan\beta = 30$, $\mu > 600$ GeV	> 500	95	86	AAD	15AB ATLS	$\tilde{g} \rightarrow \tilde{S}g$, $c\tau = 1$ m, $\tilde{S} \rightarrow \tilde{S}\tilde{G}$ and $\tilde{S} \rightarrow gg$, BR = 100%
						>1280	95	87	AAD	15AI ATLS	$\ell^\pm + \text{jets} + \cancel{E}_T$	
						>1100	95	65	AAD	15BV ATLS	pMSSM, $M_1 = 60$ GeV, $m_{\tilde{q}} < 1500$ GeV	
						>1330	95	65	AAD	15BV ATLS	mSUGRA, $m_0 > 2$ TeV	
							95	65	AAD	15BV ATLS	via $\tilde{\tau}$, natural GMSB, all $m_{\tilde{\tau}}$	
							95	65	AAD	15BV ATLS	jets + \cancel{E}_T , $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 1$ GeV	

• • • We do not use the following data for averages, fits, limits, etc. • • •

Searches Particle Listings

Supersymmetric Particle Searches

>1500	95	65	AAD	15BV ATLS	jets + \cancel{E}_T , $\tilde{g} \rightarrow \tilde{q} q, \tilde{q} \rightarrow q \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 1$ GeV
>1650	95	65	AAD	15BV ATLS	jets + \cancel{E}_T , $m_{\tilde{g}} = m_{\tilde{q}}, m_{\tilde{\chi}_1^0} = 1$ GeV
> 850	95	65	AAD	15BV ATLS	jets + \cancel{E}_T , $\tilde{g} \rightarrow g \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} < 550$ GeV
>1270	95	65	AAD	15BV ATLS	jets + \cancel{E}_T , $\tilde{g} \rightarrow q \tilde{q} W \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 100$ GeV
>1150	95	65	AAD	15BV ATLS	jets + $\ell^\pm \ell^\pm$, $\tilde{g} \rightarrow q \tilde{q} W Z \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 100$ GeV
>1320	95	65	AAD	15BV ATLS	jets + $\ell^\pm \ell^\pm$, \tilde{g} decays via sleptons, $m_{\tilde{\chi}_1^0} = 100$ GeV
>1220	95	65	AAD	15BV ATLS	τ, \tilde{q} decays via staus, $m_{\tilde{\chi}_1^0} = 100$ GeV
>1310	95	65	AAD	15BV ATLS	b-jets, $\tilde{g} \rightarrow t \tilde{\tau} \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} < 400$ GeV
>1220	95	65	AAD	15BV ATLS	b-jets, $\tilde{g} \rightarrow \tilde{\tau}_1 t$ and $\tilde{\tau}_1 \rightarrow t \tilde{\chi}_1^0$, $m_{\tilde{\tau}_1} < 1000$ GeV
>1180	95	65	AAD	15BV ATLS	b-jets, $\tilde{g} \rightarrow \tilde{\tau}_1 t$ and $\tilde{\tau}_1 \rightarrow b \tilde{\chi}_1^\pm$, $m_{\tilde{\tau}_1} < 1000$ GeV, $m_{\tilde{\chi}_1^\pm} = 60$ GeV
>1260	95	65	AAD	15BV ATLS	b-jets, $\tilde{g} \rightarrow \tilde{\tau}_1 t$ and $\tilde{g} \rightarrow c \tilde{\chi}_1^0$
>1200	95	65	AAD	15BV ATLS	b-jets, $\tilde{g} \rightarrow b_1 b$ and $b_1 \rightarrow b \tilde{\chi}_1^0$, $m_{b_1} < 1000$ GeV
>1250	95	65	AAD	15BV ATLS	b-jets, $\tilde{g} \rightarrow b \tilde{b} \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} < 400$ GeV
none, 750–1250	95	65	AAD	15BV ATLS	b-jets, \tilde{g} decay via offshell $\tilde{\tau}_1$ and b_1 , $m_{\tilde{\chi}_1^0} < 500$ GeV
>1100	95	88	AAD	15CB ATLS	jets, $\tilde{g} \rightarrow q q \tilde{\chi}_1^0$, $\tilde{\chi}_1^0 \rightarrow Z \tilde{G}$, GGM, $m_{\tilde{\chi}_1^0} = 400$ GeV and $3 < c\tau_{\tilde{\chi}_1^0} < 500$ mm
>1400	95	88	AAD	15CB ATLS	jets or \cancel{E}_T , $\tilde{g} \rightarrow q q \tilde{\chi}_1^0$, Split SUSY, $m_{\tilde{\chi}_1^0} = 100$ GeV and $15 < c\tau < 300$ mm
>1500	95	88	AAD	15CB ATLS	\cancel{E}_T , $\tilde{g} \rightarrow q q \tilde{\chi}_1^0$, Split SUSY, $m_{\tilde{\chi}_1^0} = 100$ GeV and $20 < c\tau < 250$ mm
>1300	95	90	KHACHATRY...15AZ	CMS	$\ell^\pm \ell^\pm$ + jets + \cancel{E}_T , GMSB, $\tilde{g} \rightarrow q \tilde{q} Z \tilde{G}$, $\geq 2 \gamma, \geq 1$ jet, (Razor), binole-like NLSP, $m_{\tilde{\chi}_1^0} = 375$ GeV
> 800	95	90	KHACHATRY...15AZ	CMS	$\geq 1 \gamma, \geq 2$ jet, wino-like NLSP, $m_{\tilde{\chi}_1^0} = 375$ GeV
>1280	95	91	AAD	14AX ATLS	≥ 3 b-jets + \cancel{E}_T , CMSSM
>1250	95	91	AAD	14AX ATLS	≥ 3 b-jets + \cancel{E}_T , $\tilde{g} \rightarrow b_1 b \tilde{\chi}_1^0$, simplified model, $b_1 \rightarrow b \tilde{\chi}_1^\pm$, $m_{\tilde{\chi}_1^\pm} = 60$ GeV, $m_{b_1} < 900$ GeV
>1190	95	91	AAD	14AX ATLS	≥ 3 b-jets + \cancel{E}_T , $\tilde{g} \rightarrow \tilde{\tau}_1 t \tilde{\chi}_1^0$, simplified model, $\tilde{\tau}_1 \rightarrow t \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 60$ GeV, $m_{\tilde{\tau}_1} < 1000$ GeV
>1180	95	91	AAD	14AX ATLS	≥ 3 b-jets + \cancel{E}_T , $\tilde{g} \rightarrow \tilde{\tau}_1 t \tilde{\chi}_1^\pm$, simplified model, $\tilde{\tau}_1 \rightarrow b \tilde{\chi}_1^\pm$, $m_{\tilde{\chi}_1^\pm} = 2m_{\tilde{\chi}_1^0}$, $m_{\tilde{\chi}_1^0} = 60$ GeV, $m_{\tilde{\tau}_1} < 1000$ GeV
>1250	95	91	AAD	14AX ATLS	≥ 3 b-jets + \cancel{E}_T , $\tilde{g} \rightarrow b \tilde{b} \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^0} < 400$ GeV
>1340	95	91	AAD	14AX ATLS	≥ 3 b-jets + \cancel{E}_T , $\tilde{g} \rightarrow t \tilde{\tau} \tilde{\chi}_1^0$, simplified model, $m_{\tilde{\chi}_1^0} < 400$ GeV
>1300	95	91	AAD	14AX ATLS	≥ 3 b-jets + \cancel{E}_T , $\tilde{g} \rightarrow t \tilde{b} \tilde{\chi}_1^\pm$, simplified model, $\tilde{\chi}_1^\pm \rightarrow t' \tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 2$ GeV, $m_{\tilde{\chi}_1^0} < 300$ GeV
> 950	95	92	AAD	14E ATLS	$\ell^\pm \ell^\pm (\ell^\mp \bar{\nu})$ + jets, $\tilde{g} \rightarrow t \tilde{\tau} \tilde{\chi}_1^0$, simplified model
>1000	95	92	AAD	14E ATLS	$\ell^\pm \ell^\pm (\ell^\mp \bar{\nu})$ + jets, $\tilde{g} \rightarrow t \tilde{\tau}_1$ with $\tilde{\tau}_1 \rightarrow b \tilde{\chi}_1^\pm$ simplified model, $m_{\tilde{\tau}_1} < 200$ GeV, $m_{\tilde{\chi}_1^\pm} = 118$ GeV, $m_{\tilde{\chi}_1^0} = 60$ GeV

> 640	95	92	AAD	14E ATLS	$\ell^\pm \ell^\pm (\ell^\mp \bar{\nu})$ + jets, $\tilde{g} \rightarrow t \tilde{\tau}_1$ with $\tilde{\tau}_1 \rightarrow c \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\tau}_1} = m_{\tilde{\chi}_1^0} + 20$ GeV
> 860	95	92	AAD	14E ATLS	$\ell^\pm \ell^\pm (\ell^\mp \bar{\nu})$ + jets, $\tilde{g} \rightarrow q q' \tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^{(*)} \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^\pm} = 2 m_{\tilde{\chi}_1^0}$, $m_{\tilde{\chi}_1^0} < 400$ GeV
>1040	95	92	AAD	14E ATLS	$\ell^\pm \ell^\pm (\ell^\mp \bar{\nu})$ + jets, $\tilde{g} \rightarrow q q' \tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^{(*)} \tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \rightarrow Z^{(*)} \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^0} < 520$ GeV
>1200	95	92	AAD	14E ATLS	$\ell^\pm \ell^\pm (\ell^\mp \bar{\nu})$ + jets, $\tilde{g} \rightarrow q q' \tilde{\chi}_1^\pm / \tilde{\chi}_2^0$, $\tilde{\chi}_1^\pm \rightarrow \ell^\pm \nu \tilde{\chi}_1^0$, $\tilde{\chi}_2^0 \rightarrow \ell^\pm \ell^\mp (\nu \nu) \tilde{\chi}_1^0$ simplified model
>1050	95	93	CHATRCHYAN14H	CMS	same-sign $\ell^\pm \ell^\pm$, $\tilde{g} \rightarrow t \tilde{\tau} \tilde{\chi}_1^0$ simplified model, massless $\tilde{\chi}_1^0$
> 900	95	94	CHATRCHYAN14H	CMS	same-sign $\ell^\pm \ell^\pm$, $\tilde{g} \rightarrow q q' \tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^\pm} = 0.5 m_{\tilde{g}}$, massless $\tilde{\chi}_1^0$
>1050	95	95	CHATRCHYAN14H	CMS	same-sign $\ell^\pm \ell^\pm$, $\tilde{g} \rightarrow b \tilde{\tau} \tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$ simplified model, $m_{\tilde{\chi}_1^\pm} = 300$ GeV, $m_{\tilde{\chi}_1^0} = 50$ GeV

¹ SIRUNYAN 20b searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV for events with at least one photon and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on chargino masses in a general gauge-mediated SUSY breaking (GGM) scenario TchlIn12-GGM, see Figure 4. Limits are also set on the NLSP mass in the TchlIn1F and TchlIn1G simplified models, see their Figure 5. Finally, limits are set on the gluino mass in the Tglu4A simplified model, see Figure 6.

² AABOUD 19i searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV in final states with hadronic jets, 1 or two hadronically decaying τ and \cancel{E}_T . In Tglu1F, gluino masses are excluded at 95% C.L. up to 2000 GeV for neutralino masses of 100 GeV or below. Neutralino masses up to 1000 GeV are excluded for all gluino masses below 1400 GeV. See their Fig. 9. Limits are also presented in the context of Gauge-Mediated Symmetry Breaking models: in this case, values of Λ below 110 TeV are excluded at the 95% CL for all values of $\tan\beta$ in the range $2 < \tan\beta < 60$, see their Fig 10.

³ SIRUNYAN 19AG searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV for events with two photons and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu4B simplified model and on the squark mass in the Tsqq4B simplified model, see their Figure 3.

⁴ SIRUNYAN 19AU searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV for events with at least one photon, jets, some of which are identified as originating from b -quarks, and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. In the framework of GMSB, limits are set on the gluino mass in the Tglu4C, Tglu4D and Tglu4E simplified models, and on the top squark mass in the Tstop13 simplified model, see their Figure 5.

⁵ SIRUNYAN 19CE searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV for new particles decaying to a photon and two gluons in events with at least three large-radius jets of which two have substructure and are composed of a photon and two gluons. No statistically significant excess is observed above the SM background expectation. Upper limits at 95% confidence level on the cross section for gluino pair production are set, using a Tglu1A-like stealth SUSY model. Gluino masses up to 1500–1700 GeV are excluded, depending on the neutralino mass, with the highest exclusion set for $m_{\tilde{\chi}_1^0} = 200$ GeV. See their Fig 4.

⁶ SIRUNYAN 19CH searched in 137 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV for events containing multiple jets and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu1C, Tglu2A and Tglu3A simplified models, see their Figure 13. Limits are also set on squark, sbottom and stop masses in the Tsqq1, Tsb01, Tstop1 simplified models, see their Figure 14.

⁷ SIRUNYAN 19K searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV for events with a photon, an electron or muon, and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. In the framework of GMSB, limits are set on the chargino and neutralino mass in the TchlIn1A simplified model, see their Figure 6. Limits are also set on the gluino mass in the Tglu4A simplified model, and on the squark mass in the Tsqq4A simplified model, see their Figure 7.

⁸ SIRUNYAN 19s searched in 35.9 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV for events with zero or one charged leptons, jets and \cancel{E}_T . The razor variables (M_R and R^2) are used to categorize the events. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu3A and Tglu3C simplified models, see Figures 22 and 23, and on the stop mass in the Tstop1 simplified model, see their Figure 24.

⁹ AABOUD 18AR searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV for gluino pair production in events containing large missing transverse momentum and several energetic jets, at least three of which must be identified as originating from b -quarks. No excess is found above the predicted background. In Tglu3A models, gluino masses of less than 1.97 TeV are excluded for $m_{\tilde{\chi}_1^0}$ below 300 GeV, see their Fig. 10(a). Interpretations are also provided for scenarios where Tglu3A modes mix with Tglu2A and Tglu3D, see their Fig 11.

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- 10 AABOUD 18AR searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for gluino pair production in events containing large missing transverse momentum and several energetic jets, at least three of which must be identified as originating from b -quarks. No excess is found above the predicted background. In Tglu2A models, gluino masses of less than 1.92 TeV are excluded for $m_{\tilde{\chi}_1^0}$ below 600 GeV , see their Fig. 10(b). Interpretations are also provided for scenarios where Tglu2A models mix with Tglu3A and Tglu3D, see their Fig. 11.
- 11 AABOUD 18AS searched for in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for gluino pair production in the context of AMSB or phenomenological MSSM scenarios with wino-like LSP and long-lived charginos. Events with a disappearing track due to a low-momentum pion accompanied by at least four jets are considered. No significant excess above the Standard Model expectations is observed. Exclusion limits are set at 95% confidence level on the mass of gluinos for different chargino lifetimes. Gluino masses up to 1.65 TeV are excluded assuming a chargino mass of 460 GeV and lifetime of 0.2 ns , corresponding to a mass-splitting between the charged and neutral wino of around 160 MeV . See their Fig. 9.
- 12 AABOUD 18BJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with two opposite-sign charged leptons (electrons and muons), jets and missing transverse momentum, with various requirements to be sensitive to signals with different kinematic endpoint values in the dilepton invariant mass distribution. The data are found to be consistent with the SM expectation. Results are interpreted in the Tglu1G model: gluino masses below 1850 GeV are excluded for $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$, see their Fig. 12(a).
- 13 AABOUD 18BJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with two opposite-sign charged leptons (electrons and muons), jets and missing transverse momentum, with various requirements to be sensitive to signals with different kinematic endpoint values in the dilepton invariant mass distribution. The data are found to be consistent with the SM expectation. Results are interpreted in the Tglu1H model: gluino masses below 1650 GeV are excluded for $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$, see their Fig. 13(a).
- 14 AABOUD 18U searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with at least one isolated photon, possibly jets and significant transverse momentum targeting generalised models of gauge-mediated SUSY breaking. No significant excess of events is observed above the SM prediction. Results for the di-photon channel are interpreted in terms of lower limits on the masses of gluinos in Tglu4B models, which reach as high as 2.3 TeV . Gluinos with masses below 2.15 TeV are excluded for any NLSP mass, see their Fig. 8.
- 15 AABOUD 18U searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with at least one isolated photon, possibly jets and significant transverse momentum targeting generalised models of gauge-mediated SUSY breaking. No significant excess of events is observed above the SM prediction. Results of the $\gamma + \text{jets} + \cancel{E}_T$ channel are interpreted in terms of lower limits on the masses of gluinos in GGM higgsino-bino models (mix of Tglu4B and Tglu4C), which reach as high as 2050 GeV . Gluino masses below 1600 GeV are excluded for any NLSP mass provided that $m_{\tilde{g}} - m_{\tilde{\chi}_1^0} > 50 \text{ GeV}$. See their Fig. 11.
- 16 AABOUD 18V searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with no charged leptons, jets and missing transverse momentum. The data are found to be consistent with the SM expectation. Results are interpreted in the Tglu1A model: gluino masses below 2030 GeV are excluded for massless LSP, see their Fig. 13(b).
- 17 AABOUD 18V searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with no charged leptons, jets and missing transverse momentum. The data are found to be consistent with the SM expectation. Results are interpreted in the Tglu1B model. Assuming that $m_{\tilde{\chi}_1^\pm} = 0.5 (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})$, gluino masses below 1980 GeV are excluded for massless LSP, see their Fig. 14(c). Exclusions are also shown assuming $m_{\tilde{\chi}_1^0} = 60 \text{ GeV}$, see their Fig. 14(d).
- 18 AABOUD 18V searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in events with no charged leptons, jets and missing transverse momentum. The data are found to be consistent with the SM expectation. Results are interpreted in the Tglu1E model: gluino masses below 1750 GeV are excluded for $m_{\tilde{\chi}_1^0} = 1 \text{ GeV}$ and any $m_{\tilde{\chi}_2^0}$ above 100 GeV , see their Fig. 15. Gluino mass exclusion up to 2 TeV is found for $m_{\tilde{\chi}_2^0} = 1 \text{ TeV}$.
- 19 SIRUNYAN 18AA searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one photon and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on wino masses in a general gauge-mediated SUSY breaking (GGM) scenario with bino-like $\tilde{\chi}_1^\pm$ and wino-like $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$, see Figure 7. Limits are also set on the NLSP mass in the Tchl1n1A and Tchl1ch1A simplified models, see their Figure 8. Finally, limits are set on the gluino mass in the Tglu4A and Tglu4B simplified models, see their Figure 9, and on the squark mass in the Tskq4A and Tskq4B simplified models, see their Figure 10.
- 20 SIRUNYAN 18AC searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with a single electron or muon and multiple jets. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu3A and Tglu1B simplified models, see their Figure 5.
- 21 SIRUNYAN 18AL searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least three charged leptons, in any combination of electrons and muons, jets and significant \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu3A and Tglu1C simplified models, see their Figure 5. Limits are also set on the sbottom mass in the Tsb0t2 simplified model, see their Figure 6, and on the stop mass in the Tstop7 simplified model, see their Figure 7.
- 22 SIRUNYAN 18AR searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing two opposite-charge, same-flavour leptons (electrons or muons), jets and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu4C simplified model, see their Figure 7. Limits are also set on the chargino/neutralino mass in the Tchl1n2F simplified models, see their Figure 8, and on the higgsino mass in the Tn1n1B and Tn1n1C simplified models, see their Figure 9. Finally, limits are set on the sbottom mass in the Tsb0t3 simplified model, see their Figure 10.
- 23 SIRUNYAN 18AY searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing one or more jets and significant \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A and Tglu3A simplified models, see their Figure 3. Limits are also set on squark, sbottom and stop masses in the Tskq1, Tsb0t1, Tstop1 and Tstop4 simplified models, see their Figure 3. Finally, limits are set on long-lived gluino masses in a Tglu1A simplified model where the gluino is metastable or long-lived with proper decay lengths in the range $10^{-3} \text{ mm} < c\tau < 10^5 \text{ mm}$, see their Figure 4.
- 24 SIRUNYAN 18b searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing identified hadronically decaying top quarks, no leptons, and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1 simplified model, see their Figure 8, and on the gluino mass in the Tglu3A, Tglu3B, Tglu3C and Tglu3E simplified models, see their Figure 9.
- 25 SIRUNYAN 18M searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one or more high-momentum Higgs bosons, decaying to pairs of b -quarks, and large \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1I and Tglu1J simplified models, see their Figure 3.
- 26 AABOUD 17AJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two same-sign or three leptons, jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 1.75 TeV are set on the gluino mass in Tglu3A simplified models in case of off-shell top squarks and for $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$. See their Figure 4(a).
- 27 AABOUD 17AJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two same-sign or three leptons, jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 1.57 TeV are set on the gluino mass in Tglu1E simplified models (2-step models) for $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$. See their Figure 4(b).
- 28 AABOUD 17AJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two same-sign or three leptons, jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 1.86 TeV are set on the gluino mass in Tglu1G simplified models for $m_{\tilde{\chi}_1^0} = 200 \text{ GeV}$. See their Figure 4(c).
- 29 AABOUD 17AR searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one isolated lepton, at least two jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 2.1 TeV are set on the gluino mass in Tglu1B simplified models, with $x = (m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0}) / (m_{\tilde{g}} - m_{\tilde{\chi}_1^0}) = 1/2$. Similar limits are obtained for variable x and fixed neutralino mass, $m_{\tilde{\chi}_1^0} = 60 \text{ GeV}$. See their Figure 13.
- 30 AABOUD 17AR searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one isolated lepton, at least two jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 1.74 TeV are set on the gluino mass in Tglu1E simplified model. Limits up to 1.7 TeV are also set on pMSSM models leading to similar signal event topologies. See their Figure 13.
- 31 AABOUD 17AY searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least four jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 1.8 TeV are set on the gluino mass in Tglu3A simplified models assuming $m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$. See their Figure 13.
- 32 AABOUD 17AZ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least seven jets and large missing transverse momentum. Selected events are further classified based on the presence of large R -jets or b -jets and no leptons. No significant excess above the Standard Model expectations is observed. Limits up to 1.8 TeV are set on the gluino mass in Tglu1E simplified models. See their Figure 6b.
- 33 AABOUD 17AZ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least seven jets and large missing transverse momentum. Selected events are further classified based on the presence of large R -jets or b -jets and no leptons. No significant excess above the Standard Model expectations is observed. Limits up to 1.54 TeV are set on the gluino mass in Tglu3A simplified models. See their Figure 7a.
- 34 AABOUD 17N searched in 14.7 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in final states with 2 same-flavor, opposite-sign leptons (electrons or muons), jets and large missing transverse momentum. In Tglu1J models, gluino masses are excluded at 95% C.L. up to 1300 GeV for $m_{\tilde{\chi}_1^0} = 0 \text{ GeV}$ and $m_{\tilde{\chi}_2^0} = 1100 \text{ GeV}$. See their Fig. 12 for exclusion limits as a function of $m_{\tilde{\chi}_2^0}$. Limits are also presented assuming $m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^0} + 100 \text{ GeV}$, see their Fig. 13.
- 35 AABOUD 17N searched in 14.7 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in final states with 2 same-flavor, opposite-sign leptons (electrons or muons), jets and large missing transverse momentum. In Tglu1H models, gluino masses are excluded at 95% C.L. up to 1310 GeV for $m_{\tilde{\chi}_1^0} < 400 \text{ GeV}$ and assuming $m_{\tilde{\chi}_2^0} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2$. See their Fig. 15.
- 36 AABOUD 17N searched in 14.7 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in final states with 2 same-flavor, opposite-sign leptons (electrons or muons), jets and large missing transverse momentum. In Tglu1G models, gluino masses are excluded at 95% C.L. up to 1700 GeV for small $m_{\tilde{\chi}_1^0}$. The results probe kinematic endpoints as small as $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = (m_{\tilde{g}} - m_{\tilde{\chi}_1^0})/2 = 50 \text{ GeV}$. See their Fig. 14.
- 37 KHACHATRYAN 17 searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing four or more jets, no more than one lepton, and missing transverse momentum, using the razor variables (M_R and R^2) to discriminate between signal and background processes. No evidence for an excess over the expected background is observed. Limits are derived on the gluino mass in the Tglu1A, Tglu2A and Tglu3A simplified models, see Figs. 16 and 17. Also, assuming gluinos decay only via three-body processes involving third-generation quarks plus a neutralino/chargino, and assuming $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0} + 5 \text{ GeV}$, a branching ratio-independent limit on the gluino mass is given, see Fig. 16.
- 38 KHACHATRYAN 17AD searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing at least four jets (including b -jets), missing transverse momentum and tagged top quarks. No evidence for an excess over the expected background is observed. Gluino masses up to 1550 GeV and neutralino masses up to 900 GeV are excluded at 95% C.L. See Fig. 13.
- 39 KHACHATRYAN 17AD searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing at least four jets (including b -jets), missing transverse momentum and tagged top quarks. No evidence for an excess over the expected background is observed. Gluino masses up to 1450 GeV and neutralino masses up to 820 GeV are excluded at 95% C.L. See Fig. 13.
- 40 KHACHATRYAN 17AS searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with a single electron or muon and multiple jets. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu3A and Tglu1B simplified models, see their Fig. 7.
- 41 KHACHATRYAN 17AW searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least three charged leptons, in any combination of electrons and muons, and

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- significant \mathcal{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu3A and Tglu1C simplified models, and on the sbottom mass in the Tsb02 simplified model, see their Figure 4.
- 42 KHACHATRYAN 17P searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one or more jets and large \mathcal{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A, Tglu3A, Tglu3B, Tglu3C and Tglu3D simplified models, see their Figures 7 and 8. Limits are also set on the squark mass in the Tsqk1 simplified model, see their Fig. 7, and on the sbottom mass in the Tsb01 simplified model, see Fig. 8. Finally, limits are set on the stop mass in the Tstop1, Tstop3, Tstop4, Tstop6 and Tstop7 simplified models, see Fig. 8.
- 43 KHACHATRYAN 17V searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two photons and large \mathcal{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino and squark mass in the context of general gauge mediation models Tglu4B and Tsqk4, see their Fig. 4.
- 44 SIRUNYAN 17AF searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with a single lepton (electron or muon), jets, including at least one jet originating from a b -quark, and large \mathcal{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu3A and Tglu3B simplified models, see their Figure 2.
- 45 SIRUNYAN 17AY searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one photon, jets and large \mathcal{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu4A and Tglu4B simplified models, and on the squark mass in the Tsqk4A and Tsqk4B simplified models, see their Figure 6.
- 46 SIRUNYAN 17AZ searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with one or more jets and large \mathcal{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A, Tglu3A simplified models, see their Figures 6. Limits are also set on the squark mass in the Tsqk1 simplified model (for single light squark and for 8 degenerate light squarks), on the sbottom mass in the Tsb01 simplified model and on the stop mass in the Tstop1 simplified model, see their Fig. 7. Finally, limits are set on the stop mass in the Tstop2, Tstop4 and Tstop8 simplified models, see Fig. 8.
- 47 SIRUNYAN 17P searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with multiple jets and large \mathcal{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu1C, Tglu2A, Tglu3A and Tglu3D simplified models, see their Fig. 12. Limits are also set on the squark mass in the Tsqk1 simplified model, on the stop mass in the Tstop1 simplified model, and on the sbottom mass in the Tsb01 simplified model, see Fig. 13.
- 48 SIRUNYAN 17S searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two isolated same-sign leptons, jets, and large \mathcal{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the mass of the gluino mass in the Tglu3A, Tglu3B, Tglu3C, Tglu3D and Tglu1B simplified models, see their Figures 5 and 6, and on the sbottom mass in the Tsb02 simplified model, see their Figure 6.
- 49 AABOUD 16AC searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in final states with hadronic jets, 1 or two hadronically decaying τ and \mathcal{E}_T . In Tglu1F, gluino masses are excluded at 95% C.L. up to 1570 GeV for neutralino masses of 100 GeV or below. Neutralino masses up to 700 GeV are excluded for all gluino masses between 800 GeV and 1500 GeV, while the strongest neutralino-mass exclusion of 750 GeV is achieved for gluino masses around 1400 GeV. See their Fig. 8. Limits are also presented in the context of Gauge-Mediated Symmetry Breaking models: in this case, values of A below 92 TeV are excluded at the 95% C.L. corresponding to gluino masses below 2000 GeV. See their Fig. 9.
- 50 AABOUD 16I searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in final states with one isolated electron or muon, hadronic jets, and \mathcal{E}_T . Gluino-mediated pair production of stops with a nearly mass-degenerate stop and neutralino are targeted and gluino masses are excluded at 95% C.L. up to 1460 GeV. A 100% of stops decaying via charm + neutralino is assumed. The results are also valid in case of 4-body decays $\tilde{t}_1 \rightarrow f f' b \tilde{\chi}_1^0$. See their Fig. 8.
- 51 AABOUD 16M searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two photons, hadronic jets and \mathcal{E}_T . No significant excess above the Standard Model expectations is observed. Exclusion limits at 95% C.L. are set on gluino masses in the general gauge-mediated SUSY breaking model (GGM), for bino-like NLSP. See their Fig. 3.
- 52 AABOUD 16N searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing hadronic jets, large \mathcal{E}_T , and no electrons or muons. No significant excess above the Standard Model expectations is observed. Gluino masses below 1510 GeV are excluded at the 95% C.L. in a simplified model with only gluinos and the lightest neutralino. See their Fig. 7b.
- 53 AABOUD 16N searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing hadronic jets, large \mathcal{E}_T , and no electrons or muons. No significant excess above the Standard Model expectations is observed. Gluino masses below 1500 GeV are excluded at the 95% C.L. in a simplified model with gluinos decaying via an intermediate $\tilde{\chi}_1^\pm$ to two quarks, a W boson and a $\tilde{\chi}_1^0$, for $m_{\tilde{\chi}_1^0} = 200 \text{ GeV}$. See their Fig. 8.
- 54 AAD 16AD searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing several energetic jets, of which at least three must be identified as b -jets, large \mathcal{E}_T and no electrons or muons. No significant excess above the Standard Model expectations is observed. For $\tilde{\chi}_1^0$ below 800 GeV, gluino masses below 1780 GeV are excluded at 95% C.L. for gluinos decaying via bottom squarks. See their Fig. 7a.
- 55 AAD 16AD searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing several energetic jets, of which at least three must be identified as b -jets, large \mathcal{E}_T and one electron or muon. Large-radius jets with a high mass are also used to identify highly boosted top quarks. No significant excess above the Standard Model expectations is observed. For $\tilde{\chi}_1^0$ below 700 GeV, gluino masses below 1760 GeV are excluded at 95% C.L. for gluinos decaying via top squarks. See their Fig. 7b.
- 56 AAD 16BB searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with exactly two same-sign leptons or at least three leptons, multiple hadronic jets, b -jets, and \mathcal{E}_T . No significant excess over the Standard Model expectation is found. Exclusion limits at 95% C.L. are set on the gluino mass in various simplified models (Tglu1D, Tglu1E, Tglu3A). See their Figs. 4.a, 4.b, and 4.d.
- 57 AAD 16BG searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ in final states with one isolated electron or muon, hadronic jets, and \mathcal{E}_T . The data agree with the SM background expectation in the six signal selections defined in the search, and the largest deviation is a 2.1 standard deviation excess. Gluinos are excluded at 95% C.L. up to 1600 GeV assuming they decay via the lightest chargino to the lightest neutralino as in the model Tglu1B for $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$, assuming $m_{\tilde{\chi}_1^\pm} = (m_{\tilde{g}} + m_{\tilde{\chi}_1^0})/2$. See their Fig. 6.
- 58 AAD 16V searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with \mathcal{E}_T various hadronic jet multiplicities from ≥ 7 to ≥ 10 and with various b -jet multiplicity requirements. No significant excess over the Standard Model expectation is found. Exclusion limits at 95% C.L. are set on the gluino mass in one simplified model (Tglu1E) and a pMSSM-inspired model. See their Fig. 5.
- 59 KHACHATRYAN 16AM searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with highly boosted W -bosons and b -jets, using the razor variables (M_R and R^2) to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu3C and Tglu3B simplified models, see Fig. 12.
- 60 KHACHATRYAN 16BJ searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two isolated same-sign dileptons and jets in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the following simplified models: Tglu3A and Tglu3D, see Fig. 4, Tglu3B and Tglu3C, see Fig. 5, and Tglu1B, see Fig. 7.
- 61 KHACHATRYAN 16BS searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least one energetic jet, no isolated leptons, and significant \mathcal{E}_T , using the transverse mass variable M_{T2} to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A and Tglu3A simplified models, see Fig. 10 and Table 3.
- 62 KHACHATRYAN 16BY searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two opposite-sign, same-flavour leptons, jets, and missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu4C simplified model, see Fig. 4, and on sbottom masses in the Tsb03 simplified model, see Fig. 5.
- 63 KHACHATRYAN 16V searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least four energetic jets and significant \mathcal{E}_T , no identified isolated electron or muon or charged track. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu1C, Tglu2A, and Tglu3A simplified models, see Fig. 8.
- 64 AAD 15BG searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with jets, missing \mathcal{E}_T , and two opposite-sign same flavor isolated leptons featuring either a kinematic edge, or a peak at the Z -boson mass, in the invariant mass spectrum. No evidence for a statistically significant excess over the expected SM backgrounds are observed and 95% C.L. exclusion limits are derived in a GGM simplified model of gluino pair production where the gluino decays into quarks, a Z -boson, and a massless gravitino LSP, see Fig. 12. Also, limits are set in simplified models with slepton/sneutrino intermediate states, see Fig. 13.
- 65 AAD 15BV summarized and extended ATLAS searches for gluinos and first- and second-generation squarks in final states containing jets and missing transverse momentum, with or without leptons or b -jets in the $\sqrt{s} = 8 \text{ TeV}$ data set collected in 2012. The paper reports the results of new interpretations and statistical combinations of previously published analyses, as well as new analyses. Exclusion limits at 95% C.L. are set on the gluino mass in several R-parity conserving models, leading to a generalized constraint on gluino masses exceeding 1150 GeV for lightest supersymmetric particle masses below 100 GeV. See their Figs. 10, 19, 20, 21, 23, 25, 26, 29-37.
- 66 AAD 15BX interpreted the results of a wide range of ATLAS direct searches for supersymmetry, during the first run of the LHC using the $\sqrt{s} = 7 \text{ TeV}$ and $\sqrt{s} = 8 \text{ TeV}$ data set collected in 2012, within the wider framework of the phenomenological MSSM (pMSSM). The integrated luminosity was up to 20.3 fb^{-1} . From an initial random sampling of 500 million pMSSM points, generated from the 19-parameter pMSSM, a total of 310,327 model points with $\tilde{\chi}_1^0$ LSP were selected each of which satisfies constraints from previous collider searches, precision measurements, cold dark matter energy density measurements and direct dark matter searches. The impact of the ATLAS Run 1 searches on this space was presented, considering the fraction of model points surviving, after projection into two-dimensional spaces of sparticle masses. Good complementarity is observed between different ATLAS analyses, with almost all showing regions of unique sensitivity. ATLAS searches have good sensitivity at LSP mass below 800 GeV.
- 67 AAD 15CA searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with one or more photons, hadronic jets or b -jets and \mathcal{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on gluino masses in the general gauge-mediated SUSY breaking model (GGM), for bino-like or higgsino-bino admixtures NLSP, see Fig. 8, 10, 11.
- 68 KHACHATRYAN 15AF searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least two energetic jets and significant \mathcal{E}_T , using the transverse mass variable M_{T2} to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in simplified models where the decay $\tilde{g} \rightarrow q \bar{q} \tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 13(a), or where the decay $\tilde{g} \rightarrow b \bar{b} \tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 13(b), or where the decay $\tilde{g} \rightarrow t \bar{t} \tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 13(c). See also Table 5. Exclusions in the CMSSM, assuming $\tan\beta = 30$, $A_0 = -2 \max(m_0, m_{1/2})$ and $\mu > 0$, are also presented, see Fig. 15.
- 69 KHACHATRYAN 15I searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events in which b -jets and four W -bosons are produced. Five individual search channels are combined (fully hadronic, single lepton, same-sign dilepton, opposite-sign dilepton, multi-lepton). No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in a simplified model where the decay $\tilde{g} \rightarrow t \bar{t} \tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 5. Also a simplified model with gluinos decaying into on-shell top squarks is considered, see Fig. 6.
- 70 KHACHATRYAN 15X searched in 19.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least two energetic jets, at least one of which is required to originate from a b quark, and significant \mathcal{E}_T , using the razor variables (M_R) and R^2 to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in simplified models where the decay $\tilde{g} \rightarrow b \bar{b} \tilde{\chi}_1^0$ and the decay $\tilde{g} \rightarrow t \bar{t} \tilde{\chi}_1^0$ take place with branching ratios varying between 0, 50 and 100%, see Figs. 13 and 14.
- 71 AAD 14AE searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for strongly produced supersymmetric particles in events containing jets and large missing transverse momentum, and no electrons or muons. No excess over the expected SM background is observed. Exclusion limits are derived in simplified models containing gluinos and squarks, see Figures 5, 6 and 7. Limits are also derived in the mSUGRA/CMSSM with parameters $\tan\beta = 30$, $A_0 = -2 m_0$ and $\mu > 0$, see their Fig. 8.

- ⁷² AAD 14AG searched in 20.3 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events containing one hadronically decaying τ -lepton, zero or one additional light leptons (electrons or muons), jets and large missing transverse momentum. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set in several SUSY scenarios. For an interpretation in the minimal GMSB model, see their Fig. 8. For an interpretation in the mSUGRA/CMSSM with parameters $\tan\beta = 30$, $A_0 = -2m_0$ and $\mu > 0$, see their Fig. 9. For an interpretation in the framework of natural Gauge Mediation, see Fig. 10. For an interpretation in the bRPV scenario, see their Fig. 11.
- ⁷³ AAD 14X searched in 20.3 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events with at least four leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in a general gauge-mediation model (GGM) where the decay $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$, with $\tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \tilde{G}$, takes place with a branching ratio of 100%, for two choices of $\tan\beta = 1.5$ and 30, see Fig. 11. Also some constraints on the higgsino mass parameter μ are discussed.
- ⁷⁴ CHATRCHYAN 14AH searched in 4.7 fb⁻¹ of pp collisions at $\sqrt{s} = 7$ TeV for events with at least two energetic jets and significant E_{T} , using the razor variables (M_R and R^2) to discriminate between signal and background processes. No significant excess above the Standard Model expectations is observed. Limits are set on sbottom masses in simplified models where the decay $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 28. Exclusions in the CMSSM, assuming $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, are also presented, see Fig. 26.
- ⁷⁵ CHATRCHYAN 14AH searched in 4.7 fb⁻¹ of pp collisions at $\sqrt{s} = 7$ TeV for events with at least two energetic jets and significant E_{T} , using the razor variables (M_R and R^2) to discriminate between signal and background processes. A second analysis requires at least one of the jets to be originating from a b -quark. No significant excess above the Standard Model expectations is observed. Limits are set on sbottom masses in simplified models where the decay $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Figs. 28 and 29. Exclusions in the CMSSM, assuming $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, are also presented, see Fig. 26.
- ⁷⁶ CHATRCHYAN 14AH searched in 4.7 fb⁻¹ of pp collisions at $\sqrt{s} = 7$ TeV for events with at least two energetic jets and significant E_{T} , using the razor variables (M_R and R^2) to discriminate between signal and background processes. A second analysis requires at least one of the jets to be originating from a b -quark. No significant excess above the Standard Model expectations is observed. Limits are set on sbottom masses in simplified models where the decay $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Figs. 28 and 29. Exclusions in the CMSSM, assuming $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, are also presented, see Fig. 26.
- ⁷⁷ CHATRCHYAN 14I searched in 19.5 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events containing multijets and large E_{T} . No excess over the expected SM background is observed. Exclusion limits are derived in simplified models containing gluinos that decay via $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$ with a 100% branching ratio, see Fig. 7b, or via $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ with a 100% branching ratio, see Fig. 7c, or via $\tilde{g} \rightarrow q\bar{q}W/Z\tilde{\chi}_1^0$, see Fig. 7d.
- ⁷⁸ CHATRCHYAN 14N searched in 19.3 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events containing a single isolated electron or muon and multiple jets, at least two of which are identified as originating from a b -quark. No significant excesses over the expected SM backgrounds are observed. The results are interpreted in three simplified models of gluino pair production with subsequent decay into virtual or on-shell top squarks, where each of the top squarks decays in turn into a top quark and a $\tilde{\chi}_1^0$, see Fig. 4. The models differ in which masses are allowed to vary.
- ⁷⁹ CHATRCHYAN 14R searched in 19.5 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events with at least three leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in a slepton co-NLSP simplified model (GMSB) where the decay $\tilde{g} \rightarrow q\bar{q}\ell^\pm\ell^\mp\tilde{G}$ takes place with a branching ratio of 100%, see Fig. 8.
- ⁸⁰ CHATRCHYAN 14R searched in 19.5 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events with at least three leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in a simplified model where the decay $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, see Fig. 11.
- ⁸¹ AABOUD 18BJ searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV in events with two opposite-sign charged leptons (electrons and muons), jets and missing transverse momentum, with various requirements to be sensitive to signals with different kinematic endpoint values in the dilepton invariant mass distribution. The data are found to be consistent with the SM expectation. Results are interpreted in the Tglu1H model in case of $m_{\tilde{\chi}_1^0} = 1$ GeV: for any $m_{\tilde{\chi}_2^0}$, gluino masses below 1500 GeV are excluded, see their Fig. 14(a).
- ⁸² AABOUD 18V searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV in events with no charged leptons, jets and missing transverse momentum. The data are found to be consistent with the SM expectation. Results are interpreted in a Tglu1C-like model, assuming 50% BR for each gluino decay mode. Gluino masses below 1770 GeV are excluded for any $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\chi}_1^0} = 60$ GeV, see their Fig. 16(b).
- ⁸³ AABOUD 17AZ searched in 36.1 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV for events with at least seven jets and large missing transverse momentum. Selected events are further classified based on the presence of large R -jets or b -jets and no leptons. No significant excess above the Standard Model expectations is observed. Limits are set for pMSSM models with $M_1 = 60$ GeV, $\tan(\beta) = 10$, $\mu < 0$ varying the soft-breaking parameters M_3 and μ . Gluino masses up to 1600 GeV are excluded for $m_{\tilde{\chi}_1^\pm} = 200$ GeV. See their Figure 6a and text for details on the model.
- ⁸⁴ KHACHATRYAN 16AY searched in 2.3 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV for events with one isolated high transverse momentum lepton (e or μ), hadronic jets of which at least one is identified as coming from a b -quark, and large E_{T} . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu3A simplified model, see Fig. 10, and in the Tglu3B model, see Fig. 11.
- ⁸⁵ KHACHATRYAN 16BT performed a global Bayesian analysis of a wide range of CMS results obtained with data samples corresponding to 5.0 fb⁻¹ of pp collisions at $\sqrt{s} = 7$ TeV and in 19.5 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV. The set of searches considered, both individually and in combination, includes those with all-hadronic final states, same-sign and opposite-sign dileptons, and multi-lepton final states. An interpretation was given in a scan of the 19-parameter pMSSM. No scan points with a gluino mass less than 500 GeV survived and 98% of models with a squark mass less than 300 GeV were excluded.
- ⁸⁶ AAD 15AB searched for the decay of neutral, weakly interacting, long-lived particles in 20.3 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV. Signal events require at least two reconstructed vertices possibly originating from long-lived particles decaying to jets in the inner tracking detector and muon spectrometer. No significant excess of events over the expected background was found. Results were interpreted in Stealth SUSY benchmark models where a pair of gluinos decay to long-lived singlinos, \tilde{S} , which in turn each decay to a low-mass gravitino and a pair of jets. The 95% confidence-level limits are set on the cross section \times branching ratio for the decay $\tilde{g} \rightarrow \tilde{S}g$, as a function of the singlino proper lifetime ($c\tau$). See their Fig. 10(f).
- ⁸⁷ AAD 15AI searched in 20 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events containing at least one isolated lepton (electron or muon), jets, and large missing transverse momentum. No excess of events above the expected level of Standard Model background was found. Exclusion limits at 95% C.L. are set on the gluino mass in the CMSSM/mSUGRA, see Fig. 15, in the NUHM2, see Fig. 16, and in various simplified models, see Figs. 18–22.
- ⁸⁸ AAD 15CB searched for events containing at least one long-lived particle that decays at a significant distance from its production point (displaced vertex, DV) into two leptons or into five or more charged particles in 20.3 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV. The dilepton signature is characterised by DV formed from at least two lepton candidates. Four different final states were considered for the multitrack signature, in which the DV must be accompanied by a high-transverse momentum muon or electron candidate that originates from the DV, jets or missing transverse momentum. No events were observed in any of the signal regions. Results were interpreted in SUSY scenarios involving R -parity violation, split supersymmetry, and gauge mediation. See their Fig. 12–20.
- ⁸⁹ KHACHATRYAN 15AD searched in 19.4 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events with two opposite-sign same flavor isolated leptons featuring either a kinematic edge, or a peak at the Z -boson mass, in the invariant mass spectrum. No evidence for a statistically significant excess over the expected SM backgrounds is observed and 95% C.L. exclusion limits are derived in a simplified model of gluino pair production where the gluino decays into quarks, a Z -boson, and a massless gravitino LSP, see Fig. 9.
- ⁹⁰ KHACHATRYAN 15AZ searched in 19.7 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events with either at least one photon, hadronic jets and E_{T} (single photon channel) or with at least two photons and at least one jet and using the razor variables. No significant excess above the Standard Model expectations is observed. Limits are set on gluino masses in the general gauge-mediated SUSY breaking model (GGM), for both a bino-like and wino-like neutralino NLSP scenario, see Fig. 8 and 9.
- ⁹¹ AAD 14AX searched in 20.1 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for the strong production of supersymmetric particles in events containing either zero or at least one high- p_{T} lepton, large missing transverse momentum, high jet multiplicity and at least three jets identified as originating from b -quarks. No excess over the expected SM background is observed. Limits are derived in mSUGRA/CMSSM models with $\tan\beta = 30$, $A_0 = -2m_0$ and $\mu > 0$, see their Fig. 14. Also, exclusion limits in simplified models containing gluinos and scalar top and bottom quarks are set, see their Figures 12, 13.
- ⁹² AAD 14E searched in 20.3 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for strongly produced supersymmetric particles in events containing jets and two same-sign leptons or three leptons. The search also utilises jets originating from b -quarks, missing transverse momentum and other variables. No excess over the expected SM background is observed. Exclusion limits are derived in simplified models containing gluinos and squarks, see Figures 5 and 6. In the $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^{(*)}\tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \rightarrow Z^{(*)}\tilde{\chi}_1^0$ simplified model, the following assumptions have been made: $m_{\tilde{\chi}_1^\pm} = 0.5 m_{\tilde{\chi}_2^0} + m_{\tilde{g}}$, $m_{\tilde{\chi}_2^0} = 0.5 (m_{\tilde{\chi}_1^\pm} + m_{\tilde{\chi}_1^\mp})$, $m_{\tilde{\chi}_1^\pm} < 520$ GeV. In the $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow \ell^\pm\nu\tilde{\chi}_1^0$ or $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \rightarrow \ell^\pm\ell^\mp(\nu\nu)\tilde{\chi}_1^0$ simplified model, the following assumptions have been made: $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0} = 0.5 (m_{\tilde{\chi}_1^0} + m_{\tilde{g}})$, $m_{\tilde{\chi}_1^0} < 660$ GeV. Limits are also derived in the mSUGRA/CMSSM, bRPV and GMSB models, see their Fig. 8.
- ⁹³ CHATRCHYAN 14H searched in 19.5 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events with two isolated same-sign dileptons and jets in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in simplified models where the decay $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, or where the decay $\tilde{g} \rightarrow \tilde{t}t$, $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, with varying mass of the $\tilde{\chi}_1^0$, or where the decay $\tilde{g} \rightarrow b\bar{b}$, $\tilde{b} \rightarrow t\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, with varying mass of the $\tilde{\chi}_1^\pm$, see Fig. 5.
- ⁹⁴ CHATRCHYAN 14H searched in 19.5 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events with two isolated same-sign dileptons and jets in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in simplified models where the decay $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, with varying mass of the $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^0$, see Fig. 7.
- ⁹⁵ CHATRCHYAN 14H searched in 19.5 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV for events with two isolated same-sign dileptons and jets in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in simplified models where the decay $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \rightarrow W^\pm\tilde{\chi}_1^0$ takes place with a branching ratio of 100%, for two choices of $m_{\tilde{\chi}_1^\pm}$ and fixed $m_{\tilde{\chi}_1^0}$, see Fig. 6.

R-parity violating heavy \tilde{g} (Gluino) mass limit

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1500	95	1 SIRUNYAN	19f CMS	$\tilde{g} \rightarrow jjj$
>2260	95	2 AABOUD	18Z ATLS	$\geq 4\ell, \lambda_{12k} \neq 0, m_{\tilde{\chi}_1^0} > 1000$ GeV
>1650	95	2 AABOUD	18Z ATLS	$\geq 4\ell, \lambda_{133} \neq 0, m_{\tilde{\chi}_1^0} > 500$ GeV
>1610	95	3 SIRUNYAN	18AK CMS	$\tilde{g} \rightarrow tbs, \lambda_{332}''$ coupling
>1690	95	4 SIRUNYAN	18D CMS	top quark (hadronically decaying) + jets + E_{T} , Tglu3C, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 20$ GeV, $m_{\tilde{\chi}_1^0} = 0$ GeV

Searches Particle Listings

Supersymmetric Particle Searches

none 100–1410	95	⁵ SIRUNYAN	18EA CMS	2 large jets with four-parton substructure, $\tilde{g} \rightarrow 5q$
>2100	95	⁶ AABOUD	17AI ATLS	$\geq 1\ell+ \geq 8$ jets, Tglu3A and $\tilde{\chi}_1^0 \rightarrow uds, \lambda''_{112}$ coupling, $m_{\tilde{\chi}_1^0}=1000$ GeV
>1650	95	⁷ AABOUD	17AI ATLS	$\geq 1\ell+ \geq 8$ jets, $\tilde{g} \rightarrow t\bar{t}, \tilde{t} \rightarrow b s, \lambda''_{323}$ coupling, $m_{\tilde{t}}=1000$ GeV
>1800	95	⁸ AABOUD	17AI ATLS	$\geq 1\ell+ \geq 8$ jets, Tglu1A and $\tilde{\chi}_1^0 \rightarrow qq\ell, \lambda'$ coupling, $m_{\tilde{\chi}_1^0}=1000$ GeV
>1800	95	⁹ AABOUD	17AJ ATLS	same-sign $\ell^\pm \ell^\pm / 3\ell +$ jets + \cancel{E}_T , Tglu3A, λ''_{112} coupling, $m_{\tilde{\chi}_1^0}=50$ GeV
>1750	95	¹⁰ AABOUD	17AJ ATLS	same-sign $\ell^\pm \ell^\pm / 3\ell +$ jets + \cancel{E}_T , Tglu1A and $\tilde{\chi}_1^0 \rightarrow qq\ell, \lambda'$ coupling
>1450	95	¹¹ AABOUD	17AJ ATLS	same-sign $\ell^\pm \ell^\pm / 3\ell +$ jets + $\cancel{E}_T, \tilde{g} \rightarrow t\bar{t}_1$ and $\tilde{t}_1 \rightarrow sd, \lambda''_{321}$ coupling
>1450	95	¹² AABOUD	17AJ ATLS	same-sign $\ell^\pm \ell^\pm / 3\ell +$ jets + $\cancel{E}_T, \tilde{g} \rightarrow t\bar{t}_1$ and $\tilde{t}_1 \rightarrow bd, \lambda''_{313}$ coupling
> 400	95	¹³ AABOUD	17AJ ATLS	same-sign $\ell^\pm \ell^\pm / 3\ell +$ jets + $\cancel{E}_T, \tilde{d}_R \rightarrow tb(t s), \lambda''_{313} (\lambda''_{321})$ coupling
none 625–1375	95	¹⁴ AABOUD	17AZ ATLS	≥ 7 jets + \cancel{E}_T , large R-jets and/or b-jets, $\tilde{g} \rightarrow t\bar{t}_1$ and $\tilde{t}_1 \rightarrow bs, \lambda''_{323}$ coupling
none 600–650	95	¹⁵ KHACHATRY...17Y	CMS	$\tilde{g} \rightarrow qq\bar{q}q\bar{q}, \lambda''_{212}$ coupling, $m_{\tilde{q}}=100$ GeV
none 600–1030	95	¹⁵ KHACHATRY...17Y	CMS	$\tilde{g} \rightarrow qq\bar{q}q\bar{q}, \lambda''_{212}$ coupling, $m_{\tilde{q}}=900$ GeV
none 600–650	95	¹⁵ KHACHATRY...17Y	CMS	$\tilde{g} \rightarrow qq\bar{q}q\bar{b}, \lambda''_{213}$ coupling, $m_{\tilde{q}}=100$ GeV
none 600–1080	95	¹⁵ KHACHATRY...17Y	CMS	$\tilde{g} \rightarrow qq\bar{q}q\bar{b}, \lambda''_{213}$ coupling, $m_{\tilde{q}}=900$ GeV
none 600–680	95	¹⁵ KHACHATRY...17Y	CMS	$\tilde{g} \rightarrow qq\bar{q}b\bar{b}, \lambda''_{212}$ coupling, $m_{\tilde{q}}=100$ GeV
none 600–1080	95	¹⁵ KHACHATRY...17Y	CMS	$\tilde{g} \rightarrow qq\bar{q}b\bar{b}, \lambda''_{212}$ coupling, $m_{\tilde{q}}=900$ GeV
none 600–650	95	¹⁵ KHACHATRY...17Y	CMS	$\tilde{g} \rightarrow qq\bar{b}b\bar{b}, \lambda''_{213}$ coupling, $m_{\tilde{q}}=100$ GeV
none 600–1100	95	¹⁵ KHACHATRY...17Y	CMS	$\tilde{g} \rightarrow qq\bar{b}b\bar{b}, \lambda''_{213}$ coupling, $m_{\tilde{q}}=900$ GeV
>1050	95	¹⁶ KHACHATRY...16BJ	CMS	same-sign $\ell^\pm \ell^\pm$, Tglu3A, $m_{\tilde{\chi}_1^0} < 800$ GeV
>1140	95	¹⁶ KHACHATRY...16BJ	CMS	same-sign $\ell^\pm \ell^\pm$, Tglu3B, $m_{\tilde{t}} - m_{\tilde{\chi}_1^0} = 20$ GeV, $m_{\tilde{\chi}_1^0} = 0$
>1030	95	¹⁷ KHACHATRY...16BX	CMS	$\tilde{g} \rightarrow tbs, \lambda''_{332}$ coupling
>1150	95	¹⁸ AAD	15BV ATLS	general RPC \tilde{g} decays, $m_{\tilde{\chi}_1^0} < 100$ GeV
>1350	95	¹⁹ AAD	14X ATLS	$\geq 4\ell^\pm, \tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \nu$
> 650	95	²⁰ CHATRCHYAN14P	CMS	$\tilde{g} \rightarrow jjj$
none 200–835	95	²⁰ CHATRCHYAN14P	CMS	$\tilde{g} \rightarrow bjj$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>1875	95	²¹ AABOUD	18CF ATLS	jets and large R-jets, Tglu2RPV and $\tilde{\chi}_1^0 \rightarrow qq\bar{q}, \lambda''$ coupling, $m_{\tilde{\chi}_1^0}=1000$ GeV
>1400	95	²² KHACHATRY...16BX	CMS	$\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \ell\ell\nu, \lambda_{121}$ or $\lambda_{122} \neq 0, m_{\tilde{\chi}_1^0} > 400$ GeV
>1600	95	¹⁸ AAD	15BV ATLS	pMSSM, $M_1 = 60$ GeV, $m_{\tilde{q}} < 1500$ GeV
>1280	95	¹⁸ AAD	15BV ATLS	mSUGRA, $m_0 > 2$ TeV
>1100	95	¹⁸ AAD	15BV ATLS	via $\tilde{\tau}$, natural GMSB, all $m_{\tilde{\tau}}$
>1220	95	¹⁸ AAD	15BV ATLS	b-jets, $\tilde{g} \rightarrow \tilde{t}_1 t$ and $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0, m_{\tilde{t}_1} < 1000$ GeV
>1180	95	¹⁸ AAD	15BV ATLS	b-jets, $\tilde{g} \rightarrow \tilde{t}_1 t$ and $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm, m_{\tilde{t}_1} < 1000$ GeV, $m_{\tilde{\chi}_1^0} = 60$ GeV
> 880	95	¹⁸ AAD	15BV ATLS	jets, $\tilde{g} \rightarrow \tilde{t}_1 t$ and $\tilde{t}_1 \rightarrow sb, 400 < m_{\tilde{t}_1} < 1000$ GeV
		²³ AAD	15CB ATLS	$\ell, \tilde{g} \rightarrow (e/\mu)qq$, benchmark gluino, neutralino masses

> 600	95	²³ AAD	15CB ATLS	$\ell\ell/Z, \tilde{g} \rightarrow (ee/\mu\mu/e\mu)qq, m_{\tilde{\chi}_1^0} = 400$ GeV and $0.7 < c\tau_{\tilde{\chi}_1^0} < 3 \times 10^5$ mm
>1000	95	²⁴ AAD	15X ATLS	≥ 10 jets, $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow qq\bar{q}, m_{\tilde{\chi}_1^0}=500$ GeV
> 917	95	²⁴ AAD	15X ATLS	$\geq 6,7$ jets, $\tilde{g} \rightarrow qq\bar{q}$, (light-quark, λ'' couplings)
> 929	95	²⁴ AAD	15X ATLS	$\geq 6,7$ jets, $\tilde{g} \rightarrow qq\bar{q}$, (b-quark, λ'' couplings)
>1180	95	²⁵ AAD	14AX ATLS	≥ 3 b-jets + $\cancel{E}_T, \tilde{g} \rightarrow \tilde{t}_1 t\tilde{\chi}_1^0$ simplified model, $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm, m_{\tilde{\chi}_1^\pm}=2m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_1^0}=60$ GeV, $m_{\tilde{t}_1} < 1000$ GeV
> 850	95	²⁶ AAD	14E ATLS	$\ell^\pm \ell^\pm (\ell^\mp) +$ jets, $\tilde{g} \rightarrow t\bar{t}_1$ with $\tilde{t}_1 \rightarrow bs$ simplified model
> 900	95	²⁷ CHATRCHYAN14H	CMS	same-sign $\ell^\pm \ell^\pm, \tilde{g} \rightarrow tbs$ simplified model

¹ SIRUNYAN 19F searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for three-jet resonances produced in the decay of a gluino in R-parity violating supersymmetric models. The mass range from 200 to 2000 GeV is explored in four separate mass regions. The observations show agreement with standard model expectations. The results are interpreted within the framework of R-parity violating SUSY, where pair-produced gluinos decay to a six quark final state. Gluino masses below 1500 GeV are excluded at 95% C.L. See their Fig.5.

² AABOUD 18Z searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events containing four or more charged leptons (electrons, muons and up to two hadronically decaying taus). No significant deviation from the expected SM background is observed. Limits are set on the Higgsino mass in simplified models of general gauge mediated supersymmetry Tn1n1A/Tn1n1B/Tn1n1C, see their Figure 9. Limits are also set on the wino, slepton, sneutrino and gluino mass in a simplified model of NLSP pair production with R-parity violating decays of the LSP via λ_{12k} or λ_{33} to charged leptons, see their Figures 7, 8.

³ SIRUNYAN 18AK searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events containing a single lepton, large jet and b-quark jet multiplicities, coming from R-parity-violating decays of gluinos. No excess over the expected background is observed. Limits are derived on the gluino mass, assuming the RPV $\tilde{g} \rightarrow tbs$ decay, see their Figure 9.

⁴ SIRUNYAN 18D searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events containing identified hadronically decaying top quarks, no leptons, and \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the stop mass in the Tstop1 simplified model, see their Figure 8, and on the gluino mass in the Tglu3A, Tglu3B, Tglu3C and Tglu3E simplified models, see their Figure 9.

⁵ SIRUNYAN 18EA searched in 38.2 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for the pair production of resonances, each decaying to at least four quarks. Reconstructed particles are clustered into two large jets of similar mass, each consistent with four-parton substructure. No statistically significant excess over the Standard Model expectation is observed. Limits are set on the squark and gluino mass in RPV supersymmetry models where squarks (gluinos) decay, through intermediate higgsinos, to four (five) quarks, see their Figure 4.

⁶ AABOUD 17AI searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with one or more isolated lepton, at least eight jets, either zero or many b-jets, for evidence of R-parity violating decays of the gluino. No significant excess above the Standard Model expectations is observed. Limits up to 2.1 TeV are set on the gluino mass in R-parity-violating supersymmetry models as Tglu3A with LSP decay through the non-zero λ''_{112} coupling as $\tilde{\chi}_1^0 \rightarrow uds$. See their Figure 9.

⁷ AABOUD 17AI searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with one or more isolated lepton, at least eight jets, either zero or many b-jets, for evidence of R-parity violating decays of the gluino. No significant excess above the Standard Model expectations is observed. Limits up to 1.65 TeV are set on the gluino mass in R-parity-violating supersymmetry models with $\tilde{g} \rightarrow t\bar{t}, \tilde{t} \rightarrow bs$ through the non-zero λ''_{323} coupling. See their Figure 9.

⁸ AABOUD 17AI searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with one or more isolated lepton, at least eight jets, either zero or many b-jets, for evidence of R-parity violating decays of the gluino. No significant excess above the Standard Model expectations is observed. Limits up to 1.8 TeV are set on the gluino mass in R-parity-violating supersymmetry models as Tglu1A with the LSP decay through the non-zero λ' coupling as $\tilde{\chi}_1^0 \rightarrow qq\ell$. See their Figure 9.

⁹ AABOUD 17AJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with two same-sign or three leptons, jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 1.8 TeV are set on the gluino mass in R-parity-violating supersymmetry models as Tglu3A with LSP decaying through the non-zero λ''_{112} coupling as $\tilde{\chi}_1^0 \rightarrow uds$. See their Figure 5(d).

¹⁰ AABOUD 17AJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with two same-sign or three leptons, jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 1.75 TeV are set on the gluino mass in R-parity-violating supersymmetry models as Tglu1A with LSP decaying through the non-zero λ' coupling as $\tilde{\chi}_1^0 \rightarrow qq\ell$. See their Figure 5(c).

¹¹ AABOUD 17AJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with two same-sign or three leptons, jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 1.45 TeV are set on the gluino mass in R-parity-violating supersymmetry models where $\tilde{g} \rightarrow t\bar{t}_1$ and $\tilde{t}_1 \rightarrow sd$ through the non-zero λ''_{321} coupling. See their Figure 5(b).

¹² AABOUD 17AJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with two same-sign or three leptons, jets and large missing transverse momentum. No significant excess above the Standard Model expectations is observed. Limits up to 1.45 TeV are set on the gluino mass in R-parity-violating supersymmetry models where $\tilde{g} \rightarrow t\bar{t}_1$ and $\tilde{t}_1 \rightarrow bd$ through the non-zero λ''_{313} coupling. See their Figure 5(a).

¹³ AABOUD 17AJ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV for events with two same-sign or three leptons, jets and large missing transverse momentum. No significant

- excess above the Standard Model expectations is observed. Limits up to 400 GeV are set on the down type squark (\tilde{d}_R mass in R-parity-violating supersymmetry models where $\tilde{d}_R \rightarrow tb$ through the non-zero λ''_{313} coupling or $\tilde{d}_R \rightarrow ts$ through the non-zero λ''_{321} . See their Figure 5(e) and 5(f).
- 14 AABOUD 17AZ searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with at least seven jets and large missing transverse momentum. Selected events are further classified based on the presence of large R-jets or b -jets and no leptons. No significant excess above the Standard Model expectations is observed. Limits are set for R-parity violating decays of the gluino assuming $\tilde{g} \rightarrow t\bar{t}_1$ and $t_1 \rightarrow bs$ through the non-zero λ''_{323} couplings. The range 625–1375 GeV is excluded for $m_{\tilde{t}_1} = 400 \text{ GeV}$. See their Figure 7b.
- 15 KHACHATRYAN 17Y searched in 19.7 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing at least 8 or 10 jets, possibly b -tagged, coming from R-parity-violating decays of supersymmetric particles. No excess over the expected background is observed. Limits are derived on the gluino mass, assuming various RPV decay modes, see Fig. 7.
- 16 KHACHATRYAN 16BJ searched in 2.3 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with two isolated same-sign dileptons and jets in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the following simplified models: Tglu3A and Tglu3D, see Fig. 4, Tglu3B and Tglu3C, see Fig. 5, and Tglu1B, see Fig. 7.
- 17 KHACHATRYAN 16BX searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing 0 or 1 leptons and b -tagged jets, coming from R-parity-violating decays of supersymmetric particles. No excess over the expected background is observed. Limits are derived on the gluino mass, assuming the RPV $\tilde{g} \rightarrow tbs$ decay, see Fig. 7 and 10.
- 18 AAD 15BV summarized and extended ATLAS searches for gluinos and first- and second-generation squarks in final states containing jets and missing transverse momentum, with or without leptons or b -jets in the $\sqrt{s} = 8 \text{ TeV}$ data set collected in 2012. The paper reports the results of new interpretations and statistical combinations of previously published analyses, as well as new analyses. Exclusion limits at 95% C.L. are set on the gluino mass in several R-parity conserving models, leading to a generalized constraint on gluino masses exceeding 1150 GeV for lightest supersymmetric particle masses below 100 GeV. See their Figs. 10, 19, 20, 21, 23, 25, 26, 29–37.
- 19 AAD 14X searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with at least four leptons (electrons, muons, taus) in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in an R-parity violating simplified model where the decay $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$, with $\tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \nu$, takes place with a branching ratio of 100%, see Fig. 8.
- 20 CHATRCHYAN 14P searched in 19.4 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for three-jet resonances produced in the decay of a gluino in R-parity violating supersymmetric models. No excess over the expected SM background is observed. Assuming a 100% branching ratio for the gluino decay into three light-flavour jets, limits are set on the cross section of gluino pair production, see Fig. 7, and gluino masses below 650 GeV are excluded at 95% C.L. Assuming a 100% branching ratio for the gluino decaying to one b -quark jet and two light-flavour jets, gluino masses between 200 GeV and 835 GeV are excluded at 95% C.L.
- 21 AABOUD 18cf searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with several jets, possibly b -jets, and large-radius jets for evidence of R-parity violating decays of the gluino. No significant excess above the Standard Model expectations is observed. Limits between 1000 and 1875 GeV are set on the gluino mass in R-parity-violating supersymmetry models as Tglu2RPV with the LSP decay through the non-zero λ'' coupling as $\tilde{\chi}_1^0 \rightarrow q\bar{q}q$. The most stringent limit is obtained for $m_{\tilde{\chi}_1^0} = 1000 \text{ GeV}$, the weakest for $m_{\tilde{\chi}_1^0} = 50 \text{ GeV}$. See their Figure 7(b). Figure 7(a) presents results for gluinos directly decaying into 3 quarks, Tglu1RPV.
- 22 KHACHATRYAN 16BX searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing 4 leptons coming from R-parity-violating decays of $\tilde{\chi}_1^0 \rightarrow \ell\bar{\ell}\nu$ with $\lambda_{121} \neq 0$ or $\lambda_{122} \neq 0$. No excess over the expected background is observed. Limits are derived on the gluino, squark and stop masses, see Fig. 23.
- 23 AAD 15CB searched for events containing at least one long-lived particle that decays at a significant distance from its production point (displaced vertex, DV) into two leptons or into five or more charged particles in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$. The dilepton signature is characterised by DV formed from at least two lepton candidates. Four different final states were considered for the multitrak signature, in which the DV must be accompanied by a high-transverse momentum muon or electron candidate that originates from the DV, jets or missing transverse momentum. No events were observed in any of the signal regions. Results were interpreted in SUSY scenarios involving R-parity violation, split supersymmetry, and gauge mediation. See their Fig. 12–20.
- 24 AAD 15X searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events containing large number of jets, no requirements on missing transverse momentum and no isolated electrons or muons. The sensitivity of the search is enhanced by considering the number of b -tagged jets and the scalar sum of masses of large-radius jets in an event. No evidence was found for excesses above the expected level of Standard Model background. Exclusion limits at 95% C.L. are set on the gluino mass assuming the gluino decays to various quark flavors, and for various neutralino masses. See their Fig. 11–16.
- 25 AAD 14AX searched in 20.1 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for the strong production of supersymmetric particles in events containing either zero or at least one high high- p_T lepton, large missing transverse momentum, high jet multiplicity and at least three jets identified as originating from b -quarks. No excess over the expected SM background is observed. Limits are derived in mSUGRA/CMSSM models with $\tan\beta = 30$, $A_0 = -2m_0$ and $\mu > 0$, see their Fig. 14. Also, exclusion limits in simplified models containing gluinos and scalar top and bottom quarks are set, see their Figures 12, 13.
- 26 AAD 14E searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for strongly produced supersymmetric particles in events containing jets and two same-sign leptons or three leptons. The search also utilises jets originating from b -quarks, missing transverse momentum and other variables. No excess over the expected SM background is observed. Exclusion limits are derived in simplified models containing gluinos and squarks, see Figures 5 and 6. In the $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow W^{(*)}\tilde{\chi}_2^0, \tilde{\chi}_2^0 \rightarrow Z^{(*)}\tilde{\chi}_1^0$ simplified model, the following assumptions have been made: $m_{\tilde{\chi}_1^\pm} = 0.5 m_{\tilde{\chi}_2^0} + m_{\tilde{g}}, m_{\tilde{\chi}_2^0} = 0.5 (m_{\tilde{\chi}_1^0} + m_{\tilde{\chi}_1^\pm}), m_{\tilde{\chi}_1^0} < 520 \text{ GeV}$. In the $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow \ell^\pm \nu \tilde{\chi}_1^0$ or $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_2^0, \tilde{\chi}_2^0 \rightarrow \ell^\pm \ell^\mp (\nu\nu)\tilde{\chi}_1^0$ simplified model, the following assumptions have been made: $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0} = 0.5 (m_{\tilde{\chi}_1^0} + m_{\tilde{g}}), m_{\tilde{\chi}_1^0} < 660 \text{ GeV}$. Limits are also derived in the mSUGRA/CMSSM, bRPV and GMSB models, see their Fig. 8.

27 CHATRCHYAN 14H searched in 19.5 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with two isolated same-sign dileptons and jets in the final state. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in simplified models where the R-parity violating decay $\tilde{g} \rightarrow tbs$ takes place with a branching ratio of 100%, see Fig. 8.

Long-lived \tilde{g} (Gluino) mass limit

Limits on light gluinos ($m_{\tilde{g}} < 5 \text{ GeV}$) were last listed in our PDG 14 edition: K. Olive, et al. (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1980	95	1 AABOUD	19AT ATLS	R-hadrons, Tglu1A, metastable
>2060	95	2 AABOUD	19C ATLS	R-hadrons, Tglu1A, $\tau \geq 10 \text{ ns}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>1890	95	2 AABOUD	19C ATLS	R-hadrons, Tglu1A, stable
>2400	95	3 SIRUNYAN	19BH CMS	long-lived \tilde{g} , RPV, $\tilde{g} \rightarrow \bar{t}\bar{b}\bar{s}$, $10 \text{ mm} < c\tau < 250 \text{ mm}$
>2300	95	3 SIRUNYAN	19BH CMS	long-lived \tilde{g} , GMSB, $\tilde{g} \rightarrow \bar{g}\bar{G}$, $20 \text{ mm} < c\tau < 110 \text{ mm}$
>2100	95	4 SIRUNYAN	19BT CMS	long-lived \tilde{g} , GMSB, $\tilde{g} \rightarrow \bar{g}\bar{G}$, $0.3 \text{ m} < c\tau < 30 \text{ m}$
>2500	95	4 SIRUNYAN	19BT CMS	long-lived \tilde{g} , GMSB, $\tilde{g} \rightarrow \bar{g}\bar{G}$, $c\tau = 1 \text{ m}$
>1900	95	4 SIRUNYAN	19BT CMS	long-lived \tilde{g} , GMSB, $\tilde{g} \rightarrow \bar{g}\bar{G}$, $c\tau = 100 \text{ m}$
>2370	95	5 AABOUD	18s ATLS	displaced vertex + E_T , long-lived Tglu1A, $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$, and $\tau = 0.17 \text{ ns}$
>1600	95	6 SIRUNYAN	18AY CMS	jets + E_T , Tglu1A, $c\tau < 0.1 \text{ mm}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>1750	95	6 SIRUNYAN	18AY CMS	jets + E_T , Tglu1A, $c\tau = 1 \text{ mm}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>1640	95	6 SIRUNYAN	18AY CMS	jets + E_T , Tglu1A, $c\tau = 10 \text{ mm}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>1490	95	6 SIRUNYAN	18AY CMS	jets + E_T , Tglu1A, $c\tau = 100 \text{ mm}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>1300	95	6 SIRUNYAN	18AY CMS	jets + E_T , Tglu1A, $c\tau = 1 \text{ m}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
> 960	95	6 SIRUNYAN	18AY CMS	jets + E_T , Tglu1A, $c\tau = 10 \text{ m}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
> 900	95	6 SIRUNYAN	18AY CMS	jets + E_T , Tglu1A, $c\tau = 100 \text{ m}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>2200	95	7 SIRUNYAN	18DV CMS	long-lived \tilde{g} , RPV, $\tilde{g} \rightarrow \bar{t}\bar{b}\bar{s}$, $0.6 \text{ mm} < c\tau < 80 \text{ mm}$
>1000	95	8 KHACHATRYAN 17AR	CMS	long-lived \tilde{g} , RPV, $\tilde{g} \rightarrow \bar{t}\bar{b}\bar{s}$, $c\tau = 0.3 \text{ mm}$
>1300	95	8 KHACHATRYAN 17AR	CMS	long-lived \tilde{g} , RPV, $\tilde{g} \rightarrow \bar{t}\bar{b}\bar{s}$, $c\tau = 1.0 \text{ mm}$
>1400	95	8 KHACHATRYAN 17AR	CMS	long-lived \tilde{g} , RPV, $\tilde{g} \rightarrow \bar{t}\bar{b}\bar{s}$, $2 \text{ mm} < c\tau < 30 \text{ mm}$
>1580	95	9 AABOUD	16B ATLS	long-lived R-hadrons
> 740–1590	95	10 AABOUD	16C ATLS	R-hadrons, Tglu1A, $\tau \geq 0.4 \text{ ns}, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>1570	95	10 AABOUD	16C ATLS	R-hadrons, Tglu1A, stable
>1610	95	11 KHACHATRYAN 16BW	CMS	long-lived \tilde{g} forming R-hadrons, $f = 0.1$, cloud interaction model
>1580	95	11 KHACHATRYAN 16BW	CMS	long-lived \tilde{g} forming R-hadrons, $f = 0.1$, charge-suppressed interaction model
>1520	95	11 KHACHATRYAN 16BW	CMS	long-lived \tilde{g} forming R-hadrons, $f = 0.5$, cloud interaction model
>1540	95	11 KHACHATRYAN 16BW	CMS	long-lived \tilde{g} forming R-hadrons, $f = 0.5$, charge-suppressed interaction model
>1270	95	12 AAD	15AE ATLS	\tilde{g} R-hadron, generic R-hadron model
>1360	95	12 AAD	15AE ATLS	\tilde{g} decaying to 300 GeV stable sleptons, LeptoSUSY model
>1115	95	13 AAD	15BM ATLS	\tilde{g} R-hadron, stable
>1185	95	13 AAD	15BM ATLS	$\tilde{g} \rightarrow (g/q\bar{q})\tilde{\chi}_1^0$, lifetime 10 ns, $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>1099	95	13 AAD	15BM ATLS	$\tilde{g} \rightarrow (g/q\bar{q})\tilde{\chi}_1^0$, lifetime 10 ns, $m_{\tilde{g}} - m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>1182	95	13 AAD	15BM ATLS	$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$, lifetime 10 ns, $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
>1157	95	13 AAD	15BM ATLS	$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$, lifetime 10 ns, $m_{\tilde{g}} - m_{\tilde{\chi}_1^0} = 480 \text{ GeV}$
> 869	95	13 AAD	15BM ATLS	$\tilde{g} \rightarrow (g/q\bar{q})\tilde{\chi}_1^0$, lifetime 1 ns, $m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$
> 821	95	13 AAD	15BM ATLS	$\tilde{g} \rightarrow (g/q\bar{q})\tilde{\chi}_1^0$, lifetime 1 ns, $m_{\tilde{g}} - m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$

Searches Particle Listings

Supersymmetric Particle Searches

> 836	95	13 AAD	15BMATLS	$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$, lifetime 1 ns, $m_{\tilde{\chi}_1^0} = 100$ GeV
> 836	95	13 AAD	15BMATLS	$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$, lifetime 10 ns, $m_{\tilde{g}} - m_{\tilde{\chi}_1^0} = 480$ GeV
>1000	95	14 KHACHATRYAN...15AK CMS		\tilde{g} R-hadrons, $10 \mu\text{s} < \tau < 1000$ s
> 880	95	14 KHACHATRYAN...15AK CMS		\tilde{g} R-hadrons, $10 \mu\text{s} < \tau < 1000$ s
• • • We do not use the following data for averages, fits, limits, etc. • • •				
> 985	95	15 AAD	13AA ATLS	\tilde{g} , R-hadrons, generic interaction model
> 832	95	16 AAD	13BC ATLS	R-hadrons, $\tilde{g} \rightarrow g/q\bar{q}\tilde{\chi}_1^0$, generic R-hadron model, lifetime between 10^{-5} and 10^3 s, $m_{\tilde{\chi}_1^0} = 100$ GeV
>1322	95	17 CHATRCHYAN13AB CMS		long-lived \tilde{g} forming R-hadrons, $f = 0.1$, cloud interaction model
none 200–341	95	18 AAD	12P ATLS	long-lived $\tilde{g} \rightarrow g\tilde{\chi}_1^0$, $m_{\tilde{\chi}_1^0} = 100$ GeV
> 640	95	19 CHATRCHYAN12AN CMS		long-lived $\tilde{g} \rightarrow g\tilde{\chi}_1^0$
>1098	95	20 CHATRCHYAN12L CMS		long-lived \tilde{g} forming R-hadrons, $f = 0.1$
> 586	95	21 AAD	11K ATLS	stable \tilde{g}
> 544	95	22 AAD	11P ATLS	stable \tilde{g} , GMSB scenario, $\tan\beta=5$
> 370	95	23 KHACHATRYAN...11 CMS		long lived \tilde{g}
> 398	95	24 KHACHATRYAN...11C CMS		stable \tilde{g}

- 1 AABOUD 19AT searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for metastable and stable R -hadrons. Multiple search strategies for a wide range of lifetimes, corresponding to path lengths of a few meters, are defined. No significant deviations from the expected Standard Model background are observed. Gluino R -hadrons with lifetimes of the order of 50 ns are excluded at 95% C.L. for masses below 1980 GeV using the muon-spectrometer agnostic analysis. Using the full-detector search, the observed lower limits on the mass are 2000 GeV. See their Figure 9 (top).
- 2 AABOUD 19c searched in 36.1 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for metastable and stable R -hadrons arising as excesses in the mass distribution of reconstructed tracks with high transverse momentum and large dE/dx . Gluino R -hadrons with lifetimes above 10 ns are excluded at 95% C.L. with lower mass limit range between 1000 GeV and 2060 GeV, see their Figure 5(a). Masses smaller than 1290 GeV are excluded for a lifetime of 1 ns, see their Figure 6. In the case of stable R -hadrons, the lower mass limit is 1890 GeV, see their Figure 5(b).
- 3 SIRUNYAN 19BH searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for long-lived particles decaying into jets, with each long-lived particle having a decay vertex well displaced from the production vertex. The selected events are found to be consistent with standard model predictions. Limits are set on the gluino mass in a GMSB model where the gluino is decaying via $\tilde{g} \rightarrow g\tilde{G}$, see their Figure 4 and in an RPV model of supersymmetry where the gluino is decaying via $\tilde{g} \rightarrow t\bar{b}s$, see their Figures 5. Limits are also set on the stop mass in two RPV models, see their Figure 6 (for $t \rightarrow b\bar{t}$ decays) and Figure 7 (for $t \rightarrow d\bar{d}$ decays).
- 4 SIRUNYAN 19BT searched in 137 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for long-lived particles decaying to displaced, nonprompt jets and missing transverse momentum. Candidate signal events are identified using the timing capabilities of the CMS electromagnetic calorimeter. The results of the search are found to be consistent with the background predictions. Limits are set on the gluino mass in a GMSB model where long-lived gluinos are pair produced and decaying via $\tilde{g} \rightarrow g\tilde{G}$, see their Figures 4 and 5.
- 5 AABOUD 18s searched in 32.8 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for long-lived gluinos in final states with large missing transverse momentum and at least one high-mass displaced vertex with five or more tracks. The observed yield is consistent with the expected background. Exclusion limits are derived for Tglu1A models predicting the existence of long-lived gluinos reaching roughly $m(\tilde{g}) = 2000 \text{ GeV}$ to 2370 GeV for $m(\tilde{\chi}_1^0) = 100 \text{ GeV}$ and gluino lifetimes between 0.02 and 10 ns, see their Fig. 8. Limits are presented also as a function of the lifetime (for a fixed gluino-neutralino mass difference of 100 GeV) and of the gluino and neutralino masses (for a fixed lifetime of 1 ns). See their Fig. 9 and 10 respectively.
- 6 SIRUNYAN 18AY searched in 35.9 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events containing one or more jets and significant \cancel{E}_T . No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass in the Tglu1A, Tglu2A and Tglu3A simplified models, see their Figure 3. Limits are also set on squark, sbottom and stop masses in the Tsqk1, Tsb0t1, Tstop1 and Tstop4 simplified models, see their Figure 3. Finally, limits are set on long-lived gluino masses in a Tglu1A simplified model where the gluino is metastable or long-lived with proper decay lengths in the range $10^{-3} \text{ mm} < c\tau < 10^5 \text{ mm}$, see their Figure 4.
- 7 SIRUNYAN 18bv searched in 38.5 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for long-lived particles in events with multiple jets and two displaced vertices composed of many tracks. No events with two well-separated high-track-multiplicity vertices were observed. Limits are set on the stop and the gluino mass in RPV models of supersymmetry where the stop (gluino) is decaying solely into dijet (multijet) final states, see their Figures 6 and 7.
- 8 KHACHATRYAN 17AR searched in 17.6 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for R -parity-violating SUSY in which long-lived neutralinos or gluinos decay into multijet final states. No significant excess above the Standard Model expectations is observed. Limits are set on the gluino mass for a range of mean proper decay lengths ($c\tau$), see their Fig. 7. The upper limits on the production cross section times branching ratio squared (Fig. 7) are also applicable to long-lived neutralinos.
- 9 AABOUD 16B searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for long-lived R -hadrons using observables related to large ionization losses and slow propagation velocities, which are signatures of heavy charged particles traveling significantly slower than the speed of light. Exclusion limits at 95% C.L. are set on the long-lived gluino masses exceeding 1580 GeV. See their Fig. 5.
- 10 AABOUD 16c searched in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for long-lived and stable R -hadrons identified by anomalously specific ionization energy loss in the ATLAS Pixel detector. Gluino R -hadrons with lifetimes above 0.4 ns are excluded at 95% C.L. with lower mass limit range between 740 GeV and 1590 GeV. In the case of stable R -hadrons, the lower mass limit is 1570 GeV. See their Figs. 5 and 6.

- 11 KHACHATRYAN 16BW searched in 2.5 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ for events with heavy stable charged particles, identified by their anomalously high energy deposits in the silicon tracker and/or long time-of-flight measurements by the muon system. No evidence for an excess over the expected background is observed. Limits are derived for pair production of gluinos as a function of mass, depending on the interaction model and on the fraction f , of produced gluinos hadronizing into a g -gluon state, see Fig. 4 and Table 7.
- 12 AAD 15AE searched in 19.1 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for heavy long-lived charged particles, measured through their specific ionization energy loss in the ATLAS pixel detector or their time-of-flight in the ATLAS muon system. In the absence of an excess of events above the expected backgrounds, limits are set R -hadrons in various scenarios, see Fig. 11. Limits are also set in LeptoSUSY models where the gluino decays to stable 300 GeV leptons, see Fig. 9.
- 13 AAD 15BM searched in 18.4 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for stable and metastable non-relativistic charged particles through their anomalous specific ionization energy loss in the ATLAS pixel detector. In the absence of an excess of events above the expected backgrounds, limits are set within a generic R -hadron model, on stable gluino R -hadrons (see Table 5) and on metastable gluino R -hadrons decaying to $(g/q\bar{q})$ plus a light $\tilde{\chi}_1^0$ (see Fig. 7) and decaying to $t\bar{t}$ plus a light $\tilde{\chi}_1^0$ (see Fig. 9).
- 14 KHACHATRYAN 15AK looked in a data set corresponding to 18.6 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$, and a search interval corresponding to 281 h of trigger lifetime, for long-lived particles that have stopped in the CMS detector. No evidence for an excess over the expected background in a cloud interaction model is observed. Assuming the decay $\tilde{g} \rightarrow g\tilde{\chi}_1^0$ and lifetimes between $1 \mu\text{s}$ and 1000 s, limits are derived on \tilde{g} production as a function of $m_{\tilde{\chi}_1^0}$, see Figs. 4 and 6. The exclusions require that $m_{\tilde{\chi}_1^0}$ is kinematically consistent with the minimum values of the jet energy thresholds used.
- 15 AAD 13AA searched in 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events containing colored long-lived particles that hadronize forming R -hadrons. No significant excess above the expected background was found. Long-lived R -hadrons containing a \tilde{g} are excluded for masses up to 985 GeV at 95% C.L. in a general interaction model. Also, limits independent of the fraction of R -hadrons that arrive charged in the muon system were derived, see Fig. 6.
- 16 AAD 13BC searched in 5.0 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ and in 22.9 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for bottom squark R -hadrons that have come to rest within the ATLAS calorimeter and decay at some later time to hadronic jets and a neutralino. In the absence of an excess of events above the expected backgrounds, limits are set on gluino masses for different decays, lifetimes, and neutralino masses, see their Table 6 and Fig. 10.
- 17 CHATRCHYAN 13AB looked in 5.0 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ and in 18.8 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ for events with heavy stable particles, identified by their anomalous dE/dx in the tracker or additionally requiring that it be identified as muon in the muon chambers, from pair production of \tilde{g} 's. No evidence for an excess over the expected background is observed. Limits are derived for pair production of gluinos as a function of mass (see Fig. 8 and Table 5), depending on the fraction, f , of formation of $\tilde{g}-g$ (R -gluonball) states. The quoted limit is for $f = 0.1$, while for $f = 0.5$ it degrades to 1276 GeV. In the conservative scenario where every hadronic interaction causes it to become neutral, the limit decreases to 928 GeV for $f = 0.1$.
- 18 AAD 12P looked in 31 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with pair production of long-lived gluinos. The hadronization of the gluinos leads to R -hadrons which may stop inside the detector and later decay via $\tilde{g} \rightarrow g\tilde{\chi}_1^0$ during gaps between the proton bunches. No significant excess over the expected background is observed. From a counting experiment, a limit at 95% C.L. on the cross section as a function of $m_{\tilde{g}} - m_{\tilde{\chi}_1^0} = 100 \text{ GeV}$, see Fig. 4. The limit is valid for lifetimes between 10^{-5} and 10^3 seconds and assumes the *Generic* matter interaction model for the production cross section.
- 19 CHATRCHYAN 12AN looked in 4.0 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with pair production of long-lived gluinos. The hadronization of the gluinos leads to R -hadrons which may stop inside the detector and later decay via $\tilde{g} \rightarrow g\tilde{\chi}_1^0$ during gaps between the proton bunches. No significant excess over the expected background is observed. From a counting experiment, a limit at 95% C.L. on the cross section as a function of $m_{\tilde{g}}$ is derived, see Fig. 3. The mass limit is valid for lifetimes between 10^{-5} and 10^3 seconds, for what they call "the daughter gluon energy $E_g > 100 \text{ GeV}$ and assuming the *cloud* interaction model for R -hadrons. Supersedes KHACHATRYAN 11.
- 20 CHATRCHYAN 12L looked in 5.0 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with heavy stable particles, identified by their anomalous dE/dx in the tracker or additionally requiring that it be identified as muon in the muon chambers, from pair production of \tilde{g} 's. No evidence for an excess over the expected background is observed. Limits are derived for pair production of gluinos as a function of mass (see Fig. 3), depending on the fraction, f , of formation of $\tilde{g}-g$ (R -glueball) states. The quoted limit is for $f = 0.1$, while for $f = 0.5$ it degrades to 1046 GeV. In the conservative scenario where every hadronic interaction causes it to become neutral, the limit decreases to 928 GeV for $f=0.1$. Supersedes KHACHATRYAN 11c.
- 21 AAD 11K looked in 34 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with heavy stable particles, identified by their anomalous dE/dx in the tracker or time of flight in the tile calorimeter, from pair production of \tilde{g} . No evidence for an excess over the SM expectation is observed. Limits are derived for pair production of gluinos as a function of mass (see Fig. 4), for a fraction, f , of formation of $\tilde{g}-g$ (R -gluonball). If instead of a phase space driven approach for the hadronic scattering of the R -hadrons, a triple-Regge model or a bag-model is used, the limit degrades to 566 and 562 GeV, respectively.
- 22 AAD 11P looked in 37 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with heavy stable particles, reconstructed and identified by their time of flight in the Muon System. There is no requirement on their observation in the tracker to increase the sensitivity to cases where gluinos have a large fraction, f , of formation of neutral $\tilde{g}-g$ (R -gluonball). No evidence for an excess over the SM expectation is observed. Limits are derived as a function of mass (see Fig. 4), for $f=0.1$. For fractions $f = 0.5$ and 1.0 the limit degrades to 537 and 530 GeV, respectively.
- 23 KHACHATRYAN 11 looked in 10 pb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ for events with pair production of long-lived gluinos. The hadronization of the gluinos leads to R -hadrons which may stop inside the detector and later decay via $\tilde{g} \rightarrow g\tilde{\chi}_1^0$ during gaps between the proton bunches. No significant excess over the expected background is observed. From a counting experiment, a limit at 95% C.L. on the cross section times branching ratio is derived for $m_{\tilde{g}} - m_{\tilde{\chi}_1^0} > 100 \text{ GeV}$, see their Fig. 2. Assuming 100% branching

ratio, lifetimes between 75 ns and 3×10^5 s are excluded for $m_{\tilde{g}} = 300$ GeV. The \tilde{g} mass exclusion is obtained with the same assumptions for lifetimes between 10 μ s and 1000 s, but shows some dependence on the model for R-hadron interactions with matter, illustrated in Fig. 3. From a time-profile analysis, the mass exclusion is 382 GeV for a lifetime of 10 μ s under the same assumptions as above.

²⁴ KHACHATRYAN 11c looked in 3.1 pb^{-1} of pp collisions at $\sqrt{s} = 7$ TeV for events with heavy stable particles, identified by their anomalous dE/dx in the tracker or additionally requiring that it be identified as muon in the muon chambers, from pair production of \tilde{g} . No evidence for an excess over the expected background is observed. Limits are derived for pair production of gluinos as a function of mass (see Fig. 3), depending on the fraction, f , of formation of $\tilde{g} - g$ (R-gluonball). The quoted limit is for $f=0.1$, while for $f=0.5$ it degrades to 357 GeV. In the conservative scenario where every hadronic interaction causes it to become neutral, the limit decreases to 311 GeV for $f=0.1$.

Light \tilde{G} (Gravitino) mass limits from collider experiments

The following are bounds on light (< 1 eV) gravitino indirectly inferred from its coupling to matter suppressed by the gravitino decay constant.

Unless otherwise stated, all limits assume that other supersymmetric particles besides the gravitino are too heavy to be produced. The gravitino is assumed to be undetected and to give rise to a missing energy (\cancel{E}) signature.

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, *et al.* (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
$> 3.5 \times 10^{-4}$	95	¹ AAD	15BH ATLS	jet + \cancel{E}_T , $pp \rightarrow (\tilde{q}/\tilde{g}) \tilde{G}$, $m_{\tilde{q}} = m_{\tilde{g}} = 500$ GeV
$> 3 \times 10^{-4}$	95	¹ AAD	15BH ATLS	jet + \cancel{E}_T , $pp \rightarrow (\tilde{q}/\tilde{g}) \tilde{G}$, $m_{\tilde{q}} = m_{\tilde{g}} = 1000$ GeV
$> 2 \times 10^{-4}$	95	¹ AAD	15BH ATLS	jet + \cancel{E}_T , $pp \rightarrow (\tilde{q}/\tilde{g}) \tilde{G}$, $m_{\tilde{q}} = m_{\tilde{g}} = 1500$ GeV
$> 1.09 \times 10^{-5}$	95	² ABDALLAH	05B DLPH	$e^+e^- \rightarrow \tilde{G} \tilde{G} \gamma$
$> 1.35 \times 10^{-5}$	95	³ ACHARD	04E L3	$e^+e^- \rightarrow \tilde{G} \tilde{G} \gamma$
$> 1.3 \times 10^{-5}$		⁴ HEISTER	03C ALEP	$e^+e^- \rightarrow \tilde{G} \tilde{G} \gamma$
$> 11.7 \times 10^{-6}$	95	⁵ ACOSTA	02H CDF	$p\bar{p} \rightarrow \tilde{G} \tilde{G} \gamma$
$> 8.7 \times 10^{-6}$	95	⁶ ABBIENDI,G	00D OPAL	$e^+e^- \rightarrow \tilde{G} \tilde{G} \gamma$

- ¹ AAD 15BH searched in 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV for associated production of a light gravitino and a squark or gluino. The squark (gluino) is assumed to decay exclusively to a quark (gluon) and a gravitino. No evidence was found for an excess above the expected level of Standard Model background and 95% C.L. lower limits were set on the gravitino mass as a function of the squark/gluino mass, both in the case of degenerate and non-degenerate squark/gluino masses, see Figs. 14 and 15.
- ² ABDALLAH 05B use data from $\sqrt{s} = 180\text{--}208$ GeV. They look for events with a single photon + \cancel{E} final states from which a cross section limit of $\sigma < 0.18 \text{ pb}$ at 208 GeV is obtained, allowing a limit on the mass to be set. Supersedes the results of ABREU 00Z.
- ³ ACHARD 04E use data from $\sqrt{s} = 189\text{--}209$ GeV. They look for events with a single photon + \cancel{E} final states from which a limit on the Gravitino mass is set corresponding to $\sqrt{F} > 238$ GeV. Supersedes the results of ACCIARRI 99R.
- ⁴ HEISTER 03C use the data from $\sqrt{s} = 189\text{--}209$ GeV to search for $\gamma \cancel{E}$ final states.
- ⁵ ACOSTA 02H looked in 87 pb^{-1} of $p\bar{p}$ collisions at $\sqrt{s}=1.8$ TeV for events with a high- E_T photon and \cancel{E}_T . They compared the data with a GMSB model where the final state could arise from $q\bar{q} \rightarrow \tilde{G} \tilde{G} \gamma$. Since the cross section for this process scales as $1/|F|^4$, a limit at 95% CL is derived on $|F|^{1/2} > 221$ GeV. A model independent limit for the above topology is also given in the paper.
- ⁶ ABBIENDI,G 00D searches for $\gamma \cancel{E}$ final states from $\sqrt{s}=189$ GeV.

Supersymmetry miscellaneous results

Results that do not appear under other headings or that make nonminimal assumptions.

Some earlier papers are now obsolete and have been omitted. They were last listed in our PDG 14 edition: K. Olive, *et al.* (Particle Data Group), Chinese Physics **C38** 070001 (2014) (<http://pdg.lbl.gov>).

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
		¹ AAD	20c ATLS	habemus MSSM, $m_A - \tan\beta$ plane
>65	95	² AABOUD	16AF ATLS	selected ATLAS searches on EWK sector
none 0–2	95	³ AAD	16AG ATLS	dark photon, γ_d , in SUSY- and Higgs-portal models
		⁴ AAD	13P ATLS	dark γ , hidden valley
		⁵ AALTONEN	12AB CDF	hidden-valley Higgs
none 100–185	95	⁶ AAD	11AA ATLS	scalar gluons
		⁷ CHATRCHYAN	11E CMS	$\mu\mu$ resonances
		⁸ ABAZOV	10N D0	γ_d , hidden valley

- ¹ AAD 20c uses a statistical combination of six final states $b\bar{b}b\bar{b}$, $b\bar{b}WW$, $b\bar{b}\tau\tau$, $WWWW$, $b\bar{b}\gamma\gamma$, and $WW\gamma\gamma$ to search for non-resonant and resonant production of Higgs boson pairs. The search uses 36.1 fb^{-1} of pp collisions data at $\sqrt{s} = 13$ TeV. Constraints in the habemus Minimal Supersymmetric Standard Model in the $(m_A, \tan\beta)$ parameter space are placed, see their Figure 7(b).
- ² AABOUD 16AF uses a selection of searches by ATLAS for the electroweak production of SUSY particles studying resulting constraints on dark matter candidates. They use 20 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV. A likelihood-driven scan of an effective model focusing on the gaugino-higgsino and Higgs sector of the pMSSM is performed. The ATLAS searches impact models where $m_{\tilde{\chi}_1^0} < 65$ GeV, excluding 86% of them. See their Figs. 2, 4, and 6.

- ³ AAD 16AG searches for prompt lepton-jets using 20 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV collected with the ATLAS detector. Lepton-jets are expected from decays of low-mass dark photons in SUSY-portal and Higgs-portal models. No significant excess of events is observed and 95% CL upper limits are computed on the production cross section times branching ratio for two prompt lepton-jets in models predicting 2 or 4 γ_d via SUSY-portal topologies, for γ_d mass values between 0 and 2 GeV. See their Figs 9 and 10. The results are also interpreted in terms of a 90% CL exclusion region in kinetic mixing and dark-photon mass parameter space. See their Fig. 13.
- ⁴ AAD 13P searched in 5 fb^{-1} of pp collisions at $\sqrt{s} = 7$ TeV for single lepton-jets with at least four muons; pairs of lepton-jets, each with two or more muons; and pairs of lepton-jets with two or more electrons. All of these could be signatures of Hidden Valley supersymmetric models. No statistically significant deviations from the Standard Model expectations are found. 95% C.L. limits are placed on the production cross section times branching ratio of dark photons for several parameter sets of a Hidden Valley model.
- ⁵ AALTONEN 12AB looked in 5.1 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV for anomalous production of multiple low-energy leptons in association with a W or Z boson. Such events may occur in hidden valley models in which a supersymmetric Higgs boson is produced in association with a W or Z boson, with $H \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0$ pair and with the $\tilde{\chi}_1^0$ further decaying into a dark photon (γ_d) and the unobservable lightest SUSY particle of the hidden sector. As the γ_d is expected to be light, it may decay into a lepton pair. No significant excess over the SM expectation is observed and a limit at 95% C.L. is set on the cross section for a benchmark model of supersymmetric hidden-valley Higgs production.
- ⁶ AAD 11AA looked in 34 pb^{-1} of pp collisions at $\sqrt{s} = 7$ TeV for events with ≥ 4 jets originating from pair production of scalar gluons, each decaying to two gluons. No two-jet resonances are observed over the SM background. Limits are derived on the cross section times branching ratio (see Fig. 3). Assuming 100% branching ratio for the decay to two gluons, the quoted exclusion range is obtained, except for a 5 GeV mass window around 140 GeV.
- ⁷ CHATRCHYAN 11E looked in 35 pb^{-1} of pp collisions at $\sqrt{s} = 7$ TeV for events with collimated μ pairs (leptonic jets) from the decay of hidden sector states. No evidence for new resonance production is found. Limits are derived and compared to various SUSY models (see Fig. 4) where the LSP, either the $\tilde{\chi}_1^0$ or a \tilde{q} , decays to dark sector particles.
- ⁸ ABAZOV 10N looked in 5.8 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV for events from hidden valley models in which a $\tilde{\chi}_1^0$ decays into a dark photon, γ_d , and the unobservable lightest SUSY particle of the hidden sector. As the γ_d is expected to be light, it may decay into a tightly collimated lepton pair, called lepton jet. They searched for events with \cancel{E}_T and two isolated lepton jets observable by an opposite charged lepton pair $e\bar{e}$, $e\mu$ or $\mu\mu$. No significant excess over the SM expectation is observed, and a limit at 95% C.L. on the cross section times branching ratio is derived, see their Table I. They also examined the invariant mass of the lepton jets for a narrow resonance, see their Fig. 4, but found no evidence for a signal.

REFERENCES FOR Supersymmetric Particle Searches

AAD	20C	PL B800 135103	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	20B	PL B801 135183	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
AABOUD	19AT	PR D99 092007	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	19AU	PR D100 012006	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	19C	PL B788 96	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	19G	PR D99 012001	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	19I	PR D99 012009	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AAD	19H	JHEP 1912 060	G. Aad <i>et al.</i>	(ATLAS Collab.)
ABE	19	PL B789 45	K. Abe <i>et al.</i>	(XMASS Collab.)
AJAJ	19	PR D100 022004	R. Ajaj <i>et al.</i>	(DEAP-3600 Collab.)
AMOLE	19	PR D100 022001	C. Amole <i>et al.</i>	(PICO Collab.)
APRILE	19A	PRL 122 141301	E. Aprile <i>et al.</i>	(XENONIT Collab.)
DI-MAURO	19	PR D99 123027	M. Di Mauro <i>et al.</i>	
JOHNSON	19	PR D99 103007	C. Johnson <i>et al.</i>	
LI	19D	PR D99 123519	S. Li <i>et al.</i>	
SIRUNYAN	19AG	JHEP 1906 143	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19AO	EPJ C79 305	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19AU	EPJ C79 444	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19AW	PL B790 140	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19BH	PR D99 032011	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19BI	PR D99 032014	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19BJ	PR D99 052002	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19BT	PL B777 134876	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19BU	JHEP 1908 150	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19CA	PR D100 112003	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19CE	PRL 123 241801	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19CH	JHEP 1910 244	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19CI	JHEP 1911 109	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19F	PR D99 012010	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19K	JHEP 1901 154	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19S	JHEP 1903 031	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19U	JHEP 1903 101	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
XIA	19A	PL B792 193	J. Xia <i>et al.</i>	(PandaX-II Collab.)
AABOUD	19AQ	JHEP 1806 108	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18AR	JHEP 1806 107	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18AS	JHEP 1806 022	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18AY	EPJ C78 154	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18BB	EPJ C78 250	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18BJ	EPJ C78 625	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18BT	EPJ C78 995	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18BV	JHEP 1809 050	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18CF	PL B785 136	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18CK	PR D98 092002	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18CM	PR D98 092008	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18CO	PR D98 092012	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18I	JHEP 1801 126	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18P	PR D97 032003	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18R	PR D97 052010	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18S	PR D97 052012	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18U	PR D97 092006	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18V	PR D97 112001	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18Y	PR D98 032008	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18Z	PR D98 032009	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
ABDALLAH	18	PRL 120 201101	H. Abdallah <i>et al.</i>	(H.E.S.S. Collab.)
ADHIKARI	18	NAT 564 83	G. Adhikari <i>et al.</i>	(COSINE-100 Collab.)
AGNES	18A	PR D98 102006	P. Agnes <i>et al.</i>	(DarkSide-50 Collab.)
AGNESE	18A	PRL 120 061802	R. Agnese <i>et al.</i>	(SuperCDMS Collab.)
AHNEN	18	JCAP 1803 009	M.L. Ahnen <i>et al.</i>	(MAGIC Collab.)
ALBERT	18B	JCAP 1806 043	A. Albert <i>et al.</i>	(HAWC Collab.)
ALBERT	18C	PR D98 123012	A. Albert <i>et al.</i>	(HAWC Collab.)
AMAUDRUZ	18	PRL 121 071801	P.A. Amaudruz <i>et al.</i>	(DEAP-3600 Collab.)
APRILE	18	PRL 121 111302	E. Aprile <i>et al.</i>	(XENONIT Collab.)
SIRUNYAN	18AA	PL B780 118	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18AC	PL B780 384	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)

Searches Particle Listings

Supersymmetric Particle Searches

SIRUNYAN	18AD	PL B780 432	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15BG	EPJ C75 318	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18AJ	PL B782 440	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	Also		EPJ C75 463	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18AK	PL B783 114	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15BH	EPJ C75 299	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18AL	JHEP 1802 067	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	Also		EPJ C75 408 (errat.)	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18AN	JHEP 1803 167	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15BM	EPJ C75 407	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18AO	JHEP 1803 166	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15BV	JHEP 1510 054	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18AP	JHEP 1803 160	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15BX	JHEP 1510 134	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18AR	JHEP 1803 076	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15CA	PR D92 072001	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18AT	JHEP 1804 073	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15CB	PR D92 072004	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18AY	JHEP 1805 025	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15CJ	EPJ C75 510	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18B	PL B778 263	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15CS	PR D91 012008	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18BR	JHEP 1808 016	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	Also		PR D92 059903 (errat.)	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18C	PR D97 032009	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15J	PRL 114 142001	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18D	PR D97 012007	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15K	PRL 114 161801	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18DI	JHEP 1809 065	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15O	PRL 115 031801	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18DN	JHEP 1811 079	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AAD	15X	PR D91 121016	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18DP	JHEP 1811 151	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AJAJ	15BD	EPJ C75 595	R. Aaij <i>et al.</i>	(LHCb Collab.)
SIRUNYAN	18DV	PR D98 092011	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AARTSEN	15C	EPJ C75 20	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)
SIRUNYAN	18DY	PR D98 112014	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AARTSEN	15E	EPJ C75 492	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)
SIRUNYAN	18EA	PRL 121 141804	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	ABRAMOWSKI	15	PRL 114 081301	A. Abramowski <i>et al.</i>	(H.E.S.S. Collab.)
SIRUNYAN	18EM	PRL 120 241801	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	ACKERMANN	15	PR D91 122002	M. Ackermann <i>et al.</i>	(Fermi-LAT Collab.)
SIRUNYAN	18O	PR D97 032007	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	ACKERMANN	15A	JCAP 1509 008	M. Ackermann <i>et al.</i>	(Fermi-LAT Collab.)
SIRUNYAN	18X	PL B779 166	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	ACKERMANN	15B	PRL 115 231301	M. Ackermann <i>et al.</i>	(Fermi-LAT Collab.)
AABOUD	17AF	JHEP 1708 006	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	ADRIAN-MAR.	15	JCAP 1510 068	S. Adrian-Martinez <i>et al.</i>	(ANTARES Collab.)
AABOUD	17AI	JHEP 1709 088	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	AGNES	15	PL B743 456	P. Agnes <i>et al.</i>	(DarkSide-50 Collab.)
AABOUD	17AJ	JHEP 1709 084	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	AGNES	15B	PR D92 072003	R. Agnese <i>et al.</i>	(SuperCDMS Collab.)
Also		JHEP 1908 121 (errat.)	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	BUCKLEY	15	PR D91 102001	M.R. Buckley <i>et al.</i>	
AABOUD	17AR	PR D96 112010	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	CHOI	15	PRL 114 141301	K. Choi <i>et al.</i>	(Super-Kamiokande Collab.)
AABOUD	17AX	JHEP 1711 195	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	KHACHATRYAN	15AB	JHEP 1501 096	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AABOUD	17AY	JHEP 1712 085	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	KHACHATRYAN	15AD	JHEP 1504 124	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AABOUD	17AZ	JHEP 1712 034	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	KHACHATRYAN	15AF	JHEP 1505 078	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AABOUD	17BE	EPJ C77 898	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	KHACHATRYAN	15AH	JHEP 1506 116	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AABOUD	17N	EPJ C77 144	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	KHACHATRYAN	15AK	EPJ C75 151	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AJAJ	17Z	EPJ C77 224	R. Aaij <i>et al.</i>	(LHCb Collab.)	KHACHATRYAN	15AO	EPJ C75 325	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AARTSEN	17	EPJ C77 82	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)	KHACHATRYAN	15AR	PL B743 503	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AARTSEN	17A	EPJ C77 146	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)	KHACHATRYAN	15AZ	PR D92 072006	V. Khachatryan <i>et al.</i>	(CMS Collab.)
Also		EPJ C79 214 (errat.)	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)	KHACHATRYAN	15E	PRL 114 061801	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AARTSEN	17C	EPJ C77 627	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)	KHACHATRYAN	15I	PL B745 5	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AKERIB	17	PRL 118 021303	D.S. Akerib <i>et al.</i>	(LUX Collab.)	KHACHATRYAN	15L	PL B747 98	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AKERIB	17A	PRL 118 251302	D.S. Akerib <i>et al.</i>	(LUX Collab.)	KHACHATRYAN	15O	PL B748 255	V. Khachatryan <i>et al.</i>	(CMS Collab.)
ALBERT	17A	PL B769 249	A. Albert <i>et al.</i>	(ANTARES Collab.)	KHACHATRYAN	15W	PR D91 052012	V. Khachatryan <i>et al.</i>	(CMS Collab.)
Also		PL B796 253 (errat.)	A. Albert <i>et al.</i>	(ANTARES Collab.)	KHACHATRYAN	15X	PR D91 052018	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AMOLE	17	PRL 118 251301	C. Amole <i>et al.</i>	(PICO Collab.)	ROBLIECKI	15	PL B750 247	K. Roblitzki, J. Tattersall	(MADE, HEID)
APRILE	17G	PRL 119 181301	E. Aprile <i>et al.</i>	(XENON Collab.)	AAD	14AE	JHEP 1409 176	G. Aad <i>et al.</i>	(ATLAS Collab.)
ARCHAMBAULT	17	PR D95 082001	S. Archambault <i>et al.</i>	(VERITAS Collab.)	AAD	14AG	JHEP 1409 103	G. Aad <i>et al.</i>	(ATLAS Collab.)
BATTAT	17	ASP 91 65	J.B.R. Battat <i>et al.</i>	(DRIFT-III Collab.)	AAD	14AJ	JHEP 1409 015	G. Aad <i>et al.</i>	(ATLAS Collab.)
BEHNKE	17	ASP 90 85	E. Behnke <i>et al.</i>	(PICASSO Collab.)	AAD	14AV	JHEP 1410 096	G. Aad <i>et al.</i>	(ATLAS Collab.)
CUI	17A	PRL 119 181302	X. Cui <i>et al.</i>	(PandaX-II Collab.)	AAD	14AX	JHEP 1410 024	G. Aad <i>et al.</i>	(ATLAS Collab.)
FU	17	PRL 118 071301	C. Fu <i>et al.</i>	(PandaX-II Collab.)	AAD	14B	EPJ C74 2883	G. Aad <i>et al.</i>	(ATLAS Collab.)
Also		PRL 120 049002 (errat.)	C. Fu <i>et al.</i>	(PandaX-II Collab.)	AAD	14BD	JHEP 1411 118	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN	17	PR D95 012003	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AAD	14BH	PR D90 121005	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN	17A	PRL 118 021802	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AAD	14E	JHEP 1406 035	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN	17AD	PR D96 012004	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AAD	14F	JHEP 1406 124	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN	17AR	PR D95 012009	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AAD	14G	JHEP 1405 071	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN	17AS	PR D95 012011	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AAD	14H	JHEP 1404 169	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN	17AW	EPJ C77 635	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AAD	14K	PR D90 012004	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN	17L	JHEP 1704 018	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AAD	14T	PR D90 052008	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN	17P	EPJ C77 294	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AAD	14X	PR D90 052001	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN	17S	PL B767 403	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AALTONEN	14	PR D90 012011	T. Aaltonen <i>et al.</i>	(CDF Collab.)
KHACHATRYAN	17V	PL B769 391	V. Khachatryan <i>et al.</i>	(CMS Collab.)	ACKERMANN	14	PR D89 042001	M. Ackermann <i>et al.</i>	(Fermi-LAT Collab.)
KHACHATRYAN	17Y	PL B770 257	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AKERIB	14	PRL 112 091303	D.S. Akerib <i>et al.</i>	(LUX Collab.)
SIRUNYAN	17AF	PRL 119 151802	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	ALEKSIC	14	JCAP 1402 008	J. Aleksić <i>et al.</i>	(MAGIC Collab.)
SIRUNYAN	17AS	JHEP 1710 019	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AVRORIN	14	ASP 62 12	A.D. Avrorin <i>et al.</i>	(BAIKAL Collab.)
SIRUNYAN	17AT	JHEP 1710 005	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	BUCHMUELLER	14	EPJ C74 2809	O. Buchmüller <i>et al.</i>	
SIRUNYAN	17AW	JHEP 1711 029	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	CHATRCHYAN	14A	EPJ C74 2922	O. Buchmüller <i>et al.</i>	
SIRUNYAN	17AY	JHEP 1712 142	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	CHATRCHYAN	14AH	PR D90 112001	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	17AZ	EPJ C77 710	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	CHATRCHYAN	14B	JHEP 1401 163	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	17K	EPJ C77 327	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	CHATRCHYAN	14J	JHEP 1406 055	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	17P	PR D96 032003	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	CHATRCHYAN	14N	PL B733 328	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	17S	EPJ C77 578	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	CHATRCHYAN	14P	PL B730 193	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
AABOUD	16AC	EPJ C76 683	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	CHATRCHYAN	14R	PR D90 032006	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
AABOUD	16AF	JHEP 1609 175	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	CHATRCHYAN	14U	PRL 112 161802	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
AABOUD	16B	PL B760 647	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	CZAKON	14	PRL 113 201803	M. Czaron <i>et al.</i>	(AACH, CAMB, UCB, LBL+)
AABOUD	16C	PR D93 112015	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	FELIZARDO	14	PR D89 072013	M. Felizardo <i>et al.</i>	(SIMPLE Collab.)
AABOUD	16D	PR D94 032005	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	KHACHATRYAN	14C	PL B736 37	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AABOUD	16J	PR D94 052009	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	KHACHATRYAN	14I	EPJ C74 3036	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AABOUD	16M	EPJ C76 517	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	KHACHATRYAN	14L	PR D90 092007	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AABOUD	16N	EPJ C76 392	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	KHACHATRYAN	14T	PL B739 229	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AABOUD	16P	EPJ C76 541	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	PDG	14	CP C38 070001	K. Olive <i>et al.</i>	(PDG Collab.)
AABOUD	16Q	EPJ C76 547	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	ROSKOWSKI	14	JHEP 1408 067	L. Roszkowski, E.M. Sessolo, A.J. Williams	(WINR)
AAD	16AA	PR D93 052002	G. Aad <i>et al.</i>	(ATLAS Collab.)	AAD	13	PL B718 841	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	16AD	PR D94 032003	G. Aad <i>et al.</i>	(ATLAS Collab.)	AAD	13AA	PL B720 277	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	16AG	JHEP 1602 062	G. Aad <i>et al.</i>	(ATLAS Collab.)	AAD	13AI	PL B723 15	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	16AM	JHEP 1606 067	G. Aad <i>et al.</i>	(ATLAS Collab.)	AAD	13AP	PR D88 012001	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	16AY	EPJ C76 81	G. Aad <i>et al.</i>	(ATLAS Collab.)	AAD	13AU	JHEP 1310 189	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	16B	EPJ C76 259	G. Aad <i>et al.</i>	(ATLAS Collab.)	CHATRCHYAN	13B	PL B718 879	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	16BG	EPJ C76 565	G. Aad <i>et al.</i>	(ATLAS Collab.)	AAD	13B	PR D88 112003	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	16V	PL B757 334	G. Aad <i>et al.</i>	(ATLAS Collab.)	AAD	13BD	PR D88 112006	G. Aad <i>et al.</i>	(ATLAS Collab.)
AARTSEN	16C	JCAP 1604 022	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)	AAD	13H	JHEP 1301 131	G. Aad <i>et al.</i>	(ATLAS Collab.)
AARTSEN	16D	EPJ C76 531	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)	AAD	13L	PR D87 012008	G. Aad <i>et al.</i>	(ATLAS Collab.)
ABDALLAH	16	PRL 117 111301	H. Abdallah <i>et al.</i>	(H.E.S.S. Collab.)	AAD	13P	PL B719 299	G. Aad <i>et al.</i>	(ATLAS Collab.)
ABDALLAH	16A	PRL 117 151302	H. Abdallah <i>et al.</i>	(H.E.S.S. Collab.)	AAD	13Q	PL B719 261	G. Aad <i>et al.</i>	(ATLAS Collab.)
ADRIAN-MAR.	16	PL B759 69	S. Adrian-Martinez <i>et al.</i>	(ANTARES Collab.)	AAD	13R	PL B719 280	G. Aad <i>et al.</i>	(ATLAS Collab.)
AHNEN	16	JCAP 1602 039	M.L. Ahnen <i>et al.</i>	(MAGIC and Fermi-LAT Collab.)	AALTONEN	13I	PR D88 031103	T. Aaltonen <i>et al.</i>	(CDF Collab.)
AKERIB	16	PRL 116 161301	D.S. Akerib <i>et al.</i>	(LUX Collab.)	AALTONEN	13J	PRL 110 201802	T. Aaltonen <i>et al.</i>	(CDF Collab.)
AKERIB	16A	PRL 116 161302	D.S. Akerib <i>et al.</i>	(LUX Collab.)	AARTSEN	13C	PR D88 122001	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)
AMOLE	16	PR D93 052014	C. Amole <i>et al.</i>	(PICO Collab.)	ABAZOV	13B	PR D87 052011	V.M. Abazov <i>et al.</i>	(CMS Collab.)
APRILE	16B	PR D94 122001	E. Aprile <i>et al.</i>	(XENON100 Collab.)	ABRAMOWSKI	13	PRL 110 041301	A. Abramowski <i>et al.</i>	(H.E.S.S. Collab.)
AVRORIN	16	ASP 81 12	A.D. Avrorin <i>et al.</i>	(BAIKAL Collab.)	ACKERMANN	13A	PR D88 082002	M. Ackermann <i>et al.</i>	(Fermi-LAT Collab.)
CIRELLI	16	JCAP 1607 041	M. Cirelli, M. Taoso	(LPNHE Collab.)	ADRIAN-MAR.	13	JCAP 1311 032	S. Adrian-Martinez <i>et al.</i>	(ANTARES Collab.)
KHACHATRYAN	16AA	PL B759 479	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AGNESE	13	PR D88 031104	R. Agnese <i>et al.</i>	(CDMS Collab.)
KHACHATRYAN	16AC	PL B760 178	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AGNESE	13A	PRL 111 251301	R. Agnese <i>et al.</i>	(CDMS Collab.)
KHACHATRYAN	16AM	PR D93 092009	V. Khachatryan <i>et al.</i>	(CMS Collab.)	APRILE	13	PRL 111 021301	E. Aprile <i>et al.</i>	(XENON100 Coll

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Searches Particle Listings

Supersymmetric Particle Searches

AAD	12AF	PL B714 180	G. Aad <i>et al.</i>	(ATLAS Collab.)	BARNABE-HE...	05	PL B624 186	M. Barnabe-Heider <i>et al.</i>	(PICASSO Collab.)
AAD	12AG	PL B714 197	G. Aad <i>et al.</i>	(ATLAS Collab.)	ELLIS	05	PR D71 095007	J. Ellis <i>et al.</i>	
AAD	12AN	PRL 108 181802	G. Aad <i>et al.</i>	(ATLAS Collab.)	SANGLARD	05	PR D71 122002	V. Sanglard <i>et al.</i>	(EDELWEISS Collab.)
AAD	12AS	PRL 108 261804	G. Aad <i>et al.</i>	(ATLAS Collab.)	ABBIENDI	04	EPJ C32 453	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
AAD	12AX	PR D85 012006	G. Aad <i>et al.</i>	(ATLAS Collab.)	ABBIENDI	04F	EPJ C33 149	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
Also		PR D87 099903 (errat.)	G. Aad <i>et al.</i>	(ATLAS Collab.)	ABBIENDI	04H	EPJ C35 1	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
AAD	12BJ	EPJ C72 1993	G. Aad <i>et al.</i>	(ATLAS Collab.)	ABBIENDI	04N	PL B602 167	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
AAD	12CJ	PR D86 092002	G. Aad <i>et al.</i>	(ATLAS Collab.)	ABDALLAH	04H	EPJ C34 145	J. Abdallah <i>et al.</i>	(DELPHI Collab.)
AAD	12CM	EPJ C72 2215	G. Aad <i>et al.</i>	(ATLAS Collab.)	ABDALLAH	04M	EPJ C36 1	J. Abdallah <i>et al.</i>	(DELPHI Collab.)
AAD	12CP	PL B718 411	G. Aad <i>et al.</i>	(ATLAS Collab.)	Also		EPJ C37 129 (errat.)	J. Abdallah <i>et al.</i>	(DELPHI Collab.)
AAD	12CT	JHEP 1212 124	G. Aad <i>et al.</i>	(ATLAS Collab.)	ACHARD	04	PL B580 37	P. Achard <i>et al.</i>	(L3 Collab.)
AAD	12P	EPJ C72 1965	G. Aad <i>et al.</i>	(ATLAS Collab.)	ACHARD	04E	PL B587 16	P. Achard <i>et al.</i>	(L3 Collab.)
AAD	12R	PL B707 478	G. Aad <i>et al.</i>	(ATLAS Collab.)	AKERIB	04	PRL 93 211301	D.S. Akerib <i>et al.</i>	(CDMS II Collab.)
AAD	12T	PL B709 137	G. Aad <i>et al.</i>	(ATLAS Collab.)	BALTZ	04	JHEP 0410 052	E. Baltz, P. Gondolo	
AAD	12W	PL B710 67	G. Aad <i>et al.</i>	(ATLAS Collab.)	BELANGER	04	JHEP 0403 012	G. Belanger <i>et al.</i>	
AALTONEN	12AB	PR D85 092001	T. Aaltonen <i>et al.</i>	(CDF Collab.)	BOTTINO	04	PR D69 037302	A. Bottino <i>et al.</i>	
ABAZOV	12AD	PR D86 071701	V.M. Abazov <i>et al.</i>	(DO Collab.)	DESAI	04	PR D70 083523	S. Desai <i>et al.</i>	(Super-Kamiokande Collab.)
ABBASI	12	PR D85 042002	R. Abbasi <i>et al.</i>	(IceCube Collab.)	ELLIS	04	PR D69 015005	J. Ellis <i>et al.</i>	
AKIMOV	12	PL B709 14	D.Yu. Akimov <i>et al.</i>	(ZEPLIN-III Collab.)	ELLIS	04B	PR D70 055005	J. Ellis <i>et al.</i>	
AKULA	12	PR D85 075001	S. Akula <i>et al.</i>	(NEAS, MICH)	HEISTER	04	PL B583 247	A. Heister <i>et al.</i>	(ALEPH Collab.)
ANGLOHER	12	EPJ C72 1971	G. Angloher <i>et al.</i>	(CREST-II Collab.)	PIERCE	04A	PR D70 075006	A. Pierce	
APRILE	12	PRL 109 181301	E. Aprile <i>et al.</i>	(XENON100 Collab.)	ABBIENDI	03L	PL B572 8	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ARBEY	12A	PL B708 162	A. Arbey <i>et al.</i>		ABDALLAH	03M	EPJ C31 421	J. Abdallah <i>et al.</i>	(DELPHI Collab.)
ARCHAMBAU...	12	PL B711 153	S. Archambault <i>et al.</i>	(PICASSO Collab.)	AHMED	03	ASP 19 691	B. Ahmed <i>et al.</i>	(UK Dark Matter Collab.)
BAER	12	JHEP 1205 091	H. Baer, V. Barger, A. Mustafayev	(OKLA, WISC+)	AKERIB	03	PR D68 082002	D.S. Akerib <i>et al.</i>	(CDMS Collab.)
BALAZS	12	EPJ C73 2563	C. Balazs <i>et al.</i>		BAER	03A	JCAP 0305 006	H. Baer, C. Balazs	
BECHTLE	12	JHEP 1206 098	P. Bechtle <i>et al.</i>		BAER	03A	JCAP 0309 007	H. Baer <i>et al.</i>	
BEHNKE	12	PR D86 052001	E. Behnke <i>et al.</i>	(COUAPP Collab.)	BOTTINO	03	PR D68 043506	A. Bottino <i>et al.</i>	
Also		PR D90 079902 (errat.)	E. Behnke <i>et al.</i>	(COUAPP Collab.)	BOTTINO	03A	PR D67 063519	A. Bottino, N. Fornengo, S. Scopel	
BESKIDT	12	EPJ C72 2166	C. Beskidt <i>et al.</i>	(KARLE, JINR, ITEP)	CHATTOPADHY...	03	PR D68 035005	U. Chattopadhyay, A. Corsetti, P. Nath	
BOTTINO	12	PR D85 095013	A. Bottino, N. Fornengo, S. Scopel	(TORI, SOGA)	ELLIS	03	ASP 18 395	J. Ellis, K.A. Olive, Y. Santoso	
BUCHMUEL...	12	EPJ C72 2020	O. Buchmueller <i>et al.</i>		ELLIS	03B	NP B652 259	J. Ellis <i>et al.</i>	
CAO	12A	PL B710 665	J. Cao <i>et al.</i>		ELLIS	03C	PL B565 176	J. Ellis <i>et al.</i>	
CHATRCHYAN	12	PR D85 012004	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	ELLIS	03D	PL B573 162	J. Ellis <i>et al.</i>	
CHATRCHYAN	12AE	PRL 109 171803	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	ELLIS	03E	PR D67 123502	J. Ellis <i>et al.</i>	
CHATRCHYAN	12AI	JHEP 1208 110	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	HEISTER	03C	EPJ C28 1	A. Heister <i>et al.</i>	(ALEPH Collab.)
CHATRCHYAN	12AL	JHEP 1206 169	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	HEISTER	03G	EPJ C31 1	A. Heister <i>et al.</i>	(ALEPH Collab.)
CHATRCHYAN	12AN	JHEP 1208 026	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	KLAPDOR-K...	03	ASP 18 525	H.V. Klapdor-Kleingrothaus <i>et al.</i>	
CHATRCHYAN	12AT	JHEP 1210 018	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	LAHANAS	03	PL B568 95	A. Lahanas, D. Nanopoulos	
CHATRCHYAN	12BJ	JHEP 1211 147	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	TAKEDA	03	PL B572 145	A. Takeda <i>et al.</i>	
CHATRCHYAN	12BK	JHEP 1211 172	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	ABRAMS	02	PR D66 122003	D. Abrams <i>et al.</i>	(CDMS Collab.)
CHATRCHYAN	12BO	JHEP 1212 055	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	ACOSTA	02H	PR 89 281801	G. Acosta <i>et al.</i>	(CDF Collab.)
CHATRCHYAN	12L	PL B713 408	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	ANGLOHER	02	ASP 18 43	G. Angloher <i>et al.</i>	(CREST Collab.)
DAW	12	ASP 35 397	E. Daw <i>et al.</i>	(DRIFT-III Collab.)	ARNOWITT	02	hep-ph/0211417	R. Arnowitt, B. Dutta	
DREINER	12A	EPJ C72 2005	H.K. Dreiner, M. Kramer, J. Tattersall	(BONN+)	ELLIS	02B	PL B532 318	J. Ellis, A. Ferstl, K.A. Olive	
ELLIS	12B	EPJ C72 2005	J. Ellis, K. Olive		HEISTER	02	PL B526 191	A. Heister <i>et al.</i>	(ALEPH Collab.)
FELIZARDO	12	PRL 108 201302	M. Felizardo <i>et al.</i>	(SIMPLE Collab.)	HEISTER	02E	PL B526 206	A. Heister <i>et al.</i>	(ALEPH Collab.)
FENG	12B	PR D85 075007	J. Feng, K. Matchev, D. Sanford		HEISTER	02J	PL B533 223	A. Heister <i>et al.</i>	(ALEPH Collab.)
KADASTIK	12	JHEP 1205 061	M. Kadastik <i>et al.</i>		HEISTER	02N	PL B544 73	A. Heister <i>et al.</i>	(ALEPH Collab.)
KIM	12	PRL 108 181301	S.C. Kim <i>et al.</i>	(KIMS Collab.)	KIM	02	PL B527 18	H.B. Kim <i>et al.</i>	
STREGE	12	JCAP 1203 030	C. Strege <i>et al.</i>	(LOIC, AMST, MADU, GRAN+)	KIM	02B	JHEP 0212 034	Y.G. Kim <i>et al.</i>	
AAD	11AA	EPJ C71 1828	G. Aad <i>et al.</i>	(ATLAS Collab.)	LAHANAS	02	EPJ C23 185	A. Lahanas, V.C. Spanos	
AAD	11B	PR 106 131802	G. Aad <i>et al.</i>	(ATLAS Collab.)	MORALES	02B	ASP 16 325	A. Morales <i>et al.</i>	(COSME Collab.)
AAD	11H	PRL 106 251801	G. Aad <i>et al.</i>	(ATLAS Collab.)	MORALES	02C	PL B532 8	P. Morales <i>et al.</i>	(IGEX Collab.)
AAD	11K	PL B701 1	G. Aad <i>et al.</i>	(ATLAS Collab.)	ABREU	01	EPJ C19 29	P. Abreu <i>et al.</i>	(DELPHI Collab.)
AAD	11O	PL B701 398	G. Aad <i>et al.</i>	(ATLAS Collab.)	ABREU	01B	EPJ C19 201	P. Abreu <i>et al.</i>	(DELPHI Collab.)
AAD	11P	PL B703 428	G. Aad <i>et al.</i>	(ATLAS Collab.)	BALTZ	01	PRL 86 5004	E. Baltz, P. Gondolo	
AAD	11Z	EPJ C71 1809	G. Aad <i>et al.</i>	(ATLAS Collab.)	BARATE	01	PL B499 67	R. Barate <i>et al.</i>	(ALEPH Collab.)
ABRAMOWSKI	11	PRL 106 161301	A. Abramowski <i>et al.</i>	(H.E.S.S. Collab.)	BARATE	01B	EPJ C19 415	R. Barate <i>et al.</i>	(ALEPH Collab.)
AHMED	11A	PR D84 011102	Z. Ahmed <i>et al.</i>	(CDMS and EDELWEISS Collabs.)	BARGER	01C	PL B518 117	V. Barger, C. Kao	
ARMENGAUD	11	PL B702 329	E. Armengaud <i>et al.</i>	(EDELWEISS-II Collab.)	BAUDIS	01	PR D63 022001	L. Baudis <i>et al.</i>	(Heidelberg-Moscow Collab.)
BUCHMUEL...	11	EPJ C71 1583	O. Buchmueller <i>et al.</i>		BERNABE	01	PL B509 197	R. Bernabei <i>et al.</i>	(DAMA Collab.)
BUCHMUEL...	11B	EPJ C71 1722	O. Buchmueller <i>et al.</i>		BOTTINO	01	PL B63 125003	A. Bottino <i>et al.</i>	
CHATRCHYAN	11	JHEP 1106 093	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	CHORRETTI	01	PR D64 125010	A. Corsetti, P. Nath	
CHATRCHYAN	11D	JHEP 1107 113	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	ELLIS	01B	PL B510 236	J. Ellis <i>et al.</i>	
CHATRCHYAN	11E	JHEP 1107 098	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	ELLIS	01C	PR D63 065016	J. Ellis, A. Ferstl, K.A. Olive	
CHATRCHYAN	11V	PL B704 411	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	GOMEZ	01	PL B512 252	M.E. Gomez, J.D. Vergados	
KHACHATRY...	11	PRL 106 011801	V. Khachatryan <i>et al.</i>	(CMS Collab.)	LAHANAS	01	PL B518 94	A. Lahanas, D.V. Nanopoulos, V. Spanos	
KHACHATRY...	11C	JHEP 1103 024	V. Khachatryan <i>et al.</i>	(CMS Collab.)	ABBIENDI	00	EPJ C12 1	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ROSZKOWSKI	11	PR D83 015014	L. Roszkowski <i>et al.</i>		ABBIENDI	00G	EPJ C14 51	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
AALTONEN	10	PRL 104 011801	T. Aaltonen <i>et al.</i>	(CDF Collab.)	ABBIENDI	00H	EPJ C14 187	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
AALTONEN	10R	PRL 105 081802	T. Aaltonen <i>et al.</i>	(CDF Collab.)	Also		EPJ C16 707 (errat.)	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
AALTONEN	10Z	PRL 105 191801	T. Aaltonen <i>et al.</i>	(CDF Collab.)	ABBIENDI,G	00D	EPJ C18 253	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ABAZOV	10L	PL B693 95	V.M. Abazov <i>et al.</i>	(DO Collab.)	ABREU	00J	PL B479 129	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABAZOV	10M	PRL 105 191802	V.M. Abazov <i>et al.</i>	(DO Collab.)	ABREU	00Q	PL B478 15	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABAZOV	10N	PRL 105 211802	V.M. Abazov <i>et al.</i>	(DO Collab.)	ABREU	00T	PL B485 95	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABAZOV	10P	PRL 105 221802	V.M. Abazov <i>et al.</i>	(DO Collab.)	ABREU	00U	PL B487 36	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABDO	10	JCAP 1004 014	A.A. Abdo <i>et al.</i>	(Fermi-LAT Collab.)	ABREU	00V	EPJ C16 211	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ACKERMANN	10	JCAP 1005 025	M. Ackermann	(Fermi-LAT Collab.)	ABREU	00W	PL B489 38	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ARMENGAUD	10	PL B687 294	E. Armengaud <i>et al.</i>	(EDELWEISS-II Collab.)	ABREU	00Z	EPJ C17 53	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ELLIS	10	EPJ C69 201	J. Ellis, A. Mustafayev, K. Olive		ABUSAIID	00	PRL 84 5699	R. Abusaidi <i>et al.</i>	(CDMS Collab.)
ABAZOV	09M	PRL 102 161802	V.M. Abazov <i>et al.</i>	(DO Collab.)	ACCIARRI	00D	PL B472 420	M. Acciarri <i>et al.</i>	(L3 Collab.)
ABBASI	09B	PRL 102 201302	R. Abbasi <i>et al.</i>	(IceCube Collab.)	ACCOMANDO	00	NP B585 124	E. Accomando <i>et al.</i>	
AHMED	09	PRL 102 011301	Z. Ahmed <i>et al.</i>	(CDMS Collab.)	BERNABE	00	PL B480 23	R. Bernabei <i>et al.</i>	(DAMA Collab.)
ANGLOHER	09	ASP 31 270	G. Angloher <i>et al.</i>	(CREST Collab.)	BERNABE	00C	EPJ C18 283	R. Bernabei <i>et al.</i>	(DAMA Collab.)
BUCHMUEL...	09	EPJ C64 391	O. Buchmueller <i>et al.</i>	(LOIC, FNAL, CERN+)	BERNABE	00D	NPJ 2 15	R. Bernabei <i>et al.</i>	(DAMA Collab.)
DREINER	09	EPJ C62 547	H. Dreiner <i>et al.</i>		BOEHM	00B	PR D62 035012	C. Boehm, A. Djoudi, M. Drees	
LEBEDENKO	09	PR D80 052010	V.N. Lebedenko <i>et al.</i>	(ZEPLIN-III Collab.)	ELLIS	00	PR D62 075010	J. Ellis <i>et al.</i>	
LEBEDENKO	09A	PRL 103 151302	V.N. Lebedenko <i>et al.</i>	(ZEPLIN-III Collab.)	FENG	00	PL B482 388	J.L. Feng, K.T. Matchev, F. Wilczek	
SORENSEN	09	NIM A601 339	P. Sorensen <i>et al.</i>	(XENON10 Collab.)	LEP	00	CERN-EP-2000-016	LEP Collabs.	(ALEPH, DELPHI, L3, OPAL, SLD+)
ABAZOV	08F	PL B659 856	V.M. Abazov <i>et al.</i>	(DO Collab.)	MORALES	00	PL B489 268	A. Morales <i>et al.</i>	(IGEX Collab.)
ANGLE	08	PRL 100 021303	J. Angle <i>et al.</i>	(XENON10 Collab.)	PDG	00	EPJ C15 1	D.E. Groom <i>et al.</i>	(PDG Collab.)
ANGLE	08A	PRL 101 091301	J. Angle <i>et al.</i>	(XENON10 Collab.)	SPOONER	00	PL B473 330	N.J.C. Spooner <i>et al.</i>	(UK Dark Matter Col.)
BEDNYAKOV	08	PAN 71 111	V.A. Bednyakov, H.P. Klapdor-Kleingrothaus, I.V. Krivosheina		ACCIARRI	99R	PL B456 283	M. Acciarri <i>et al.</i>	(L3 Collab.)
BEHNKE	08	SCI 319 933	E. Behnke	(COUAPP Collab.)	ACCIARRI	99R	PL B470 268	M. Acciarri <i>et al.</i>	(L3 Collab.)
BENETTI	08	ASP 28 495	P. Benetti <i>et al.</i>	(WARP Collab.)	ACCIARRI	99W	PL B471 280	M. Acciarri <i>et al.</i>	(L3 Collab.)
BUCHMUEL...	08	JHEP 0809 117	O. Buchmueller <i>et al.</i>		AMBRÓSIO	99	PR D60 082002	M. Ambrosio <i>et al.</i>	(Macro Collab.)
ELLIS	08	PR D78 075012	J. Ellis, K. Olive, P. Sandick	(CERN, MINN)	BAUDIS	99	PR D59 022001	L. Baudis <i>et al.</i>	(Heidelberg-Moscow Collab.)
ABULENCIA	07H	PRL 98 131804	A. Abulencia <i>et al.</i>	(CDF Collab.)	BELLI	99C	NP B563 97	P. Belli <i>et al.</i>	(DAMA Collab.)
ALNER	07A	ASP 28 287	G.J. Alner <i>et al.</i>	(ZEPLIN-II Collab.)	OOTANI	99	PL B461 371	W. Ootani <i>et al.</i>	
CALIBBI	07	JHEP 0709 081	L. Calibbi <i>et al.</i>		ABREU	98P	PL B444 491	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ELLIS	07	JHEP 0706 079	J. Ellis, K. Olive, P. Sandick	(CERN, MINN)	ACCIARRI	98F	EPJ C4 207	M. Acciarri <i>et al.</i>	(L3 Collab.)
LEE	07A	PRL 99 091301	H.S. Lee <i>et al.</i>	(KIMS Collab.)	ACKERS-TAFF	98K	PL B433 195	K. Ackers-Taff <i>et al.</i>	(OPAL Collab.)
ABBIENDI	06B	EPJ C46 307	G. Abbiendi <i>et al.</i>	(OPAL Collab.)	BARATE	98K	PL B433 176	R. Barate <i>et al.</i>	(ALEPH Collab.)
ACHTERBERG	06	ASP 26 129	A. Achterberg <i>et al.</i>	(AMANDA Collab.)	BARATE	98C	EPJ C4 433	R. Barate <i>et al.</i>	(ALEPH Collab.)
ACKERMANN	06	ASP 24 459	O. Ackermann <i>et al.</i>	(AMANDA Collab.)	BERNABE	98C	PL B436 379	R. Bernabei <i>et al.</i>	(DAMA Collab.)
AKERIB	06	PR D73 011102	D.S. Akerib <i>et al.</i>	(CDMS Collab.)	ELLIS	98			

FALK	93	PL B318 354	T. Falk <i>et al.</i>	(UCB, UCSB, MINN)
KELLEY	93	PR D47 2461	S. Kelley <i>et al.</i>	(TAMU, ALAB)
MIZUTA	93	PL B298 120	S. Mizuta, M. Yamaguchi	(TOHO)
MORI	93	PR D48 5505	M. Mori <i>et al.</i>	(KEK, NIIG, TOKY, TOKA+)
BOTTINO	92	MPL A7 733	A. Bottino <i>et al.</i>	(TORI, ZARA)
Also		PL B265 57	A. Bottino <i>et al.</i>	(TORI, INFN)
DECAMP	92	PRPL 216 253	D. Decamp <i>et al.</i>	(ALEPH Collab.)
LOPEZ	92	NP B370 445	J.L. Lopez, D.V. Nanopoulos, K.J. Yuan	(TAMU)
MCDONALD	92	PL B283 80	J. McDonald, K.A. Olive, M. Srednicki	(USB+)
ABREU	91F	NP B367 511	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ALEXANDER	91F	ZPHY C52 175	G. Alexander <i>et al.</i>	(OPAL Collab.)
BOTTINO	91	PL B265 57	A. Bottino <i>et al.</i>	(TORI, INFN)
GELMINI	91	NP B351 623	G.B. Gelmini, P. Gondolo, E. Roulet	(UCLA, TRST)
GRIEST	91	PR D43 3191	K. Griest, D. Seckel	
KAMIONKOW..	91	PR D44 3021	M. Kamionkowski	(CHIC, FNAL)
MORI	91B	PL B270 89	M. Mori <i>et al.</i>	(Kamiokande Collab.)
NOJIRI	91	PL B261 76	M.M. Nojiri	(KEK)
OLIVE	91	NP B355 208	K.A. Olive, M. Srednicki	(MINN, UCSB)
ROSZKOWSKI	91	PL B262 59	L. Roszkowski	(CERN)
GRIEST	90	PR D41 3565	K. Griest, M. Kamionkowski, M.S. Turner	(UCB+)
BARBIERI	89C	NP B313 725	R. Barbieri, M. Frigeni, G. Giudice	
OLIVE	89	PL B230 78	K.A. Olive, M. Srednicki	(MINN, UCSB)
ELLIS	88D	NP B307 883	J. Ellis, R. Flores	
GRIEST	88B	PR D38 2357	K. Griest	
OLIVE	88	PL B205 553	K.A. Olive, M. Srednicki	(MINN, UCSB)
SREDNICKI	88	NP B310 693	M. Srednicki, R. Watkins, K.A. Olive	(MINN, UCSB)
ELLIS	84	NP B238 453	J. Ellis <i>et al.</i>	(CERN)
GOLDBERG	83	PRL 50 1419	H. Goldberg	(NEAS)
KRAUSS	83	NP B227 556	L.M. Krauss	(HARV)
VYSOTSKII	83	SJNP 37 948	M.I. Vysotsky	(ITEP)

Translated from YAF 37 1597.

Technicolor

See the related review(s):

Dynamical Electroweak Symmetry Breaking: Implications of the H^0

The latest unpublished results are described in "Dynamical Electroweak Symmetry Breaking" review.

MASS LIMITS for Resonances in Models of Dynamical Electroweak Symmetry Breaking

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>2400	95	1 AAD	16W ATLS	color octet vector resonance
		2 KHACHATRY...16E	CMS	top-color Z'
		3 AAD	15AB ATLS	$h \rightarrow \pi_V \pi_V$
>1800	95	4 AAD	15AO ATLS	top-color Z'
		5 AAD	15BB ATLS	$pp \rightarrow \rho_T / a_{1T} \rightarrow Wh$ or Zh
>1140	95	6 AAD	15Q ATLS	$h \rightarrow \pi_V \pi_V$
		7 AAIJ	15AN LHCB	$h \rightarrow \pi_V \pi_V$
		8 KHACHATRY...15C	CMS	$\rho_T \rightarrow WZ$
		9 KHACHATRY...15W	CMS	$H \rightarrow \pi_V \pi_V$
none 200–700, 750–890	95	10 AAD	14AT ATLS	$pp \rightarrow \omega_T \rightarrow Z\gamma$
none 275–960	95	10 AAD	14AT ATLS	$pp \rightarrow a_T \rightarrow W\gamma$
> 703 > 494	95	11 AAD	14V ATLS	color singlet techni-vector
		12 AAD	13AN ATLS	$pp \rightarrow a_T \rightarrow W\gamma$
		13 AAD	13AN ATLS	$pp \rightarrow \omega_T \rightarrow Z\gamma$
		14 AAD	13AQ ATLS	top-color Z'
none 500–1740	95	15 CHATRCHYAN13AP	CMS	top-color Z'
>1300	95	14 CHATRCHYAN13BM	CMS	top-color Z'
>2100	95	16 BAAK	12 RVUE	QCD-like technicolor
none 167–687	95	17 CHATRCHYAN12AF	CMS	$\rho_T \rightarrow WZ$
> 805	95	14 AALTONEN	11AD CDF	top-color Z'
> 805	95	14 AALTONEN	11AE CDF	top-color Z'
> 280	95	18 CHIVUKULA	11 RVUE	top-Higgs
		19 CHIVUKULA	11A RVUE	techni- π
		20 AALTONEN	10I CDF	$p\bar{p} \rightarrow \rho_T / \omega_T \rightarrow W\pi_T$
		21 ABZOV	10A D0	$\rho_T \rightarrow WZ$
> 207	95	22 ABZOV	07I D0	$p\bar{p} \rightarrow \rho_T / \omega_T \rightarrow W\pi_T$
		23 ABULENCIA	05A CDF	$\rho_T \rightarrow e^+ e^-, \mu^+ \mu^-$
		24 CHEKANOV	02B ZEUS	color octet techni- π
		25 ABZOV	01B D0	$\rho_T \rightarrow e^+ e^-$
none 90–206.7	95	26 ABDALLAH	01 DLPH	$e^+ e^- \rightarrow \rho_T$
> 600	95	27 AFFOLDER	00F CDF	color-singlet techni- ρ , $\rho_T \rightarrow W\pi_T, 2\pi_T$
		28 AFFOLDER	00K CDF	color-octet techni- ρ , $\rho_{T8} \rightarrow 2\pi_{LQ}$
none 350–440	95	29 ABE	99F CDF	color-octet techni- ρ , $\rho_{T8} \rightarrow \bar{b}b$
none 260–480	95	30 ABE	99N CDF	techni- ω , $\omega_T \rightarrow \gamma \bar{\gamma} b$
		31 ABE	97G CDF	color-octet techni- ρ , $\rho_{T8} \rightarrow 2j_{ets}$

¹ AAD 16w search for color octet vector resonance decaying to $b\bar{b}$ in pp collisions at $\sqrt{s} = 8$ TeV. The vector like quark B is assumed to decay to bH . See their Fig.3 and Fig.4 for limits on $\sigma \cdot B$.

² KHACHATRYAN 16E search for top-color Z' decaying to $t\bar{t}$. The quoted limit is for $\Gamma_{Z'}/m_{Z'} = 0.012$. Also exclude $m_{Z'} < 2.9$ TeV for wider topcolor Z' with $\Gamma_{Z'}/m_{Z'} = 0.1$.

- ³ AAD 15AB search for long-lived hidden valley π_V particles which are produced in pairs by the decay of a scalar boson. π_V is assumed to decay into dijets. See their Fig. 10 for the limit on σB .
- ⁴ AAD 15AO search for top-color Z' decaying to $t\bar{t}$. The quoted limit is for $\Gamma_{Z'}/m_{Z'} = 0.012$.
- ⁵ AAD 15BB search for minimal walking technicolor (MWT) isotriplet vector and axial-vector resonances decaying to Wh or Zh . See their Fig. 3 for the exclusion limit in the MWT parameter space.
- ⁶ AAD 15Q search for long-lived hidden valley π_V particles which are produced in pairs by the decay of scalar boson. π_V is assumed to decay into dijets. See their Fig. 5 and Fig. 6 for the limit on σB .
- ⁷ AAIJ 15AN search for long-lived hidden valley π_V particles which are produced in pairs by the decay of scalar boson with a mass of 120GeV. π_V is assumed to decay into dijets. See their Fig. 4 for the limit on σB .
- ⁸ KHACHATRYAN 15C search for a vector techni-resonance decaying to WZ . The limit assumes $M_{\pi_T} = (3/4) M_{\rho_T} - 25$ GeV. See their Fig.3 for the limit in $M_{\pi_T} - M_{\rho_T}$ plane of the low scale technicolor model.
- ⁹ KHACHATRYAN 15W search for long-lived hidden valley π_V particles which are produced in pairs in the decay of heavy higgs boson H . π_V is assumed to decay into $\ell^+ \ell^-$. See their Fig. 7 and Fig. 8 for the limits on σB .
- ¹⁰ AAD 14AT search for techni- ω and techni- a resonances decaying to $V\gamma$ with $V = W(\rightarrow \ell\nu)$ or $Z(\rightarrow \ell^+ \ell^-)$.
- ¹¹ AAD 14V search for vector techni-resonances decaying into electron or muon pairs in pp collisions at $\sqrt{s} = 8$ TeV. See their table IX for exclusion limits with various assumptions.
- ¹² AAD 13AN search for vector techni-resonance a_T decaying into $W\gamma$.
- ¹³ AAD 13AN search for vector techni-resonance ω_T decaying into $Z\gamma$.
- ¹⁴ Search for top-color Z' decaying to $t\bar{t}$. The quoted limit is for $\Gamma_{Z'}/m_{Z'} = 0.012$.
- ¹⁵ CHATRCHYAN 13AP search for top-color leptophobic Z' decaying to $t\bar{t}$. The quoted limit is for $\Gamma_{Z'}/m_{Z'} = 0.012$.
- ¹⁶ BAAK 12 give electroweak oblique parameter constraints on the QCD-like technicolor models. See their Fig. 28.
- ¹⁷ CHATRCHYAN 12AF search for a vector techni-resonance decaying to WZ . The limit assumes $M_{\pi_T} = (3/4) M_{\rho_T} - 25$ GeV. See their Fig. 3 for the limit in $M_{\pi_T} - M_{\rho_T}$ plane of the low scale technicolor model.
- ¹⁸ Using the LHC limit on the Higgs boson production cross section, CHIVUKULA 11 obtain a limit on the top-Higgs mass > 300 GeV at 95% CL assuming 150 GeV top-pion mass.
- ¹⁹ Using the LHC limit on the Higgs boson production cross section, CHIVUKULA 11A obtain a limit on the technipion mass ruling out the region $110 \text{ GeV} < m_P < 2m_t$. Existence of color techni-fermions, top-color mechanism, and $N_{TC} \geq 3$ are assumed.
- ²⁰ AALTONEN 10I search for the vector techni-resonances (ρ_T, ω_T) decaying into $W\pi_T$ with $W \rightarrow \ell\nu$ and $\pi_T \rightarrow b\bar{b}, b\bar{c}$, or $b\bar{u}$. See their Fig.3 for the exclusion plot in $M_{\pi_T} - M_{\rho_T}$ plane.
- ²¹ ABZOV 10A search for a vector techni-resonance decaying into WZ . The limit assumes $M_{\rho_T} < M_{\pi_T} + M_W$.
- ²² ABZOV 07I search for the vector techni-resonances (ρ_T, ω_T) decaying into $W\pi_T$ with $W \rightarrow e\nu$ and $\pi_T \rightarrow b\bar{b}$ or $b\bar{c}$. See their Fig. 2 for the exclusion plot in $M_{\pi_T} - M_{\rho_T}$ plane.
- ²³ ABULENCIA 05A search for resonances decaying to electron or muon pairs in $p\bar{p}$ collisions. at $\sqrt{s} = 1.96$ TeV. The limit assumes Technicolor-scale mass parameters $M_V = M_A = 500$ GeV.
- ²⁴ CHEKANOV 02B search for color octet techni- π P decaying into dijets in ep collisions. See their Fig. 5 for the limit on $\sigma(ep \rightarrow ePX) \cdot B(P \rightarrow 2j)$.
- ²⁵ ABZOV 01B searches for vector techni-resonances (ρ_T, ω_T) decaying to $e^+ e^-$. The limit assumes $M_{\rho_T} = M_{\omega_T} < M_{\pi_T} + M_W$.
- ²⁶ The limit is independent of the π_T mass. See their Fig. 9 and Fig. 10 for the exclusion plot in the $M_{\rho_T} - M_{\pi_T}$ plane. ABDALLAH 01 limit on the technipion mass is $M_{\pi_T} > 79.8$ GeV for $N_D=2$, assuming its point-like coupling to gauge bosons.
- ²⁷ AFFOLDER 00F search for ρ_T decaying into $W\pi_T$ or $\pi_T\pi_T$ with $W \rightarrow \ell\nu$ and $\pi_T \rightarrow \bar{b}b, \bar{b}c$. See Fig.1 in the above Note on "Dynamical Electroweak Symmetry Breaking" for the exclusion plot in the $M_{\rho_T} - M_{\pi_T}$ plane.
- ²⁸ AFFOLDER 00K search for the ρ_{T8} decaying into $\pi_{LQ}\pi_{LQ}$ with $\pi_{LQ} \rightarrow b\nu$. For $\pi_{LQ} \rightarrow c\nu$, the limit is $M_{\rho_{T8}} > 510$ GeV. See their Fig. 2 and Fig. 3 for the exclusion plot in the $M_{\rho_{T8}} - M_{\pi_{LQ}}$ plane.
- ²⁹ ABE 99F search for a new particle X decaying into $b\bar{b}$ in $p\bar{p}$ collisions at $E_{cm} = 1.8$ TeV. See Fig. 7 in the above Note on "Dynamical Electroweak Symmetry Breaking" for the upper limit on $\sigma(p\bar{p} \rightarrow X) \times B(X \rightarrow b\bar{b})$. ABE 99F also exclude top gluons of width $\Gamma = 0.3M$ in the mass interval $280 < M < 670$ GeV, of width $\Gamma = 0.5M$ in the mass interval $340 < M < 640$ GeV, and of width $\Gamma = 0.7M$ in the mass interval $375 < M < 560$ GeV.
- ³⁰ ABE 99N search for the techni- ω decaying into $\gamma\pi_T$. The technipion is assumed to decay $\pi_T \rightarrow b\bar{b}$. See Fig. 2 in the above Note on "Dynamical Electroweak Symmetry Breaking" for the exclusion plot in the $M_{\omega_T} - M_{\pi_T}$ plane.
- ³¹ ABE 97G search for a new particle X decaying into dijets in $p\bar{p}$ collisions at $E_{cm} = 1.8$ TeV. See Fig. 5 in the above Note on "Dynamical Electroweak Symmetry Breaking" for the upper limit on $\sigma(p\bar{p} \rightarrow X) \times B(X \rightarrow 2j)$.

REFERENCES FOR Technicolor

AAD	16W	PL B758 249	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRY...	16E	PR D93 012001	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AAD	15AB	PR D92 012010	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	15AO	JHEP 1508 148	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	15BB	EPL C75 263	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	15Q	PL B743 15	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAIJ	15AN	EPL C75 152	R. Aaij <i>et al.</i>	(LHCb Collab.)
KHACHATRY...	15C	PL B740 83	V. Khachatryan <i>et al.</i>	(CMS Collab.)
KHACHATRY...	15W	PR D91 052012	V. Khachatryan <i>et al.</i>	(CMS Collab.)
AAD	14AT	PL B738 428	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	14V	PR D90 052005	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	13AN	PR D87 112003	G. Aad <i>et al.</i>	(ATLAS Collab.)
Also		PR D91 119901 (err.)	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	13AQ	PR D88 012004	G. Aad <i>et al.</i>	(ATLAS Collab.)
CHATRCHYAN	13AP	PR D87 072002	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
CHATRCHYAN	13BM	PRL 111 211804	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
Also		PRL 112 119903 (err.)	S. Chatrchyan <i>et al.</i>	(CMS Collab.)

See key on page 999

Searches Particle Listings

Technicolor, Quark and Lepton Compositeness

BAAK	12	EPJ C72 2003	M. Baak <i>et al.</i>	(Gfitter Group)
CHATRCHYAN	12AF	PRL 109 141801	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
AALTONEN	11AD	PR D84 072003	T. Aaltonen <i>et al.</i>	(CDF Collab.)
AALTONEN	11AE	PR D84 072004	T. Aaltonen <i>et al.</i>	(CDF Collab.)
CHIVUKULA	11	PR D84 095022	R.S. Chivukula <i>et al.</i>	
CHIVUKULA	11A	PR D84 115025	R. S. Chivukula <i>et al.</i>	
AALTONEN	10I	PRL 104 111802	T. Aaltonen <i>et al.</i>	(CDF Collab.)
ABAZOV	10A	PRL 104 061801	V.M. Abazov <i>et al.</i>	(DO Collab.)
ABAZOV	07I	PRL 98 221801	V.M. Abazov <i>et al.</i>	(DO Collab.)
ABULENCIA	05A	PRL 95 252001	A. Abulencia <i>et al.</i>	(CDF Collab.)
CHEKANOV	02B	PL B531 9	S. Chekanov <i>et al.</i>	(ZEUS Collab.)
ABAZOV	01B	PRL 87 061802	V.M. Abazov <i>et al.</i>	(DO Collab.)
ABDALLAH	01	EPJ C22 17	J. Abdallah <i>et al.</i>	(DELPHI Collab.)
AFFOLDER	00F	PRL 84 1110	T. Affolder <i>et al.</i>	(CDF Collab.)
AFFOLDER	00K	PRL 85 2056	T. Affolder <i>et al.</i>	(CDF Collab.)
ABE	99F	PRL 82 2038	F. Abe <i>et al.</i>	(CDF Collab.)
ABE	99N	PRL 83 3124	F. Abe <i>et al.</i>	(CDF Collab.)
ABE	97G	PR D56 5263	F. Abe <i>et al.</i>	(CDF Collab.)

Quark and Lepton Compositeness, Searches for

The latest unpublished results are described in the “Quark and Lepton Compositeness” review.

See the related review(s):

Searches for Quark and Lepton Compositeness

CONTENTS:

- Scale Limits for Contact Interactions: $\Lambda(eeee)$
- Scale Limits for Contact Interactions: $\Lambda(ee\mu\mu)$
- Scale Limits for Contact Interactions: $\Lambda(ee\tau\tau)$
- Scale Limits for Contact Interactions: $\Lambda(\ell\ell\ell\ell)$
- Scale Limits for Contact Interactions: $\Lambda(eeqq)$
- Scale Limits for Contact Interactions: $\Lambda(\mu\mu qq)$
- Scale Limits for Contact Interactions: $\Lambda(\ell\nu\ell\nu)$
- Scale Limits for Contact Interactions: $\Lambda(e\nu qq)$
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- Scale Limits for Contact Interactions: $\Lambda(\nu\nu qq)$
- Mass Limits for Excited e (e^*)
 - Limits for Excited e (e^*) from Pair Production
 - Limits for Excited e (e^*) from Single Production
 - Limits for Excited e (e^*) from $e^+e^- \rightarrow \gamma\gamma$
 - Indirect Limits for Excited e (e^*)
- Mass Limits for Excited μ (μ^*)
 - Limits for Excited μ (μ^*) from Pair Production
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 - Limits for Excited τ (τ^*) from Pair Production
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- Mass Limits for Excited Neutrino (ν^*)
 - Limits for Excited ν (ν^*) from Pair Production
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 - Limits for Excited q (q^*) from Pair Production
 - Limits for Excited q (q^*) from Single Production
- Mass Limits for Color Sextet Quarks (q_6)
- Mass Limits for Color Octet Charged Leptons (ℓ_8)
- Mass Limits for Color Octet Neutrinos (ν_8)
- Mass Limits for W_8 (Color Octet W Boson)

SCALE LIMITS for Contact Interactions: $\Lambda(eeee)$

Limits are for Λ_{LL}^{\pm} only. For other cases, see each reference.

$\Lambda_{LL}^+(TeV)$	$\Lambda_{LL}^-(TeV)$	CL%	DOCUMENT ID	TECN	COMMENT
>8.3	>10.3	95	¹ BOURILKOV 01	RVUE	$E_{cm} = 192\text{--}208$ GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>4.5	>7.0	95	² SCHAE	07A ALEP	$E_{cm} = 189\text{--}209$ GeV
>5.3	>6.8	95	ABDALLAH 06C	DLPH	$E_{cm} = 130\text{--}207$ GeV
>4.7	>6.1	95	³ ABBIENDI 04G	OPAL	$E_{cm} = 130\text{--}207$ GeV
>4.3	>4.9	95	ACCARI 00P	L3	$E_{cm} = 130\text{--}189$ GeV

- A combined analysis of the data from ALEPH, DELPHI, L3, and OPAL.
- SCHAE 07A limits are from R_C , Q_{FB}^{depl} , and hadronic cross section measurements.
- ABBIENDI 04G limits are from $e^+e^- \rightarrow e^+e^-$ cross section at $\sqrt{s} = 130\text{--}207$ GeV.

SCALE LIMITS for Contact Interactions: $\Lambda(ee\mu\mu)$

Limits are for Λ_{LL}^{\pm} only. For other cases, see each reference.

$\Lambda_{LL}^+(TeV)$	$\Lambda_{LL}^-(TeV)$	CL%	DOCUMENT ID	TECN	COMMENT
>6.6	>9.5	95	¹ SCHAE	07A ALEP	$E_{cm} = 189\text{--}209$ GeV
>8.5	>3.8	95	ACCARI 00P	L3	$E_{cm} = 130\text{--}189$ GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>7.3	>7.6	95	ABDALLAH 06C	DLPH	$E_{cm} = 130\text{--}207$ GeV
>8.1	>7.3	95	² ABBIENDI 04G	OPAL	$E_{cm} = 130\text{--}207$ GeV

- SCHAE 07A limits are from R_C , Q_{FB}^{depl} , and hadronic cross section measurements.
- ABBIENDI 04G limits are from $e^+e^- \rightarrow \mu\mu$ cross section at $\sqrt{s} = 130\text{--}207$ GeV.

SCALE LIMITS for Contact Interactions: $\Lambda(ee\tau\tau)$

Limits are for Λ_{LL}^{\pm} only. For other cases, see each reference.

$\Lambda_{LL}^+(TeV)$	$\Lambda_{LL}^-(TeV)$	CL%	DOCUMENT ID	TECN	COMMENT
>7.9	>5.8	95	¹ SCHAE	07A ALEP	$E_{cm} = 189\text{--}209$ GeV
>7.9	>4.6	95	ABDALLAH 06C	DLPH	$E_{cm} = 130\text{--}207$ GeV
>4.9	>7.2	95	² ABBIENDI 04G	OPAL	$E_{cm} = 130\text{--}207$ GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>5.4	>4.7	95	ACCARI 00P	L3	$E_{cm} = 130\text{--}189$ GeV

- SCHAE 07A limits are from R_C , Q_{FB}^{depl} , and hadronic cross section measurements.
- ABBIENDI 04G limits are from $e^+e^- \rightarrow \tau\tau$ cross section at $\sqrt{s} = 130\text{--}207$ GeV.

SCALE LIMITS for Contact Interactions: $\Lambda(\ell\ell\ell\ell)$

Lepton universality assumed. Limits are for Λ_{LL}^{\pm} only. For other cases, see each reference.

$\Lambda_{LL}^+(TeV)$	$\Lambda_{LL}^-(TeV)$	CL%	DOCUMENT ID	TECN	COMMENT
>7.9	>10.3	95	¹ SCHAE	07A ALEP	$E_{cm} = 189\text{--}209$ GeV
>9.1	>8.2	95	ABDALLAH 06C	DLPH	$E_{cm} = 130\text{--}207$ GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>7.7	>9.5	95	² ABBIENDI 04G	OPAL	$E_{cm} = 130\text{--}207$ GeV
			³ BABICH 03	RVUE	
>9.0	>5.2	95	ACCARI 00P	L3	$E_{cm} = 130\text{--}189$ GeV

- SCHAE 07A limits are from R_C , Q_{FB}^{depl} , and hadronic cross section measurements.
- ABBIENDI 04G limits are from $e^+e^- \rightarrow \ell^+\ell^-$ cross section at $\sqrt{s} = 130\text{--}207$ GeV.
- BABICH 03 obtain a bound $-0.175 \text{ TeV}^{-2} < 1/\Lambda_{LL}^2 < 0.095 \text{ TeV}^{-2}$ (95%CL) in a model independent analysis allowing all of $\Lambda_{LL}, \Lambda_{LR}, \Lambda_{RL}, \Lambda_{RR}$ to coexist.

SCALE LIMITS for Contact Interactions: $\Lambda(eeqq)$

Limits are for Λ_{LL}^{\pm} only. For other cases, see each reference.

$\Lambda_{LL}^+(TeV)$	$\Lambda_{LL}^-(TeV)$	CL%	DOCUMENT ID	TECN	COMMENT
> 4.5	>12.8	95	¹ ABRAMOWICZ19	ZEUS	($eeqq$)
>23.9	>16.8	95	² SIRUNYAN 19AC	CMS	($eeqq$)
>24	>37	95	³ AABOUD 17AT	ATLS	($eeqq$)
> 8.4	>10.2	95	⁴ ABDALLAH 09	DLPH	($eebb$)
> 9.4	>5.6	95	⁵ SCHAE	07A ALEP	($eecc$)
> 9.4	>4.9	95	⁴ SCHAE	07A ALEP	($eebb$)
>23.3	>12.5	95	⁶ CHEUNG 01B	RVUE	($eeuu$)
>11.1	>26.4	95	⁶ CHEUNG 01B	RVUE	($eedd$)
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>15.5	>19.5	95	⁷ AABOUD 16U	ATLS	($eeqq$)
>13.5	>18.3	95	⁸ KHACHATRYAN 15AE	CMS	($eeqq$)
>16.4	>20.7	95	⁹ AAD 14BE	ATLS	($eeqq$)
> 9.5	>12.1	95	¹⁰ AAD 13E	ATLS	($eeqq$)
>10.1	>9.4	95	¹¹ AAD 12AB	ATLS	($eeqq$)
> 4.2	>4.0	95	¹² AARON 11C	H1	($eeqq$)
> 3.8	>3.8	95	¹³ ABDALLAH 11	DLPH	($eecc$)
>12.9	>7.2	95	¹⁴ SCHAE	07A ALEP	($eeqq$)
> 3.7	>5.9	95	¹⁵ ABULENCIA 06L	CDF	($eeqq$)

- ABRAMOWICZ 19 limits are from Q^2 spectrum measurements of $e^\pm p \rightarrow e^\pm X$.
- SIRUNYAN 19AC limits are from e^+e^- mass distribution in pp collisions at $\sqrt{s} = 13$ TeV.
- AABOUD 17AT limits are from pp collisions at $\sqrt{s} = 13$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$.
- ABDALLAH 09 and SCHAE 07A limits are from R_B , A_{FB}^b .
- SCHAE 07A limits are from R_C , Q_{FB}^{depl} , and hadronic cross section measurements.
- CHEUNG 01B is an update of BARGER 98E.
- AABOUD 16U limits are from pp collisions at $\sqrt{s} = 13$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$.
- KHACHATRYAN 15AE limit is from e^+e^- mass distribution in pp collisions at $E_{cm} = 8$ TeV.
- AAD 14BE limits are from pp collisions at $\sqrt{s} = 8$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$.
- AAD 13E limits are from e^+e^- mass distribution in pp collisions at $E_{cm} = 7$ TeV.
- AAD 12AB limits are from e^+e^- mass distribution in pp collisions at $E_{cm} = 7$ TeV.
- AARON 11C limits are from Q^2 spectrum measurements of $e^\pm p \rightarrow e^\pm X$.
- ABDALLAH 11 limit is from $e^+e^- \rightarrow t\bar{t}$ cross section. $\Lambda_{LL} = \Lambda_{LR} = \Lambda_{RL} = \Lambda_{RR}$ is assumed.
- SCHAE 07A limit assumes quark flavor universality of the contact interactions.
- ABULENCIA 06L limits are from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV.

SCALE LIMITS for Contact Interactions: $\Lambda(\mu\mu qq)$

$\Lambda_{LL}^+(TeV)$	$\Lambda_{LL}^-(TeV)$	CL%	DOCUMENT ID	TECN	COMMENT
>30.4	>20.4	95	¹ SIRUNYAN 19AC	CMS	($\mu\mu qq$)
>20	>30	95	² AABOUD 17AT	ATLS	($\mu\mu qq$)

Searches Particle Listings

Quark and Lepton Compositeness

• • • We do not use the following data for averages, fits, limits, etc. • • •

>15.8	>21.8	95	³ AABOUD	16U ATLS	($\mu\mu qq$)
>12.0	>15.2	95	⁴ KHACHATRYAN	15AE CMS	($\mu\mu qq$)
>12.5	>16.7	95	⁵ AAD	14BE ATLS	($\mu\mu qq$)
> 9.6	>12.9	95	⁶ AAD	13E ATLS	($\mu\mu qq$) (isosinglet)
> 9.5	>13.1	95	⁷ CHATRCHYAN	13K CMS	($\mu\mu qq$) (isosinglet)
> 8.0	>7.0	95	⁸ AAD	12AB ATLS	($\mu\mu qq$) (isosinglet)

¹ SIRUNYAN 19AC limits are from $\mu^+\mu^-$ mass distribution in pp collisions at $\sqrt{s} = 13$ TeV.

² AABOUD 17AT limits are from pp collisions at $\sqrt{s} = 13$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$.

³ AABOUD 16U limits are from pp collisions at $\sqrt{s} = 13$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$.

⁴ KHACHATRYAN 15AE limit is from $\mu^+\mu^-$ mass distribution in pp collisions at $E_{cm} = 8$ TeV.

⁵ AAD 14BE limits are from pp collisions at $\sqrt{s} = 8$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$.

⁶ AAD 13E limits are from $\mu^+\mu^-$ mass distribution in pp collisions at $E_{cm} = 7$ TeV.

⁷ CHATRCHYAN 13K limits are from $\mu^+\mu^-$ mass distribution in pp collisions at $E_{cm} = 7$ TeV.

⁸ AAD 12AB limits are from $\mu^+\mu^-$ mass distribution in pp collisions at $E_{cm} = 7$ TeV.

SCALE LIMITS for Contact Interactions: $\Lambda(\ell\nu\ell\nu)$

VALUE (TeV)	CL%	DOCUMENT ID	TECN	COMMENT
>3.10	90	¹ JODIDIO	86 SPEC	$\Lambda_{LL}^{\pm}(\nu_{\mu}\nu_e\mu e)$

• • • We do not use the following data for averages, fits, limits, etc. • • •

>3.8		² DIAZCRUZ	94 RVUE	$\Lambda_{LL}^+(\tau\nu_{\tau}e\nu_e)$
>8.1		² DIAZCRUZ	94 RVUE	$\Lambda_{LL}^-(\tau\nu_{\tau}e\nu_e)$
>4.1		³ DIAZCRUZ	94 RVUE	$\Lambda_{LL}^+(\tau\nu_{\tau}\mu\nu_{\mu})$
>6.5		³ DIAZCRUZ	94 RVUE	$\Lambda_{LL}^-(\tau\nu_{\tau}\mu\nu_{\mu})$

¹ JODIDIO 86 limit is from $\mu^+ \rightarrow \overline{\nu}_{\mu} e^+ \nu_e$. Chirality invariant interactions $L = (g^2/\Lambda^2)$ [$\eta_{LL}(\overline{\nu}_{\mu} L \gamma^{\alpha} \mu_L)(\overline{e} L \gamma^{\alpha} \nu_e) + \eta_{LR}(\overline{\nu}_{\mu} L \gamma^{\alpha} \nu_e)(\overline{e} R \gamma^{\alpha} \mu_R)$] with $g^2/4\pi = 1$ and $(\eta_{LL}, \eta_{LR}) = (0, \pm 1)$ are taken. No limits are given for Λ_{LL}^{\pm} with $(\eta_{LL}, \eta_{LR}) = (\pm 1, 0)$. For more general constraints with right-handed neutrinos and chirality nonconserving contact interactions, see their text.

² DIAZCRUZ 94 limits are from $\Gamma(\tau \rightarrow e\nu\nu)$ and assume flavor-dependent contact interactions with $\Lambda(\tau\nu_{\tau}e\nu_e) \ll \Lambda(\mu\nu_{\mu}e\nu_e)$.

³ DIAZCRUZ 94 limits are from $\Gamma(\tau \rightarrow \mu\nu\nu)$ and assume flavor-dependent contact interactions with $\Lambda(\tau\nu_{\tau}\mu\nu_{\mu}) \ll \Lambda(\mu\nu_{\mu}e\nu_e)$.

SCALE LIMITS for Contact Interactions: $\Lambda(e\nu qq)$

VALUE (TeV)	CL%	DOCUMENT ID	TECN
>2.81	95	¹ AFFOLDER	01I CDF

¹ AFFOLDER 00i bound is for a scalar interaction $\overline{q}_R q_L \overline{\nu}_e \nu_e$.

SCALE LIMITS for Contact Interactions: $\Lambda(qqqq)$

$\Lambda_{LL}^+(\text{TeV})$	$\Lambda_{LL}^-(\text{TeV})$	CL%	DOCUMENT ID	TECN	COMMENT
>13.1 none	>21.8	95	¹ AABOUD	17AK ATLS	pp dijet angl.

• • • We do not use the following data for averages, fits, limits, etc. • • •

>12.8	>17.5	95	² AABOUD	18AV ATLS	$pp \rightarrow t\bar{t}t\bar{t}$
>11.5	>14.7	95	³ SIRUNYAN	18DD CMS	pp dijet angl.
>12.0	>17.5	95	⁴ SIRUNYAN	17F CMS	pp dijet angl.
			⁵ AAD	16s ATLS	pp dijet angl.
			⁶ AAD	15AR ATLS	$pp \rightarrow t\bar{t}t\bar{t}$
			⁷ AAD	15BY ATLS	$pp \rightarrow t\bar{t}t\bar{t}$
> 8.1	>12.0	95	⁸ AAD	15L ATLS	pp dijet angl.
> 9.0	>11.7	95	⁹ KHACHATRYAN	15J CMS	pp dijet angl.
> 5		95	¹⁰ FABBRICHESI	14 RVUE	$q\bar{q}t\bar{t}$

¹ AABOUD 17AK limit is from dijet angular distribution in pp collisions at $\sqrt{s} = 13$ TeV. u , d , and s quarks are assumed to be composite.

² AABOUD 18AV obtain limit on t_R compositeness $2\pi/\Lambda_{RR}^2 < 1.6 \text{ TeV}^{-2}$ at 95% CL from $t\bar{t}t\bar{t}$ production in the pp collisions at $E_{cm} = 13$ TeV.

³ SIRUNYAN 18DD limit is from dijet angular distribution in pp collisions at $\sqrt{s} = 13$ TeV.

⁴ SIRUNYAN 17F limit is from dijet angular cross sections in pp collisions at $E_{cm} = 13$ TeV. All quarks are assumed to be composite.

⁵ AAD 16s limit is from dijet angular selections in pp collisions at $E_{cm} = 13$ TeV. u , d , and s quarks are assumed to be composite.

⁶ AAD 15AR obtain limit on the t_R compositeness $2\pi/\Lambda_{RR}^2 < 6.6 \text{ TeV}^{-2}$ at 95% CL from the $t\bar{t}t\bar{t}$ production in the pp collisions at $E_{cm} = 8$ TeV.

⁷ AAD 15BY obtain limit on the t_R compositeness $2\pi/\Lambda_{RR}^2 < 15.1 \text{ TeV}^{-2}$ at 95% CL from the $t\bar{t}t\bar{t}$ production in the pp collisions at $E_{cm} = 8$ TeV.

⁸ AAD 15L limit is from dijet angular distribution in pp collisions at $E_{cm} = 8$ TeV. u , d , and s quarks are assumed to be composite.

⁹ KHACHATRYAN 15J limit is from dijet angular distribution in pp collisions at $E_{cm} = 8$ TeV. u , d , s , c , and b quarks are assumed to be composite.

¹⁰ FABBRICHESI 14 obtain bounds on chromoelectric and chromomagnetic form factors of the top-quark using $pp \rightarrow t\bar{t}$ and $p\bar{p} \rightarrow t\bar{t}$ cross sections. The quoted limit on the $q\bar{q}t\bar{t}$ contact interaction is derived from their bound on the chromoelectric form factor.

SCALE LIMITS for Contact Interactions: $\Lambda(\nu\nu qq)$

Limits are for Λ_{LL}^{\pm} only. For other cases, see each reference.

$\Lambda_{LL}^+(\text{TeV})$	$\Lambda_{LL}^-(\text{TeV})$	CL%	DOCUMENT ID	TECN	COMMENT
>5.0	>5.4	95	¹ MCFARLAND	98 CCFR	νN scattering

¹ MCFARLAND 98 assumed a flavor universal interaction. Neutrinos were mostly of muon type.

MASS LIMITS for Excited e (e^*)

Most e^+e^- experiments assume one-photon or Z exchange. The limits from some e^+e^- experiments which depend on λ have assumed transition couplings which are chirality violating ($\eta_L = \eta_R$). However they can be interpreted as limits for chirality-conserving interactions after multiplying the coupling value λ by $\sqrt{2}$; see Note.

Excited leptons have the same quantum numbers as other ortho- and vector mesons. See also the searches for ortho- and vector mesons in the "Searches for Heavy Leptons" section.

Limits for Excited e (e^*) from Pair Production

These limits are obtained from $e^+e^- \rightarrow e^*e^*$ and thus rely only on the (electroweak) charge of e^* . Form factor effects are ignored unless noted. For the case of limits from Z decay, the e^* coupling is assumed to be of sequential type. Possible t channel contribution from transition magnetic coupling is neglected. All limits assume a dominant $e^* \rightarrow e\gamma$ decay except the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>103.2	95	¹ ABBIENDI	02G OPAL	$e^+e^- \rightarrow e^*e^*$ Homodoublet type
>102.8	95	² ACHARD	03B L3	$e^+e^- \rightarrow e^*e^*$ Homodoublet type

¹ From e^+e^- collisions at $\sqrt{s} = 183\text{--}209$ GeV. $f = f'$ is assumed.

² From e^+e^- collisions at $\sqrt{s} = 189\text{--}209$ GeV. $f = f'$ is assumed. ACHARD 03B also obtain limit for $f = -f'$: $m_{e^*} > 96.6$ GeV.

Limits for Excited e (e^*) from Single Production

These limits are from $e^+e^- \rightarrow e^*e$, $W \rightarrow e^*\nu$, or $ep \rightarrow e^*X$ and depend on transition magnetic coupling between e and e^* . All limits assume $e^* \rightarrow e\gamma$ decay except as noted. Limits from LEP, UA2, and H1 are for chiral coupling, whereas all other limits are for nonchiral coupling, $\eta_L = \eta_R = 1$. In most papers, the limit is expressed in the form of an excluded region in the $\lambda\text{--}m_{e^*}$ plane. See the original papers.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>4800	95	¹ AABOUD	19AZ ATLS	$pp \rightarrow e^*e^*X$
>3900	95	² SIRUNYAN	19Z CMS	$pp \rightarrow e^*e^*X$
>2450	95	³ KHACHATRYAN	16AQ CMS	$pp \rightarrow e^*e^*X$
>3000	95	⁴ AAD	15AP ATLS	$pp \rightarrow e^{(*)}e^*X$
>2200	95	⁵ AAD	13BB ATLS	$pp \rightarrow e^*e^*X$
>1900	95	⁶ CHATRCHYAN	13AE CMS	$pp \rightarrow e^*e^*X$
>1870	95	⁷ AAD	12AZ ATLS	$pp \rightarrow e^{(*)}e^*X$

¹ AABOUD 19AZ search for single e^* production in pp collisions at $\sqrt{s} = 13$ TeV. The limit quoted above is from $e^* \rightarrow e q \bar{q}$ and $e^* \rightarrow \nu W$ decays assuming $f = f' = 1$ and $m_{e^*} = \Lambda$. The contact interaction is included in e^* production and decay amplitudes. See their Fig. 6 for exclusion limits in $m_{e^*} - \Lambda$ plane.

² SIRUNYAN 19Z search for e^* production in $\ell\ell\gamma$ final states in pp collisions at $\sqrt{s} = 13$ TeV. The quoted limit assumes $\Lambda = m_{e^*}$, $f = f' = 1$. The contact interaction is included in the e^* production and decay amplitudes.

³ KHACHATRYAN 16AQ search for single e^* production in pp collisions at $\sqrt{s} = 8$ TeV. The limit above is from the $e^* \rightarrow e\gamma$ search channel assuming $f = f' = 1$, $m_{e^*} = \Lambda$. See their Table 7 for limits in other search channels or with different assumptions.

⁴ AAD 15AP search for e^* production in events with three or more charged leptons in pp collisions at $\sqrt{s} = 8$ TeV. The quoted limit assumes $\Lambda = m_{e^*}$, $f = f' = 1$. The contact interaction is included in the e^* production and decay amplitudes.

⁵ AAD 13BB search for single e^* production in pp collisions with $e^* \rightarrow e\gamma$ decay. $f = f' = 1$, and e^* production via contact interaction with $\Lambda = m_{e^*}$ are assumed.

⁶ CHATRCHYAN 13AE search for single e^* production in pp collisions with $e^* \rightarrow e\gamma$ decay. $f = f' = 1$, and e^* production via contact interaction with $\Lambda = m_{e^*}$ are assumed.

⁷ AAD 12AZ search for e^* production via four-fermion contact interaction in pp collisions with $e^* \rightarrow e\gamma$ decay. The quoted limit assumes $\Lambda = m_{e^*}$. See their Fig. 8 for the exclusion plot in the mass-coupling plane.

See key on page 999

Searches Particle Listings

Quark and Lepton Compositeness

Limits for Excited e (e^*) from $e^+e^- \rightarrow \gamma\gamma$

These limits are derived from indirect effects due to e^* exchange in the t channel and depend on transition magnetic coupling between e and e^* . All limits are for $\lambda_\gamma = 1$. All limits except ABE 89j and ACHARD 02d are for nonchiral coupling with $\eta_L = \eta_R = 1$. We choose the chiral coupling limit as the best limit and list it in the Summary Table.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>356	95	¹ ABDALLAH 04N	DLPH	$\sqrt{s} = 161\text{--}208$ GeV
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
>310	95	ACHARD 02d	L3	$\sqrt{s} = 192\text{--}209$ GeV

¹ ABDALLAH 04N also obtain a limit on the excited electron mass with ee^* chiral coupling, $m_{e^*} > 295$ GeV at 95% CL.

Indirect Limits for Excited e (e^*)

These limits make use of loop effects involving e^* and are therefore subject to theoretical uncertainty.

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
• • •	We do not use the following data for averages, fits, limits, etc. • • •		
	¹ DORENBOS... 89	CHRM	$\overline{\nu}_\mu e \rightarrow \overline{\nu}_\mu e, \nu_\mu e \rightarrow \nu_\mu e$
	² GRIFOLS 86	THEO	$\nu_\mu e \rightarrow \nu_\mu e$
	³ RENARD 82	THEO	$g-2$ of electron

¹ DORENBOSCH 89 obtain the limit $\lambda_\gamma^2 \Lambda_{\text{cut}}^2 / m_{e^*}^2 < 2.6$ (95% CL), where Λ_{cut} is the cutoff scale, based on the one-loop calculation by GRIFOLS 86. If one assumes that $\Lambda_{\text{cut}} = 1$ TeV and $\lambda_\gamma = 1$, one obtains $m_{e^*} > 620$ GeV. However, one generally expects $\lambda_\gamma \approx m_{e^*} / \Lambda_{\text{cut}}$ in composite models.

² GRIFOLS 86 uses $\nu_\mu e \rightarrow \nu_\mu e$ and $\overline{\nu}_\mu e \rightarrow \overline{\nu}_\mu e$ data from CHARM Collaboration to derive mass limits which depend on the scale of compositeness.

³ RENARD 82 derived from $g-2$ data limits on mass and couplings of e^* and μ^* . See figures 2 and 3 of the paper.

MASS LIMITS for Excited μ (μ^*)

Limits for Excited μ (μ^*) from Pair Production

These limits are obtained from $e^+e^- \rightarrow \mu^* \mu^*$ and thus rely only on the (electroweak) charge of μ^* . Form factor effects are ignored unless noted. For the case of limits from Z decay, the μ^* coupling is assumed to be of sequential type. All limits assume a dominant $\mu^* \rightarrow \mu\gamma$ decay except the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>103.2	95	¹ ABBIENDI 02G	OPAL	$e^+e^- \rightarrow \mu^* \mu^*$ Homodoublet type
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
>102.8	95	² ACHARD 03B	L3	$e^+e^- \rightarrow \mu^* \mu^*$ Homodoublet type

¹ From e^+e^- collisions at $\sqrt{s} = 183\text{--}209$ GeV. $f = f'$ is assumed.

² From e^+e^- collisions at $\sqrt{s} = 189\text{--}209$ GeV. $f = f'$ is assumed. ACHARD 03B also obtain limit for $f = -f'$: $m_{\mu^*} > 96.6$ GeV.

Limits for Excited μ (μ^*) from Single Production

These limits are from $e^+e^- \rightarrow \mu^* \mu$ and depend on transition magnetic coupling between μ and μ^* . All limits assume $\mu^* \rightarrow \mu\gamma$ decay. Limits from LEP are for chiral coupling, whereas all other limits are for nonchiral coupling, $\eta_L = \eta_R = 1$. In most papers, the limit is expressed in the form of an excluded region in the $\lambda\text{--}m_{\mu^*}$ plane. See the original papers.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>3800	95	¹ SIRUNYAN 19Z	CMS	$pp \rightarrow \mu^* \mu^* X$
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
>2800	95	² AAD 16BMATLS		$pp \rightarrow \mu^* \mu^* X$
>2470	95	³ KHACHATRYAN 16AQ	CMS	$pp \rightarrow \mu^* \mu^* X$
>3000	95	⁴ AAD 15AP	ATLS	$pp \rightarrow \mu^* \mu^* X$
>2200	95	⁵ AAD 13BB	ATLS	$pp \rightarrow \mu^* \mu^* X$
>1900	95	⁶ CHATRCHYAN 13AE	CMS	$pp \rightarrow \mu^* \mu^* X$
>1750	95	⁷ AAD 12AZ	ATLS	$pp \rightarrow \mu^* \mu^* X$

¹ SIRUNYAN 19Z search for μ^* production in $\ell\ell\gamma$ final states in pp collisions at $\sqrt{s} = 13$ TeV. The quoted limit assumes $\Lambda = m_{\mu^*}$, $f = f' = 1$. The contact interaction is included in the μ^* production and decay amplitudes.

² AAD 16BM search for μ^* production in $\mu\mu jj$ events in pp collisions at $\sqrt{s} = 8$ TeV. Both the production and decay are assumed to occur via a contact interaction with $\Lambda = m_{\mu^*}$.

³ KHACHATRYAN 16AQ search for single μ^* production in pp collisions at $\sqrt{s} = 8$ TeV. The limit above is from the $\mu^* \rightarrow \mu\gamma$ search channel assuming $f = f' = 1$, $m_{\mu^*} = \Lambda$. See their Table 7 for limits in other search channels or with different assumptions.

⁴ AAD 15AP search for μ^* production in events with three or more charged leptons in pp collisions at $\sqrt{s} = 8$ TeV. The quoted limit assumes $\Lambda = m_{\mu^*}$, $f = f' = 1$. The contact interaction is included in the μ^* production and decay amplitudes.

⁵ AAD 13BB search for single μ^* production in pp collisions with $\mu^* \rightarrow \mu\gamma$ decay. $f = f' = 1$, and μ^* production via contact interaction with $\Lambda = m_{\mu^*}$ are assumed.

⁶ CHATRCHYAN 13AE search for single μ^* production in pp collisions with $\mu^* \rightarrow \mu\gamma$ decay. $f = f' = 1$, and μ^* production via contact interaction with $\Lambda = m_{\mu^*}$ are assumed.

⁷ AAD 12AZ search for μ^* production via four-fermion contact interaction in pp collisions with $\mu^* \rightarrow \mu\gamma$ decay. The quoted limit assumes $\Lambda = m_{\mu^*}$. See their Fig. 8 for the exclusion plot in the mass-coupling plane.

Indirect Limits for Excited μ (μ^*)

These limits make use of loop effects involving μ^* and are therefore subject to theoretical uncertainty.

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
• • •	We do not use the following data for averages, fits, limits, etc. • • •		
	¹ RENARD 82	THEO	$g-2$ of muon

¹ RENARD 82 derived from $g-2$ data limits on mass and couplings of e^* and μ^* . See figures 2 and 3 of the paper.

MASS LIMITS for Excited τ (τ^*)

Limits for Excited τ (τ^*) from Pair Production

These limits are obtained from $e^+e^- \rightarrow \tau^* \tau^*$ and thus rely only on the (electroweak) charge of τ^* . Form factor effects are ignored unless noted. For the case of limits from Z decay, the τ^* coupling is assumed to be of sequential type. All limits assume a dominant $\tau^* \rightarrow \tau\gamma$ decay except the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>103.2	95	¹ ABBIENDI 02G	OPAL	$e^+e^- \rightarrow \tau^* \tau^*$ Homodoublet type
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
>102.8	95	² ACHARD 03B	L3	$e^+e^- \rightarrow \tau^* \tau^*$ Homodoublet type

¹ From e^+e^- collisions at $\sqrt{s} = 183\text{--}209$ GeV. $f = f'$ is assumed.

² From e^+e^- collisions at $\sqrt{s} = 189\text{--}209$ GeV. $f = f'$ is assumed. ACHARD 03B also obtain limit for $f = -f'$: $m_{\tau^*} > 96.6$ GeV.

Limits for Excited τ (τ^*) from Single Production

These limits are from $e^+e^- \rightarrow \tau^* \tau$ and depend on transition magnetic coupling between τ and τ^* . All limits assume $\tau^* \rightarrow \tau\gamma$ decay. Limits from LEP are for chiral coupling, whereas all other limits are for nonchiral coupling, $\eta_L = \eta_R = 1$. In most papers, the limit is expressed in the form of an excluded region in the $\lambda\text{--}m_{\tau^*}$ plane. See the original papers.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>2500	95	¹ AAD 15AP	ATLS	$pp \rightarrow \tau^* \tau^* X$
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
> 180	95	² ACHARD 03B	L3	$e^+e^- \rightarrow \tau^* \tau^*$
> 185	95	³ ABBIENDI 02G	OPAL	$e^+e^- \rightarrow \tau^* \tau^*$

¹ AAD 15AP search for τ^* production in events with three or more charged leptons in pp collisions at $\sqrt{s} = 8$ TeV. The quoted limit assumes $\Lambda = m_{\tau^*}$, $f = f' = 1$. The contact interaction is included in the τ^* production and decay amplitudes.

² ACHARD 03B result is from e^+e^- collisions at $\sqrt{s} = 189\text{--}209$ GeV. $f = f' = \Lambda / m_{\tau^*}$ is assumed. See their Fig. 4 for the exclusion plot in the mass-coupling plane.

³ ABBIENDI 02G result is from e^+e^- collisions at $\sqrt{s} = 183\text{--}209$ GeV. $f = f' = \Lambda / m_{\tau^*}$ is assumed for τ^* coupling. See their Fig. 4c for the exclusion limit in the mass-coupling plane.

MASS LIMITS for Excited Neutrino (ν^*)

Limits for Excited ν (ν^*) from Pair Production

These limits are obtained from $e^+e^- \rightarrow \nu^* \nu^*$ and thus rely only on the (electroweak) charge of ν^* . Form factor effects are ignored unless noted. The ν^* coupling is assumed to be of sequential type unless otherwise noted. All limits assume a dominant $\nu^* \rightarrow \nu\gamma$ decay except the limits from $\Gamma(Z)$.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>1600	95	¹ AAD 15AP	ATLS	$pp \rightarrow \nu^* \nu^* X$
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
		² ABBIENDI 04N	OPAL	
> 102.6	95	³ ACHARD 03B	L3	$e^+e^- \rightarrow \nu^* \nu^*$ Homodoublet type

¹ AAD 15AP search for ν^* pair production in events with three or more charged leptons in pp collisions at $\sqrt{s} = 8$ TeV. The quoted limit assumes $\Lambda = m_{\nu^*}$, $f = f' = 1$. The contact interaction is included in the ν^* production and decay amplitudes.

² From e^+e^- collisions at $\sqrt{s} = 192\text{--}209$ GeV, ABBIENDI 04N obtain limit on $\sigma(e^+e^- \rightarrow \nu^* \nu^*) B^2(\nu^* \rightarrow \nu\gamma)$. See their Fig. 2. The limit ranges from 20 to 45 fb for $m_{\nu^*} > 45$ GeV.

³ From e^+e^- collisions at $\sqrt{s} = 189\text{--}209$ GeV. $f = -f'$ is assumed. ACHARD 03B also obtain limit for $f = f'$: $m_{\nu_e^*} > 101.7$ GeV, $m_{\nu_\mu^*} > 101.8$ GeV, and $m_{\nu_\tau^*} > 92.9$ GeV.

See their Fig. 4 for the exclusion plot in the mass-coupling plane.

Searches Particle Listings

Quark and Lepton Compositeness

Limits for Excited ν (ν^*) from Single Production

These limits are from $e^+e^- \rightarrow \nu\nu^*$, $Z \rightarrow \nu\nu^*$, or $e p \rightarrow \nu^* X$ and depend on transition magnetic coupling between ν/e and ν^* . Assumptions about ν^* decay mode are given in footnotes.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>213	95	¹ AARON 08	H1	$e p \rightarrow \nu^* X$
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
>190	95	² ACHARD 03b	L3	$e^+e^- \rightarrow \nu\nu^*$
none 50–150	95	³ ADLOFF 02	H1	$e p \rightarrow \nu^* X$
>158	95	⁴ CHEKANOV 02b	ZEUS	$e p \rightarrow \nu^* X$

- AARON 08 search for single ν^* production in $e p$ collisions with the decays $\nu^* \rightarrow \nu\gamma$, νZ , $e W$. The quoted limit assumes $f = -f' = \Lambda/m_{\nu^*}$. See their Fig. 3 and Fig. 4 for the exclusion plots in the mass-coupling plane.
- ACHARD 03b result is from e^+e^- collisions at $\sqrt{s} = 189\text{--}209$ GeV. The quoted limit is for ν_e^* . $f = -f' = \Lambda/m_{\nu^*}$ is assumed. See their Fig. 4 for the exclusion plot in the mass-coupling plane.
- ADLOFF 02 search for single ν^* production in $e p$ collisions with the decays $\nu^* \rightarrow \nu\gamma$, νZ , $e W$. The quoted limit assumes $f = -f' = \Lambda/m_{\nu^*}$. See their Fig. 1 for the exclusion plots in the mass-coupling plane.
- CHEKANOV 02b search for single ν^* production in $e p$ collisions with the decays $\nu^* \rightarrow \nu\gamma$, νZ , $e W$. $f = -f' = \Lambda/m_{\nu^*}$ is assumed for the e^* coupling. CHEKANOV 02b also obtain limit for $f = f' = \Lambda/m_{\nu^*}$: $m_{\nu^*} > 135$ GeV. See their Fig. 5c and Fig. 5d for the exclusion plot in the mass-coupling plane.

MASS LIMITS for Excited q (q^*)

Limits for Excited q (q^*) from Pair Production

These limits are mostly obtained from $e^+e^- \rightarrow q^*\bar{q}^*$ and thus rely only on the (electroweak) charge of the q^* . Form factor effects are ignored unless noted. Assumptions about the q^* decay are given in the comments and footnotes.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>338	95	¹ AALTONEN 10H	CDF	$q^* \rightarrow t W^-$
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
none 700–1200	95	² SIRUNYAN 18v	CMS	$p p \rightarrow t^*_{3/2} \bar{t}^*_{3/2} \rightarrow t \bar{t} g g$
> 45.6	95	³ BARATE 98u	ALEP	$Z \rightarrow q^* \bar{q}^*$
> 41.7	95	⁴ ADRIANI 93M	L3	u or d type, $Z \rightarrow q^* \bar{q}^*$
> 44.7	95	⁵ BARDADIN... 92	RVUE	u -type, $\Gamma(Z)$
> 40.6	95	⁶ BARDADIN... 92	RVUE	d -type, $\Gamma(Z)$
> 44.2	95	⁷ DECAP 92	ALEP	u -type, $\Gamma(Z)$
> 45	95	⁸ DECAP 92	ALEP	d -type, $\Gamma(Z)$
> 45	95	⁹ DECAP 92	ALEP	u or d type, $Z \rightarrow q^* \bar{q}^*$
> 45	95	¹⁰ ABREU 91F	DLPH	u -type, $\Gamma(Z)$
> 45	95	¹¹ ABREU 91F	DLPH	d -type, $\Gamma(Z)$

- AALTONEN 10H obtain limits on the $q^* \bar{q}^*$ production cross section in $p\bar{p}$ collisions. See their Fig. 3.
- SIRUNYAN 18v search for pair production of spin $3/2$ excited top quarks. $B(t^*_{3/2} \rightarrow t g) = 1$ is assumed.
- BARATE 98u obtain limits on the form factor. See their Fig. 16 for limits in mass-form factor plane.
- ADRIANI 93M limit is valid for $B(q^* \rightarrow qg) > 0.25$ (0.17) for up (down) type.
- BARDADIN-OTWINOWSKA 92 limit based on $\Delta\Gamma(Z) < 36$ MeV.
- These limits are independent of decay modes.
- Limit is for $B(q^* \rightarrow qg) + B(q^* \rightarrow q\gamma) = 1$.

Limits for Excited q (q^*) from Single Production

These limits are from $e^+e^- \rightarrow q^*\bar{q}$, $p\bar{p} \rightarrow q^* X$, or $p p \rightarrow q^* X$ and depend on transition magnetic couplings between q and q^* . Assumptions about q^* decay mode are given in the footnotes and comments.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
none 1500–2600	95	¹ AABOUD 18AB	ATLS	$p p \rightarrow b^* X$, $b^* \rightarrow b g$
none 1500–5300	95	² AABOUD 18BA	ATLS	$p p \rightarrow q^* X$, $q^* \rightarrow q \gamma$
none 1000–5500	95	³ SIRUNYAN 18AG	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q \gamma$
none 1000–1800	95	⁴ SIRUNYAN 18AG	CMS	$p p \rightarrow b^* X$, $b^* \rightarrow b \gamma$
none 600–6000	95	⁵ SIRUNYAN 18B0	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q g$
none 1200–5000	95	⁶ SIRUNYAN 18P	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q W$
none 1200–4700	95	⁷ SIRUNYAN 18P	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q Z$
>6000	95	⁸ AABOUD 17AK	ATLS	$p p \rightarrow q^* X$, $q^* \rightarrow q g$
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
none 600–5400	95	⁹ KHACHATRY...17W	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q g$
none 1100–2100	95	¹⁰ AABOUD 16	ATLS	$p p \rightarrow b^* X$, $b^* \rightarrow b g$
>1500	95	¹¹ AAD 16AH	ATLS	$p p \rightarrow b^* X$, $b^* \rightarrow t W$
>4400	95	¹² AAD 16AI	ATLS	$p p \rightarrow q^* X$, $q^* \rightarrow q \gamma$
>5200	95	¹³ AAD 16AV	ATLS	$p p \rightarrow q^* X$, $q^* \rightarrow W b$
>1390	95	¹⁴ AAD 16S	ATLS	$p p \rightarrow q^* X$, $q^* \rightarrow q g$
>5000	95	¹⁵ KHACHATRY...16I	CMS	$p p \rightarrow b^* X$, $b^* \rightarrow t W$
none 500–1600	95	¹⁶ KHACHATRY...16K	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q g$
>4060	95	¹⁷ AAD 15V	ATLS	$p p \rightarrow q^* X$, $q^* \rightarrow q g$
>3500	95	¹⁸ KHACHATRY...15V	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q g$
>3500	95	¹⁹ AAD 14A	ATLS	$p p \rightarrow q^* X$, $q^* \rightarrow q \gamma$
>3200	95	²⁰ KHACHATRY...14	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q W$
>2900	95	²¹ KHACHATRY...14	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q Z$
none 700–3500	95	²² KHACHATRY...14J	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q \gamma$
>2380	95	²³ CHATRCHYAN 13AJ	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q W$
>2150	95	²⁴ CHATRCHYAN 13AJ	CMS	$p p \rightarrow q^* X$, $q^* \rightarrow q Z$

- AABOUD 18AB assume $\Lambda = m_{b^*}$, $f_5 = f = f' = 1$. The contact interactions are not included in b^* production and decay amplitudes.
- AABOUD 18BA search for first-generation excited quarks (u^* and d^*) with degenerate mass, assuming $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes.
- SIRUNYAN 18AG search for first-generation excited quarks (u^* and d^*) with degenerate mass, assuming $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$.
- SIRUNYAN 18AG search for excited b quark assuming $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$.
- SIRUNYAN 18B0 assume $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes.
- SIRUNYAN 18P use the hadronic decay of W or Z , assuming $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$.
- AABOUD 17AK assume $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes. Only the decay of $q^* \rightarrow g u$ and $q^* \rightarrow g d$ is simulated as the benchmark signals in the analysis.
- KHACHATRYAN 17W assume $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes.
- AABOUD 16 assume $\Lambda = m_{b^*}$, $f_5 = f = f' = 1$. The contact interactions are not included in the b^* production and decay amplitudes.
- AAD 16AH search for b^* decaying to $t W$ in $p p$ collisions at $\sqrt{s} = 8$ TeV. $f_g = f_L = f_R = 1$ are assumed. See their Fig. 12b for limits on $\sigma \cdot B$.
- AAD 16AI assume $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$.
- AAD 16AV search for single production of vector-like quarks decaying to $W b$ in $p p$ collisions. See their Fig. 8 for the limits on couplings and mixings.
- AAD 16S assume $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes.
- KHACHATRYAN 16I search for b^* decaying to $t W$ in $p p$ collisions at $\sqrt{s} = 8$ TeV. $\kappa_L^b = g_L = 1$, $\kappa_R^b = g_R = 0$ are assumed. See their Fig. 8 for limits on $\sigma \cdot B$.
- KHACHATRYAN 16K assume $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes.
- KHACHATRYAN 16L search for resonances decaying to dijets in $p p$ collisions at $\sqrt{s} = 8$ TeV using the data scouting technique which increases the sensitivity to the low mass resonances.
- AAD 15V assume $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes.
- KHACHATRYAN 15v assume $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes.
- AAD 14A assume $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$.
- KHACHATRYAN 14 use the hadronic decay of W , assuming $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$.
- KHACHATRYAN 14 use the hadronic decay of Z , assuming $\Lambda = m_{q^*}$, $f_5 = f = f' = 1$.
- KHACHATRYAN 14J assume $f_5 = f = f' = \Lambda / m_{q^*}$.
- CHATRCHYAN 13AJ use the hadronic decay of W .
- CHATRCHYAN 13AJ use the hadronic decay of Z .

MASS LIMITS for Color Sextet Quarks (q_6)

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>84	95	¹ ABE 89D	CDF	$p\bar{p} \rightarrow q_6 \bar{q}_6$

- ABE 89D look for pair production of unit-charged particles which leave the detector before decaying. In the above limit the color sextet quark is assumed to fragment into a unit-charged or neutral hadron with equal probability and to have long enough lifetime not to decay within the detector. A limit of 121 GeV is obtained for a color decuplet.

MASS LIMITS for Color Octet Charged Leptons (ℓ_8)

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>86	95	¹ ABE 89D	CDF	Stable ℓ_8 : $p\bar{p} \rightarrow \ell_8 \bar{\ell}_8$
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
		² ABT 93	H1	$e g: e p \rightarrow e_8 X$

- ABE 89D look for pair production of unit-charged particles which leave the detector before decaying. In the above limit the color octet lepton is assumed to fragment into a unit-charged or neutral hadron with equal probability and to have long enough lifetime not to decay within the detector. The limit improves to 99 GeV if it always fragments into a unit-charged hadron.
- ABT 93 search for e_8 production via e -gluon fusion in $e p$ collisions with $e_8 \rightarrow e g$. See their Fig. 3 for exclusion plot in the m_{e_8} - Λ plane for $m_{e_8} = 35\text{--}220$ GeV.

MASS LIMITS for Color Octet Neutrinos (ν_8)

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>110	90	¹ BARGER 89	RVUE	$\nu_8: p\bar{p} \rightarrow \nu_8 \bar{\nu}_8$
• • •		We do not use the following data for averages, fits, limits, etc. • • •		
none 3.8–29.8	95	² KIM 90	AMY	$\nu_8: e^+e^- \rightarrow$ acoplanar jets
none 9–21.9	95	³ BARTEL 87B	JADE	$\nu_8: e^+e^- \rightarrow$ acoplanar jets

See key on page 999

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Quark and Lepton Compositeness, Extra Dimensions

- ¹ BARGER 89 used ABE 89B limit for events with large missing transverse momentum. Two-body decay $\nu g \rightarrow \nu g$ is assumed.
- ² KIM 90 is at $E_{cm} = 50\text{--}60.8$ GeV. The same assumptions as in BARTEL 87B are used.
- ³ BARTEL 87B is at $E_{cm} = 46.3\text{--}46.78$ GeV. The limit assumes the νg pair production cross section to be eight times larger than that of the corresponding heavy neutrino pair production. This assumption is not valid in general for the weak couplings, and the limit can be sensitive to its $SU(2)_L \times U(1)_Y$ quantum numbers.

MASS LIMITS for W_8 (Color Octet W Boson)

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
	¹ ALBAJAR 89	UA1	$p\bar{p} \rightarrow W_8 X, W_8 \rightarrow W g$
¹ ALBAJAR 89 give $\sigma(W_8 \rightarrow W + \text{jet})/\sigma(W) < 0.019$ (90% CL) for $m_{W_8} > 220$ GeV.			

REFERENCES FOR Searches for Quark and Lepton Compositeness

ABOUD 19AZ	EPJ C79 803	M. Aaboud et al.	(ATLAS Collab.)
ABRAMOWICZ 19	PR D99 092006	H. Abramowicz et al.	(ZEUS Collab.)
SIRUNYAN 19AC	JHEP 1904 114	A.M. Sirunyan et al.	(CMS Collab.)
SIRUNYAN 19Z	JHEP 1904 015	A.M. Sirunyan et al.	(CMS Collab.)
AABOUD 18AB	PR D98 032016	M. Aaboud et al.	(ATLAS Collab.)
AABOUD 18AV	JHEP 1807 089	M. Aaboud et al.	(ATLAS Collab.)
AABOUD 18BA	EPJ C78 102	M. Aaboud et al.	(ATLAS Collab.)
SIRUNYAN 18AG	PL B781 390	A.M. Sirunyan et al.	(CMS Collab.)
SIRUNYAN 18BO	JHEP 1808 130	A.M. Sirunyan et al.	(CMS Collab.)
SIRUNYAN 18DD	EPJ C78 789	A.M. Sirunyan et al.	(CMS Collab.)
SIRUNYAN 18P	PR D97 072006	A.M. Sirunyan et al.	(CMS Collab.)
SIRUNYAN 18V	PL B778 349	A.M. Sirunyan et al.	(CMS Collab.)
AABOUD 17AK	PR D96 052004	M. Aaboud et al.	(ATLAS Collab.)
AABOUD 17AT	JHEP 1710 182	M. Aaboud et al.	(ATLAS Collab.)
KHACHATRYAN 17W	PL B769 520	V. Khachatryan et al.	(CMS Collab.)
SIRUNYAN 17F	JHEP 1707 013	A.M. Sirunyan et al.	(CMS Collab.)
AABOUD 16	PL B759 229	M. Aaboud et al.	(ATLAS Collab.)
AABOUD 16U	PL B761 372	M. Aaboud et al.	(ATLAS Collab.)
AAD 16AH	JHEP 1602 110	G. Aad et al.	(ATLAS Collab.)
AAD 16AI	JHEP 1603 041	G. Aad et al.	(ATLAS Collab.)
AAD 16AV	EPJ C76 442	G. Aad et al.	(ATLAS Collab.)
AAD 16BM	NJP 18 073021	G. Aad et al.	(ATLAS Collab.)
AAD 16S	PL B754 302	G. Aad et al.	(ATLAS Collab.)
KHACHATRYAN 16AQ	JHEP 1603 125	V. Khachatryan et al.	(CMS Collab.)
KHACHATRYAN 16I	JHEP 1601 166	V. Khachatryan et al.	(CMS Collab.)
KHACHATRYAN 16K	PRL 116 071801	V. Khachatryan et al.	(CMS Collab.)
KHACHATRYAN 16L	PRL 117 031802	V. Khachatryan et al.	(CMS Collab.)
AAD 15AP	JHEP 1508 138	G. Aad et al.	(ATLAS Collab.)
AAD 15AR	JHEP 1508 105	G. Aad et al.	(ATLAS Collab.)
AAD 15BY	JHEP 1510 150	G. Aad et al.	(ATLAS Collab.)
AAD 15L	PRL 114 221802	G. Aad et al.	(ATLAS Collab.)
AAD 15V	PR D91 052007	G. Aad et al.	(ATLAS Collab.)
KHACHATRYAN 15AE	JHEP 1504 025	V. Khachatryan et al.	(CMS Collab.)
KHACHATRYAN 15J	PL B746 79	V. Khachatryan et al.	(CMS Collab.)
KHACHATRYAN 15V	PR D91 052009	V. Khachatryan et al.	(CMS Collab.)
AAD 14A	PL B728 562	G. Aad et al.	(ATLAS Collab.)
AAD 14BE	EPJ C74 3134	G. Aad et al.	(ATLAS Collab.)
FABBRICHESI 14	PR D89 074028	M. Fabbrichesi, M. Pinamonti, A. Toneo	
KHACHATRYAN 14	JHEP 1408 173	V. Khachatryan et al.	(CMS Collab.)
KHACHATRYAN 14J	PL B738 274	V. Khachatryan et al.	(CMS Collab.)
AAD 13BB	NJP 15 093011	G. Aad et al.	(ATLAS Collab.)
AAD 13E	PR D87 015010	G. Aad et al.	(ATLAS Collab.)
CHATRCHYAN 13AE	PL B720 309	S. Chatrchyan et al.	(CMS Collab.)
CHATRCHYAN 13AJ	PL B723 280	S. Chatrchyan et al.	(CMS Collab.)
CHATRCHYAN 13K	PR D87 032001	S. Chatrchyan et al.	(CMS Collab.)
AAD 12AB	PL B712 40	G. Aad et al.	(ATLAS Collab.)
AAD 12AZ	PR D85 072003	G. Aad et al.	(ATLAS Collab.)
AARON 11C	PL B705 52	F. D. Aaron et al.	(H1 Collab.)
ABDALLAH 11	EPJ C71 1555	J. Abdallah et al.	(DELPHI Collab.)
AALTONEN 10H	PL 104 091801	T. Aaltonen et al.	(CDF Collab.)
ABDALLAH 09	EPJ C60 1	J. Abdallah et al.	(DELPHI Collab.)
AARON 08	PL B663 382	F.D. Aaron et al.	(H1 Collab.)
SCHAEF 07A	EPJ C49 411	S. Schaefer et al.	(ALEPH Collab.)
ABDALLAH 06C	EPJ C45 589	J. Abdallah et al.	(DELPHI Collab.)
ABULENCIA 06L	PRL 96 211801	A. Abulencia et al.	(CDF Collab.)
ABBIENDI 04G	EPJ C33 173	G. Abbiendi et al.	(OPAL Collab.)
ABBIENDI 04N	PL B602 167	G. Abbiendi et al.	(OPAL Collab.)
ABDALLAH 04N	EPJ C37 405	J. Abdallah et al.	(DELPHI Collab.)
ACHARD 03B	PL B568 23	P. Achard et al.	(L3 Collab.)
BABICH 03	EPJ C29 103	A.A. Babich et al.	
ABBIENDI 02G	PL B544 57	G. Abbiendi et al.	(OPAL Collab.)
ACHARD 02D	PL B531 28	P. Achard et al.	(L3 Collab.)
ADLOFF 02	PL B525 9	C. Adloff et al.	(H1 Collab.)
CHEKANOV 02D	PL B549 32	S. Chekanov et al.	(ZEUS Collab.)
AFFOLDER 01I	PRL 87 231803	T. Affolder et al.	(CDF Collab.)
BOURLIKOV 01	PR D64 071701	D. Bourlikov	
CHEUNG 01B	PL B517 167	K. Cheung	
ACCIARRI 00P	PL B489 81	M. Acciarri et al.	(L3 Collab.)
AFFOLDER 00I	PR D62 012004	T. Affolder et al.	(CDF Collab.)
BARATE 98U	EPJ C4 571	R. Barate et al.	(ALEPH Collab.)
BARGER 98E	PR D57 391	V. Barger et al.	
MCFARLAND 98	EPJ C1 509	K.S. McFarland et al.	(CCFR/NuTeV Collab.)
DIAZCRUZ 94	PR D49 2149	J.L. Diaz Cruz, O.A. Sampayo	(CINV)
ABT 93M	NP B396 3	I. Abt et al.	(H1 Collab.)
ADRIANI 93N	PRPL 236 1	O. Adriani et al.	(L3 Collab.)
BARDADIN 92	ZPHY C55 163	M. Bardadin-Ottowinska	(CLER)
DECAMP 92	PRPL 216 253	D. Decamp et al.	(ALEPH Collab.)
PDG 92	PR D45 51	K. Hikasa et al.	(KEK, LBL, BOST+)
ABREU 91F	NP B367 511	P. Abreu et al.	(DELPHI Collab.)
KIM 90	PL B240 243	G.N. Kim et al.	(AMY Collab.)
ABE 89B	PRL 62 1825	F. Abe et al.	(CDF Collab.)
ABE 89D	PRL 63 1447	F. Abe et al.	(CDF Collab.)
ABE 89J	ZPHY C45 175	K. Abe et al.	(VENUS Collab.)
ALBAJAR 89	ZPHY C44 15	C. Albajar et al.	(UA1 Collab.)
BARGER 89	PL B220 464	V. Barger et al.	(WISC, KEK)
DORENBOSCH 89	ZPHY C41 567	J. Dorenbosch et al.	(CHARM Collab.)
BARTEL 87B	ZPHY C36 15	W. Bartel et al.	(JADE Collab.)
GRIFOLS 86	PL B68B 264	J.A. Grifols, S. Peris	(BARC)
JODIDIO 86	PR D34 1967	A. Jodidio et al.	(LBL, NWES, TRIU)
Also 86	PR D37 237 (erratum)	A. Jodidio et al.	(LBL, NWES, TRIU)
RENARD 82	PL B16B 264	F.M. Renard	(CERN)

Extra Dimensions

For explanation of terms used and discussion of significant model dependence of following limits, see the “Extra Dimensions” review. Footnotes describe originally quoted limit. δ indicates the number of extra dimensions.

Limits not encoded here are summarized in the “Extra Dimensions” review, where the latest unpublished results are also described.

See the related review(s):

Extra Dimensions

CONTENTS:

- Limits on R from Deviations in Gravitational Force Law
- Limits on R from On-Shell Production of Gravitons: $\delta = 2$
- Mass Limits on M_{TT}
- Limits on $1/R = M_C$
- Limits on Kaluza-Klein Gravitons in Warped Extra Dimensions
- Limits on Kaluza-Klein Gluons in Warped Extra Dimensions
- Black Hole Production Limits
 - Semiclassical Black Holes
 - Quantum Black Holes

Limits on R from Deviations in Gravitational Force Law

This section includes limits on the size of extra dimensions from deviations in the Newtonian ($1/r^2$) gravitational force law at short distances. Deviations are parametrized by a gravitational potential of the form $V = -(G m m')/r [1 + \alpha \exp(-r/R)]$. For δ toroidal extra dimensions of equal size, $\alpha = 8\delta/3$. Quoted bounds are for $\delta = 2$ unless otherwise noted.

VALUE (μm)	CL%	DOCUMENT ID	TECN	COMMENT
< 30	95	¹ KAPNER 07		Torsion pendulum
• • • We do not use the following data for averages, fits, limits, etc. • • •				
		² BERGE 18	MICR	Space accelerometer
		³ FAYET 18A	MICR	Space accelerometer
		⁴ HADDOCK 18		Neutron scattering
		⁵ KLIMCHITSKY 17A		Torsion oscillator
		⁶ XU 13		Nuclei properties
		⁷ BEZERRA 11		Torsion oscillator
		⁸ SUSHKOV 11		Torsion pendulum
		⁹ BEZERRA 10		Microcantilever
		¹⁰ MASUDA 09		Torsion pendulum
		¹¹ GERACI 08		Microcantilever
		¹² TRENNEL 08		Newton's constant
		¹³ DECCA 07A		Torsion oscillator
< 47	95	¹⁴ TU 07		Torsion pendulum
		¹⁵ SMULLIN 05		Microcantilever
<130	95	¹⁶ HOYLE 04		Torsion pendulum
		¹⁷ CHIAVERINI 03		Microcantilever
< 200	95	¹⁸ LONG 03		Microcantilever
<190	95	¹⁹ HOYLE 01		Torsion pendulum
		²⁰ HOSKINS 85		Torsion pendulum

- ¹ KAPNER 07 search for new forces, probing a range of $\alpha \simeq 10^{-3}\text{--}10^5$ and length scales $R \simeq 10\text{--}1000$ μm . For $\delta = 1$ the bound on R is 44 μm . For $\delta = 2$, the bound is expressed in terms of M_* , here translated to a bound on the radius. See their Fig. 6 for details on the bound.
- ² BERGE 18 uses results from the MICROSCOPE experiment to obtain constraints on non-Newtonian forces with strengths $10^{-11} \lesssim |\alpha| \lesssim 10^{-7}$ and length scales $R \gtrsim 10^5$ m. See their Figure 1 for more details. These constraints do not place limits on the size of extra flat dimensions.
- ³ FAYET 18A uses results from the MICROSCOPE experiment to obtain constraints on an EP-violating force possibly arising from a new $U(1)$ gauge boson. For $R \gtrsim 10^7$ m the limits are $|\alpha| \lesssim$ a few 10^{-13} to a few 10^{-11} depending on the coupling, corresponding to $|\epsilon| \lesssim 10^{-24}$ for the coupling of the new spin-1 or spin-0 mediator. These constraints do not place limits on the size of extra flat dimensions. This extends the results of FAYET 18.
- ⁴ HADDOCK 18 obtain constraints on non-Newtonian forces with strengths $10^{22} \lesssim |\alpha| \lesssim 10^{24}$ and length scales $R \simeq 0.01\text{--}10$ nm. See their Figure 8 for more details. These constraints do not place limits on the size of extra flat dimensions.
- ⁵ KLIMCHITSKY 17A uses an experiment that measures the difference of Casimir forces to obtain bounds on non-Newtonian forces with strengths $|\alpha| \simeq 10^5\text{--}10^{17}$ and length scales $R = 0.03\text{--}10$ μm . See their Fig. 3. These constraints do not place limits on the size of extra flat dimensions.
- ⁶ XU 13 obtain constraints on non-Newtonian forces with strengths $|\alpha| \simeq 10^{34}\text{--}10^{36}$ and length scales $R \simeq 1\text{--}10$ fm. See their Fig. 4 for more details. These constraints do not place limits on the size of extra flat dimensions.
- ⁷ BEZERRA 11 obtain constraints on non-Newtonian forces with strengths $10^{11} \lesssim |\alpha| \lesssim 10^{18}$ and length scales $R = 30\text{--}1260$ nm. See their Fig. 2 for more details. These constraints do not place limits on the size of extra flat dimensions.
- ⁸ SUSHKOV 11 obtain improved limits on non-Newtonian forces with strengths $10^7 \lesssim |\alpha| \lesssim 10^{11}$ and length scales 0.4 $\mu\text{m} < R < 4$ μm (95% CL). See their Fig. 2. These bounds do not place limits on the size of extra flat dimensions. However, a model dependent bound of $M_* > 70$ TeV is obtained assuming gauge bosons that couple to baryon number also propagate in $(4 + \delta)$ dimensions.
- ⁹ BEZERRA 10 obtain improved constraints on non-Newtonian forces with strengths $10^{19} \lesssim |\alpha| \lesssim 10^{29}$ and length scales $R = 1.6\text{--}14$ nm (95% CL). See their Fig. 1. This bound does not place limits on the size of extra flat dimensions.

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Extra Dimensions

- ¹⁰ MASUDA 09 obtain improved constraints on non-Newtonian forces with strengths $10^9 \lesssim |\alpha| \lesssim 10^{11}$ and length scales $R = 1.0\text{--}2.9 \mu\text{m}$ (95% CL). See their Fig. 3. This bound does not place limits on the size of extra flat dimensions.
- ¹¹ GERACI 08 obtain improved constraints on non-Newtonian forces with strengths $|\alpha| > 14,000$ and length scales $R = 5\text{--}15 \mu\text{m}$. See their Fig. 9. This bound does not place limits on the size of extra flat dimensions.
- ¹² TRENKEL 08 uses two independent measurements of Newton's constant G to constrain new forces with strength $|\alpha| \simeq 10^{-4}$ and length scales $R = 0.02\text{--}1 \text{ m}$. See their Fig. 1. This bound does not place limits on the size of extra flat dimensions.
- ¹³ DECCA 07A search for new forces and obtain bounds in the region with strengths $|\alpha| \simeq 10^{13}\text{--}10^{18}$ and length scales $R = 20\text{--}86 \text{ nm}$. See their Fig. 6. This bound does not place limits on the size of extra flat dimensions.
- ¹⁴ TU 07 search for new forces probing a range of $|\alpha| \simeq 10^{-1}\text{--}10^5$ and length scales $R \simeq 20\text{--}1000 \mu\text{m}$. For $\delta = 1$ the bound on R is $53 \mu\text{m}$. See their Fig. 3 for details on the bound.
- ¹⁵ SMULLIN 05 search for new forces, and obtain bounds in the region with strengths $\alpha \simeq 10^{3}\text{--}10^8$ and length scales $R = 6\text{--}20 \mu\text{m}$. See their Figs. 1 and 16 for details on the bound. This work does not place limits on the size of extra flat dimensions.
- ¹⁶ HOYLE 04 search for new forces, probing α down to 10^{-2} and distances down to $10 \mu\text{m}$. Quoted bound on R is for $\delta = 2$. For $\delta = 1$, bound goes to $160 \mu\text{m}$. See their Fig. 34 for details on the bound.
- ¹⁷ CHIAVERINI 03 search for new forces, probing α above 10^4 and λ down to $3 \mu\text{m}$, finding no signal. See their Fig. 4 for details on the bound. This bound does not place limits on the size of extra flat dimensions.
- ¹⁸ LONG 03 search for new forces, probing α down to 3, and distances down to about $10 \mu\text{m}$. See their Fig. 4 for details on the bound.
- ¹⁹ HOYLE 01 search for new forces, probing α down to 10^{-2} and distances down to $20 \mu\text{m}$. See their Fig. 4 for details on the bound. The quoted bound is for $\alpha \geq 3$.
- ²⁰ HOSKINS 85 search for new forces, probing distances down to 4 mm . See their Fig. 13 for details on the bound. This bound does not place limits on the size of extra flat dimensions.

Limits on R from On-Shell Production of Gravitons: $\delta = 2$

This section includes limits on on-shell production of gravitons in collider and astrophysical processes. Bounds quoted are on R , the assumed common radius of the flat extra dimensions, for $\delta = 2$ extra dimensions. Studies often quote bounds in terms of derived parameter; experiments are actually sensitive to the masses of the KK gravitons: $m_{\tilde{g}} = |\vec{p}|/R$. See the Review on "Extra Dimensions" for details. Bounds are given in μm for $\delta = 2$.

VALUE (μm)	CL%	DOCUMENT ID	TECN	COMMENT
< 4.8	95	¹ SIRUNYAN	18s CMS	$pp \rightarrow jG$
< 0.00016	95	² HANNESTAD	03	Neutron star heating
• • • We do not use the following data for averages, fits, limits, etc. • • •				
< 8.0	95	³ AABOUD	18f ATLS	$pp \rightarrow jG$
< 89	95	⁴ SIRUNYAN	18bv CMS	$pp \rightarrow ZG$
		⁵ SIRUNYAN	17aq CMS	$pp \rightarrow \gamma G$
< 90	95	⁶ AABOUD	16f ATLS	$pp \rightarrow \gamma G$
		⁷ KHACHATRYAN	16n CMS	$pp \rightarrow \gamma G$
		⁸ AAD	15cs ATLS	$pp \rightarrow \gamma G$
< 127	95	⁹ AAD	13c ATLS	$pp \rightarrow \gamma G$
< 34.4	95	¹⁰ AAD	13d ATLS	$pp \rightarrow jj$
< 0.0087	95	¹¹ AJELLO	12 FLAT	Neutron star γ sources
< 245	95	¹² AALTONEN	08ac CDF	$p\bar{p} \rightarrow \gamma G, jG$
< 615	95	¹³ ABAZOV	08s D0	$p\bar{p} \rightarrow \gamma G$
< 0.916	95	¹⁴ DAS	08	Supernova cooling
< 350	95	¹⁵ ABULENCIA,A	06 CDF	$p\bar{p} \rightarrow jG$
< 270	95	¹⁶ ABDALLAH	05b DLPH	$e^+e^- \rightarrow \gamma G$
< 210	95	¹⁷ ACHARD	04e L3	$e^+e^- \rightarrow \gamma G$
< 480	95	¹⁸ ACOSTA	04c CDF	$p\bar{p} \rightarrow jG$
< 0.00038	95	¹⁹ CASSE	04	Neutron star γ sources
< 610	95	²⁰ ABAZOV	03 D0	$p\bar{p} \rightarrow jG$
< 0.96	95	²¹ HANNESTAD	03	Supernova cooling
< 0.096	95	²² HANNESTAD	03	Diffuse γ background
< 0.051	95	²³ HANNESTAD	03	Neutron star γ sources
< 300	95	²⁴ HEISTER	03c ALEP	$e^+e^- \rightarrow \gamma G$
		²⁵ FAIRBAIRN	01	Cosmology
< 0.66	95	²⁶ HANHART	01	Supernova cooling
		²⁷ CASSISI	00	Red giants
<1300	95	²⁸ ACCIARRI	99s L3	$e^+e^- \rightarrow ZG$

- ¹ SIRUNYAN 18s search for $pp \rightarrow jG$, using 35.9 fb^{-1} of data at $\sqrt{s} = 13 \text{ TeV}$ to place lower limits on M_D for two to six extra dimensions (see their Table VII), from which this bound on R is derived. This limit supersedes that in KHACHATRYAN 15AL.
- ² HANNESTAD 03 obtain a limit on R from the heating of old neutron stars by the surrounding cloud of trapped KK gravitons. Limits for all $\delta \leq 7$ are given in their Tables V and VI. These limits supersede those in HANNESTAD 02.
- ³ AABOUD 18f search for $pp \rightarrow jG$, using 36.1 fb^{-1} of data at $\sqrt{s} = 13 \text{ TeV}$ to place lower limits on M_D for two to six extra dimensions (see their Table 7), from which this bound on R is derived. This limit supersedes that in AABOUD 16D.
- ⁴ SIRUNYAN 18bv search for $pp \rightarrow ZG$, using 35.9 fb^{-1} of data at $\sqrt{s} = 13 \text{ TeV}$ to place lower limits on M_D for two to seven extra dimensions (see their Figure 11), from which this bound on R is derived.
- ⁵ SIRUNYAN 17aq search for $pp \rightarrow \gamma G$, using 12.9 fb^{-1} of data at $\sqrt{s} = 13 \text{ TeV}$ to place limits on M_D for three to six extra dimensions (see their Table 3).
- ⁶ AABOUD 16f search for $pp \rightarrow \gamma G$, using 3.2 fb^{-1} of data at $\sqrt{s} = 13 \text{ TeV}$ to place limits on M_D for two to six extra dimensions (see their Figure 9), from which this bound on R is derived.
- ⁷ KHACHATRYAN 16n search for $pp \rightarrow \gamma G$, using 19.6 fb^{-1} of data at $\sqrt{s} = 8 \text{ TeV}$ to place limits on M_D for three to six extra dimensions (see their Table 5).
- ⁸ AAD 15cs search for $pp \rightarrow \gamma G$, using 20.3 fb^{-1} of data at $\sqrt{s} = 8 \text{ TeV}$ to place lower limits on M_D for two to six extra dimensions (see their Fig. 18).

- ⁹ AAD 13c search for $pp \rightarrow \gamma G$, using 4.6 fb^{-1} of data at $\sqrt{s} = 7 \text{ TeV}$ to place bounds on M_D for two to six extra dimensions, from which this bound on R is derived.
- ¹⁰ AAD 13p search for the dijet decay of quantum black holes in 4.8 fb^{-1} of data produced in pp collisions at $\sqrt{s} = 7 \text{ TeV}$ to place bounds on M_D for two to seven extra dimensions, from which these bounds on R are derived. Limits on M_D for all $\delta \leq 7$ are given in their Table 3.
- ¹¹ AJELLO 12 obtain a limit on R from the gamma-ray emission of point γ sources that arise from the photon decay of KK gravitons which are gravitationally bound around neutron stars. Limits for all $\delta \leq 7$ are given in their Table 7.
- ¹² AALTONEN 08ac search for $p\bar{p} \rightarrow \gamma G$ and $p\bar{p} \rightarrow jG$ at $\sqrt{s} = 1.96 \text{ TeV}$ with 2.0 fb^{-1} and 1.1 fb^{-1} respectively, in order to place bounds on the fundamental scale and size of the extra dimensions. See their Table III for limits on all $\delta \leq 6$.
- ¹³ ABAZOV 08s search for $p\bar{p} \rightarrow \gamma G$, using 1 fb^{-1} of data at $\sqrt{s} = 1.96 \text{ TeV}$ to place bounds on M_D for two to eight extra dimensions, from which these bounds on R are derived. See their paper for intermediate values of δ .
- ¹⁴ DAS 08 obtain a limit on R from Kaluza-Klein graviton cooling of SN1987A due to plasmon-plasmon annihilation.
- ¹⁵ ABULENCIA,A 06 search for $p\bar{p} \rightarrow jG$ using 368 pb^{-1} of data at $\sqrt{s} = 1.96 \text{ TeV}$. See their Table II for bounds for all $\delta \leq 6$.
- ¹⁶ ABDALLAH 05b search for $e^+e^- \rightarrow \gamma G$ at $\sqrt{s} = 180\text{--}209 \text{ GeV}$ to place bounds on the size of extra dimensions and the fundamental scale. Limits for all $\delta \leq 6$ are given in their Table 6. These limits supersede those in ABREU 00z.
- ¹⁷ ACHARD 04 search for $e^+e^- \rightarrow \gamma G$ at $\sqrt{s} = 189\text{--}209 \text{ GeV}$ to place bounds on the size of extra dimensions and the fundamental scale. See their Table 8 for limits with $\delta \leq 8$. These limits supersede those in ACCIARRI 99r.
- ¹⁸ ACOSTA 04c search for $p\bar{p} \rightarrow jG$ at $\sqrt{s} = 1.8 \text{ TeV}$ to place bounds on the size of extra dimensions and the fundamental scale. See their paper for bounds on $\delta = 4, 6$.
- ¹⁹ CASSE 04 obtain a limit on R from the gamma-ray emission of point γ sources that arises from the photon decay of gravitons around newly born neutron stars, applying the technique of HANNESTAD 03 to neutron stars in the galactic bulge. Limits for all $\delta \leq 7$ are given in their Table I.
- ²⁰ ABAZOV 03 search for $p\bar{p} \rightarrow jG$ at $\sqrt{s} = 1.8 \text{ TeV}$ to place bounds on M_D for 2 to 7 extra dimensions, from which these bounds on R are derived. See their paper for bounds on intermediate values of δ . We quote results without the approximate NLO scaling introduced in the paper.
- ²¹ HANNESTAD 03 obtain a limit on R from graviton cooling of supernova SN1987A. Limits for all $\delta \leq 7$ are given in their Tables V and VI.
- ²² HANNESTAD 03 obtain a limit on R from gravitons emitted in supernovae and which subsequently decay, contaminating the diffuse cosmic γ background. Limits for all $\delta \leq 7$ are given in their Tables V and VI. These limits supersede those in HANNESTAD 02.
- ²³ HANNESTAD 03 obtain a limit on R from gravitons emitted in two recent supernovae and which subsequently decay, creating point γ sources. Limits for all $\delta \leq 7$ are given in their Tables V and VI. These limits are corrected in the published erratum.
- ²⁴ HEISTER 03c use the process $e^+e^- \rightarrow \gamma G$ at $\sqrt{s} = 189\text{--}209 \text{ GeV}$ to place bounds on the size of extra dimensions and the scale of gravity. See their Table 4 for limits with $\delta \leq 6$ for derived limits on M_D .
- ²⁵ FAIRBAIRN 01 obtains bounds on R from over production of KK gravitons in the early universe. Bounds are quoted in paper in terms of fundamental scale of gravity. Bounds depend strongly on temperature of QCD phase transition and range from $R < 0.13 \mu\text{m}$ to $0.001 \mu\text{m}$ for $\delta=2$; bounds for $\delta=3,4$ can be derived from Table 1 in the paper.
- ²⁶ HANHART 01 obtain bounds on R from limits on graviton cooling of supernova SN1987A using numerical simulations of proto-neutron star neutrino emission.
- ²⁷ CASSISI 00 obtain rough bounds on M_D (and thus R) from red giant cooling for $\delta=2,3$. See their paper for details.
- ²⁸ ACCIARRI 99s search for $e^+e^- \rightarrow ZG$ at $\sqrt{s}=189 \text{ GeV}$. Limits on the gravity scale are found in their Table 2, for $\delta \leq 4$.

Mass Limits on M_{TT}

This section includes limits on the cut-off mass scale, M_{TT} , of dimension-8 operators from KK graviton exchange in models of large extra dimensions. Ambiguities in the UV-divergent summation are absorbed into the parameter λ , which is taken to be $\lambda = \pm 1$ in the following analyses. Bounds for $\lambda = -1$ are shown in parenthesis after the bound for $\lambda = +1$, if appropriate. Different papers use slightly different definitions of the mass scale. The definition used here is related to another popular convention by $M_{TT}^4 = (2/\pi) \Lambda_{*}^4$, as discussed in the above Review on "Extra Dimensions."

VALUE (TeV)	CL%	DOCUMENT ID	TECN	COMMENT
> 9.02	95	¹ SIRUNYAN	18dd CMS	$pp \rightarrow$ dijet, ang. distrib.
> 20.6	95	² GIUDICE	03 RVUE	Dim-6 operators
• • • We do not use the following data for averages, fits, limits, etc. • • •				
> 6.9	95	³ SIRUNYAN	19ac CMS	$pp \rightarrow e^+e^-, \mu^+\mu^-, \gamma\gamma$
> 7.0	95	⁴ SIRUNYAN	18du CMS	$pp \rightarrow \gamma\gamma$
> 6.5	95	⁵ AABOUD	17ap ATLS	$pp \rightarrow \gamma\gamma$
> 3.8	95	⁶ AAD	14be ATLS	$pp \rightarrow e^+e^-, \mu^+\mu^-$
> 3.2	95	⁷ AAD	13e ATLS	$pp \rightarrow e^+e^-, \mu^+\mu^-, \gamma\gamma$
		⁸ BAAK	12 RVUE	Electroweak
> 0.90	95	⁹ AARON	11 H1	$e^\pm p \rightarrow e^\pm X$
> 1.48	95	¹⁰ ABAZOV	09ae D0	$p\bar{p} \rightarrow$ dijet, ang. distrib.
> 1.45	95	¹¹ ABAZOV	09d D0	$p\bar{p} \rightarrow e^+e^-, \gamma\gamma$
> 1.1	95	¹² SCHAE	07a ALEP	$e^+e^- \rightarrow e^+e^-$
> 0.898	95	¹³ ABDALLAH	06c DLPH	$e^+e^- \rightarrow \ell^+\ell^-$
> 0.853	95	¹⁴ GERDES	06	$p\bar{p} \rightarrow e^+e^-, \gamma\gamma$
> 0.96	95	¹⁵ ABAZOV	05v D0	$p\bar{p} \rightarrow \mu^+\mu^-$
> 0.78	95	¹⁶ CHEKANOV	04b ZEUS	$e^\pm p \rightarrow e^\pm X$
> 0.805	95	¹⁷ ABBIENDI	03d OPAL	$e^+e^- \rightarrow \gamma\gamma$
> 0.7	95	¹⁸ ACHARD	03d L3	$e^+e^- \rightarrow ZZ$
> 0.82	95	¹⁹ ADLOFF	03 H1	$e^\pm p \rightarrow e^\pm X$
> 1.28	95	²⁰ GIUDICE	03 RVUE	
> 0.80	95	²¹ HEISTER	03c ALEP	$e^+e^- \rightarrow \gamma\gamma$

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> 0.84	(> 0.99)	95	22	ACHARD	02D L3	$e^+e^- \rightarrow \gamma\gamma$
> 1.2	(> 1.1)	95	23	ABBOTT	01 D0	$p\bar{p} \rightarrow e^+e^-, \gamma\gamma$
> 0.60	(> 0.63)	95	24	ABBIENDI	00R OPAL	$e^+e^- \rightarrow \mu^+\mu^-$
> 0.63	(> 0.50)	95	24	ABBIENDI	00R OPAL	$e^+e^- \rightarrow \tau^+\tau^-$
> 0.68	(> 0.61)	95	24	ABBIENDI	00R OPAL	$e^+e^- \rightarrow \mu^+\mu^-, \tau^+\tau^-$
			25	ABREU	00A DLPH	$e^+e^- \rightarrow \gamma\gamma$
> 0.680	(> 0.542)	95	26	ABREU	00S DLPH	$e^+e^- \rightarrow \mu^+\mu^-, \tau^+\tau^-$
> 15-28		99.7	27	CHANG	00B RVUE	Electroweak
> 0.98		95	28	CHEUNG	00 RVUE	$e^+e^- \rightarrow \gamma\gamma$
> 0.29-0.38		95	29	GRAESSER	00 RVUE	$(g-2)_\mu$
> 0.50-1.1		95	30	HAN	00 RVUE	Electroweak
> 2.0	(> 2.0)	95	31	MATHEWS	00 RVUE	$p\bar{p} \rightarrow jj$
> 1.0	(> 1.1)	95	32	MELE	00 RVUE	$e^+e^- \rightarrow VV$
			33	ABBIENDI	99P OPAL	
			34	ACCIARRI	99M L3	
			35	ACCIARRI	99S L3	
> 1.412	(> 1.077)	95	36	BOURLIKOV	99	$e^+e^- \rightarrow e^+e^-$

- 1 SIRUNYAN 18DD use dijet angular distributions in 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to place a lower bound on Λ_T , here converted to M_{TT} . This updates the results of SIRUNYAN 17f.
- 2 GIUDICE 03 place bounds on Λ_6 , the coefficient of the gravitationally-induced dimension-6 operator $(2\pi\lambda/\Lambda_6^2)(\sum \bar{\psi}_i\gamma_\mu\psi_i)(\sum \bar{\psi}_j\gamma_\mu\psi_j)$, using data from a variety of experiments. Results are quoted for $\lambda=\pm 1$ and are independent of δ .
- 3 SIRUNYAN 19AC use 35.9 (36.3) fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV in the dielectron (dimuon) channels to place a lower limit on Λ_T , here converted to M_{TT} . The dielectron and dimuon channels are combined with previous results in the diphoton channel to set the best limit. Bounds on individual channels and different priors can be found in their Table 2. This updates the results in KHACHATRYAN 15AE.
- 4 SIRUNYAN 18DU use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to place lower limits on M_{TT} (equivalent to their M_S). This updates the results of CHATRCHYAN 12R.
- 5 ABOUD 17AP use 36.7 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to place lower limits on M_{TT} (equivalent to their M_S). This updates the results of AAD 13As.
- 6 AAD 14BE use 20 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV in the dilepton channel to place lower limits on M_{TT} (equivalent to their M_S).
- 7 AAD 13E use 4.9 and 5.0 fb⁻¹ of data from pp collisions at $\sqrt{s} = 7$ TeV in the dielectron and dimuon channels, respectively, to place lower limits on M_{TT} (equivalent to their M_S). The dielectron and dimuon channels are combined with previous results in the diphoton channel to set the best limit. Bounds on individual channels and different priors can be found in their Table VIII.
- 8 BAAK 12 use electroweak precision observables to place bounds on the ratio Λ_T/M_D as a function of M_D . See their Fig. 22 for constraints with a Higgs mass of 120 GeV.
- 9 AARON 11C search for deviations in the differential cross section of $e^\pm p \rightarrow e^\pm X$ in 446 pb⁻¹ of data taken at $\sqrt{s} = 301$ and 319 GeV to place a bound on M_{TT} .
- 10 ABZOV 09AE use dijet angular distributions in 0.7 fb⁻¹ of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to place lower bounds on Λ_T (equivalent to their M_S), here converted to M_{TT} .
- 11 ABZOV 09b use 1.05 fb⁻¹ of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to place lower bounds on Λ_T (equivalent to their M_S), here converted to M_{TT} .
- 12 SCHAE 07A use e^+e^- collisions at $\sqrt{s} = 189-209$ GeV to place lower limits on Λ_T , here converted to limits on M_{TT} .
- 13 ABDALLAH 06C use e^+e^- collisions at $\sqrt{s} \sim 130-207$ GeV to place lower limits on M_{TT} , which is equivalent to their definition of M_S . Bound shown includes all possible final state leptons, $\ell = e, \mu, \tau$. Bounds on individual leptonic final states can be found in their Table 31.
- 14 GERDES 06 use 100 to 110 pb⁻¹ of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV, as recorded by the CDF Collaboration during Run I of the Tevatron. Bound shown includes a K -factor of 1.3. Bounds on individual e^+e^- and $\gamma\gamma$ final states are found in their Table I.
- 15 ABZOV 05v use 246 pb⁻¹ of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to search for deviations in the differential cross section to $\mu^+\mu^-$ from graviton exchange.
- 16 CHEKA NOV 04B search for deviations in the differential cross section of $e^\pm p \rightarrow e^\pm X$ with 130 pb⁻¹ of combined data and Q^2 values up to 40,000 GeV² to place a bound on M_{TT} .
- 17 ABBIENDI 03D use e^+e^- collisions at $\sqrt{s}=181-209$ GeV to place bounds on the ultraviolet scale M_{TT} , which is equivalent to their definition of M_S .
- 18 ACHARD 03D look for deviations in the cross section for $e^+e^- \rightarrow ZZ$ from $\sqrt{s} = 200-209$ GeV to place a bound on M_{TT} .
- 19 ADLOFF 03 search for deviations in the differential cross section of $e^\pm p \rightarrow e^\pm X$ at $\sqrt{s}=301$ and 319 GeV to place bounds on M_{TT} .
- 20 GIUDICE 03 review existing experimental bounds on M_{TT} and derive a combined limit.
- 21 HEISTER 03C use e^+e^- collisions at $\sqrt{s}=189-209$ GeV to place bounds on the scale of dim-8 gravitational interactions. Their M_S^\pm is equivalent to our M_{TT} with $\lambda=\pm 1$.
- 22 ACHARD 02 search for s -channel graviton exchange effects in $e^+e^- \rightarrow \gamma\gamma$ at $E_{cm} = 192-209$ GeV.
- 23 ABBOTT 01 search for variations in differential cross sections to e^+e^- and $\gamma\gamma$ final states at the Tevatron.
- 24 ABBIENDI 00R uses e^+e^- collisions at $\sqrt{s}=189$ GeV.
- 25 ABREU 00A search for s -channel graviton exchange effects in $e^+e^- \rightarrow \gamma\gamma$ at $E_{cm} = 189-202$ GeV.
- 26 ABREU 00S uses e^+e^- collisions at $\sqrt{s}=183$ and 189 GeV. Bounds on μ and τ individual final states given in paper.
- 27 CHANG 00B derive 3σ limit on M_{TT} of (28,19,15) TeV for $\delta=(2,4,6)$ respectively assuming the presence of a torsional coupling in the gravitational action. Highly model dependent.
- 28 CHEUNG 00 obtains limits from anomalous diphoton production at OPAL due to graviton exchange. Original limit for $\delta=4$. However, unknown UV theory renders δ dependence unreliable. Original paper works in HLZ convention.
- 29 GRAESSER 00 obtains a bound from graviton contributions to $g-2$ of the muon through loops of 0.29 TeV for $\delta=2$ and 0.38 TeV for $\delta=4,6$. Limits scale as $\lambda^{1/2}$. However

- calculational scheme not well-defined without specification of high-scale theory. See the "Extra Dimensions Review."
- 30 HAN 00 calculates corrections to gauge boson self-energies from KK graviton loops and constrain them using S and T . Bounds on M_{TT} range from 0.5 TeV ($\delta=6$) to 1.1 TeV ($\delta=2$); see text. Limits have strong dependence, $\lambda^{\delta+2}$, on unknown λ coefficient.
 - 31 MATHEWS 00 search for evidence of graviton exchange in CDF and D0 dijet production data. See their Table 2 for slightly stronger δ -dependent bounds. Limits expressed in terms of $\tilde{M}_S^4 = M_{TT}^4/8$.
 - 32 MELE 00 obtains bound from KK graviton contributions to $e^+e^- \rightarrow VV$ ($V=\gamma, W, Z$) at LEP. Authors use Hewett conventions.
 - 33 ABBIENDI 99P search for s -channel graviton exchange effects in $e^+e^- \rightarrow \gamma\gamma$ at $E_{cm}=189$ GeV. The limits $G_\pm > 660$ GeV and $G_- > 634$ GeV are obtained from combined $E_{cm}=183$ and 189 GeV data, where G_\pm is a scale related to the fundamental gravity scale.
 - 34 ACCIARRI 99M search for the reaction $e^+e^- \rightarrow \gamma G$ and s -channel graviton exchange effects in $e^+e^- \rightarrow \gamma\gamma, W^+W^-, ZZ, e^+e^-, \mu^+\mu^-, \tau^+\tau^-, q\bar{q}$ at $E_{cm}=183$ GeV. Limits on the gravity scale are listed in their Tables 1 and 2.
 - 35 ACCIARRI 99S search for the reaction $e^+e^- \rightarrow ZG$ and s -channel graviton exchange effects in $e^+e^- \rightarrow \gamma\gamma, W^+W^-, ZZ, e^+e^-, \mu^+\mu^-, \tau^+\tau^-, q\bar{q}$ at $E_{cm}=189$ GeV. Limits on the gravity scale are listed in their Tables 1 and 2.
 - 36 BOURLIKOV 99 performs global analysis of LEP data on e^+e^- collisions at $\sqrt{s}=183$ and 189 GeV. Bound is on Λ_T .

Limits on $1/R = M_C$

This section includes limits on $1/R = M_C$, the compactification scale in models with one TeV-sized extra dimension, due to exchange of Standard Model KK excitations. Bounds assume fermions are not in the bulk, unless stated otherwise. See the "Extra Dimensions" review for discussion of model dependence.

VALUE (TeV)	CL%	DOCUMENT ID	TECN	COMMENT
>4.16	95	1 AAD	12CC ATLS	$pp \rightarrow t\bar{t}$
>6.1		2 BARBIERI	04 RVUE	Electroweak
• • • We do not use the following data for averages, fits, limits, etc. • • •				
		3 ABOUD	18AV ATLS	$pp \rightarrow t\bar{t}t\bar{t}$
		4 ABOUD	18CE ATLS	$pp \rightarrow t\bar{t}t\bar{t}$
>3.8	95	5 ACCOMANDO 15	RVUE	Electroweak
>3.40	95	6 KHACHATRYAN 15T	CMS	$pp \rightarrow \ell X$
		7 CHATRCHYAN 13AQ	CMS	$pp \rightarrow \ell X$
>1.38	95	8 CHATRCHYAN 13W	CMS	$pp \rightarrow \gamma\gamma, \delta=6, M_D=5$ TeV
>0.715	95	9 EDELHAUSER 13	RVUE	$pp \rightarrow \ell\bar{\ell} + X$
>1.40	95	10 AAD	12CP ATLS	$pp \rightarrow \gamma\gamma, \delta=6, M_D=5$ TeV
>1.23	95	11 AAD	12X ATLS	$pp \rightarrow \gamma\gamma, \delta=6, M_D=5$ TeV
>0.26	95	12 ABZOV	12M D0	$p\bar{p} \rightarrow \mu\mu$
>0.75	95	13 BAAK	12 RVUE	Electroweak
		14 FLACKE	12 RVUE	Electroweak
>0.43	95	15 NISHIWAKI	12 RVUE	$H \rightarrow WW, \gamma\gamma$
>0.729	95	16 AAD	11F ATLS	$pp \rightarrow \gamma\gamma, \delta=6, M_D=5$ TeV
>0.961	95	17 AAD	11X ATLS	$pp \rightarrow \gamma\gamma, \delta=6, M_D=5$ TeV
>0.477	95	18 ABZOV	10P D0	$p\bar{p} \rightarrow \gamma\gamma, \delta=6, M_D=5$ TeV
>1.59	95	19 ABZOV	09AE D0	$p\bar{p} \rightarrow$ dijet, angular dist.
>0.6	95	20 HAISCH	07 RVUE	$B \rightarrow X_s \gamma$
>0.6	90	21 GOGOLADZE	06 RVUE	Electroweak
>3.3	95	22 CORNET	00 RVUE	Electroweak
> 3.3-3.8	95	23 RIZZO	00 RVUE	Electroweak

- 1 AAD 12CC use 4.9 and 5.0 fb⁻¹ of data from pp collisions at $\sqrt{s} = 7$ TeV in the dielectron and dimuon channels, respectively, to place a lower bound on the mass of the lightest KK Z/γ boson (equivalent to $1/R = M_C$). The limit quoted here assumes a flat prior corresponding to when the pure Z/γ KK cross section term dominates. See their Section 15 for more details.
- 2 BARBIERI 04 use electroweak precision observables to place a lower bound on the compactification scale $1/R$. Both the gauge bosons and the Higgs boson are assumed to propagate in the bulk.
- 3 ABOUD 18AV use 36.1 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV in final states with multiple b-jets, to place a lower bound on the compactification scale in a model with two universal extra dimensions. Assuming the radii of the two extra dimensions are equal, a lower limit of 1.8 TeV for the Kaluza-Klein mass is obtained.
- 4 ABOUD 18CE use 36.1 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV in final states with same-charge leptons and b-jets, to place a lower bound on the compactification scale in a model with two universal extra dimensions. Assuming the radii of the two extra dimensions are equal, a lower limit of 1.45 TeV for the Kaluza-Klein mass is obtained.
- 5 ACCOMANDO 15 use electroweak precision observables to place a lower bound on the compactification scale $1/R$. See their Fig. 2 for the bound as a function of $\sin\beta$, which parametrizes the VEV contribution from brane and bulk Higgs fields. The quoted value is for the minimum bound which occurs at $\sin\beta = 0.45$.
- 6 KHACHATRYAN 15T use 19.7 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV to place a lower bound on the compactification scale $1/R$.
- 7 CHATRCHYAN 13AQ use 5.0 fb⁻¹ of data from pp collisions at $\sqrt{s} = 7$ TeV and a further 3.7 fb⁻¹ of data at $\sqrt{s} = 8$ TeV to place a lower bound on the compactification scale $1/R$, in models with universal extra dimensions and Standard Model fields propagating in the bulk. See their Fig. 5 for the bound as a function of the universal bulk fermion mass parameter μ .
- 8 CHATRCHYAN 13W use diphoton events with large missing transverse momentum in 4.93 fb⁻¹ of data produced from pp collisions at $\sqrt{s} = 7$ TeV to place a lower bound on the compactification scale in a universal extra dimension model with gravitational decays. The bound assumes that the cutoff scale Λ , for the radiative corrections to the Kaluza-Klein masses, satisfies $\Lambda/M_C = 20$. The model parameters are chosen such that the decay $\gamma^* \rightarrow G\gamma$ occurs with an appreciable branching fraction.
- 9 EDELHAUSER 13 use 19.6 and 20.6 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV analyzed by the CMS Collaboration in the dielectron and dimuon channels, respectively,

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to place a lower bound on the mass of the second lightest Kaluza-Klein Z/γ boson (converted to a limit on $1/R = M_C$). The bound assumes Standard Model fields propagating in the bulk and that the cutoff scale Λ , for the radiative corrections to the Kaluza-Klein masses, satisfies $\Lambda/M_C = 20$.

10 AAD 12CP use diphoton events with large missing transverse momentum in 4.8 fb^{-1} of data produced from pp collisions at $\sqrt{s} = 7 \text{ TeV}$ to place a lower bound on the compactification scale in a universal extra dimension model with gravitational decays. The bound assumes that the cutoff scale Λ , for the radiative corrections to the Kaluza-Klein masses, satisfies $\Lambda/M_C = 20$. The model parameters are chosen such that the decay $\gamma^* \rightarrow G\gamma$ occurs with an appreciable branching fraction.

11 AAD 12X use diphoton events with large missing transverse momentum in 1.07 fb^{-1} of data produced from pp collisions at $\sqrt{s} = 7 \text{ TeV}$ to place a lower bound on the compactification scale in a universal extra dimension model with gravitational decays. The bound assumes that the cutoff scale Λ , for the radiative corrections to the Kaluza-Klein masses, satisfies $\Lambda/M_C = 20$. The model parameters are chosen such that the decay $\gamma^* \rightarrow G\gamma$ occurs with an appreciable branching fraction.

12 ABAZOV 12M use same-sign dimuon events in 7.3 fb^{-1} of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ to place a lower bound on the compactification scale $1/R$, in models with universal extra dimensions where all Standard Model fields propagate in the bulk.

13 BAAK 12 use electroweak precision observables to place a lower bound on the compactification scale $1/R$, in models with universal extra dimensions and Standard Model fields propagating in the bulk. Bound assumes a 125 GeV Higgs mass. See their Fig. 25 for the bound as a function of the Higgs mass.

14 FLACKE 12 use electroweak precision observables to place a lower bound on the compactification scale $1/R$, in models with universal extra dimensions and Standard Model fields propagating in the bulk. See their Fig. 1 for the bound as a function of the universal bulk fermion mass parameter μ .

15 NISHIWAKI 12 use up to 2 fb^{-1} of data from the ATLAS and CMS experiments that constrains the production cross section of a Higgs-like particle to place a lower bound on the compactification scale $1/R$ in universal extra dimension models. The quoted bound assumes Standard Model fields propagating in the bulk and a 125 GeV Higgs mass. See their Fig. 1 for the bound as a function of the Higgs mass.

16 AAD 11F use diphoton events with large missing transverse energy in 3.1 pb^{-1} of data produced from pp collisions at $\sqrt{s} = 7 \text{ TeV}$ to place a lower bound on the compactification scale in a universal extra dimension model with gravitational decays. The bound assumes that the cutoff scale Λ , for the radiative corrections to the Kaluza-Klein masses, satisfies $\Lambda/M_C = 20$. The model parameters are chosen such that the decay $\gamma^* \rightarrow G\gamma$ occurs with an appreciable branching fraction.

17 AAD 11X use diphoton events with large missing transverse energy in 36 pb^{-1} of data produced from pp collisions at $\sqrt{s} = 7 \text{ TeV}$ to place a lower bound on the compactification scale in a universal extra dimension model with gravitational decays. The bound assumes that the cutoff scale Λ , for the radiative corrections to the Kaluza-Klein masses, satisfies $\Lambda/M_C = 20$. The model parameters are chosen such that the decay $\gamma^* \rightarrow G\gamma$ occurs with an appreciable branching fraction.

18 ABAZOV 10P use diphoton events with large missing transverse energy in 6.3 fb^{-1} of data produced from $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ to place a lower bound on the compactification scale in a universal extra dimension model with gravitational decays. The bound assumes that the cutoff scale Λ , for the radiative corrections to the Kaluza-Klein masses, satisfies $\Lambda/M_C = 20$. The model parameters are chosen such that the decay $\gamma^* \rightarrow G\gamma$ occurs with an appreciable branching fraction.

19 ABAZOV 09AE use dijet angular distributions in 0.7 fb^{-1} of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ to place a lower bound on the compactification scale.

20 HAISCH 07 use inclusive B -meson decays to place a Higgs mass independent bound on the compactification scale $1/R$ in the minimal universal extra dimension model.

21 GOGOLADZE 06 use electroweak precision observables to place a lower bound on the compactification scale in models with universal extra dimensions. Bound assumes a 115 GeV Higgs mass. See their Fig. 3 for the bound as a function of the Higgs mass.

22 CORNET 00 translates a bound on the coefficient of the 4-fermion operator $(\bar{\ell}\gamma_\mu\tau^a\ell)(\bar{\ell}\gamma^\mu\tau^a\ell)$ derived by Hagiwara and Matsumoto into a limit on the mass scale of KK W bosons.

23 RIZZO 00 obtains limits from global electroweak fits in models with a Higgs in the bulk (3.8 TeV) or on the standard brane (3.3 TeV).

Limits on Kaluza-Klein Gravitons in Warped Extra Dimensions

This section places limits on the mass of the first Kaluza-Klein (KK) excitation of the graviton in the warped extra dimension model of Randall and Sundrum. Bounds in parenthesis assume Standard Model fields propagate in the bulk. Experimental bounds depend strongly on the warp parameter, k . See the "Extra Dimensions" review for a full discussion.

Here we list limits for the value of the warp parameter $k/\overline{M}_P = 0.1$.

VALUE (TeV)	CL%	DOCUMENT ID	TECN	COMMENT
>4.25	95	1 SIRUNYAN	18BB CMS	$pp \rightarrow G \rightarrow e^+e^-, \mu^+\mu^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
		2 AAD	20C ATLS	$pp \rightarrow G \rightarrow HH$
		3 AABOUD	19A ATLS	$pp \rightarrow G \rightarrow HH$
		4 AABOUD	19o ATLS	$pp \rightarrow G \rightarrow HH$
		5 AAD	19d ATLS	$pp \rightarrow G \rightarrow WW, ZZ$
		6 SIRUNYAN	19 CMS	$pp \rightarrow G \rightarrow HH$
		7 SIRUNYAN	19BE CMS	$pp \rightarrow G \rightarrow HH$
		8 SIRUNYAN	19CF CMS	$pp \rightarrow G \rightarrow HH$
		9 AABOUD	18AK ATLS	$pp \rightarrow G \rightarrow WW$
		10 AABOUD	18AL ATLS	$pp \rightarrow G \rightarrow ZZ$
		11 AABOUD	18BF ATLS	$pp \rightarrow G \rightarrow ZZ$
		12 AABOUD	18Bi ATLS	$pp \rightarrow G \rightarrow t\bar{t}$
		13 AABOUD	18Cj ATLS	$pp \rightarrow G \rightarrow VV, VH, \ell\bar{\ell}$
		14 AABOUD	18CQ ATLS	$pp \rightarrow G \rightarrow HH$
		15 AABOUD	18CWATLS	$pp \rightarrow G \rightarrow HH$
		16 SIRUNYAN	18AF CMS	$pp \rightarrow G \rightarrow HH$
		17 SIRUNYAN	18As CMS	$pp \rightarrow G \rightarrow ZZ$
		18 SIRUNYAN	18AX CMS	$pp \rightarrow G \rightarrow WW$

>1.8	95	19 SIRUNYAN	18Bk CMS	$pp \rightarrow G \rightarrow ZZ$
		20 SIRUNYAN	18Bo CMS	$pp \rightarrow G \rightarrow jj$
		21 SIRUNYAN	18cwCMS	$pp \rightarrow G \rightarrow HH$
		22 SIRUNYAN	18DJ CMS	$pp \rightarrow G \rightarrow ZZ$
>4.1	95	23 SIRUNYAN	18Du CMS	$pp \rightarrow G \rightarrow \gamma\gamma$
		24 SIRUNYAN	18f CMS	$pp \rightarrow G \rightarrow HH$
		25 SIRUNYAN	18i CMS	$pp \rightarrow G \rightarrow b\bar{b}$
		26 SIRUNYAN	18P CMS	$pp \rightarrow G \rightarrow WW, ZZ$
>4.1	95	27 AABOUD	17AP ATLS	$pp \rightarrow G \rightarrow \gamma\gamma$
		28 AAD	16R ATLS	$pp \rightarrow G \rightarrow WW, ZZ$
		29 AAD	15AU ATLS	$pp \rightarrow G \rightarrow ZZ$
		30 AAD	15AZ ATLS	$pp \rightarrow G \rightarrow WW$
		31 AAD	15CT ATLS	$pp \rightarrow G \rightarrow WW, ZZ$
>2.68	95	32 AAD	14V ATLS	$pp \rightarrow G \rightarrow e^+e^-, \mu^+\mu^-$
>1.23 (>0.84)	95	33 AAD	13A ATLS	$pp \rightarrow G \rightarrow WW$
>0.94 (>0.71)	95	34 AAD	13AO ATLS	$pp \rightarrow G \rightarrow WW$
>2.23	95	35 AAD	13As ATLS	$pp \rightarrow \gamma\gamma, e^+e^-, \mu^+\mu^-$
>0.845	95	36 AAD	12AD ATLS	$pp \rightarrow G \rightarrow ZZ$
		37 AALTONEN	12v CDF	$p\bar{p} \rightarrow G \rightarrow ZZ$
		38 BAAK	12 RVUE	Electroweak
		39 AALTONEN	11G CDF	$p\bar{p} \rightarrow G \rightarrow ZZ$
>1.058	95	40 AALTONEN	11R CDF	$p\bar{p} \rightarrow G \rightarrow e^+e^-, \gamma\gamma$
>0.754	95	41 ABAZOV	11H D0	$p\bar{p} \rightarrow G \rightarrow WW$
>0.607		42 AALTONEN	10N CDF	$p\bar{p} \rightarrow G \rightarrow WW$
>1.05		43 ABAZOV	10F D0	$p\bar{p} \rightarrow G \rightarrow e^+e^-, \gamma\gamma$
		44 AALTONEN	08S CDF	$p\bar{p} \rightarrow G \rightarrow ZZ$
>0.90		45 ABAZOV	08J D0	$p\bar{p} \rightarrow G \rightarrow e^+e^-, \gamma\gamma$
		46 AALTONEN	07G CDF	$p\bar{p} \rightarrow G \rightarrow \gamma\gamma$
>0.889		47 AALTONEN	07H CDF	$p\bar{p} \rightarrow G \rightarrow e\bar{e}$
>0.785		48 ABAZOV	05N D0	$p\bar{p} \rightarrow G \rightarrow \ell\ell, \gamma\gamma$
>0.71		49 ABULENCIA	05A CDF	$p\bar{p} \rightarrow G \rightarrow \ell\bar{\ell}$

1 SIRUNYAN 18BB use $35.9 (36.3) \text{ fb}^{-1}$ of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for dilepton resonances in the dielectron (dimuon) channel. See their paper for other limits with warp parameter values $k/\overline{M}_P = 0.01$ and 0.05 . This updates the results of KHACHATRYAN 17T.

2 AAD 20C use 36.1 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for Higgs boson pair production in the $b\bar{b}b\bar{b}, b\bar{b}W^+W^-$, and $b\bar{b}\tau^+\tau^-$ final states. See their Figure 5(b)(c) for limits on the cross section as a function of the KK graviton mass. In the case of $k/\overline{M}_P = 1$ and 2, gravitons are excluded in the mass range 260–3000 GeV and 260–1760 GeV, respectively.

3 AABOUD 19A use 36.1 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for Higgs boson pair production in the $b\bar{b}b\bar{b}$ final state. See their Figure 9 for limits on the cross section times branching fraction as a function of the KK graviton mass. Assuming $k/\overline{M}_P = 1$, gravitons in the mass range 313–1362 GeV are excluded. This updates the results of AABOUD 16I.

4 AABOUD 19o use 36.1 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for Higgs boson pair production in the $b\bar{b}WW$ final state. See their Figure 12 for limits on the cross section times branching fraction as a function of the KK graviton mass for $k/\overline{M}_P = 1$ and $k/\overline{M}_P = 2$.

5 AAD 19p use 139 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for diboson resonances in the all-hadronic final state. See their Figure 9(b) for the limit on the cross section times branching fraction as a function of the KK graviton mass, including theoretical values for $k/\overline{M}_P = 1$. This updates the results of AABOUD 18F.

6 SIRUNYAN 19 use 35.9 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for Higgs boson pair production in the $\gamma\gamma b\bar{b}$ final state. See their Figure 9 for limits on the cross section times branching fraction as a function of the KK graviton mass. Assuming $k/\overline{M}_P = 1$, gravitons in the mass range 290–810 GeV are excluded. This updates the result of KHACHATRYAN 16Bq.

7 SIRUNYAN 19BE use 35.9 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for Higgs boson pair production by combining the results from four final states: $b\bar{b}\gamma\gamma, b\bar{b}\tau^+\tau^-, b\bar{b}b\bar{b}$, and $b\bar{b}VV$. See their Figure 7 for limits on the cross section times branching fraction as a function of the KK graviton mass.

8 SIRUNYAN 19CF use 35.9 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for Higgs boson pair production in the $b\bar{b}q\bar{q}\ell\nu$ final state. See their Figure 7 for limits on the cross section times branching fraction as a function of the KK graviton mass, including theoretical values for $k/\overline{M}_P = 0.1$ and 0.3 .

9 AABOUD 18AK use 36.1 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for WW resonances in $\ell\nu q\bar{q}$ final states ($\ell = e, \mu$). See their Figure 7(d) for the limit on the cross section times branching fraction as a function of the KK graviton mass, including theoretical values for $k/\overline{M}_P = 1$. This updates the results of AABOUD 16AE.

10 AABOUD 18AL use 36.1 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for diboson resonances in the $\ell\ell q\bar{q}$ and $\nu\tau q\bar{q}$ final states. See their Figure 14 for the limit on cross section times branching fraction as a function of the KK graviton mass, including theoretical values for $k/\overline{M}_P = 0.5$ and 1 . This updates the results of AABOUD 16AE.

11 AABOUD 18BF use 36.1 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for ZZ resonances in the $\ell\ell\ell\ell$ and $\ell\ell\nu\bar{\nu}$ final states ($\ell = e, \mu$). See their Figure 10 for the limit on the cross section times branching fraction as a function of the KK graviton mass, including theoretical values for $k/\overline{M}_P = 1$.

12 AABOUD 18Bi use 36.1 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for top-quark pairs decaying into the lepton-plus jets topology. See their Figure 16 for the limit on the KK graviton mass as a function of the cross section times branching fraction, including theoretical values for $k/\overline{M}_P = 1$.

13 AABOUD 18Cj combine the searches for heavy resonances decaying into bosonic and leptonic final states from 36.1 fb^{-1} of pp collision data at $\sqrt{s} = 13 \text{ TeV}$. The lower limit on the KK graviton mass, with $k/\overline{M}_P = 1$, is 2.3 TeV.

14 AABOUD 18CQ use 36.1 fb^{-1} of data from pp collisions at $\sqrt{s} = 13 \text{ TeV}$ to search for Higgs boson pair production in the $b\bar{b}\tau^+\tau^-$ final state. See their Figure 2 for limits on the cross section times branching fraction as a function of the KK graviton mass. Assuming $k/\overline{M}_P = 1$, gravitons in the mass range 325–885 GeV are excluded.

- ¹⁵ AABOUD 18CW use 36.1 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for Higgs boson pair production in the $\gamma\gamma b\bar{b}$ final state. See their Figure 7 for limits on the cross section times branching fraction as a function of the KK graviton mass.
- ¹⁶ SIRUNYAN 18AF use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for Higgs boson pair production in the $b\bar{b}b\bar{b}$ final state. See their Figure 9 for limits on the cross section times branching fraction as a function of the KK graviton mass, including theoretical values for $k/\overline{M}_P = 0.5$. This updates the results of KHACHATRYAN 15R.
- ¹⁷ SIRUNYAN 18AS use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for ZZ resonances in the $\ell\ell\nu\bar{\nu}$ final state ($\ell = e, \mu$). See their Figure 5 for the limit on the KK graviton mass as a function of the cross section times branching fraction, including theoretical values for $k/\overline{M}_P = 0.1, 0.5$, and 1.0.
- ¹⁸ SIRUNYAN 18AX use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for WW resonances in $\ell\nu q\bar{q}$ final states ($\ell = e, \mu$). See their Figure 6 for the limit on the KK graviton mass as a function of the cross section times branching fraction, including theoretical values for $k/\overline{M}_P = 0.5$. This updates the results of KHACHATRYAN 14A.
- ¹⁹ SIRUNYAN 18BK use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for ZZ resonances in the $\nu\bar{\nu}q\bar{q}$ final state. See their Figure 4 for the limit on the KK graviton mass as a function of the cross section times branching fraction, including theoretical values for $k/\overline{M}_P = 0.5$.
- ²⁰ SIRUNYAN 18BO use up to 36 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for dijet resonances. Besides the quoted bound, KK graviton masses between 1.9 TeV and 2.5 TeV are also excluded. See their Figure 11 for the limit on the product of the cross section, branching fraction and acceptance as a function of the KK graviton mass. This updates the results of KHACHATRYAN 17W.
- ²¹ SIRUNYAN 18CW use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for Higgs boson pair production in the $b\bar{b}b\bar{b}$ final state. See their Figure 8 for limits on the cross section times branching fraction as a function of the KK graviton mass, including theoretical values for $k/\overline{M}_P = 0.5$.
- ²² SIRUNYAN 18DJ use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for ZZ resonances in $2\ell q$ final states ($\ell = e, \mu$). See their Figure 6 for the limit on the KK graviton mass as a function of the cross section times branching fraction. Assuming $k/\overline{M}_P = 0.5$, a graviton mass is excluded below 925 GeV.
- ²³ SIRUNYAN 18DU use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV, in the diphoton channel to place a lower limit on the mass of the lightest KK graviton. See their paper for limits with other warp parameter values $k/\overline{M}_P = 0.01$ and 0.2. This updates the results of KHACHATRYAN 16M.
- ²⁴ SIRUNYAN 18F use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for Higgs boson pair production in the $b\bar{b}\ell\nu\ell\nu$ final state. See their Figure 7 for limits on the cross section times branching fraction as a function of the KK graviton mass, including theoretical values for $k/\overline{M}_P = 0.1$.
- ²⁵ SIRUNYAN 18I use 19.7 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV to search for narrow resonances decaying to bottom quark pairs. See their Figure 3 for the limit on the KK graviton mass as a function of the cross section times branching fraction in the mass range of 325–1200 GeV.
- ²⁶ SIRUNYAN 18P use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for diboson resonances with dijet final states. See their Figure 6 for the limit on the KK graviton mass as a function of the cross section times branching fraction, including theoretical values for $k/\overline{M}_P = 0.5$. This updates the results of SIRUNYAN 17AK.
- ²⁷ AABOUD 17AP use 36.7 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV in the diphoton channel to place a lower limit on the mass of the lightest KK graviton. This updates the results of AABOUD 16H.
- ²⁸ AAD 16R use 20.3 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV to place a lower bound on the mass of the lightest KK graviton. See their Figure 4 for the limit on the KK graviton mass as a function of the cross section times branching fraction.
- ²⁹ AAD 15AU use 20 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV to search for KK gravitons in a warped extra dimension decaying to ZZ dibosons. See their Figure 2 for limits on the KK graviton mass as a function of the cross section times branching fraction.
- ³⁰ AAD 15AZ use 20.3 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV to place a lower bound on the mass of the lightest KK graviton. See their Figure 2 for limits on the KK graviton mass as a function of the cross section times branching ratio.
- ³¹ AAD 15CT use 20.3 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV to place a lower bound on the mass of the lightest KK graviton. See their Figures 6b and 6c for the limit on the KK graviton mass as a function of the cross section times branching fraction.
- ³² AAD 14V use 20.3 (20.5) fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV in the dielectron (dimuon) channels to place a lower bound on the mass of the lightest KK graviton. This updates the results of AAD 12CC.
- ³³ AAD 13A use 4.7 fb⁻¹ of data from pp collisions at $\sqrt{s} = 7$ TeV in the $\ell\nu\ell\nu$ channel, to place a lower bound on the mass of the lightest KK graviton.
- ³⁴ AAD 13AO use 4.7 fb⁻¹ of data from pp collisions at $\sqrt{s} = 7$ TeV in the $\ell\nu jj$ channel, to place a lower bound on the mass of the lightest KK graviton.
- ³⁵ AAD 13AS use 4.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 7$ TeV in the diphoton channel to place lower limits on the mass of the lightest KK graviton. The diphoton channel is combined with previous results in the dielectron and dimuon channels to set the best limit. See their Table 2 for warp parameter values k/\overline{M}_P between 0.01 and 0.1. This updates the results of AAD 12V.
- ³⁶ AAD 12AD use 1.02 fb⁻¹ of data from pp collisions at $\sqrt{s} = 7$ TeV to search for KK gravitons in a warped extra dimension decaying to ZZ dibosons in the $lljj$ and $llll$ channels ($\ell = e, \mu$). The limit is quoted for the combined $lljj + llll$ channels. See their Figure 5 for limits on the cross section $\sigma(G \rightarrow ZZ)$ as a function of the graviton mass.
- ³⁷ AALTONEN 12V use 6 fb⁻¹ of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to search for KK gravitons in a warped extra dimension decaying to ZZ dibosons in the $lljj$ and $llll$ channels ($\ell = e, \mu$). It provides improved limits over the previous analysis in AALTONEN 11G. See their Figure 16 for limits from all channels combined on the cross section times branching ratio $\sigma(p\bar{p} \rightarrow G^* \rightarrow ZZ)$ as a function of the graviton mass.
- ³⁸ BAAK 12 use electroweak precision observables to place a lower bound on the compactification scale $k e^{-\pi k R}$, assuming Standard Model fields propagate in the bulk and the Higgs is confined to the IR brane. See their Fig. 27 for more details.
- ³⁹ AALTONEN 11G use 2.5–2.9 fb⁻¹ of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to search for KK gravitons in a warped extra dimension decaying to ZZ dibosons via the $eeee, ee\mu\mu, \mu\mu\mu\mu, eejj$, and $\mu\mu jj$ channels. See their Fig. 20 for limits on the cross section $\sigma(G \rightarrow ZZ)$ as a function of the graviton mass.
- ⁴⁰ AALTONEN 11R uses 5.7 fb⁻¹ of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV in the dielectron channel to place a lower bound on the mass of the lightest graviton. It provides combined limits with the diphoton channel analysis of AALTONEN 11U. For

warp parameter values k/\overline{M}_P between 0.01 to 0.1 the lower limit on the mass of the lightest graviton is between 612 and 1058 GeV. See their Table I for more details.

- ⁴¹ ABAZOV 11H use 5.4 fb⁻¹ of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to place a lower bound on the mass of the lightest graviton. Their 95% C.L. exclusion limit does not include masses less than 300 GeV.
- ⁴² AALTONEN 10N use 2.9 fb⁻¹ of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to place a lower bound on the mass of the lightest graviton.
- ⁴³ ABAZOV 10F use 5.4 fb⁻¹ of data from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to place a lower bound on the mass of the lightest graviton. For warp parameter values of k/\overline{M}_P between 0.01 and 0.1 the lower limit on the mass of the lightest graviton is between 560 and 1050 GeV. See their Fig. 3 for more details.
- ⁴⁴ AALTONEN 08s use $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to search for KK gravitons in warped extra dimensions. They search for graviton resonances decaying to four electrons via two Z bosons using 1.1 fb⁻¹ of data. See their Fig. 8 for limits on $\sigma \cdot B(G \rightarrow ZZ)$ versus the graviton mass.
- ⁴⁵ ABAZOV 08J use $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to search for KK gravitons in warped extra dimensions. They search for graviton resonances decaying to electrons and photons using 1 fb⁻¹ of data. For warp parameter values of k/\overline{M}_P between 0.01 and 0.1 the lower limit on the mass of the lightest excitation is between 300 and 900 GeV. See their Fig. 4 for more details.
- ⁴⁶ AALTONEN 07G use $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to search for KK gravitons in warped extra dimensions. They search for graviton resonances decaying to photons using 1.2 fb⁻¹ of data. For warp parameter values of $k/\overline{M}_P = 0.1, 0.05$, and 0.01 the bounds on the graviton mass are 850, 694, and 230 GeV, respectively. See their Fig. 3 for more details. See also AALTONEN 07H.
- ⁴⁷ AALTONEN 07H use $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to search for KK gravitons in warped extra dimensions. They search for graviton resonances decaying to electrons using 1.3 fb⁻¹ of data. For a warp parameter value of $k/\overline{M}_P = 0.1$ the bound on the graviton mass is 807 GeV. See their Fig. 4 for more details. A combined analysis with the diphoton data of AALTONEN 07G yields for $k/\overline{M}_P = 0.1$ a graviton mass lower bound of 889 GeV.
- ⁴⁸ ABAZOV 05u use $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to search for KK gravitons in warped extra dimensions. They search for graviton resonances decaying to muons, electrons or photons, using 260 pb⁻¹ of data. For warp parameter values of $k/\overline{M}_P = 0.1, 0.05$, and 0.01, the bounds on the graviton mass are 785, 650 and 250 GeV respectively. See their Fig. 3 for more details.
- ⁴⁹ ABULENCIA 05A use $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to search for KK gravitons in warped extra dimensions. They search for graviton resonances decaying to muons or electrons, using 200 pb⁻¹ of data. For warp parameter values of $k/\overline{M}_P = 0.1, 0.05$, and 0.01, the bounds on the graviton mass are 710, 510 and 170 GeV respectively.

Limits on Kaluza-Klein Gluons in Warped Extra Dimensions

This section places limits on the mass of the first Kaluza-Klein (KK) excitation of the gluon in warped extra dimension models with Standard Model fields propagating in the bulk. Bounds are given for a specific benchmark model with $\Gamma/m = 15.3\%$ where Γ is the width and m the mass of the KK gluon. See the "Extra Dimensions" review for more discussion.

VALUE (TeV)	CL%	DOCUMENT ID	TECN	COMMENT
>3.8	95	¹ AABOUD 18BI ATLS	$g_{KK} \rightarrow t\bar{t} \rightarrow \ell j$	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
		² AABOUD 19AS ATLS	$g_{KK} \rightarrow t\bar{t} \rightarrow jj$	
		³ SIRUNYAN 19AL CMS	$g_{KK} \rightarrow t\bar{t}$	
>2.5	95	⁴ CHATRCHYAN 13BM CMS	$g_{KK} \rightarrow t\bar{t}$	
		⁵ CHEN 13A	$B \rightarrow X_S \gamma$	
>1.5	95	⁶ AAD 12BV ATLS	$g_{KK} \rightarrow t\bar{t} \rightarrow \ell j$	

¹ AABOUD 18BI use 36.1 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV. This result updates AAD 13AQ.

² AABOUD 19AS use 36.1 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV. An upper bound of 3.4 TeV is placed on the KK gluon mass for $\Gamma/m = 30\%$.

³ SIRUNYAN 19AL use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to place limits on a KK gluon decaying to a top quark and a heavy vector-like fermion, T. KK gluon masses between 1.5 and 2.3 TeV and between 2.0 and 2.4 TeV are excluded for T masses of 1.2 and 1.5 TeV, respectively.

⁴ CHATRCHYAN 13BM use 19.7 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV. Bound is for a width of approximately 15–20% of the KK gluon mass.

⁵ CHEN 13A place limits on the KK mass scale for a specific warped model with custodial symmetry and bulk fermions. See their Figures 4 and 5.

⁶ AAD 12BV use 2.05 fb⁻¹ of data from pp collisions at $\sqrt{s} = 7$ TeV.

Black Hole Production Limits

Semiclassical Black Holes

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
	¹ SIRUNYAN 18DA CMS	$pp \rightarrow \text{multijet}$	
	² AAD 16N ATLS	$pp \rightarrow \text{multijet}$	
	³ AAD 16O ATLS	$pp \rightarrow \ell + (\ell\ell/lj/jj)$	
	⁴ AAD 13AW ATLS	$pp \rightarrow \mu\mu$	

¹ SIRUNYAN 18DA use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for semiclassical black holes decaying to multijet final states. No excess of events above the expected level of standard model background was observed. Exclusions at 95% CL are set on the mass threshold for black hole production as a function of the higher-dimensional Planck scale for rotating and nonrotating black holes under several model assumptions (ADD, 2, 4, 6 extra dimensions model) in the 7.1–10.3 TeV range. These limits supersede those in SIRUNYAN 17CP.

² AAD 16N use 3.6 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for semiclassical black hole decays to multijet final states. No excess of events above the expected level of Standard Model background was observed. Exclusion contours at 95% C.L. are set on the mass threshold for black hole production versus higher-dimensional Planck scale for rotating black holes (ADD, 6 extra dimensions model).

Searches Particle Listings

Extra Dimensions

- ³ AAD 16o use 3.2 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for semi-classical black hole decays to high-mass final states with leptons and jets. No excess of events above the expected level of Standard Model background was observed. Exclusion contours at 95% C.L. are set on the mass threshold for black hole production versus higher-dimensional Planck scale for rotating black holes (ADD, 2 to 6 extra dimensions).
- ⁴ AAD 13aw use 20.3 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV to search for semi-classical black hole decays to like-sign dimuon final states using large track multiplicity. No excess of events above the expected level of Standard Model background was observed. Exclusion contours at 95% C.L. are set on the mass threshold for black hole production versus higher-dimensional Planck scale in various extra dimensions, rotating and non-rotating models.

Quantum Black Holes

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
● ● ●	We do not use the following data for averages, fits, limits, etc. ● ● ●		
¹	AABOUD 18BA ATLS	$pp \rightarrow \gamma j$	
²	AABOUD 18CM ATLS	$pp \rightarrow e\mu, e\tau, \mu\tau$	
³	SIRUNYAN 18AT CMS	$pp \rightarrow e\mu$	
⁴	SIRUNYAN 18DD CMS	$pp \rightarrow$ dijet, ang. distrib.	
⁵	AABOUD 17AK ATLS	$pp \rightarrow jj$	
⁶	SIRUNYAN 17CP CMS	$pp \rightarrow jj$	
⁷	KHACHATRYAN...16BE CMS	$pp \rightarrow e\mu$	
⁸	KHACHATRYAN...15V CMS	$pp \rightarrow jj$	
⁹	AAD 14AL ATLS	$pp \rightarrow \ell j$	
¹⁰	AAD 14V ATLS	$pp \rightarrow ee, \mu\mu$	
¹¹	CHATRCHYAN13A CMS	$pp \rightarrow jj$	

- ¹ AABOUD 18BA use 36.7 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for quantum black hole decays to final states with a photon and a jet. No excess of events above the expected level of Standard Model background was observed. Exclusion limits at 95% C.L. are set on mass thresholds for black hole production in ADD (6 extra dimensions) and RS1 models. Assuming the black hole mass threshold is equal to the Planck scale, mass thresholds below 7.1 TeV and 4.4 TeV are excluded for the ADD and RS1 models, respectively. These limits supersede those in AAD 16A1.
- ² AABOUD 18CM use 36.1 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for quantum black hole decays with different-flavor high-mass dilepton final states. No excess of events above the expected level of Standard Model background was observed. Exclusion limits at 95% C.L. are set on mass thresholds for black hole production in ADD (6 extra dimensions) and RS1 models. Assuming the black hole mass threshold is equal to the higher-dimensional Planck scale, mass thresholds below 5.6 (3.4), 4.9 (2.9), and 4.5 (2.6) TeV are excluded in the $e\mu, e\tau$ and $\mu\tau$ channels for the ADD (RS1) models, respectively. These limits supersede those in AABOUD 16P.
- ³ SIRUNYAN 18AT use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for quantum black hole decays to $e\mu$ final states. In Figure 4, lower mass limits of 5.3, 5.5 and 5.6 TeV are placed in a model with 4, 5 and 6 extra dimensions, respectively, and a lower mass limit of 3.6 TeV is found for a single warped dimension.
- ⁴ SIRUNYAN 18DD use 35.9 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for quantum black hole decays in dijet angular distributions. A lower mass limit of 5.9 (8.2) TeV is placed in the RS (ADD) model with one (six) extra dimension(s).
- ⁵ AABOUD 17AK use 37 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for quantum black hole decays to final states with dijets. No excess of events above the expected level of Standard Model background was observed. Exclusion limits at 95% C.L. are set on mass thresholds for black hole production in an ADD (6 extra dimensions) model. Assuming the black hole mass threshold is equal to the higher-dimensional Planck scale, mass thresholds below 8.9 TeV are excluded.
- ⁶ SIRUNYAN 17CP use 2.3 fb⁻¹ of data from pp collisions at $\sqrt{s} = 13$ TeV to search for quantum black holes decaying to dijet final states. No excess of events above the expected level of standard model background was observed. Limits on the quantum black hole mass threshold are set as a function of the higher-dimensional Planck scale, under the assumption that the mass threshold must exceed the above Planck scale. Depending on the model, mass thresholds in the range up to 5.1–9.0 TeV are excluded.
- ⁷ KHACHATRYAN 16BE use 19.7 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV to search for quantum black holes undergoing lepton flavor violating decay to the $e\mu$ final state. No excess of events above the expected level of standard model background was observed. Exclusion limits at 95% CL are set on mass thresholds for black hole production in the ADD (2–6 flat extra dimensions), RS1 (1 warped extra dimension), and a model with a Planck scale at the TeV scale from a renormalization of the gravitational constant (no extra dimensions). Limits on the black hole mass threshold are set assuming that it is equal to the higher-dimensional Planck scale. Mass thresholds for quantum black holes in the range up to 3.15–3.63 TeV are excluded in the ADD model. In the RS1 model, mass thresholds below 2.81 TeV are excluded in the PDG convention for the Schwarzschild radius. In the model with no extra dimensions, mass thresholds below 1.99 TeV are excluded.
- ⁸ KHACHATRYAN 15V use 19.7 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV to search for quantum black holes decaying to dijet final states. No excess of events above the expected level of standard model background was observed. Exclusion limits at 95% CL are set on mass thresholds for black hole production in the ADD (2–6 flat extra dimensions) and RS1 (1 warped extra dimension) model. Limits on the black hole mass threshold are set as a function of the higher-dimensional Planck scale, under the assumption that the mass threshold must exceed the above Planck scale. Depending on the model, mass thresholds in the range up to 5.0–6.3 TeV are excluded. This paper supersedes CHATRCHYAN 13AD.
- ⁹ AAD 14AL use 20.3 fb⁻¹ of data from pp collisions at $\sqrt{s} = 8$ TeV to search for quantum black hole decays to final states with high-invariant-mass lepton + jet. No excess of events above the expected level of Standard Model background was observed. Exclusion limits at 95% C.L. are set on mass thresholds for black hole production in ADD (6 extra dimensions) model. Assuming the black hole mass threshold is equal to the higher-dimensional Planck scale, mass thresholds below 5.3 TeV are excluded.
- ¹⁰ AAD 14V use 20.3 (20.5) fb⁻¹ of data in the dielectron (dimuon) channels from pp collisions at $\sqrt{s} = 8$ TeV to search for quantum black hole decays involving high-mass dilepton resonances. No excess of events above the expected level of Standard Model background was observed. Exclusion limits at 95% C.L. are set on mass thresholds for black hole production in ADD (6 extra dimensions) and RS1 models. Assuming the black hole mass threshold is equal to the higher-dimensional Planck scale, mass thresholds below 3.65 TeV and 2.24 TeV are excluded for the ADD and RS1 models, respectively.

- ¹¹ CHATRCHYAN 13A use 5 fb⁻¹ of data from pp collisions at $\sqrt{s} = 7$ TeV to search for quantum black holes decaying to dijet final states. No excess of events above the expected level of standard model background was observed. Exclusion limits at 95% CL are set on mass thresholds for black hole production in the ADD (2–6 flat extra dimensions) and RS (1 warped extra dimension) model. Limits on the black hole mass threshold are set as a function of the higher-dimensional Planck scale, under assumption that the mass threshold must exceed the above Planck scale. Depending on the model, mass thresholds in the range up to 4.0–5.3 TeV are excluded.

REFERENCES FOR Extra Dimensions

AAD	20C	PL B800	135103	G. Aad <i>et al.</i>	(ATLAS Collab.)
AABOUD	19A	JHEP	1901 030	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	19AS	PR D99	092004	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	19O	JHEP	1904 092	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AAD	19D	JHEP	1909 091	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	19	PL B788	7	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19AC	JHEP	1904 114	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19AL	EPJ C79	208	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19BE	PRL 122	121803	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19CF	JHEP	1910 125	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
AABOUD	18AK	JHEP	1803 042	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18AL	JHEP	1803 009	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18AV	JHEP	1807 089	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18BA	EPJ C78	102	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18BF	EPJ C78	293	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18BI	EPJ C78	565	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18CE	JHEP	1812 039	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18CJ	PR D98	052008	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18CM	PR D98	092008	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18CQ	PRL 121	191801	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18CW	JHEP	1811 040	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18F	PL B777	91	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	18I	JHEP	1801 126	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
BERGE	18	PRL 120	141101	J. Berge <i>et al.</i>	(MICROSCOPE Collab.)
FAYET	18	PR D97	055039	P. Fayet	(EPOL)
FAYET	18A	PR D99	055043	P. Fayet	(ENSP, EPOL)
HADDOCK	18	PR D97	062002	C. Haddock <i>et al.</i>	(NAGO, KEK, OSAK+)
SIRUNYAN	18AF	PL B781	244	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18AS	JHEP	1803 003	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18AT	JHEP	1804 073	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18AX	JHEP	1805 088	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18BB	JHEP	1806 120	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18BK	JHEP	1807 075	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18BO	JHEP	1808 130	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18BV	EPJ C78	291	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18CW	JHEP	1808 152	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18DA	JHEP	1811 042	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18DD	EPJ C78	789	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18DJ	JHEP	1809 101	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18DU	PR D98	092001	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18F	JHEP	1801 054	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18I	PRL 120	201801	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18P	PR D97	072006	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18S	PR D97	092005	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
AABOUD	17AK	PR D96	052004	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	17AP	PL B775	105	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN...17T	PL B768	57		V. Khachatryan <i>et al.</i>	(CMS Collab.)
KHACHATRYAN...17W	PL B769	520		V. Khachatryan <i>et al.</i>	(CMS Collab.)
KLIMCHITSKYA...	17A	PR D95	123013	G.L. Klimchitskaya, V.M. Mostepanenko	(CMS Collab.)
SIRUNYAN	17AK	PL B774	533	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	17AQ	JHEP	1710 073	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	17CP	PL B774279		A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	17F	JHEP	1707 013	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
AABOUD	16AE	JHEP	1609 173	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	16D	PR D94	032005	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	16F	JHEP	1606 059	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	16H	JHEP	1609 001	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	16I	PR D94	052002	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	16P	EPJ C76	541	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AAD	16A1	JHEP	1603 041	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	16N	JHEP	1603 026	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	16O	PL B760	520	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	16R	PL B755	285	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN...16BE	EPJ C76	317		V. Khachatryan <i>et al.</i>	(CMS Collab.)
KHACHATRYAN...16BQ	PR D94	052012		V. Khachatryan <i>et al.</i>	(CMS Collab.)
KHACHATRYAN...16M	PRL 117	051802		V. Khachatryan <i>et al.</i>	(CMS Collab.)
KHACHATRYAN...16N	PL B755	102		V. Khachatryan <i>et al.</i>	(CMS Collab.)
AAD	15AU	EPJ C75	69	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	15AZ	EPJ C75	209	G. Aad <i>et al.</i>	(ATLAS Collab.)
Also	EPJ C75	370 (errat.)		G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	15CS	PR D91	012008	G. Aad <i>et al.</i>	(ATLAS Collab.)
Also	PR D92	059903 (errat.)		G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	15CT	JHEP	1512 055	G. Aad <i>et al.</i>	(ATLAS Collab.)
ACCOMANDO	15	MPL A30	1540010	E. Accomando	(SHMP)
KHACHATRYAN...15AE	JHEP	1504 025		V. Khachatryan <i>et al.</i>	(CMS Collab.)
KHACHATRYAN...15AL	EPJ C75	235		V. Khachatryan <i>et al.</i>	(CMS Collab.)
KHACHATRYAN...15R	PL B749	560		V. Khachatryan <i>et al.</i>	(CMS Collab.)
KHACHATRYAN...15T	PR D91	092005		V. Khachatryan <i>et al.</i>	(CMS Collab.)
KHACHATRYAN...15V	PR D91	052009		V. Khachatryan <i>et al.</i>	(CMS Collab.)
AAD	14AL	PRL 112	091804	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	14BE	EPJ C74	3134	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	14V	PR D90	052005	G. Aad <i>et al.</i>	(ATLAS Collab.)
KHACHATRYAN...14A	JHEP	1408 174		V. Khachatryan <i>et al.</i>	(CMS Collab.)
AAD	13A	PL B718	860	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	13AO	PR D87	112006	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	13AQ	PR D88	012004	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	13AS	NJP 15	043007	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	13AW	PR D88	072001	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	13C	PRL 110	011802	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	13D	JHEP	1301 029	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	13E	PR D87	015010	G. Aad <i>et al.</i>	(ATLAS Collab.)
CHATRCHYAN	13A	JHEP	1301 013	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
CHATRCHYAN	13AD	JHEP	1307 178	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
CHATRCHYAN	13AQ	PR D87	072005	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
CHATRCHYAN	13BM	PRL 111	211804	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
Also	PRL 112	119903 (errat.)		S. Chatrchyan <i>et al.</i>	(CMS Collab.)
CHATRCHYAN	13W	JHEP	1303 111	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
CHEN	13A	CP C37	063102	J.-B. Chen <i>et al.</i>	(DALI)
EDELHAUSER	13	JHEP	1308 091	L. Edelhauser, T. Flacke, M. Kramer	(AACH, KAIST)
XU	13	JP G40	035107	J. Xu <i>et al.</i>	
AAD	12AD	PL B712	331	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	12BV	JHEP	1209 041	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	12CC	JHEP	1211 138	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	12CP	PL B718	411	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	12X	PL B710	519	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	12Y	PL B710	538	G. Aad <i>et al.</i>	(ATLAS Collab.)
AALTONEN	12M	PR D85	012008	T. Aaltonen <i>et al.</i>	(CDF Collab.)
ABAZOV	12M	PRL 108	131802	V.M. Abazov <i>et al.</i>	(DO Collab.)

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Searches Particle Listings
Extra Dimensions, WIMP and Dark Matter Searches

AJELLO	12	JCAP 1202 012	M. Ajello <i>et al.</i>	(Fermi-LAT Collab.)
BAAK	12	EPJ C72 2003	M. Baak <i>et al.</i>	(Glitter Group)
CHATRCHYAN	12R	PRL 108 111801	S. Chattrchyan <i>et al.</i>	(CMS Collab.)
FLACKE	12	PR D85 126007	T. Flacke, C. Pasold	(WURZ)
NISHIWAKI	12	PL B707 506	K. Nishiwaki <i>et al.</i>	(KOBÉ, OSAK)
AAD	11F	PRL 106 121803	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	11X	EPJ C71 1744	G. Aad <i>et al.</i>	(ATLAS Collab.)
AALTONEN	11G	PR D83 112008	T. Aaltonen <i>et al.</i>	(CDF Collab.)
AALTONEN	11R	PRL 107 051801	T. Aaltonen <i>et al.</i>	(CDF Collab.)
AALTONEN	11U	PR D83 011102	T. Aaltonen <i>et al.</i>	(CDF Collab.)
AARON	11C	PL B705 52	F. D. Aaron <i>et al.</i>	(H1 Collab.)
ABAZOV	11H	PRL 107 011801	V.M. Abazov <i>et al.</i>	(D0 Collab.)
BEZERRA	11	PR D83 075004	V.B. Bezerra <i>et al.</i>	
SUSHKOV	11	PRL 107 171101	A.O. Sushkov <i>et al.</i>	
AALTONEN	10N	PRL 104 241801	T. Aaltonen <i>et al.</i>	(CDF Collab.)
ABAZOV	10F	PRL 104 241802	V.M. Abazov <i>et al.</i>	(D0 Collab.)
ABAZOV	10P	PRL 105 221802	V.M. Abazov <i>et al.</i>	(D0 Collab.)
BEZERRA	10	PR D81 055003	V.B. Bezerra <i>et al.</i>	
ABAZOV	09AE	PRL 103 191803	V.M. Abazov <i>et al.</i>	(D0 Collab.)
ABAZOV	09D	PRL 102 051601	V.M. Abazov <i>et al.</i>	(D0 Collab.)
MASUDA	09	PRL 102 171101	M. Masuda, M. Sasaki	(ICRR)
AALTONEN	08AC	PRL 101 181602	T. Aaltonen <i>et al.</i>	(CDF Collab.)
AALTONEN	08S	PR D78 012008	T. Aaltonen <i>et al.</i>	(CDF Collab.)
ABAZOV	08J	PRL 100 091802	V.M. Abazov <i>et al.</i>	(D0 Collab.)
ABAZOV	08S	PRL 101 011601	V.M. Abazov <i>et al.</i>	(D0 Collab.)
DAS	08	PR D78 063011	P.K. Das, V.H.S. Kumar, P.K. Suresh	
GERACI	08	PR D78 022002	A.A. Geraci <i>et al.</i>	(STAN)
TRENKEL	08	PR D77 122001	C. Trenkel	
AALTONEN	07G	PRL 99 171801	T. Aaltonen <i>et al.</i>	(CDF Collab.)
AALTONEN	07H	PRL 99 171802	T. Aaltonen <i>et al.</i>	(CDF Collab.)
DECCA	07A	EPJ C51 963	R.S. Decca <i>et al.</i>	
HAISCH	07	PR D76 034014	U. Haisch, A. Weiler	
KAPNER	07	PRL 98 021101	D.J. Kapner <i>et al.</i>	
SCHAEF	07A	EPJ C49 411	S. Schaefer <i>et al.</i>	(ALEPH Collab.)
TU	07	PRL 98 201101	L.-C. Tu <i>et al.</i>	
ABDALLAH	06C	EPJ C45 589	J. Abdallah <i>et al.</i>	(DELPHI Collab.)
ABULENCIA	A	PRL 97 171802	A. Abulencia <i>et al.</i>	(CDF Collab.)
GERDES	06	PR D73 112008	D. Gerdes <i>et al.</i>	
GOGOLADZE	06	PR D74 093012	I. Gogoladze, C. Macesanu	
ABAZOV	05N	PRL 95 091801	V.M. Abazov <i>et al.</i>	(D0 Collab.)
ABAZOV	05V	PRL 95 161602	V.M. Abazov <i>et al.</i>	(D0 Collab.)
ABDALLAH	05B	EPJ C38 395	J. Abdallah <i>et al.</i>	(DELPHI Collab.)
ABULENCIA	05A	PRL 95 252001	A. Abulencia <i>et al.</i>	(CDF Collab.)
SMULLIN	05	PR D72 122001	S.J. Smullin <i>et al.</i>	
ACHARD	04E	PL B587 16	P. Achard <i>et al.</i>	(L3 Collab.)
ACOSTA	04C	PRL 92 121802	D. Acosta <i>et al.</i>	(CDF Collab.)
BARBIERI	04	NP B703 127	R. Barbieri <i>et al.</i>	
CASSE	04	PRL 92 111102	M. Casse <i>et al.</i>	
CHEKANOV	04B	PL B591 23	S. Chekanov <i>et al.</i>	(ZEUS Collab.)
HOYLE	04	PR D70 042004	C.D. Hoyle <i>et al.</i>	(WASH)
ABAZOV	03	PRL 90 251802	V.M. Abazov <i>et al.</i>	(D0 Collab.)
ABBIENDI	03D	EPJ C26 331	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ACHARD	03D	PL B572 133	P. Achard <i>et al.</i>	(L3 Collab.)
ADLOFF	03	PL B568 35	C. Adloff <i>et al.</i>	(H1 Collab.)
CHIAVERINI	03	PRL 90 151101	J. Chiaverini <i>et al.</i>	
GIUDICE	03	NP B663 377	G.F. Giudice, A. Strumia	
HANNESSTAD	03	PR D67 125008	S. Hannestad, G.G. Raffelt	
Also		PR D69 029901(errat.)	S. Hannestad, G.G. Raffelt	
HEISTER	03C	EPJ C28 1	A. Heister <i>et al.</i>	(ALEPH Collab.)
LONG	03	Nature 421 922	J.C. Long <i>et al.</i>	
ACHARD	02	PL B524 65	P. Achard <i>et al.</i>	(L3 Collab.)
ACHARD	02D	PL B531 28	P. Achard <i>et al.</i>	(L3 Collab.)
HANNESSTAD	02	PRL 88 071301	S. Hannestad, G. Raffelt	
ABBOTT	01	PRL 86 1156	B. Abbott <i>et al.</i>	(D0 Collab.)
FAIRBAIRN	01	PL B508 335	M. Fairbairn	
HANHART	01	PL B509 1	C. Hanhart <i>et al.</i>	
HOYLE	01	PRL 86 1418	C.D. Hoyle <i>et al.</i>	
ABBIENDI	00R	EPJ C13 553	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ABREU	00A	PL B491 67	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABREU	00S	PL B485 45	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABREU	00Z	EPJ C17 53	P. Abreu <i>et al.</i>	(DELPHI Collab.)
CASSISI	00	PL B481 323	S. Cassisi <i>et al.</i>	
CHANG	00B	PRL 85 3765	L.N. Chang <i>et al.</i>	
CHEUNG	00	PR D61 015005	K. Cheung	
CORNET	00	PR D61 037701	F. Cornet, M. Relano, J. Rico	
GRAESSER	00	PR D61 074019	M.L. Graesser	
HAN	00	PR D62 125018	T. Han, D. Marfatia, R.-J. Zhang	
MATHEWS	00	JHEP 0007 008	P. Mathews, S. Raychaudhuri, K. Sridhar	
MELE	00	PR D61 117901	S. Mele, E. Sanchez	
RIZZO	00	PR D61 016007	T.G. Rizzo, J.D. Wells	
ABBIENDI	99P	PL B465 303	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ACCIARRI	99M	PL B464 135	M. Acciari <i>et al.</i>	(L3 Collab.)
ACCIARRI	99R	PL B470 268	M. Acciari <i>et al.</i>	(L3 Collab.)
ACCIARRI	99S	PL B470 281	M. Acciari <i>et al.</i>	(L3 Collab.)
BOURLIKOV	99	JHEP 9908 006	D. Bourlikov	
HOSKINS	85	PR D32 3084	J.K. Hoskins <i>et al.</i>	

WIMP and Dark Matter Searches

We omit papers on CHAMP's, millicharged particles, and other exotic particles.

GALACTIC WIMP SEARCHES

These limits are for weakly-interacting stable particles that may constitute the invisible mass in the galaxy. Unless otherwise noted, a local mass density of 0.3 GeV/cm³ is assumed; see each paper for velocity distribution assumptions. In the papers the limit is given as a function of the χ^0 mass. Here we list limits only for typical mass values of sub-GeV, GeV, 20 GeV, 100 GeV, and 1 TeV. Specific limits on supersymmetric dark matter particles may be found in the Supersymmetry section.

Spin-Independent Cross Section Limits
for Dark Matter Particle (χ^0) on Nucleon

For m_{χ^0} in GeV range

We provide here limits for $m_{\chi^0} < 5$ GeV

VALUE (pb)	CL %	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<1 \times 10^{-2}$	90	1 ABDELHAME...19A	CRES	CaWO ₄
$<5.4 \times 10^{-6}$	90	2 AGNESE	19A	SCDM GeV-scale WIMPs on Ge
<1	90	3 AKERIB	19	LUX light DM on Xe via Migdal/brem effect
$<1 \times 10^{-6}$	90	4 AMOLE	19	PICO C ₃ F ₈
$<1.6 \times 10^{-3}$	90	5 APRILE	19c	XE1T DM on Xe
$<1 \times 10^{-7}$	90	6 APRILE	19d	XE1T DM on Xe
<0.1	90	7 ARMENGAUD	19	EDEL GeV-scale WIMPs on Ge
$<1.6 \times 10^3$	90	8 KOBAYASHI	19	XMAS annual modulation Xe
$<7 \times 10^2$	90	9 LIU	19b	CDEX Ge; sub-GeV DM via Migdal
$<7 \times 10^{-7}$	90	10 AGNES	18	DS50 GeV-scale WIMPs on Ar
$<1.5 \times 10^{-5}$	95	11 AGNESE	18	SCDM GeV-scale WIMPs on Ge
$<2 \times 10^{-8}$	90	12 APRILE	18	XE1T Xe, Si
$<4.5 \times 10^{-3}$	90	13 ARNAUD	18	NEWS low mass WIMP, Ne
$<8 \times 10^{-6}$	90	14 JIANG	18	CDEX GeV-scale WIMPs on Ge
$<3 \times 10^{-5}$	90	15 YANG	18	CDEX WIMPs on Ge
$<1 \times 10^{-6}$	90	16 AKERIB	17	LUX Xe
$<1 \times 10^2$	90	17 ANGLOHER	17A	CRES GeV-scale WIMPs
$<7 \times 10^{-5}$	90	18 ANGLOHER	16	CRES CaWO ₄
$<3 \times 10^{-5}$	90	19 APRILE	16	X100 Xe
$<4.3 \times 10^{-4}$	90	20 ARMENGAUD	16	EDE3 GeV-scale WIMPs on Ge
$<7 \times 10^{-5}$	90	21 HEHN	16	EDE3 Si WIMP on Ge
$<6 \times 10^{-5}$	90	22 ZHAO	16	CDEX GeV-scale WIMPs on Ge
$<1 \times 10^{-4}$	90	23 AMOLE	15	PICO C ₃ F ₈
$<8 \times 10^{-5}$	90	24 XIAO	15	PNDX WIMPs on Xe
$<3 \times 10^{-5}$	90	25 AGNESE	14	SCDM GeV-scale WIMPs
$<1 \times 10^{-3}$	90	26 AKERIB	14	LUX WIMP on Xe
$<9 \times 10^{-4}$	90	27 LI	13b	TEXO WIMPs on Ge
$<3 \times 10^{-4}$	90	28 ARCHAMBAU.12	PICA	C ₄ F ₁₀
$<2 \times 10^{-4}$	90	29 AALSETH	11	CGNT GeV WIMPs on Ge
$<5 \times 10^{-4}$	90	30 AHMED	11b	CDM2 GeV-scale WIMPs on Ge
$<8 \times 10^{-5}$	90	31 ANGLE	11	XE10 Xe
$<5 \times 10^{-4}$	90	32 AKERIB	10	CDM2 WIMPs on Ge/Si

- 1 ABDELHAMEED 19A search for GeV scale dark matter Si scatter on CaWO₄; no signal, limits placed in σ vs. mass plane for $m(\text{DM}) \sim 0.1\text{--}10$ GeV. The listed limit is for $m(\text{DM}) = 1$ GeV.
- 2 AGNESE 19A search for 1.5–10 GeV WIMP scatter on Ge in CDMSlite dataset. Limits set in a likelihood analysis. No signal was observed. Limit reported for $m(\chi) = 5$ GeV.
- 3 AKERIB 19 search for 0.4–5 GeV DM using bremsstrahlung photons and “Migdal” electrons; 1.4×10^4 kg d exposure of liquid Xe; constraint $\sigma^{SI}(\chi N) < 1$ pb for $m(\chi) = 5$ GeV in light scalar mediator model.
- 4 AMOLE 19 search for Si WIMP scatter on C₃F₈ in PICO-60 bubble chamber; no signal; set limit for spin independent coupling $\sigma^{SI}(\chi N) < 1 \times 10^{-6}$ pb for $m(\chi) = 5$ GeV.
- 5 APRILE 19c search for light DM scatter on Xe via atomic excitation, ionization (Migdal effect) or bremsstrahlung; no signal, limits placed in σ vs. $m(\text{DM})$ plane for $m(\text{DM}) \sim 0.085\text{--}2$ GeV. The listed limit is for $m(\text{DM}) = 1$ GeV.
- 6 APRILE 19d search for light DM scatter on Xe via ionization to probe Si, SD, and χ e cross sections; with 22 t d exposure, limits placed in various σ vs. $m(\text{DM})$ planes. Quoted limit is for $m(\text{DM}) = 5$ GeV.
- 7 ARMENGAUD 19search for GeV scale WIMP scatter on Ge; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 0.045\text{--}10$ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 8 KOBAYASHI 19 search for sub-GeV WIMP annual modulation in Xe via brems; no signal; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m \sim 0.3\text{--}1$ GeV; quoted limit is for $m(\chi) = 0.5$ GeV.
- 9 LIU 19b search for sub-GeV DM using Migdal effect on Ge at CDEX-1B; no signal, require $\sigma^{SI}(\chi N) < 7 \times 10^2$ pb for $m(\chi) = 0.1$ GeV.
- 10 AGNES 18 search for 1.8–20 GeV WIMP Si scatter on Ar; quoted limit is for $m(\chi) = 5$ GeV.
- 11 AGNESE 18 search for GeV scale WIMPs using CDMSlite; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m \sim 1.5\text{--}20$ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 12 APRILE 18 search for WIMP scatter on 1 t yr Xe; no signal, limits set in $\sigma(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 6\text{--}1000$ GeV; quoted limit is for $m = 6$ GeV.
- 13 ARNAUD 18 search for low mass WIMP scatter on Ne via SPC at NEWS-G; limits set in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m \sim 0.5\text{--}20$ GeV; quoted limit is for $m = 5$ GeV.
- 14 JIANG 18 search for GeV scale WIMP scatter on Ge; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 3\text{--}10$ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 15 YANG 18 search for WIMP scatter on Ge; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 2\text{--}10$ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 16 AKERIB 17 search for WIMP scatter on Xe; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5\text{--}1 \times 10^5$ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 17 ANGLOHER 17A search for GeV scale WIMP scatter on Al₂O₃ crystal; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 0.15\text{--}10$ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 18 ANGLOHER 16 search for GeV scale WIMP scatter on CaWO₄; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 0.5\text{--}30$ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 19 APRILE 16 search for low mass WIMPs via ionization at XENON100; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m \sim 3.5\text{--}20$ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 20 ARMENGAUD 16 search for GeV scale WIMP scatter on Ge; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4\text{--}30$ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 21 HEHN 16 search for low mass WIMPs via Si scatter on Ge target using profile likelihood analysis; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4\text{--}30$ GeV; quoted limit is for $m(\chi) = 5$ GeV.

Searches Particle Listings

WIMP and Dark Matter Searches

- ²² ZHAO 16 search for GeV-scale WIMP scatter on Ge; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ –30 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- ²³ AMOLE 15 search for WIMP scatter on C_3F_8 in PICO-2L; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ –25 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- ²⁴ XIAO 15 search for WIMP scatter on Xe with PandaX-I; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ –100 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- ²⁵ AGNESE 14 search for GeV scale WIMPs SI scatter at SuperCDMS; no signal, limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 3.5$ –30 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- ²⁶ AKERIB 14 search for WIMP scatter on Xe; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ –5000 GeV. Limit given for $m(\chi) = 5$ GeV.
- ²⁷ LI 13b search for WIMP scatter on Ge; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ –100 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- ²⁸ ARCHAMBAULT 12 search for low mass WIMP scatter on C_4F_{10} ; limits set in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m \sim 4$ –12 GeV; quoted limit is for $m = 5$ GeV.
- ²⁹ AALSETH 11 search for GeV-scale SI WIMP scatter on Ge; limits placed on $\sigma^{SI}(\chi N)$ for $m(\chi) \sim 3.5$ –100 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- ³⁰ AHMED 11b search for GeV scale WIMP scatter on Ge in CDMS II; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m \sim 4$ –12 GeV.
- ³¹ ANGLE 11 search for GeV scale WIMPs in Xenon-10; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ –20 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- ³² AKERIB 10 search for WIMP scatter on Ge/Si in CDMS2; limits place in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for m 3–100 GeV. Limit given for $m(DM)=5$ GeV

For $m_{\chi 0} = 20$ GeV

For limits from X^0 annihilation in the Sun, the assumed annihilation final state is shown in parenthesis in the comment.

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<7 \times 10^{-5}$	90	1 ANGLOHER 19 CRES	CaWO ₄	
$<3 \times 10^{-7}$	90	2 KIM 19A KIMS	Nal	
		3 KOBAYASHI 19 XMAS	SI WIMP on Xe	
		4 SEONG 19 BELL	$T \rightarrow \gamma A, A \rightarrow \chi\chi$	
$<3.5 \times 10^{-5}$	90	5 YANG 19 CDEX	annual modulation Ge	
$<2 \times 10^{-7}$	90	6 ABE 18c XMAS	X^0 -Xe modulation	
$<1.44 \times 10^{-5}$	90	7 ADHIKARI 18 C100	Nal	
$<3 \times 10^{-7}$	90	8 AGNES 18 DS50	X^0 -Ar	
$<5 \times 10^{-6}$	95	9 AGNESE 18 SCDM	Ge	
$<4 \times 10^{-8}$	90	10 AGNESE 18a SCDM	Ge	
$<6 \times 10^{-11}$	90	11 APRILE 18 XE1T	Xe, Si	
$<4.5 \times 10^{-3}$	90	12 ARNAUD 18 NEWS	GeV WIMPs on Ne	
$<2 \times 10^{-6}$	90	13 AARTSEN 17 ICCB	ν , earth	
$<2 \times 10^{-10}$	90	14 AKERIB 17 LUX	Xe	
$<1 \times 10^{-3}$	90	15 BARBOSA-D... 17 ICCB	Nal	
$<1.7 \times 10^{-10}$	90	16 CUI 17A PNDX	WIMPs on Xe	
$<7.3 \times 10^{-7}$	90	AGNES 16 DS50	Ar	
$<1 \times 10^{-5}$	90	17 AGNESE 16 CDMS	Ge	
$<2 \times 10^{-4}$	90	18 AGUILAR-AR... 16 DMIC	Si CCDs	
$<4.5 \times 10^{-5}$	90	19 ANGLOHER 16 CRES	CaWO ₄	
$<2 \times 10^{-6}$	90	20 APRILE 16 X100	Xe	
$<9.4 \times 10^{-8}$	90	21 ARMENGAUD 16 EDE3	Ge	
$<1.0 \times 10^{-7}$	90	22 HEHN 16 EDE3	Ge	
$<5 \times 10^{-6}$	90	23 ZHAO 16 CDEX	Ge	
$<1 \times 10^{-5}$	90	AGNES 15 DS50	Ar	
$<1.5 \times 10^{-6}$	90	24 AGNESE 15a CDM2	Ge	
$<1.5 \times 10^{-7}$	90	25 AGNESE 15b CDM2	Ge	
$<2 \times 10^{-6}$	90	26 AMOLE 15 PICO	C_3F_8	
$<1.2 \times 10^{-5}$	90	CHOI 15 SKAM	H, solar ν ($b\bar{b}$)	
$<1.19 \times 10^{-6}$	90	CHOI 15 SKAM	H, solar ν ($\tau^+ \tau^-$)	
$<2 \times 10^{-8}$	90	27 XIAO 15 PNDX	Xe	
$<2.0 \times 10^{-7}$	90	28 AGNESE 14 SCDM	Ge	
$<3.7 \times 10^{-5}$	90	29 AGNESE 14a SCDM	Ge	
$<1 \times 10^{-9}$	90	30 AKERIB 14 LUX	Xe	
$<2 \times 10^{-6}$	90	31 ANGLOHER 14 CRES	CaWO ₄	
$<5 \times 10^{-6}$	90	32 FELIZARDO 14 SMPL	C_2ClF_5	
$<8 \times 10^{-6}$	90	33 LEE 14a KIMS	Csl	
$<2 \times 10^{-4}$	90	34 LIU 14a CDEX	Ge	
$<1 \times 10^{-5}$	90	35 YUE 14 CDEX	Ge	
$<1.08 \times 10^{-4}$	90	36 AARTSEN 13 ICCB	H, solar ν ($\tau^+ \tau^-$)	
$<1.5 \times 10^{-5}$	90	37 ABE 13b XMAS	Xe	
$<3.1 \times 10^{-6}$	90	38 AGNESE 13 CDM2	Si	
$<3.4 \times 10^{-6}$	90	39 AGNESE 13a CDM2	Si	
$<2.2 \times 10^{-6}$	90	40 AGNESE 13a CDM2	Si	
		41 BERNABEI 13a DAMA	Nal modulation	
$<1.2 \times 10^{-4}$	90	42 LI 13b TEXO	Ge	
		43 ZHAO 13 CDEX	Ge	
$<1.2 \times 10^{-7}$	90	44 AKIMOV 12 ZEP3	Xe	
		45 ANGLOHER 12 CRES	CaWO ₄	
$<8 \times 10^{-6}$	90	46 ANGLOHER 12 CRES	CaWO ₄	
$<7 \times 10^{-9}$	90	47 APRILE 12 X100	Xe	
$<7 \times 10^{-7}$	90	48 ARMENGAUD 12 EDE2	Ge	
		49 BARRETO 12 DMIC	CCD	
$<2 \times 10^{-6}$	90	50 BEHNKE 12 COUP	CF_3I	
$<7 \times 10^{-6}$	90	51 FELIZARDO 12 SMPL	C_2ClF_5	
$<1.5 \times 10^{-6}$	90	52 KIM 12 KIMS	Csl	
$<5 \times 10^{-5}$	90	53 AALSETH 11 CGNT	Ge	

		50 AALSETH 11a CGNT	Ge
$<5 \times 10^{-7}$	90	51 AHMED 11 CDM2	Ge, inelastic
$<2.7 \times 10^{-7}$	90	52 AHMED 11a RVUE	Ge
$<3 \times 10^{-6}$	90	53 ANGLE 11 XE10	Xe
$<7 \times 10^{-8}$	90	54 APRILE 11 X100	Xe
		55 APRILE 11a X100	Xe, inelastic
$<2 \times 10^{-8}$	90	45 APRILE 11b X100	Xe
		56 HORN 11 ZEP3	Xe
$<2 \times 10^{-7}$	90	57 AHMED 10 CDM2	Ge
$<1 \times 10^{-5}$	90	58 AKERIB 10 CDM2	Si, Ge, low threshold
$<1 \times 10^{-7}$	90	APRILE 10 X100	Xe
$<2 \times 10^{-6}$	90	ARMENGAUD 10 EDE2	Ge
$<4 \times 10^{-5}$	90	FELIZARDO 10 SMPL	C_2ClF_3
$<1.5 \times 10^{-7}$	90	58 AHMED 09 CDM2	Ge
$<2 \times 10^{-4}$	90	59 LIN 09 TEXO	Ge
		60 AALSETH 08 CGNT	Ge

- ¹ ANGLOHER 19 search for low mass WIMP scatter on CaWO₄; no signal; limits placed on Wilson coefficients for $m(\chi) = 0.6$ –60 GeV.
- ² KIM 19a search for WIMP scatter in Nal KIMS experiment; no signal; require $\sigma^{SI}(\chi n) < 7 \times 10^{-5}$ pb for $m(\chi) = 20$ GeV.
- ³ KOBAYASHI 19 search for WIMP scatter in XMASS single-phase liquid Xe detector; no signal; require $\sigma^{SI}(\chi N) < 3 \times 10^{-7}$ pb for $m(\chi) = 20$ GeV.
- ⁴ SEONG 19 search for $T \rightarrow \gamma A, A \rightarrow \chi\chi$ via CP-odd Higgs; no signal; limits on BF set; model dependent conversion to WIMP-nucleon scattering cross section limits $\sigma^{SI} < 10^{-36}$ cm² for $m(\chi) = 0.01$ –1 GeV.
- ⁵ YANG 19 search for low mass wimps via annual modulation in Ge; no signal; require $\sigma^{SI}(\chi N) < 3.5 \times 10^{-5}$ pb for $m(\chi) = 20$ GeV.
- ⁶ ABE 18c search for WIMP annual modulation signal for $m(WIMP)$: 6–20 GeV; limits set on SI WIMP-nucleon cross section: see Fig. 6.
- ⁷ ADHIKARI 18 search for WIMP scatter on Nal; no signal; require $\sigma^{SI} < 1.44 \times 10^{-5}$ pb for $m(WIMP) = 20$ GeV; inconsistent with DAMA/LIBRA result.
- ⁸ AGNES 18 search low mass $m(WIMP)$: 1.8–20 GeV scatter on Ar; limits on SI WIMP-nucleon cross section set in Fig. 8.
- ⁹ AGNESE 18 give limits for $\sigma^{SI}(\chi N)$ for $m(WIMP)$ between 1.5 and 20 GeV using CDMSlite mode data.
- ¹⁰ AGNESE 18a search for WIMP scatter on Ge at SuperCDMS; 1 event, consistent with expected background; set limit in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m \sim 10$ –250 GeV.
- ¹¹ APRILE 18 search for WIMP scatter on 1 t yr Xe; no signal, limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 6$ –1000 GeV.
- ¹² ARNAUD 18 search for low mass WIMP scatter on Ne via SPC at NEWS-G; limits set in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m \sim 0.5$ –20 GeV.
- ¹³ AARTSEN 17 obtain $\sigma(SI) < 6 \times 10^{-6}$ pb for $m(wimp) = 20$ GeV from ν from earth.
- ¹⁴ AKERIB 17 search for WIMP scatter on Xe; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ – 1×10^5 GeV.
- ¹⁵ BARBOSA-DE-SOUZA 17 search for annual modulation of WIMP scatter on Nal using an exposure of 61 kg yr of DM-Ice17 for recoil energy in the 4–20 keV range (DAMA found modulation for recoil energy < 5 keV). No modulation seen. Sensitivity insufficient to distinguish DAMA signal from null.
- ¹⁶ CUI 17a search for SI WIMP scatter; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m \sim 10$ – 1×10^4 GeV using 54 ton-day exposure of Xe.
- ¹⁷ AGNESE 16 CDMSlite excludes low mass WIMPs 1.6–5.5 GeV and SI scattering cross section depending on $m(WIMP)$; see Fig. 4.
- ¹⁸ AGUILAR-AREVALO 16 search low mass 1–10 GeV WIMP scatter on Si CCDs; set limits Fig. 11.
- ¹⁹ ANGLOHER 16 search for GeV scale WIMP scatter on CaWO₄; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 0.5$ –30 GeV.
- ²⁰ APRILE 16 search for low mass WIMPs via ionization at XENON100; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m \sim 3.5$ –20 GeV.
- ²¹ ARMENGAUD 16 search for GeV scale WIMP scatter on Ge; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ –30 GeV.
- ²² HEHN 16 search for low mass WIMPs via Si scatter on Ge target using profile likelihood analysis; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ –30 GeV.
- ²³ ZHAO 16 search for GeV-scale WIMP scatter on Ge; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ –30 GeV.
- ²⁴ AGNESE 15a reanalyse AHMED 11b low threshold data. See their Fig. 12 (left) for improved limits extending down to 5 GeV.
- ²⁵ AGNESE 15b reanalyse AHMED 10 data.
- ²⁶ See their Fig. 7 for limits extending down to 4 GeV.
- ²⁷ XIAO 15 search for WIMP scatter on Xe with PandaX-I; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ –100 GeV.
- ²⁸ This limit value is provided by the authors. See their Fig. 4 for limits extending down to $m_{\chi 0} = 3.5$ GeV.
- ²⁹ This limit value is provided by the authors. AGNESE 14a result is from CDMSlite mode operation with enhanced sensitivity to low mass $m_{\chi 0}$. See their Fig. 3 for limits extending down to $m_{\chi 0} = 3.5$ GeV (see also Fig. 4 in AGNESE 14).
- ³⁰ See their Fig. 5 for limits extending down to $m_{\chi 0} = 5.5$ GeV.
- ³¹ See their Fig. 5 for limits extending down to $m_{\chi 0} = 1$ GeV.
- ³² See their Fig. 5 for limits extending down to $m_{\chi 0} = 5$ GeV.
- ³³ LIU 14a result is based on prototype CDEX-0 detector. See their Fig. 13 for limits extending down to $m_{\chi 0} = 2$ GeV.
- ³⁴ See their Fig. 4 for limits extending down to $m_{\chi 0} = 4.5$ GeV.
- ³⁵ AARTSEN 13 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the sun in data taken between June 2010 and May 2011.
- ³⁶ See their Fig. 8 for limits extending down to $m_{\chi 0} = 7$ GeV.
- ³⁷ This limit value is provided by the authors. AGNESE 13 use data taken between Oct. 2006 and July 2007. See their Fig. 4 for limits extending down to $m_{\chi 0} = 7$ GeV.

- ³⁸ This limit value is provided by the authors. AGNESE 13A use data taken between July 2007 and Sep. 2008. Three candidate events are seen. Assuming these events are real, the best fit parameters are $m_{\chi^0} = 8.6$ GeV and $\sigma = 1.9 \times 10^{-8}$ pb.
- ³⁹ This limit value is provided by the authors. Limit from combined data of AGNESE 13 and AGNESE 13A. See their Fig. 4 for limits extending down to $m_{\chi^0} = 5.5$ GeV.
- ⁴⁰ BERNABEI 13A search for annual modulation of counting rate in the 2–6 keV recoil energy interval, in a 14 yr live time exposure of 1.33 t yr. Find a modulation of 0.0112 ± 0.0012 counts/(day kg keV) with 9.3 sigma C.L. Find period and phase in agreement with expectations from DM particles.
- ⁴¹ LI 13b search for WIMP scatter on Ge; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ –100 GeV.
- ⁴² See their Fig. 5 for limits for $m_{\chi^0} = 4$ –12 GeV.
- ⁴³ ANGLOHER 12 observe excess events above the expected background which are consistent with χ^0 with mass ~ 25 GeV (or 12 GeV) and spin-independent χ^0 -nucleon cross section of 2×10^{-6} pb (or 4×10^{-5} pb).
- ⁴⁴ Reanalysis of ANGLOHER 09 data with all three nuclides. See also BROWN 12.
- ⁴⁵ See also APRILE 14A.
- ⁴⁶ See their Fig. 4 for limits extending down to $m_{\chi^0} = 7$ GeV.
- ⁴⁷ See their Fig. 13 for cross section limits for m_{χ^0} between 1.2 and 10 GeV.
- ⁴⁸ See also DAHL 12 for a criticism.
- ⁴⁹ See their Fig. 4 for limits extending to $m_{\chi^0} = 3.5$ GeV.
- ⁵⁰ AALSETH 11A find indications of annual modulation of the data, the energy spectrum being compatible with χ^0 mass around 8 GeV. See also AALSETH 13.
- ⁵¹ AHMED 11 search for χ^0 inelastic scattering. See their Fig. 8–10 for limits. The inelastic cross section reduces to the elastic cross section at the limit of zero mass splitting (Fig. 8, left).
- ⁵² AHMED 11A combine CDMS II and EDELWEISS data.
- ⁵³ ANGLE 11 show limits down to $m_{\chi^0} = 4$ GeV on Fig. 3.
- ⁵⁴ APRILE 11 reanalyze APRILE 10 data.
- ⁵⁵ APRILE 11A search for χ^0 inelastic scattering. See their Fig. 2 and 3 for limits. See also APRILE 14A.
- ⁵⁶ HORN 11 perform detector calibration by neutrons. Earlier results are only marginally affected.
- ⁵⁷ See their Fig. 10 and 12 for limits extending to χ^0 mass of 1 GeV.
- ⁵⁸ Superseded by AHMED 10.
- ⁵⁹ See their Fig. 6(a) for cross section limits for m_{χ^0} extending down to 2 GeV.
- ⁶⁰ See their Fig. 2 for cross section limits for m_{χ^0} between 4 and 10 GeV.

For $m_{\chi^0} = 100$ GeV

For limits from χ^0 annihilation in the Sun, the assumed annihilation final state is shown in parenthesis in the comment.

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
$<4 \times 10^{-8}$	90	1 ABE	19 XMAS	Xe
$<3.9 \times 10^{-9}$	90	2 AJAJ	19 DEAP	Ar
$<2.3 \times 10^{-6}$	90	3 ADHIKARI	18 C100	Nal
$<1.14 \times 10^{-8}$	90	4 AGNES	18A D550	Ar
$<2 \times 10^{-8}$	90	5 AGNESE	18A CDMS	Ge
$<1.2 \times 10^{-8}$	90	6 AMAUDRUZ	18 DEAP	Ar
$<9.12 \times 10^{-11}$	90	7 APRILE	18 XE1T	Xe
		8 REN	18 PNDX	SIDM at PDX-II
$<1.7 \times 10^{-10}$	90	9 AKERIB	17 LUX	Xe
$<1.2 \times 10^{-10}$	90	10 APRILE	17G XE1T	Xe
$<1.2 \times 10^{-10}$	90	11 CUI	17A PNDX	Xe
$<2.0 \times 10^{-8}$	90	AGNES	16 D550	Ar
$<1 \times 10^{-9}$	90	12 AKERIB	16 LUX	Xe
$<1 \times 10^{-9}$	90	13 APRILE	16B X100	Xe
$<2 \times 10^{-8}$	90	14 TAN	16 PNDX	Xe
$<4 \times 10^{-10}$	90	15 TAN	16B PNDX	Xe
$<6 \times 10^{-8}$	90	AGNES	15 D550	Ar
$<4 \times 10^{-8}$	90	16 AGNESE	15B CDM2	Ge
$<7.13 \times 10^{-6}$	90	CHOI	15 SKAM	H, solar ν ($b\bar{b}$)
$<6.26 \times 10^{-7}$	90	CHOI	15 SKAM	H, solar ν ($W^+ W^-$)
$<2.76 \times 10^{-7}$	90	CHOI	15 SKAM	H, solar ν ($\tau^+ \tau^-$)
$<1.5 \times 10^{-8}$	90	17 XIAO	15 PNDX	Xe
$<1 \times 10^{-9}$	90	AKERIB	14 LUX	Xe
$<4.0 \times 10^{-6}$	90	18 AVROBIN	14 BAIK	H, solar ν ($W^+ W^-$)
$<1.0 \times 10^{-4}$	90	18 AVROBIN	14 BAIK	H, solar ν ($b\bar{b}$)
$<1.6 \times 10^{-6}$	90	18 AVROBIN	14 BAIK	H, solar ν ($\tau^+ \tau^-$)
$<5 \times 10^{-6}$	90	FELIZARDO	14 SMPL	C ₂ ClF ₅
$<6.01 \times 10^{-7}$	90	19 AARTSEN	13 ICCB	H, solar ν ($W^+ W^-$)
$<3.30 \times 10^{-5}$	90	19 AARTSEN	13 ICCB	H, solar ν ($b\bar{b}$)
$<1.9 \times 10^{-6}$	90	20 ADRIAN-MAR.13	ANTR	H, solar ν ($W^+ W^-$)
$<1.2 \times 10^{-4}$	90	20 ADRIAN-MAR.13	ANTR	H, solar ν ($b\bar{b}$)
$<7.6 \times 10^{-7}$	90	20 ADRIAN-MAR.13	ANTR	H, solar ν ($\tau^+ \tau^-$)
$<2 \times 10^{-6}$	90	21 AGNESE	13 CDM2	Si
$<1.6 \times 10^{-6}$	90	22 BOLIEV	13 BAKS	H, solar ν ($W^+ W^-$)
$<1.9 \times 10^{-5}$	90	22 BOLIEV	13 BAKS	H, solar ν ($b\bar{b}$)
$<7.1 \times 10^{-7}$	90	22 BOLIEV	13 BAKS	H, solar ν ($\tau^+ \tau^-$)
$<3.2 \times 10^{-4}$	90	23 LI	13B TEXO	WIMPs on Ge
$<1.67 \times 10^{-6}$	90	24 ABBASI	12 ICCB	H, solar ν ($W^+ W^-$)
$<1.07 \times 10^{-4}$	90	24 ABBASI	12 ICCB	H, solar ν ($b\bar{b}$)
$<4 \times 10^{-8}$	90	AKIMOV	12 ZEP3	Xe
$<1.4 \times 10^{-6}$	90	25 ANGLOHER	12 CRES	CaWO ₄

$<3 \times 10^{-9}$	90	26 APRILE	12 X100	Xe
$<3 \times 10^{-7}$	90	BEHNKE	12 COUP	CF ₃ I
$<7 \times 10^{-6}$		FELIZARDO	12 SMPL	C ₂ ClF ₅
$<2.5 \times 10^{-7}$	90	27 KIM	12 KIMS	Csl
$<2 \times 10^{-4}$	90	AALSETH	11 CGNT	Ge
		28 AHMED	11 CDM2	Ge, inelastic
$<3.3 \times 10^{-8}$	90	29 AHMED	11A RVUE	Ge
		30 AJELLO	11 FLAT	
$<3 \times 10^{-8}$	90	31 APRILE	11 X100	Xe
		32 APRILE	11A X100	Xe, inelastic
$<1 \times 10^{-8}$	90	26 APRILE	11B X100	Xe
$<5 \times 10^{-8}$	90	33 ARMENGAUD	11 EDE2	Ge
		34 HORN	11 ZEP3	Xe
$<4 \times 10^{-8}$	90	AHMED	10 CDM2	Ge
$<9 \times 10^{-6}$	90	AKERIB	10 CDM2	Si, Ge, low threshold
		35 AKIMOV	10 ZEP3	Xe, inelastic
$<5 \times 10^{-8}$	90	APRILE	10 X100	Xe
$<1 \times 10^{-7}$	90	ARMENGAUD	10 EDE2	Ge
$<3 \times 10^{-5}$	90	FELIZARDO	10 SMPL	C ₂ ClF ₃
$<5 \times 10^{-8}$	90	36 AHMED	09 CDM2	Ge
		37 ANGLE	09 XE10	Xe, inelastic
		LIN	09 TEXO	Ge
$<3 \times 10^{-4}$	90	38 GIULIANI	05 RVUE	

- ¹ ABE 19 search for SI DD in single phase Xe; no signal; require $\sigma^{SI}(\chi p) < 4 \times 10^{-8}$ pb for $m(\chi) \sim 100$ GeV.
- ² AJAJ 19 search for SI WIMP-nucleon scatter with 758 tonne day exposure of single phase liquid Ar; no signal; require $\sigma^{SI}(\chi N) < 3.9 \times 10^{-9}$ pb for $m(\chi) = 100$ GeV.
- ³ ADHIKARI 18 search for WIMP scatter on Na; limit set $\sigma^{SI}(\chi p) < 2.3 \times 10^{-6}$ pb for $m(\chi) = 100$ GeV.
- ⁴ AGNES 18A search for WIMP scatter on 46.4 kg Ar; no signal; require $\sigma^{SI}(\chi N) < 1.14 \times 10^{-8}$ pb for $m(\chi) = 100$ GeV.
- ⁵ AGNESE 18A set limit $\sigma^{SI}(\chi N) < 2 \times 10^{-8}$ pb for $m(\text{WIMP}) = 100$ GeV.
- ⁶ AMAUDRUZ 18 search for WIMP scatter on Ar with DEAP-3600; limits set: $\sigma^{SI}(\chi p) < 1.2 \times 10^{-8}$ pb for $m(\text{WIMP}) = 100$ GeV.
- ⁷ APRILE 18 search for WIMP scatter on 1.3 t liquid Xe; no signal; require $\sigma^{SI}(\chi p) < 9.12 \times 10^{-11}$ pb for $m(\chi) = 100$ GeV.
- ⁸ REN 18 search for self-interacting DM at Panda-X-II with a total exposure of 54 ton day; limits set in $m(\text{DM})$ vs. $m(\text{mediator})$ plane.
- ⁹ AKERIB 17 exclude SI cross section $> 1.7 \times 10^{-10}$ pb for $m(\text{WIMP}) = 100$ GeV. Uses complete LUX data set.
- ¹⁰ APRILE 17G set limit $\sigma^{SI}(\chi p) < 1.2 \times 10^{-10}$ pb for $m(\text{WIMP}) = 100$ GeV using 1 ton fiducial mass Xe TPC. Exposure is 34.2 live days.
- ¹¹ CUI 17A search for SI WIMP scatter; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m \sim 10$ – 1×10^4 GeV using 54 ton-day exposure of Xe.
- ¹² AKERIB 16 re-analysis of 2013 data exclude SI cross section $> 1 \times 10^{-9}$ pb for $m(\text{WIMP}) = 100$ GeV on Xe target.
- ¹³ APRILE 16B combined 447 live days using Xe target exclude $\sigma(\text{SI}) > 1.1 \times 10^{-9}$ pb for $m(\text{WIMP}) = 50$ GeV.
- ¹⁴ TAN 16 search for WIMP scatter off Xe target; see SI exclusion plot Fig. 6.
- ¹⁵ TAN 16B search for WIMP-p scatter off Xe target; see Fig. 5 for SI exclusion.
- ¹⁶ AGNESE 15B reanalyze AHMED 10 data.
- ¹⁷ XIAO 15 search for WIMP scatter on Xe with PandaX-II; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ –100 GeV.
- ¹⁸ AVROBIN 14 search for neutrinos from the Sun arising from the pair annihilation of χ^0 trapped by the Sun in data taken between 1998 and 2003. See their Table 1 for limits assuming annihilation into neutrino pairs.
- ¹⁹ AARTSEN 13 search for neutrinos from the Sun arising from the pair annihilation of χ^0 trapped by the sun in data taken between June 2010 and May 2011.
- ²⁰ ADRIAN-MARTINEZ 13 search for neutrinos from the Sun arising from the pair annihilation of χ^0 trapped by the sun in data taken between Jan. 2007 and Dec. 2008.
- ²¹ AGNESE 13 use data taken between Oct. 2006 and July 2007.
- ²² BOLIEV 13 search for neutrinos from the Sun arising from the pair annihilation of χ^0 trapped by the sun in data taken from 1978 to 2009. See also SUVOROVA 13 for an older analysis of the same data.
- ²³ LI 13b search for WIMP scatter on Ge; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ –100 GeV.
- ²⁴ ABBASI 12 search for neutrinos from the Sun arising from the pair annihilation of χ^0 trapped by the Sun. The amount of χ^0 depends on the χ^0 -proton cross section.
- ²⁵ Reanalysis of ANGLOHER 09 data with all three nuclides. See also BROWN 12.
- ²⁶ See also APRILE 14A.
- ²⁷ See their Fig. 6 for a limit on inelastically scattering χ^0 for $m_{\chi^0} = 70$ GeV.
- ²⁸ AHMED 11 search for χ^0 inelastic scattering. See their Fig. 8–10 for limits.
- ²⁹ AHMED 11A combine CDMS and EDELWEISS data.
- ³⁰ AJELLO 11 search for e^\pm flux from χ^0 annihilations in the Sun. Models in which χ^0 annihilates into an intermediate long-lived weakly interacting particles or χ^0 scatters inelastically are constrained. See their Fig. 6–8 for limits.
- ³¹ APRILE 11 reanalyze APRILE 10 data.
- ³² APRILE 11A search for χ^0 inelastic scattering. See their Fig. 2 and 3 for limits. See also APRILE 14A.
- ³³ Supersedes ARMENGAUD 10. A limit on inelastic cross section is also given.
- ³⁴ HORN 11 perform detector calibration by neutrons. Earlier results are only marginally affected.
- ³⁵ AKIMOV 10 give cross section limits for inelastically scattering dark matter. See their Fig. 4.
- ³⁶ Superseded by AHMED 10.
- ³⁷ ANGLE 09 search for χ^0 inelastic scattering. See their Fig. 4 for limits.
- ³⁸ GIULIANI 05 analyzes the spin-independent χ^0 -nucleon cross section limits with both isoscalar and isovector couplings. See their Fig. 3 and 4 for limits on the couplings.

Searches Particle Listings
WIMP and Dark Matter Searches

For $m_{\chi^0} = 1 \text{ TeV}$

For limits from X^0 annihilation in the Sun, the assumed annihilation final state is shown in parenthesis in the comment.

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 3 \times 10^{-6}$	90	1 YAGUNA	19	Ar; l-spin viol DM
$< 3.8 \times 10^{-8}$	90	2 AGNES	18A	DS50 Ar
$< 8.24 \times 10^{-10}$	90	3 APRILE	18	XE1T Xe
$< 2 \times 10^{-9}$	90	4 AKERIB	17	LUX Xe
< 0.3	90	5 CHEN	17E	PNDX $\chi N \rightarrow \chi^* \rightarrow \chi \gamma$
$< 1.2 \times 10^{-9}$	90	6 CUI	17A	PNDX SI WIMPs on Xe
$< 8.6 \times 10^{-8}$	90	AGNES	16	DS50 Ar
$< 2 \times 10^{-7}$	90	AGNES	15	DS50 Ar
$< 2 \times 10^{-7}$	90	7 AGNESE	15B	CDM2 Ge
$< 1 \times 10^{-8}$	90	AKERIB	14	LUX Xe
$< 2.2 \times 10^{-6}$	90	8 AVRORIN	14	BAIK H, solar ν ($W^+ W^-$)
$< 5.5 \times 10^{-5}$	90	8 AVRORIN	14	BAIK H, solar ν ($b\bar{b}$)
$< 6.8 \times 10^{-7}$	90	8 AVRORIN	14	BAIK H, solar ν ($\tau^+ \tau^-$)
$< 3.46 \times 10^{-7}$	90	9 AARTSEN	13	ICCB H, solar ν ($W^+ W^-$)
$< 7.75 \times 10^{-6}$	90	9 AARTSEN	13	ICCB H, solar ν ($b\bar{b}$)
$< 6.9 \times 10^{-7}$	90	10 ADRIAN-MAR.13	ANTR	H, solar ν ($W^+ W^-$)
$< 1.5 \times 10^{-5}$	90	10 ADRIAN-MAR.13	ANTR	H, solar ν ($b\bar{b}$)
$< 1.8 \times 10^{-7}$	90	10 ADRIAN-MAR.13	ANTR	H, solar ν ($\tau^+ \tau^-$)
$< 4.3 \times 10^{-6}$	90	11 BOLIEV	13	BAKS H, solar ν ($W^+ W^-$)
$< 3.4 \times 10^{-5}$	90	11 BOLIEV	13	BAKS H, solar ν ($b\bar{b}$)
$< 1.2 \times 10^{-6}$	90	11 BOLIEV	13	BAKS H, solar ν ($\tau^+ \tau^-$)
$< 2.12 \times 10^{-7}$	90	12 ABBASI	12	ICCB H, solar ν ($W^+ W^-$)
$< 6.56 \times 10^{-6}$	90	12 ABBASI	12	ICCB H, solar ν ($b\bar{b}$)
$< 4 \times 10^{-7}$	90	AKIMOV	12	ZEP3 Xe
$< 1.1 \times 10^{-5}$	90	13 ANGIOHER	12	CRES CaWO ₄
$< 2 \times 10^{-8}$	90	14 APRILE	12	X100 Xe
$< 2 \times 10^{-6}$	90	BEHNKE	12	COUP CF ₃ I
$< 4 \times 10^{-6}$		FELIZARDO	12	SMP L C ₂ ClF ₅
$< 1.5 \times 10^{-6}$	90	KIM	12	KIMS Csl
		15 AHMED	11	CDM2 Ge, inelastic
$< 1.5 \times 10^{-7}$	90	16 AHMED	11A	RVUE Ge
$< 2 \times 10^{-7}$	90	17 APRILE	11	X100 Xe
$< 8 \times 10^{-8}$	90	14 APRILE	11B	X100 Xe
$< 2 \times 10^{-7}$	90	18 ARMENGAUD	11	EDE2 Ge
		19 HORN	11	ZEP3 Xe
$< 2 \times 10^{-7}$	90	AHMED	10	CDM2 Ge
$< 4 \times 10^{-7}$	90	APRILE	10	X100 Xe
$< 6 \times 10^{-7}$	90	ARMENGAUD	10	EDE2 Ge
$< 3.5 \times 10^{-7}$	90	20 AHMED	09	CDM2 Ge

- 1 YAGUNA 19 recasts DEAP-3600 single-phase liquid argon results in limit for isospin violating DM; for $f_n/f_p = -0.69$, requires $\sigma^{SI}(\chi p) < 3 \times 10^{-6}$ pb for $m(\chi) = 1 \text{ TeV}$.
- 2 AGNES 18A search for WIMP scatter on 46.4 kg Ar; no signal; require $\sigma^{SI}(\chi N) < 3.8 \times 10^{-8}$ pb for $m(\chi) = 1 \text{ TeV}$.
- 3 APRILE 18 search for WIMP scatter on 1.3 t Xe; no signal seen; require $\sigma^{SI}(\chi p) < 8.24 \times 10^{-10}$ pb for $m(\chi) = 1 \text{ TeV}$.
- 4 AKERIB 17 search for WIMP scatter on Xe using complete LUX data set; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5\text{--}1 \times 10^5 \text{ GeV}$.
- 5 CHEN 17E search for inelastic WIMP scatter on Xe; require $\sigma^{SI}(\chi N) < 0.3 \text{ pb}$ for $m(\chi) = 1 \text{ TeV}$ and (mass difference) = 300 keV.
- 6 CUI 17A search for WIMP scatter using 54 ton-day exposure of Xe; limits placed in $\sigma^{SI}(\chi N)$ vs. $m(\chi)$ plane for $m \sim 10\text{--}1 \times 10^4 \text{ GeV}$.
- 7 AGNESE 15B reanalyse AHMED 10 data.
- 8 AVRORIN 14 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the Sun in data taken between 1998 and 2003. See their Table 1 for limits assuming annihilation into neutrino pairs.
- 9 AARTSEN 13 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the sun in data taken between June 2010 and May 2011.
- 10 ADRIAN-MARTINEZ 13 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the sun in data taken between Jan. 2007 and Dec. 2008.
- 11 BOLIEV 13 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the sun in data taken from 1978 to 2009. See also SUVOROVA 13 for an older analysis of the same data.
- 12 ABBASI 12 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the Sun. The amount of X^0 depends on the X^0 -proton cross section.
- 13 Reanalysis of ANGIOHER 09 data with all three nuclides. See also BROWN 12.
- 14 See also APRILE 14A.
- 15 AHMED 11 search for X^0 inelastic scattering. See their Fig. 8–10 for limits.
- 16 AHMED 11A combine CDMs and EDELWEISS data.
- 17 APRILE 11 reanalyse APRILE 10 data.
- 18 Supersedes ARMENGAUD 10. A limit on inelastic cross section is also given.
- 19 HORN 11 perform detector calibration by neutrons. Earlier results are only marginally affected.
- 20 Superseded by AHMED 10.

Spin-Dependent Cross Section Limits
for Dark Matter Particle (X^0) on Proton

For m_{χ^0} in GeV range

We provide here limits for $m_{\chi^0} < 5 \text{ GeV}$

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 1 \times 10^6$	95	1 ABDELHAME...19	CRES	GeV-scale WIMPs on Li
$< 3 \times 10^{-4}$	90	2 AMOLE	19	PICO C ₃ F ₈
$< 1.7 \times 10^4$	90	3 APRILE	19c	XE1T light DM on Xe via Migdal/brem effect
$< 8 \times 10^6$	90	4 ARMENGAUD	19	EDEL GeV-scale WIMPs on Ge
< 70	90	5 XIA	19A	PNDX SD WIMP on Xe
< 100	90	6 AGNESE	18	SCDM GeV-scale WIMPs on Ge
< 1	90	7 AKERIB	17A	LUX Xe
< 0.6	90	8 FU	17	PNDX SD WIMP on Xe
< 0.2	90	9 AMOLE	15	PICO C ₃ F ₈
$< 1.6 \times 10^{-1}$	90	10 ARCHAMBAU.12	PICA	19F
1 ABDELHA MEED 19 search for SD WIMP scatter on ⁷ Li; limits placed on $\sigma^{SD}(\chi p)$ for $m(\chi) \sim 0.8\text{--}20 \text{ GeV}$; quoted limit is for $m(\chi) = 1 \text{ GeV}$.				
2 AMOLE 19 search for SD WIMP scatter on C ₃ F ₈ in PICO-60 bubble chamber; no signal; set limit for spin dependent coupling $\sigma^{SD}(\chi p) < 2 \times 10^{-4} \text{ pb}$ for $m(\chi) = 5 \text{ GeV}$.				
3 APRILE 19c search for light DM on Xe via Migdal/brem effect; no signal, require $\sigma^{SD}(\chi p) < 1.7 \times 10^4 \text{ pb}$ for $m(\chi) = 1 \text{ GeV}$.				
4 ARMENGAUD 19 search for GeV scale WIMP scatter on Ge; limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 0.5\text{--}10 \text{ GeV}$; quoted limit is for $m(\chi) = 5 \text{ GeV}$.				
5 XIA 19A search for WIMP scatter on Xe in PandaX-II; limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5\text{--}1 \times 10^5 \text{ GeV}$; quoted limit is for $m(\chi) = 5 \text{ GeV}$.				
6 AGNESE 18 search for GeV scale WIMPs with CDMs lite; limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 1.5\text{--}20 \text{ GeV}$; quoted limit is for $m(\chi) = 5 \text{ GeV}$.				
7 AKERIB 17A search for SD WIMP scatter on Xe using 129.5 kg yr exposure; limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 6\text{--}1 \times 10^5 \text{ GeV}$.				
8 FU 17 search for SD WIMP scatter on Xe; limits set in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4\text{--}1 \times 10^3 \text{ GeV}$; quoted limit is for $m(\chi) = 5 \text{ GeV}$.				
9 AMOLE 15 search for WIMP scatter on C ₃ F ₈ in PICO-2L; limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4\text{--}1 \times 10^4 \text{ GeV}$; quoted limit is for $m(\chi) = 5 \text{ GeV}$.				
10 ARCHAMBAULT 12 search for SD WIMP scatter in ¹⁹ F with PICASSO; limits set in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m \sim 4\text{--}500 \text{ GeV}$; quoted limit is for $m(\chi) = 5 \text{ GeV}$.				

For $m_{\chi^0} = 20 \text{ GeV}$

For limits from X^0 annihilation in the Sun, the assumed annihilation final state is shown in parenthesis in the comment.

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 3 \times 10^5$	95	1 ABDELHAME...19	CRES	⁷ Li
$< 2.5 \times 10^{-5}$	90	2 AMOLE	19	PICO C ₃ F ₈
$< 2.5 \times 10^{-4}$	90	3 APRILE	19A	XE1T Xe, SD
$< 1 \times 10^{-3}$	90	4 XIA	19A	PNDX SD WIMP on Xe
< 30	95	5 AGNESE	18	SCDM Ge
$< 1 \times 10^{-3}$	90	6 AKERIB	17A	LUX Xe
$< 1.32 \times 10^{-2}$	90	7 BEHNKE	17	PICA C ₄ F ₁₀
$< 2 \times 10^{-3}$	90	8 FU	17	PNDX SD WIMP on Xe
$< 5 \times 10^{-4}$	90	9 AMOLE	16A	PICO C ₃ F ₈
$< 2 \times 10^{-6}$	90	10 KHACHATRY...16A	CMS	8 TeV $p p \rightarrow Z + \cancel{e} T$; $Z \rightarrow \ell \bar{\ell}$
$< 1.2 \times 10^{-3}$	90	AMOLE	15	PICO C ₃ F ₈
$< 1.43 \times 10^{-3}$	90	CHOI	15	SKAM H, solar ν ($b\bar{b}$)
$< 1.42 \times 10^{-4}$	90	CHOI	15	SKAM H, solar ν ($\tau^+ \tau^-$)
$< 5 \times 10^{-3}$	90	FELIZARDO	14	SMP L C ₂ ClF ₅
$< 1.29 \times 10^{-2}$	90	11 AARTSEN	13	ICCB H, solar ν ($\tau^+ \tau^-$)
$< 3.17 \times 10^{-2}$	90	12 APRILE	13	X100 Xe
$< 3 \times 10^{-2}$	90	13 ARCHAMBAU.12	PICA	F (C ₄ F ₁₀)
$< 6 \times 10^{-2}$	90	BEHNKE	12	COUP CF ₃ I
< 20	90	DAW	12	DRFT F (CF ₄)
$< 7 \times 10^{-3}$	90	FELIZARDO	12	SMP L C ₂ ClF ₅
< 0.15	90	KIM	12	KIMS Csl
$< 1 \times 10^5$	90	14 AHLEN	11	DMTP F (CF ₄)
< 1	90	14 BEHNKE	11	COUP CF ₃ I
$< 1.5 \times 10^{-2}$	90	15 TANAKA	11	SKAM H, solar ν ($b\bar{b}$)
< 0.2	90	ARCHAMBAU...09	PICA	F
< 4	90	LEBEDENKO	09A	ZEP3 Xe
< 0.6	90	ANGLE	08A	XE10 Xe
< 100	90	ALNER	07	ZEP2 Xe
< 1	90	LEE	07A	KIMS Csl
< 20	90	16 AKERIB	06	CDMS ⁷³ Ge, ²⁹ Si
< 2	90	SHIMIZU	06A	CNTR F (CaF ₂)
< 0.5	90	ALNER	05	NAIA NaI
< 1.5	90	BARNABE-HE...05	PICA	F (C ₄ F ₁₀)
< 1.5	90	GIRARD	05	SMP L F (C ₂ ClF ₅)
< 35	90	MIUCHI	03	BOLO LiF
< 30	90	TAKEDA	03	BOLO NaF

- ¹ ABDELHAMEED 19 uses Li_2MoO_4 target to set limit for spin dependent coupling $\sigma^{SD}(\chi p) < 3 \times 10^5$ pb for $m(\chi) = 20$ GeV.
- ² AMOLE 19 search for SD WIMP scatter on C_3F_8 in PICO-60 bubble chamber; no signal: set limit for spin dependent coupling $\sigma^{SD}(\chi p) < 2.5 \times 10^{-5}$ pb for $m(\chi) = 20$ GeV.
- ³ APRILE 19A search for SD WIMP scatter on 1 t yr Xe; no signal, limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m \sim 6$ –1000 GeV.
- ⁴ XIA 19A search for WIMP scatter on Xe in PandaX-II; limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ – 1×10^5 GeV.
- ⁵ AGNESE 18 give limits for $\sigma^{SD}(\rho\chi)$ for $m(\text{WIMP})$ between 1.5 and 20 GeV using CDMs lite mode data.
- ⁶ AKERIB 17A search for SD WIMP scatter on Xe using 129.5 kg yr exposure; limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 6$ – 1×10^5 GeV.
- ⁷ BEHNKE 17 show final Picasso results based on 231.4 kg d exposure at SNOLab for WIMP scatter on C_4F_{10} search via superheated droplet; require $\sigma(\text{SD}) < 1.32 \times 10^{-2}$ pb for $m(\text{WIMP}) = 20$ GeV.
- ⁸ FU 17 search for SD WIMP scatter on Xe; limits set in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ – 1×10^3 GeV.
- ⁹ AMOLE 16A require SD WIMP- p scattering $< 5 \times 10^{-4}$ pb for $m(\text{WIMP}) = 20$ GeV; bubbles from C_3F_8 target.
- ¹⁰ KHACHATRYAN 16AJ require SD WIMP- $p < 2 \times 10^{-6}$ pb for $m(\text{WIMP}) = 20$ GeV from $pp \rightarrow Z + \ell\bar{\ell}$; $Z \rightarrow \ell\bar{\ell}$ signal.
- ¹¹ AARTSEN 13 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the sun in data taken between June 2010 and May 2011.
- ¹² The value has been provided by the authors. APRILE 13 note that the proton limits on Xe are highly sensitive to the theoretical model used. See also APRILE 14A.
- ¹³ ARCHAMBAULT 12 search for WIMP scatter on C_4F_{10} ; limits set in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m \sim 4$ –500 GeV.
- ¹⁴ Use a direction-sensitive detector.
- ¹⁵ TANAKA 11 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the Sun. The amount of X^0 depends on the X^0 -proton cross section.
- ¹⁶ See also AKERIB 05.

For $m_{X^0} = 100$ GeV

For limits from X^0 annihilation in the Sun, the assumed annihilation final state is shown in parenthesis in the comment.

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 4 \times 10^{-5}$	90	¹ AMOLE 19	PICO	C_3F_8
$< 4 \times 10^{-4}$	90	² APRILE 19A	XE1T	Xe, SD
$< 8 \times 10^{-4}$	90	³ XIA 19A	PNDX	SD WIMP on Xe
$< 8 \times 10^{-4}$	90	⁴ AKERIB 17A	LUX	Xe
$< 5 \times 10^{-5}$	90	⁵ AMOLE 17	PICO	C_3F_8
$< 3.3 \times 10^{-2}$	90	⁶ APRILE 17A	X100	Xe inelastic
$< 2.8 \times 10^{-1}$	90	⁷ BATTAT 17	DRFT	CS_2
$< 1.5 \times 10^{-3}$	90	⁸ FU 17	PNDX	Xe
< 0.553 –0.019	95	⁹ AABOUD 16b	ATLS	$pp \rightarrow j + E_T$
$< 1 \times 10^{-5}$	90	¹⁰ AABOUD 16f	ATLS	$pp \rightarrow \gamma + E_T$
$< 1 \times 10^{-4}$	90	¹¹ AARTSEN 16c	ICCB	solar $\nu (W^+ W^-)$
$< 2 \times 10^{-4}$	90	¹² ADRIAN-MARTINEZ 16	ANTR	solar $\nu (W W, b\bar{b}, \tau\bar{\tau})$
$< 3 \times 10^{-3}$	90	¹³ AKERIB 16A	LUX	Xe
$< 5 \times 10^{-4}$	90	¹⁴ AMOLE 16	PICO	CF_3I
$< 1.5 \times 10^{-3}$	90	¹⁵ AMOLE 15	PICO	C_3F_8
$< 3.19 \times 10^{-3}$	90	¹⁶ CHOI 15	SKAM	H, solar $\nu (b\bar{b})$
$< 2.80 \times 10^{-4}$	90	¹⁷ CHOI 15	SKAM	H, solar $\nu (W^+ W^-)$
$< 1.24 \times 10^{-4}$	90	¹⁸ CHOI 15	SKAM	H, solar $\nu (\tau^+ \tau^-)$
$< 8 \times 10^2$	90	¹⁹ NAKAMURA 15	NAGE	CF_4
$< 1.7 \times 10^{-3}$	90	²⁰ AVRORIN 14	BAIK	H, solar $\nu (W^+ W^-)$
$< 4.5 \times 10^{-2}$	90	²¹ AVRORIN 14	BAIK	H, solar $\nu (b\bar{b})$
$< 7.1 \times 10^{-4}$	90	²² AVRORIN 14	BAIK	H, solar $\nu (\tau^+ \tau^-)$
$< 6 \times 10^{-3}$	90	²³ FELIZARDO 14	SMPL	C_2ClF_5
$< 2.68 \times 10^{-4}$	90	²⁴ AARTSEN 13	ICCB	H, solar $\nu (W^+ W^-)$
$< 1.47 \times 10^{-2}$	90	²⁵ AARTSEN 13	ICCB	H, solar $\nu (b\bar{b})$
$< 8.5 \times 10^{-4}$	90	²⁶ ADRIAN-MARTINEZ 13	ANTR	H, solar $\nu (W^+ W^-)$
$< 5.5 \times 10^{-2}$	90	²⁷ ADRIAN-MARTINEZ 13	ANTR	H, solar $\nu (b\bar{b})$
$< 3.4 \times 10^{-4}$	90	²⁸ ADRIAN-MARTINEZ 13	ANTR	H, solar $\nu (\tau^+ \tau^-)$
$< 1.00 \times 10^{-2}$	90	²⁹ APRILE 13	X100	Xe
$< 7.1 \times 10^{-4}$	90	³⁰ BOLIEV 13	BAKS	H, solar $\nu (W^+ W^-)$
$< 8.4 \times 10^{-3}$	90	³¹ BOLIEV 13	BAKS	H, solar $\nu (b\bar{b})$
$< 3.1 \times 10^{-4}$	90	³² BOLIEV 13	BAKS	H, solar $\nu (\tau^+ \tau^-)$
$< 7.07 \times 10^{-4}$	90	³³ ABBASI 12	ICCB	H, solar $\nu (W^+ W^-)$
$< 4.53 \times 10^{-2}$	90	³⁴ ABBASI 12	ICCB	H, solar $\nu (b\bar{b})$
$< 7 \times 10^{-2}$	90	³⁵ ARCHAMBAULT 12	PICA	$\text{F} (\text{C}_4\text{F}_{10})$
$< 1 \times 10^{-2}$	90	³⁶ BEHNKE 12	COUP	CF_3I
< 1.8	90	³⁷ DAW 12	DRFT	$\text{F} (\text{CF}_4)$
$< 9 \times 10^{-3}$	90	³⁸ FELIZARDO 12	SMPL	C_2ClF_5
$< 2 \times 10^{-2}$	90	³⁹ KIM 12	KIMS	CsI
$< 2 \times 10^3$	90	⁴⁰ AHLEN 11	DMTP	$\text{F} (\text{CF}_4)$
$< 7 \times 10^{-2}$	90	⁴¹ BEHNKE 11	COUP	CF_3I
$< 2.7 \times 10^{-4}$	90	⁴² TANAKA 11	SKAM	H, solar $\nu (W^+ W^-)$
$< 4.5 \times 10^{-3}$	90	⁴³ TANAKA 11	SKAM	H, solar $\nu (b\bar{b})$
$< 6 \times 10^3$	90	⁴⁴ FELIZARDO 10	SMPL	C_2ClF_3
< 0.4	90	⁴⁵ MIUCHI 10	NAGE	CF_4
< 0.8	90	⁴⁶ ARCHAMBAULT 09	PICA	F
< 1.0	90	⁴⁷ LEBEDENKO 09A	ZEP3	Xe
< 1.0	90	⁴⁸ ANGLE 08A	XE10	Xe

< 15	90	ALNER 07	ZEP2	Xe
< 0.2	90	LEE 07A	KIMS	CsI
$< 1 \times 10^4$	90	¹⁵ MIUCHI 07	NAGE	$\text{F} (\text{CF}_4)$
< 5	90	²⁵ AKERIB 06	CDMS	$^{73}\text{Ge}, ^{29}\text{Si}$
< 2	90	SHIMIZU 06A	CNTR	$\text{F} (\text{CaF}_2)$
< 0.3	90	ALNER 05	NAIA	Nal
< 2	90	BARNABE-HE.05	PICA	$\text{F} (\text{C}_4\text{F}_{10})$
< 100	90	BENOIT 05	EDEL	^{73}Ge
< 1.5	90	GIRARD 05	SMPL	$\text{F} (\text{C}_2\text{ClF}_5)$
< 0.7	90	²⁶ GIULIANI 05A	RVUE	
	90	²⁷ GIULIANI 04	RVUE	
	90	²⁸ GIULIANI 04A	RVUE	
< 35	90	MIUCHI 03	BOLO	LiF
< 40	90	TAKEDA 03	BOLO	Naf

- ¹ AMOLE 19 search for SD WIMP scatter on C_3F_8 in PICO-60 bubble chamber; no signal: set limit for spin dependent coupling $\sigma^{SD}(\chi p) < 4 \times 10^{-5}$ pb for $m(\chi) = 100$ GeV.
- ² APRILE 19A search for SD WIMP scatter on 1 t yr Xe; no signal, limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m \sim 6$ –1000 GeV.
- ³ XIA 19A search for WIMP scatter on Xe in PandaX-II; limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ – 1×10^5 GeV.
- ⁴ AKERIB 17A search for SD WIMP scatter on Xe using 129.5 kg yr exposure; limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 6$ – 1×10^5 GeV.
- ⁵ AMOLE 17 require $\sigma(\text{WIMP-}p)^{SD} < 5 \times 10^{-5}$ pb for $m(\text{WIMP}) = 100$ GeV using PICO-60 1167 kg-days exposure at SNOLab.
- ⁶ APRILE 17A require require $\sigma(\text{WIMP-}p)(\text{inelastic})^{SD} < 3.3 \times 10^{-2}$ pb for $m(\text{WIMP}) = 100$ GeV, based on 7640 kg day exposure at LNGS.
- ⁷ BATTAT 17 use directional detection of CS_2 ions to require $\sigma(\text{SD}) < 2.8 \times 10^{-1}$ pb for 100 GeV WIMP with a 55 days exposure at the Bouby Underground Science Facility.
- ⁸ FU 17 from a 33000 kg d exposure at CJPL, PANDAX II derive for $m(\text{DM}) = 100$ GeV, $\sigma^{SD}(\text{WIMP-}p) < 2 \times 10^{-3}$ pb.
- ⁹ AABOUD 16b use ATLAS 13 TeV 3.2 fb $^{-1}$ of data to search for monojet plus missing E_T ; agree with SM rates; present limits on large extra dimensions, compressed SUSY spectra and wimp pair production.
- ¹⁰ AABOUD 16f search for monophoton plus missing E_T events at ATLAS with 13 TeV and 3.2 fb $^{-1}$; signal agrees with SM background; place limits on SD WIMP-proton scattering vs. mediator mass and large extra dimension models.
- ¹¹ AARTSEN 16c search for high energy ν s from WIMP annihilation in solar core; limits set on SD WIMP- p scattering (Fig. 8).
- ¹² ADRIAN-MARTINEZ 16 search for WIMP annihilation into ν s from solar core; exclude SD cross section $< \text{few } 10^{-4}$ depending on $m(\text{WIMP})$.
- ¹³ AKERIB 16A using 2013 data exclude SD WIMP-proton scattering $> 3 \times 10^{-3}$ pb for $m(\text{WIMP}) = 100$ GeV.
- ¹⁴ AMOLE 16 use bubble technique on CF_3I target to exclude SD WIMP- p scattering $> 5 \times 10^{-4}$ pb for $m(\text{WIMP}) = 100$ GeV.
- ¹⁵ Use a direction-sensitive detector.
- ¹⁶ AVRORIN 14 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the Sun in data taken between 1998 and 2003. See their Table 1 for limits assuming annihilation into neutrino pairs.
- ¹⁷ AARTSEN 13 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the sun in data taken between June 2010 and May 2011.
- ¹⁸ ADRIAN-MARTINEZ 13 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the sun in data taken between Jan. 2007 and Dec. 2008.
- ¹⁹ The value has been provided by the authors. APRILE 13 note that the proton limits on Xe are highly sensitive to the theoretical model used. See also APRILE 14A.
- ²⁰ BOLIEV 13 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the sun in data taken from 1978 to 2009. See also SUVOROVA 13 for an older analysis of the same data.
- ²¹ ABBASI 12 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the Sun. The amount of X^0 depends on the X^0 -proton cross section.
- ²² ARCHAMBAULT 12 search for WIMP scatter on C_4F_{10} ; limits set in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m \sim 4$ –500 GeV.
- ²³ TANAKA 11 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the Sun. The amount of X^0 depends on the X^0 -proton cross section.
- ²⁴ See their Fig. 3 for limits on spin-dependent proton couplings for X^0 mass of 50 GeV.
- ²⁵ See also AKERIB 05.
- ²⁶ GIULIANI 05A analyze available data and give combined limits.
- ²⁷ GIULIANI 04 reanalyze COLLAR 00 data and give limits for spin-dependent X^0 -proton coupling.
- ²⁸ GIULIANI 04A give limits for spin-dependent X^0 -proton couplings from existing data.

For $m_{X^0} = 1$ TeV

For limits from X^0 annihilation in the Sun, the assumed annihilation final state is shown in parenthesis in the comment.

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 3 \times 10^{-4}$	90	¹ AMOLE 19	PICO	C_3F_8
$< 4 \times 10^{-3}$	90	² APRILE 19A	XE1T	Xe, SD
$< 5 \times 10^{-3}$	90	³ XIA 19A	PNDX	SD WIMP on Xe
	90	⁴ ALBERT 18c	HAWC	DM annihilation in Sun to long-lived mediator
$< 2.05 \times 10^{-5}$	90	⁵ AARTSEN 17A	ICCB	ν , sun
$< 7 \times 10^{-3}$	90	⁶ AKERIB 17A	LUX	Xe

Searches Particle Listings

WIMP and Dark Matter Searches

< 2 × 10 ⁻²	90	7 FU	17 PNDX	SD WIMP on Xe
< 1 × 10 ⁻²	90	8 ADRIAN-MAR.16B	ANTR	solar μ from WIMP annih.
< 1.5 × 10 ³	90	AMOLE	15 PICO	C ₃ F ₈
< 2.7 × 10 ⁻³	90	NAKAMURA	15 NAGE	CF ₄
< 6.9 × 10 ⁻²	90	9 AVRORIN	14 BAIK	H, solar ν ($W^+ W^-$)
< 8.4 × 10 ⁻⁴	90	9 AVRORIN	14 BAIK	H, solar ν ($b\bar{b}$)
< 4.48 × 10 ⁻⁴	90	9 AVRORIN	14 BAIK	H, solar ν ($\tau^+ \tau^-$)
< 1.00 × 10 ⁻²	90	10 AARTSEN	13 ICCB	H, solar ν ($W^+ W^-$)
< 8.9 × 10 ⁻⁴	90	10 AARTSEN	13 ICCB	H, solar ν ($b\bar{b}$)
< 2.0 × 10 ⁻²	90	11 ADRIAN-MAR.13	ANTR	H, solar ν ($W^+ W^-$)
< 2.3 × 10 ⁻⁴	90	11 ADRIAN-MAR.13	ANTR	H, solar ν ($b\bar{b}$)
< 7.57 × 10 ⁻²	90	11 ADRIAN-MAR.13	ANTR	H, solar ν ($\tau^+ \tau^-$)
< 5.4 × 10 ⁻³	90	12 APRILE	13 X100	Xe
< 4.2 × 10 ⁻²	90	13 BOLIEV	13 BAKS	H, solar ν ($W^+ W^-$)
< 1.5 × 10 ⁻³	90	13 BOLIEV	13 BAKS	H, solar ν ($b\bar{b}$)
< 2.50 × 10 ⁻⁴	90	13 BOLIEV	13 BAKS	H, solar ν ($\tau^+ \tau^-$)
< 7.86 × 10 ⁻³	90	14 ABBASI	12 ICCB	H, solar ν ($W^+ W^-$)
< 8 × 10 ⁻²	90	14 ABBASI	12 ICCB	H, solar ν ($b\bar{b}$)
< 8	90	BEHNKE	12 COUP	CF ₃ I
< 6 × 10 ⁻²	90	DAW	12 DRFT	F (CF ₄)
< 8 × 10 ⁻²	90	FELIZARDO	12 SMPL	C ₂ ClF ₅
< 8 × 10 ⁻²	90	KIM	12 KIMS	Csl
< 0.4	90	15 AHLEN	11 DMTP	F (CF ₄)
< 2 × 10 ⁻³	90	BEHNKE	11 COUP	CF ₃ I
< 2 × 10 ⁻²	90	16 TANAKA	11 SKAM	H, solar ν ($b\bar{b}$)
< 1 × 10 ⁻³	90	16 TANAKA	11 SKAM	H, solar ν ($W^+ W^-$)
< 2 × 10 ⁻⁴	90	17 ABBASI	10 ICCB	KK dark matter
< 8.7 × 10 ⁻⁴	90	15 MIUCHI	10 NAGE	CF ₄
< 2.2 × 10 ⁻²	90	ABBASI	09B ICCB	H, solar ν ($W^+ W^-$)
< 3	90	ABBASI	09B ICCB	H, solar ν ($b\bar{b}$)
< 6	90	ARCHAMBAU.09	PICA	F
< 9	90	LEBEDENKO	09A ZEP3	Xe
< 100	90	ANGLE	08A XE10	Xe
< 0.8	90	ALNER	07 ZEP2	Xe
< 4 × 10 ⁴	90	LEE	07A KIMS	Csl
< 30	90	15 MIUCHI	07 NAGE	F (CF ₄)
< 1.5	90	18 AKERIB	06 CDMS	⁷³ Ge, ²⁹ Si
< 15	90	ALNER	05 NAIA	NaI
< 600	90	BARNABE-HE.05	PICA	F (C ₄ F ₁₀)
< 10	90	BENOIT	05 EDEL	⁷³ Ge
< 260	90	GIRARD	05 SMPL	F (C ₂ ClF ₅)
< 150	90	MIUCHI	03 BOLO	LiF
	90	TAKEDA	03 BOLO	NaF

- 1 AMOLE 19 search for SD WIMP scatter on C₃F₈ in PICO-60 bubble chamber; no signal: set limit for spin dependent coupling $\sigma^{SD}(\chi p) < 3 \times 10^{-4}$ pb for $m(\chi) = 1000$ GeV.
- 2 APRILE 19A search for SD WIMP scatter on 1 t yr Xe; no signal, limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m \sim 6$ -1000 GeV.
- 3 XIA 19A search for WIMP scatter on Xe in PandaX-II; limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ -1 × 10⁵ GeV.
- 4 ALBERT 18c search for DM annihilation in Sun to long-lived mediator (LLM) which decays outside Sun, for DM masses above 1 TeV; assuming LLM, limits set on $\sigma^{SD}(\chi p)$.
- 5 AARTSEN 17A search for neutrinos from solar WIMP annihilation into $\tau^+ \tau^-$ in 532 days of live time.
- 6 AKERIB 17A search for SD WIMP scatter on Xe using 129.5 kg yr exposure; limits placed in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 6$ -1 × 10⁵ GeV.
- 7 FU 17 search for SD WIMP scatter on Xe; limits set in $\sigma^{SD}(\chi p)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ -1 × 10³ GeV.
- 8 ADRIAN-MARTINEZ 16B search for secluded DM via WIMP annihilation in solar core into light mediator which later decays to μ or ν s; limits presented in Figures 3 and 4.
- 9 AVRORIN 14 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the Sun in data taken between 1998 and 2003. See their Table 1 for limits assuming annihilation into neutrino pairs.
- 10 AARTSEN 13 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the sun in data taken between June 2010 and May 2011.
- 11 ADRIAN-MARTINEZ 13 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the sun in data taken between Jan. 2007 and Dec. 2008.
- 12 The value has been provided by the authors. APRILE 13 note that the proton limits on Xe are highly sensitive to the theoretical model used. See also APRILE 14A.
- 13 BOLIEV 13 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the sun in data taken from 1978 to 2009. See also SUVOROVA 13 for an older analysis of the same data.
- 14 ABBASI 12 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the Sun. The amount of X^0 depends on the X^0 -proton cross section.
- 15 Use a direction-sensitive detector.
- 16 TANAKA 11 search for neutrinos from the Sun arising from the pair annihilation of X^0 trapped by the Sun. The amount of X^0 depends on the X^0 -proton cross section.
- 17 ABBASI 10 search for ν_μ from annihilations of Kaluza-Klein photon dark matter in the Sun.
- 18 See also AKERIB 05.

Spin-Dependent Cross Section Limits for Dark Matter Particle (X^0) on Neutron

For m_{X^0} in GeV range

We provide here limits for $m_{X^0} < 5$ GeV

VALUE (pb)	CL %	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
< 1 × 10 ¹⁰	95	1 ABDELHAMEE.19	CRES	SD low mass DM on Li
< 2.3 × 10 ²	90	2 APRILE	19c XE1T	light DM on Xe via Migdal/brem effect
< 1 × 10 ⁻²	90	3 APRILE	19D XE1T	light DM on Xe via ionization
< 4 × 10 ⁴	90	4 ARMENGAUD	19 EDEL	GeV-scale WIMPs on Ge
< 8 × 10 ⁻²	90	5 XIA	19A PNDX	SD WIMP on Xe
< 3	90	6 AGNESE	18 SCDM	GeV-scale WIMPs on Ge
< 3	90	7 JIANG	18 CDEX	GeV-scale WIMPs on Ge
< 10	90	8 YANG	18 CDEX	WIMPs on Ge
< 1 × 10 ⁻¹	90	9 AKERIB	17A LUX	Xe
< 0.1	90	10 FU	17 PNDX	SD WIMP on Xe
< 20	90	11 ZHAO	16 CDEX	GeV-scale WIMPs on Ge
< 150	90	12 AHMED	11B CDM2	GeV-scale WIMPs on Ge

- 1 ABDELHAMEED 19 search for GeV-scale WIMP SD scatter on ⁷Li crystal; set limit $\sigma^{SD}(\chi n)$ for $m(\chi) \sim 0.8$ -20 GeV; quoted limit for $m(\chi) = 1$ GeV.
- 2 APRILE 19C search for light DM on Xe via Migdal/bremsstrahlung effect; no signal, require $\sigma^{SD}(\chi n) < 230$ pb for $m(\chi) = 1$ GeV.
- 3 APRILE 19D search for light DM scatter on Xe via ionization; no signal, limits placed in σ vs. $m(\text{DM}) \sim 3$ -6 GeV; quoted limit is for $m(\text{DM}) = 5$ GeV.
- 4 ARMENGAUD 19 search for GeV scale WIMP scatter on Ge; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 0.5$ -10 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 5 XIA 19A search for WIMP scatter on Xe in PandaX-II; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ -1 × 10⁵ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 6 AGNESE 18 search for GeV scale WIMPs scatter at CDMSlite; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m \sim 1.5$ -20 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 7 JIANG 18 search for GeV scale WIMP scatter on Ge; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 3$ -10 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 8 YANG 18 search for WIMP scatter on Ge; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 2$ -10 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 9 AKERIB 17A search for SD WIMP scatter on Xe with 129.5 kg yr exposure; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ -1 × 10⁵ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 10 FU 17 search for SD WIMP scatter on Xe; limits set in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ -1 × 10³ GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 11 ZHAO 16 search for GeV-scale WIMP scatter on Ge; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ -30 GeV; quoted limit is for $m(\chi) = 5$ GeV.
- 12 AHMED 11B search for GeV scale WIMP scatter on Ge in CDMS II; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m \sim 4$ -12 GeV. Limit given for $m(\chi) = 5$ GeV.

For $m_{X^0} = 20$ GeV

VALUE (pb)	CL %	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
< 8 × 10 ⁻⁶	90	1 APRILE	19A XE1T	Xe, SD
< 3 × 10 ⁻⁵	90	2 XIA	19A PNDX	SD WIMP on Xe
< 1.5	95	3 AGNESE	18 SCDM	Ge
< 2.5 × 10 ⁻⁵	90	4 AKERIB	17A LUX	Xe
< 7 × 10 ⁻⁵	90	5 FU	17 PNDX	SD WIMP on Xe
< 2	90	6 ZHAO	16 CDEX	GeV-scale WIMPs on Ge
< 0.09	90	7 FELIZARDO	14 SMPL	C ₂ ClF ₅
< 8	90	7 UCHIDA	14 XMAS	¹²⁹ Xe, inelastic
< 1.13 × 10 ⁻³	90	8 APRILE	13 X100	Xe
< 0.02	90	AKIMOV	12 ZEP3	Xe
< 0.06	90	AHMED	09 CDM2	Ge
< 0.04	90	LEBEDENKO	09A ZEP3	Xe
< 50	90	9 LIN	09 TEXO	Ge
< 6 × 10 ⁻³	90	ANGLE	08A XE10	Xe
< 0.5	90	ALNER	07 ZEP2	Xe
< 25	90	LEE	07A KIMS	Csl
< 0.3	90	10 AKERIB	06 CDMS	⁷³ Ge, ²⁹ Si
< 30	90	SHIMIZU	06A CNTR	F (CaF ₂)
< 60	90	ALNER	05 NAIA	NaI
< 20	90	BARNABE-HE.05	PICA	F (C ₄ F ₁₀)
< 10	90	BENOIT	05 EDEL	⁷³ Ge
< 4	90	KLAPDOR-K...	05 HDMS	⁷³ Ge (enriched)
< 600	90	TAKEDA	03 BOLO	NaF

- 1 APRILE 19A search for SD WIMP scatter on 1 t yr Xe; no signal: limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m \sim 6$ -1000 GeV.
- 2 XIA 19A search for WIMP scatter on Xe in PandaX-II; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ -1 × 10⁵ GeV.
- 3 AGNESE 18 give limits for $\sigma^{SD}(n\chi)$ for $m(\text{WIMP})$ between 1.5 and 20 GeV using CDMSlite mode data.
- 4 AKERIB 17A search for SD WIMP scatter on Xe with 129.5 kg yr exposure; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ -1 × 10⁵ GeV.
- 5 FU 17 search for SD WIMP scatter on Xe; limits set in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ -1 × 10³ GeV.
- 6 ZHAO 16 search for GeV-scale WIMP scatter on Ge; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ -30 GeV.
- 7 Derived limit from search for inelastic scattering $X^0 + ^{129}\text{Xe} \rightarrow X^0 + ^{129}\text{Xe}^*(39.58 \text{ keV})$.
- 8 The value has been provided by the authors. See also APRILE 14A.
- 9 See their Fig. 6(b) for cross section limits for m_{X^0} extending down to 2 GeV.
- 10 See also AKERIB 05.

See key on page 999

Searches Particle Listings

WIMP and Dark Matter Searches

For $m_{\chi^0} = 100$ GeV

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 1.5 \times 10^{-5}$	90	¹ APRILE 19A	XE1T	Xe, SD
$< 4 \times 10^{-3}$	90	² SUZUKI 19	XMAS	¹²⁹ Xe, inelastic
$< 2 \times 10^{-5}$	90	³ XIA 19A	PNDX	SD WIMP on Xe
$< 2.5 \times 10^{-5}$	90	⁴ AKERIB 17A	LUX	Xe
$< 7 \times 10^{-5}$	90	⁵ FU 17	PNDX	SD WIMP on Xe
< 0.1	90	FELIZARDO 14	SMPL	C ₂ ClF ₅
< 0.05	90	⁶ UCHIDA 14	XMAS	¹²⁹ Xe, inelastic
$< 4.68 \times 10^{-4}$	90	⁷ APRILE 13	X100	Xe
< 0.01	90	AKIMOV 12	ZEP3	Xe
		⁸ FELIZARDO 10	SMPL	C ₂ ClF ₃
	90	AHMED 09	CDM2	Ge
< 0.01	90	LEBEDENKO 09A	ZEP3	Xe
< 100	90	LIN 09	TEXO	Ge
< 0.01	90	ANGLE 08A	XE10	Xe
< 0.05	90	⁹ BEDNYAKOV 08	RVUE	Ge
< 0.08	90	ALNER 07	ZEP2	Xe
< 6	90	LEE 07A	KIMS	CsI
< 0.07	90	¹⁰ AKERIB 06	CDMS	⁷³ Ge, ²⁹ Si
< 30	90	SHIMIZU 06A	CNTR	F (C ₄ F ₂)
< 10	90	ALNER 05	NAIA	NaI
< 30	90	BARNABE-HE...05	PICA	F (C ₄ F ₁₀)
< 0.7	90	BENOIT 05	EDEL	⁷³ Ge
< 0.2		¹¹ GIULIANI 05A	RVUE	
< 1.5	90	KLAPDOR-K... 05	HDMS	⁷³ Ge (enriched)
		¹² GIULIANI 04	RVUE	
		¹³ GIULIANI 04A	RVUE	
		¹⁴ MIUCHI 03	BOLO	LiF
< 800	90	TAKEDA 03	BOLO	NaF

- ¹ APRILE 19A search for SD WIMP scatter on 1 t yr Xe; no signal, limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m \sim 6$ –1000 GeV.
- ² SUZUKI 19 search in single phase liquid xenon detector for inelastic scattering $X^0 + ^{129}\text{Xe} \rightarrow X^0 + ^{129}\text{Xe}^*$ (39.58 keV); no signal: require $\sigma(\chi n)^{SD} < 4 \times 10^{-3}$ pb for $m(\chi) = 100$ GeV.
- ³ XIA 19A search for WIMP scatter on Xe in PandaX-II; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ – 1×10^5 GeV.
- ⁴ AKERIB 17A search for SD WIMP scatter on Xe with 129.5 kg yr exposure; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ – 1×10^5 GeV.
- ⁵ FU 17 search for SD WIMP scatter on Xe; limits set in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ – 1×10^3 GeV.
- ⁶ UCHIDA 14 derived limit from search for inelastic scattering $X^0 + ^{129}\text{Xe} \rightarrow X^0 + ^{129}\text{Xe}^*$ (39.58 keV).
- ⁷ The value has been provided by the authors. See also APRILE 14A.
- ⁸ See their Fig. 3 for limits on spin-dependent neutron couplings for X^0 mass of 50 GeV.
- ⁹ BEDNYAKOV 08 reanalyze KLAPDOR-KLEINGROTHAUS 05 and BAUDIS 01 data.
- ¹⁰ See also AKERIB 05.
- ¹¹ GIULIANI 05A analyze available data and give combined limits.
- ¹² GIULIANI 04 reanalyze COLLAR 00 data and give limits for spin-dependent X^0 -neutron coupling.
- ¹³ GIULIANI 04A give limits for spin-dependent X^0 -neutron couplings from existing data.
- ¹⁴ MIUCHI 03 give model-independent limit for spin-dependent X^0 -proton and neutron cross sections. See their Fig. 5.

For $m_{\chi^0} = 1$ TeV

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 1.2 \times 10^{-4}$	90	¹ APRILE 19A	XE1T	Xe, SD
$< 2 \times 10^{-4}$	90	² XIA 19A	PNDX	Xe
$< 2.5 \times 10^{-4}$	90	³ AKERIB 17A	LUX	Xe
$< 4 \times 10^{-4}$	90	⁴ FU 17	PNDX	SD WIMP on Xe
< 0.07	90	FELIZARDO 14	SMPL	C ₂ ClF ₅
< 0.2	90	⁵ UCHIDA 14	XMAS	¹²⁹ Xe, inelastic
$< 3.64 \times 10^{-3}$	90	⁶ APRILE 13	X100	Xe
< 0.08	90	AKIMOV 12	ZEP3	Xe
< 0.2	90	AHMED 09	CDM2	Ge
< 0.1	90	LEBEDENKO 09A	ZEP3	Xe
< 0.1	90	ANGLE 08A	XE10	Xe
< 0.25	90	⁷ BEDNYAKOV 08	RVUE	Ge
< 0.6	90	ALNER 07	ZEP2	Xe
< 30	90	LEE 07A	KIMS	CsI
< 0.5	90	⁸ AKERIB 06	CDMS	⁷³ Ge, ²⁹ Si
< 40	90	ALNER 05	NAIA	NaI
< 200	90	BARNABE-HE...05	PICA	F (C ₄ F ₁₀)
< 4	90	BENOIT 05	EDEL	⁷³ Ge
< 10	90	KLAPDOR-K... 05	HDMS	⁷³ Ge (enriched)
$< 4 \times 10^3$	90	TAKEDA 03	BOLO	NaF

- ¹ APRILE 19A search for SD WIMP scatter on 1 t yr Xe; no signal, limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m \sim 6$ –1000 GeV.
- ² XIA 19A search for WIMP scatter on Xe in PandaX-II; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ – 1×10^5 GeV.
- ³ AKERIB 17A search for SD WIMP scatter on Xe with 129.5 kg yr exposure; limits placed in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 5$ – 1×10^5 GeV.

- ⁴ FU 17 search for SD WIMP scatter on Xe; limits set in $\sigma^{SD}(\chi n)$ vs. $m(\chi)$ plane for $m(\chi) \sim 4$ – 1×10^3 GeV.
- ⁵ Derived limit from search for inelastic scattering $X^0 + ^{129}\text{Xe} \rightarrow X^0 + ^{129}\text{Xe}^*$ (39.58 keV).
- ⁶ The value has been provided by the authors. See also APRILE 14A.
- ⁷ BEDNYAKOV 08 reanalyze KLAPDOR-KLEINGROTHAUS 05 and BAUDIS 01 data.
- ⁸ See also AKERIB 05.

Cross-Section Limits for Dark Matter Particles (X^0) on electron

For m_{χ^0} in GeV range

We provide here limits for $m_{\chi^0} < 5$ GeV

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 2 \times 10^6$	90	¹ AKERIB 20	LUX	mirror DM with Xe
		² ABRAMOFF 19	SENS	WIMP-e scatter on Si
		³ AGUILAR-AR...19A	DMIC	MeV scale DM scatter on e in Si
$< 1 \times 10^{-4}$	90	⁴ APRILE 19D	XE1T	light DM on Xe via ionization
$< 9 \times 10^{-3}$	90	⁵ AGNES 18B	DS50	Ar
$< 1 \times 10^4$	90	⁶ AGNESE 18B	SCDM	e χ scatter
$< 5 \times 10^3$	90	⁷ CRISLER 18	SENS	Si CCD
		⁸ APRILE 17	X100	Xe, annual modulation

- ¹ AKERIB 20 search for mirror DM with LUX 95 d \times 118 kg data for mirror e scatter from Xe; no signal, limits placed in kinetic mixing parameter vs. mirror e temperature $T \sim 0.1$ –0.9 keV plane.
- ² ABRAMOFF 19 search for MeV-scale WIMP scatter from Si skipper-CCD; limits placed on $\sigma(\chi e)$ for $m(\chi) \sim 0.5$ –100 MeV depending on DM form factors. Limit given for $m(\text{DM}) = 1$ MeV.
- ³ AGUILAR-AREVALO 19A search for MeV scale DM scatter from e in Si CCDs at SNO-LAB; no signal, limits placed in $\sigma(e)$ vs. $m(\text{DM})$ plane for $m(\text{DM}) \sim 0.6$ –100 MeV.
- ⁴ APRILE 19D search for light DM scatter on Xe via ionization; no signal, limits placed in σ on nucleus vs. $m(\text{DM})$ plane for $m(\text{DM}) \sim 0.02$ –10 GeV; quoted limit is for $m(\text{DM}) = 0.2$ GeV.
- ⁵ AGNES 18B search for MeV scale WIMP scatter from e in Ar; no signal, limits set in σ_e vs. $m(\chi)$ plane for $m \sim 20$ –1000 MeV and two choices of form factor F(DM); quoted limit for $m(\chi) = 100$ MeV and $F = 1$.
- ⁶ AGNESE 18B search for e χ scatter in SuperCDMS; limits placed in $\sigma(e\chi)$ vs. $m(\chi)$ plane for $m \sim 0.3$ – 1×10^4 MeV for two assumed form factors and also in $m(\text{dark photon})$ vs. kinetic mixing plane. Limit given for $m(\chi) = 1$ GeV and $F=1$.
- ⁷ CRISLER 18 search for $\chi e \rightarrow \chi e$ scatter in Si CCD; place limits on MeV DM in σ_e vs. $m(\chi)$ plane for $m \sim 0.5$ –1000 MeV for different form factors; quoted limit is for $F(\text{DM}) = 1$ and $m(\chi) = 10$ MeV.
- ⁸ APRILE 17 search for WIMP-e annual modulation signal for recoil energy in the 2.0–5.8 keV interval using 4 years data with Xe. No significant effect seen.

Cross-Section Limits for Dark Matter Particles (X^0) on Nuclei

For m_{χ^0} in GeV range

We provide here limits for $m_{\chi^0} < 5$ GeV

VALUE (nb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
< 0.03	90	¹ UCHIDA 14	XMAS	¹²⁹ Xe, inelastic
< 0.08	90	² ANGLOHER 02	CRES	Al
		³ BENOIT 00	EDEL	Ge
< 0.04	95	⁴ KLIMENKO 98	CNTR	⁷³ Ge, inel.
< 0.8		ALESSAND... 96	CNTR	O
< 6		ALESSAND... 96	CNTR	Te
< 0.02	90	⁵ BELLI 96	CNTR	¹²⁹ Xe, inel.
		⁶ BELLI 96c	CNTR	¹²⁹ Xe
$< 4 \times 10^{-3}$	90	⁷ BERNABEI 96	CNTR	Na
< 0.3	90	⁷ BERNABEI 96	CNTR	I
< 0.2	95	⁸ SARSA 96	CNTR	Na
< 0.015	90	⁹ SMITH 96	CNTR	Na
< 0.05	95	¹⁰ GARCIA 95	CNTR	Natural Ge
< 0.1	95	QUENBY 95	CNTR	Na
< 90	90	¹¹ SNOWDEN... 95	MICA	¹⁶ O
$< 4 \times 10^3$	90	¹¹ SNOWDEN... 95	MICA	³⁹ K
< 0.7	90	BACCI 92	CNTR	Na
< 0.12	90	¹² REUSSER 91	CNTR	Natural Ge
< 0.06	95	CALDWELL 88	CNTR	Natural Ge

- ¹ UCHIDA 14 limit is for inelastic scattering $X^0 + ^{129}\text{Xe} \rightarrow X^0 + ^{129}\text{Xe}^*$ (39.58 keV).
- ² ANGLOHER 02 limit is for spin-dependent WIMP-Aluminum cross section.
- ³ BENOIT 00 find four event categories in Ge detectors and suggest that low-energy surface nuclear recoils can explain anomalous events reported by UKDMC and Sclay NaI experiments.
- ⁴ KLIMENKO 98 limit is for inelastic scattering $X^0 \text{ } ^{73}\text{Ge} \rightarrow X^0 \text{ } ^{73}\text{Ge}^*$ (13.26 keV).
- ⁵ BELLI 96 limit for inelastic scattering $X^0 \text{ } ^{129}\text{Xe} \rightarrow X^0 \text{ } ^{129}\text{Xe}^*$ (39.58 keV).
- ⁶ BELLI 96c use background subtraction and obtain $\sigma < 150$ pb (< 1.5 fb) (90% CL) for spin-dependent (independent) X^0 -proton cross section. The confidence level is from R. Bernabei, private communication, May 20, 1999.
- ⁷ BERNABEI 96 use pulse shape discrimination to enhance the possible signal. The limit here is from R. Bernabei, private communication, September 19, 1997.
- ⁸ SARSA 96 search for annual modulation of WIMP signal. See SARSA 97 for details of the analysis. The limit here is from M.L. Sarsa, private communication, May 26, 1997.

Searches Particle Listings
WIMP and Dark Matter Searches

- ⁹ SMITH 96 use pulse shape discrimination to enhance the possible signal. A dark matter density of 0.4 GeV cm^{-3} is assumed.
- ¹⁰ GARCIA 95 limit is from the event rate. A weaker limit is obtained from searches for diurnal and annual modulation.
- ¹¹ SNOWDEN-IFFT 95 look for recoil tracks in an ancient mica crystal. Similar limits are also given for ^{27}Al and ^{28}Si . See COLLAR 96 and SNOWDEN-IFFT 96 for discussion on potential backgrounds.
- ¹² REUSSER 91 limit here is changed from published (0.04) after reanalysis by authors. J.L. Vuilleumier, private communication, March 29, 1996.

For $m_{\chi^0} = 100 \text{ GeV}$

VALUE (nb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
< 3 $\times 10^{-3}$	90	1 UCHIDA	14 XMAS	^{129}Xe , inelastic
< 0.3	90	2 ANGLOHER	02 CRES	Al
		3 BELLI	02 RVUE	
		4 BERNABEI	02c DAMA	
		5 GREEN	02 RVUE	
		6 ULLIO	01 RVUE	
		7 BENOIT	00 EDEL	Ge
< 4 $\times 10^{-3}$	90	8 BERNABEI	00D	^{129}Xe , inel.
		9 AMBROSIO	99 MCRO	
		10 BRHLIK	99 RVUE	
< 8 $\times 10^{-3}$	95	11 KLIMENKO	98 CNTR	^{73}Ge , inel.
< 0.08	95	12 KLIMENKO	98 CNTR	^{73}Ge , inel.
< 4		ALESSAND...	96 CNTR	O
< 25		ALESSAND...	96 CNTR	Te
< 6 $\times 10^{-3}$	90	13 BELLI	96 CNTR	^{129}Xe , inel.
		14 BELLI	96c CNTR	^{129}Xe
< 1 $\times 10^{-3}$	90	15 BERNABEI	96 CNTR	Na
< 0.3	90	15 BERNABEI	96 CNTR	I
< 0.7	95	16 SARSA	96 CNTR	Na
< 0.03	90	17 SMITH	96 CNTR	Na
< 0.8	90	17 SMITH	96 CNTR	I
< 0.35	95	18 GARCIA	95 CNTR	Natural Ge
< 0.6	95	QUENBY	95 CNTR	Na
< 3	95	QUENBY	95 CNTR	I
< 1.5 $\times 10^2$	90	19 SNOWDEN...	95 MICA	^{16}O
< 4 $\times 10^2$	90	19 SNOWDEN...	95 MICA	^{39}K
< 0.08	90	20 BECK	94 CNTR	^{76}Ge
< 2.5	90	BACCI	92 CNTR	Na
< 3	90	BACCI	92 CNTR	I
< 0.9	90	21 REUSSER	91 CNTR	Natural Ge
< 0.7	95	CALDWELL	88 CNTR	Natural Ge

- ¹ UCHIDA 14 limit is for inelastic scattering $\chi^0 + ^{129}\text{Xe} \rightarrow \chi^0 + ^{129}\text{Xe}^*$ (39.58 keV).
- ² ANGLOHER 02 limit is for spin-dependent WIMP-Aluminum cross section.
- ³ BELLI 02 discuss dependence of the extracted WIMP cross section on the assumptions of the galactic halo structure.
- ⁴ BERNABEI 02c analyze the DAMA data in the scenario in which χ^0 scatters into a slightly heavier state as discussed by SMITH 01.
- ⁵ GREEN 02 discusses dependence of extracted WIMP cross section limits on the assumptions of the galactic halo structure.
- ⁶ ULLIO 01 disfavor the possibility that the BERNABEI 99 signal is due to spin-dependent WIMP coupling.
- ⁷ BENOIT 00 find four event categories in Ge detectors and suggest that low-energy surface nuclear recoils can explain anomalous events reported by UKDMC and Saclay Nal experiments.
- ⁸ BERNABEI 00D limit is for inelastic scattering $\chi^0 ^{129}\text{Xe} \rightarrow \chi^0 ^{129}\text{Xe}$ (39.58 keV).
- ⁹ AMBROSIO 99 search for upgoing muon events induced by neutrinos originating from WIMP annihilations in the Sun and Earth.
- ¹⁰ BRHLIK 99 discuss the effect of astrophysical uncertainties on the WIMP interpretation of the BERNABEI 99 signal.
- ¹¹ KLIMENKO 98 limit is for inelastic scattering $\chi^0 ^{73}\text{Ge} \rightarrow \chi^0 ^{73}\text{Ge}^*$ (13.26 keV).
- ¹² KLIMENKO 98 limit is for inelastic scattering $\chi^0 ^{73}\text{Ge} \rightarrow \chi^0 ^{73}\text{Ge}^*$ (66.73 keV).
- ¹³ BELLI 96 limit for inelastic scattering $\chi^0 ^{129}\text{Xe} \rightarrow \chi^0 ^{129}\text{Xe}^*$ (39.58 keV).
- ¹⁴ BELLI 96c use background subtraction and obtain $\sigma < 0.35 \text{ pb}$ ($< 0.15 \text{ fb}$) (90% CL) for spin-dependent (independent) χ^0 -proton cross section. The confidence level is from R. Bernabei, private communication, September 19, 1997.
- ¹⁵ BERNABEI 96 use pulse shape discrimination to enhance the possible signal. The limit here is from R. Bernabei, private communication, September 19, 1997.
- ¹⁶ SARSA 96 search for annual modulation of WIMP signal. See SARSA 97 for details of the analysis. The limit here is from M.L. Sarsa, private communication, May 26, 1997.
- ¹⁷ SMITH 96 use pulse shape discrimination to enhance the possible signal. A dark matter density of 0.4 GeV cm^{-3} is assumed.
- ¹⁸ GARCIA 95 limit is from the event rate. A weaker limit is obtained from searches for diurnal and annual modulation.
- ¹⁹ SNOWDEN-IFFT 95 look for recoil tracks in an ancient mica crystal. Similar limits are also given for ^{27}Al and ^{28}Si . See COLLAR 96 and SNOWDEN-IFFT 96 for discussion on potential backgrounds.
- ²⁰ BECK 94 uses enriched ^{76}Ge (86% purity).
- ²¹ REUSSER 91 limit here is changed from published (0.3) after reanalysis by authors. J.L. Vuilleumier, private communication, March 29, 1996.

For $m_{\chi^0} = 1 \text{ TeV}$

VALUE (nb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
< 0.03	90	1 UCHIDA	14 XMAS	^{129}Xe , inelastic
< 3	90	2 ANGLOHER	02 CRES	Al
		3 BENOIT	00 EDEL	Ge
		4 BERNABEI	99D CNTR	SIMP
		5 DERBIN	99 CNTR	SIMP
< 0.06	95	6 KLIMENKO	98 CNTR	^{73}Ge , inel.
< 0.4	95	7 KLIMENKO	98 CNTR	^{73}Ge , inel.
< 40		ALESSAND...	96 CNTR	O
< 700		ALESSAND...	96 CNTR	Te
< 0.05	90	8 BELLI	96 CNTR	^{129}Xe , inel.
< 1.5	90	9 BELLI	96 CNTR	^{129}Xe , inel.
		10 BELLI	96c CNTR	^{129}Xe
< 0.01	90	11 BERNABEI	96 CNTR	Na
< 9	90	11 BERNABEI	96 CNTR	I
< 7	95	12 SARSA	96 CNTR	Na
< 0.3	90	13 SMITH	96 CNTR	Na
< 6	90	13 SMITH	96 CNTR	I
< 6	95	14 GARCIA	95 CNTR	Natural Ge
< 8	95	QUENBY	95 CNTR	Na
< 50	95	QUENBY	95 CNTR	I
< 700	90	15 SNOWDEN...	95 MICA	^{16}O
< 1 $\times 10^3$	90	15 SNOWDEN...	95 MICA	^{39}K
< 0.8	90	16 BECK	94 CNTR	^{76}Ge
< 30	90	BACCI	92 CNTR	Na
< 30	90	BACCI	92 CNTR	I
< 15	90	17 REUSSER	91 CNTR	Natural Ge
< 6	95	CALDWELL	88 CNTR	Natural Ge

- ¹ UCHIDA 14 limit is for inelastic scattering $\chi^0 + ^{129}\text{Xe} \rightarrow \chi^0 + ^{129}\text{Xe}^*$ (39.58 keV).
- ² ANGLOHER 02 limit is for spin-dependent WIMP-Aluminum cross section.
- ³ BENOIT 00 find four event categories in Ge detectors and suggest that low-energy surface nuclear recoils can explain anomalous events reported by UKDMC and Saclay Nal experiments.
- ⁴ BERNABEI 99D search for SIMPs (Strongly Interacting Massive Particles) in the mass range 10^3 – 10^{16} GeV. See their Fig. 3 for cross-section limits.
- ⁵ DERBIN 99 search for SIMPs (Strongly Interacting Massive Particles) in the mass range 10^2 – 10^{14} GeV. See their Fig. 3 for cross-section limits.
- ⁶ KLIMENKO 98 limit is for inelastic scattering $\chi^0 ^{73}\text{Ge} \rightarrow \chi^0 ^{73}\text{Ge}^*$ (13.26 keV).
- ⁷ KLIMENKO 98 limit is for inelastic scattering $\chi^0 ^{73}\text{Ge} \rightarrow \chi^0 ^{73}\text{Ge}^*$ (66.73 keV).
- ⁸ BELLI 96 limit for inelastic scattering $\chi^0 ^{129}\text{Xe} \rightarrow \chi^0 ^{129}\text{Xe}^*$ (39.58 keV).
- ⁹ BELLI 96 limit for inelastic scattering $\chi^0 ^{129}\text{Xe} \rightarrow \chi^0 ^{129}\text{Xe}^*$ (236.14 keV).
- ¹⁰ BELLI 96c use background subtraction and obtain $\sigma < 0.7 \text{ pb}$ ($< 0.7 \text{ fb}$) (90% CL) for spin-dependent (independent) χ^0 -proton cross section. The confidence level is from R. Bernabei, private communication, May 20, 1999.
- ¹¹ BERNABEI 96 use pulse shape discrimination to enhance the possible signal. The limit here is from R. Bernabei, private communication, September 19, 1997.
- ¹² SARSA 96 search for annual modulation of WIMP signal. See SARSA 97 for details of the analysis. The limit here is from M.L. Sarsa, private communication, May 26, 1997.
- ¹³ SMITH 96 use pulse shape discrimination to enhance the possible signal. A dark matter density of 0.4 GeV cm^{-3} is assumed.
- ¹⁴ GARCIA 95 limit is from the event rate. A weaker limit is obtained from searches for diurnal and annual modulation.
- ¹⁵ SNOWDEN-IFFT 95 look for recoil tracks in an ancient mica crystal. Similar limits are also given for ^{27}Al and ^{28}Si . See COLLAR 96 and SNOWDEN-IFFT 96 for discussion on potential backgrounds.
- ¹⁶ BECK 94 uses enriched ^{76}Ge (86% purity).
- ¹⁷ REUSSER 91 limit here is changed from published (5) after reanalysis by authors. J.L. Vuilleumier, private communication, March 29, 1996.

Miscellaneous Results from Underground Dark Matter Searches

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
		1 ABRAOFF	19 SENS	MeV DM e-Si; dark photon Si absorption
		2 ADHIKARI	19 C100	annual modulation Nal
		3 AMARE	19 ANAI	annual modulation Nal
		4 APRILE	19 XE1T	π (Xe)
		5 BRINGMANN	19	cosmic ray DM
		6 BRUNE	19	Majoran DM
		7 CHOI	19 THEO	290 TeV IceCube ν
		8 HA	19 C100	inelastic boosted dark γ
		9 KLOPF	19	$n \rightarrow \chi e^+ e^-$
		10 AARTSEN	18D ICCB	relic WIMP $\chi \rightarrow \nu X$
		11 ABE	18F XMAS	$A'e \rightarrow A'e$
		12 AGNES	18B D550	Ar
		13 AGNESE	18B SCDM	MeV DM e-Si; dark photon Si absorption
		14 AKERIB	18A LUX	Xe
		15 ARMENGAUD	18 EDE3	Ge

See key on page 999

Searches Particle Listings

WIMP and Dark Matter Searches

$<1 \times 10^{-12}$	90	16 KACHULIS	18 SKAM	boosted DM on e
		17 AGUILAR-AR...	17 DMIC	γ' on Si
		18 APRILE	17 X100	Xe
		19 APRILE	17d X100	Xe
		20 APRILE	17H X100	keV bosonic DM search
		21 APRILE	17K X100	$\chi N \rightarrow \chi^* \rightarrow \chi\gamma$
$<4 \times 10^{-3}$	90	22 ANGIOHER	16A CRES	CaWO ₄
		23 APRILE	15 X100	Event rate modulation
		24 APRILE	15A X100	Electron scattering

- 1 ABRAMOFF 19 search for MeV scale DM via DM-e scattering and dark photon DM via absorption in Si; limits set in coupling vs. $m(\chi)$ plane and on dark photon in $m(A)$ vs. kinetic mixing parameter plane.
- 2 ADHIKARI 19 search for annual modulation signal from WIMP scatter on NaI with 1.7 yr exposure; result consistent with both DAMA/LIBRA and null hypothesis.
- 3 AMARE 19 is ANAIS-112 search for WIMP scatter annual modulation on NaI; 157.55 kg yr exposure; result compatible with null hypothesis; confirm goal of reaching sensitivity at 3σ to DAMA/LIBRA result in 5 years.
- 4 APRILE 19 search for WIMP-pion scattering in Xe; no signal: require $\sigma(\chi\pi) < 6.4 \times 10^{-10}$ pb for $m(\chi) = 30$ GeV.
- 5 BRINGMANN 19 derive theoretically limits on GeV and sub-GeV mass dark matter, in its high energy component generated by interaction with cosmic rays; place limits on σ_{SI} and $\sigma_{SD} < 10^5$ pb.
- 6 BRUNE 19 examine possibility of Majoron dark matter; limits placed on Majoron mass vs. coupling from SN1987a and ν -less double beta decay.
- 7 CHOI 19 from multimessenger observation finds limit on $\sigma(\nu\chi)/m(\text{DM}) < 5.1 \times 10^{-23}$ cm²/GeV based on 290 TeV IceCube neutrino event.
- 8 HA 19 search for inelastic boosted MeV scale dark photon using COSINE-100 data; limits placed in m vs. epsilon plane for various mediators.
- 9 KLOPF 19 search for DM via $n \rightarrow \chi e^+ e^-$; no signal: limits placed in branching fraction vs. $m(e^+ e^-)$ plane.
- 10 AARTSEN 18d search for long-lived DM particles decaying $\chi \rightarrow \nu X$; no excess seen; for DM masses above 10 TeV, excluding lifetimes shorter than 10^{28} s.
- 11 ABE 18r search for keV mass ALPs and hidden photons (HP) scatter on electrons; limits set on mass vs. coupling.
- 12 AGNES 18b search for MeV-scale DM scatter on electrons in Ar; no signal; require $\sigma(\chi e) < 9 \times 10^{-3}$ pb for DM form factor $F(\text{DM}) = 1$ and < 300 pb for $F(\text{DM})$ proportional to $1/q^2$ for $m(\chi) = 100$ MeV.
- 13 AGNESE 18a search for MeV scale DM via DM-e scattering and dark photon DM via absorption in Si; limits set on MeV DM in coupling vs. $m(\chi)$ plane and on dark photon in $m(A')$ vs. kinetic mixing plane.
- 14 AKERIB 18a search for annual and diurnal modulation of DM scattering rate on electrons for recoil energy between 2 and 6 keVee; no signal found.
- 15 ARMENGAUD 18 search for ALP from the Sun and galactic bosonic DM, interacting in Ge; no signal; limits set for 0.8–500 keV DM particles.
- 16 KACHULIS 18 search for an excess of elastically scattered electrons above the atmospheric neutrino background in Super-K; limits placed for simple annihilation or decay in the Sun or galactic center producing "boosted" dark matter.
- 17 AGUILAR-AREVALO 17 search for hidden photon DM scatter on Si target CCD; limit kinetic mixing $\kappa < 1 \times 10^{-12}$ for $m = 10$ eV.
- 18 APRILE 17 search for WIMP-e annual modulation signal for recoil energy in the 2.0–5.8 keV interval using 4 years data with Xe. No significant effect seen.
- 19 APRILE 17d set limits on 14 WIMP-nucleon different interaction operators. No deviations found using 225 live days in the 6.6–240 keV recoil energy range.
- 20 APRILE 17H search for keV bosonic DM via $e\chi \rightarrow e$, looking for electronic recoils with 224.6 live days of data and 34 kg of LXe. Limits set on $\chi e e$ coupling for $m(\chi) = 8$ –125 keV.
- 21 APRILE 17K search for magnetic inelastic DM via $\chi N \rightarrow \chi^* \rightarrow \chi\gamma$. Limits set in DM magnetic moment vs. mass splitting plane for two DM masses corresponding to the DAMA/LIBRA best fit values.
- 22 ANGIOHER 16A require q^2 dependent scattering $< 8 \times 10^{-3}$ pb for asymmetric DM $m(\text{WIMP}) = 3$ GeV on CaWO₄ target. It uses a local dark matter density of 0.38 GeV/cm³.
- 23 APRILE 15 search for periodic variation of electronic recoil event rate in the data between Feb. 2011 and Mar. 2012. No significant modulation is found for periods up to 500 days.
- 24 APRILE 15A search for X^0 scattering off electrons. See their Fig. 4 for limits on cross section through axial-vector coupling for m_{X^0} between 0.6 GeV and 1 TeV. For $m_{X^0} = 2$ GeV, $\sigma < 60$ pb (90%CL) is obtained.

X^0 Annihilation Cross Section

Limits are on σv for X^0 pair annihilation at threshold.

VALUE (cm ³ s ⁻¹)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<0.8 \times 10^{-22}$	95	1 ABEYSEKARA 19	HAWC	DM annihilation to γ s within galactic substructure
$<4 \times 10^{-26}$	95	2 ALBERT 19b	HAWC	annihilation/decay to γ in M31
$<7 \times 10^{-27}$	95	3 CHEUNG 19		$\chi\chi \rightarrow e^+ e^-$ and $b\bar{b}$
		4 DI-MAURO 19	FLAT	Fermi-LAT M31 and M33
		5 JOHNSON 19	FLAT	P-wave DM; Fermi-LAT
$<2 \times 10^{-26}$	95	6 LI 19d	FLAT	$\chi\chi \rightarrow \gamma$
$<1 \times 10^{-32}$		7 NG 19		sterile ν decay/annihilation
		8 QUEIROZ 19		semi-annihilating DM
$<4 \times 10^{-28}$	95	9 ABDALLAH 18	HESS	$X^0 X^0 \rightarrow \gamma X$; galactic halo
$<1 \times 10^{-23}$	95	10 AHNEN 18	MGIC	$X^0 X^0 \rightarrow \gamma X$; Ursa Major II
$<1 \times 10^{-22}$	95	11 ALBERT 18b	HAWC	$X^0 X^0 \rightarrow \gamma X$; Andromeda
$<1 \times 10^{-26}$	95	12 CHANG 18a		$\chi\chi \rightarrow b\bar{b} \rightarrow \gamma$
		13 LISANTI 18	THEO	Fermi, γ ; galaxy groups

$<1.2 \times 10^{-23}$	95	14 MAZZIOTTA 18	FLAT	Fermi-LAT CRE data
$<1 \times 10^{-23}$	90	15 AARTSEN 17c	ICCB	$\chi\chi \rightarrow$ neutrinos
$<1.32 \times 10^{-25}$	95	16 ALBERT 17a	ANTR	ν , DM annihilation
$<7 \times 10^{-21}$	90	17 ARCHAMBAULT 17	VRTS	γ dwarf galaxies
$<1 \times 10^{-28}$		18 AVROIRIN 17	BAIK	cosmic ν
		19 BOUDAUD 17		MeV DM to $e^+ e^-$
		20 AARTSEN 16d	ICCB	ν , galactic center
$<6 \times 10^{-26}$	95	21 ABDALLAH 16	HESS	Central Galactic Halo
$<1 \times 10^{-27}$	95	22 ABDALLAH 16a	HESS	WIMP+WIMP $\rightarrow \gamma\gamma$; galactic center
$<3 \times 10^{-26}$	95	23 AHNEN 16	MGFL	Satellite galaxy, $m(\text{WIMP})=100$ GeV
$<1.9 \times 10^{-21}$	90	24 AVROIRIN 16	BAIK	ν s from galactic center
$<3 \times 10^{-26}$	95	25 CAPUTO 16	FLAT	small Magellanic cloud
$<1 \times 10^{-25}$	95	26 FORNATA 16	FLAT	Fermi-LAT γ -ray anisotropy
$<5 \times 10^{-27}$		27 LEITE 16		WIMP, radio
$<2 \times 10^{-26}$	95	28 LI 16	FLAT	dwarf galaxies
$<1 \times 10^{-25}$	95	29 LI 16a	FLAT	Fermi-LAT; M31
$<1 \times 10^{-26}$		30 LIANG 16	FLAT	Fermi-LAT, gamma line
$<1 \times 10^{-25}$	95	31 LU 16	FLAT	Fermi-LAT and AMS-02
$<1 \times 10^{-23}$	95	32 SHIRASAKI 16	FLAT	extra galactic
		33 AARTSEN 15c	ICCB	ν , Galactic halo
		34 AARTSEN 15e	ICCB	ν , Galactic center
		35 ABRAMOWSKI15	HESS	Galactic center
		36 ACKERMANN 15	FLAT	monochromatic γ
		37 ACKERMANN 15a	FLAT	isotropic γ background
		38 ACKERMANN 15b	FLAT	Satellite galaxy
		39 ADRIAN-MAR. 15	ANTR	ν , Galactic center
$<2.90 \times 10^{-26}$	95	40,41 ACKERMANN 14	FLAT	Satellite galaxy, $m = 10$ GeV
$<1.84 \times 10^{-25}$	95	40,42 ACKERMANN 14	FLAT	Satellite galaxy, $m = 100$ GeV
$<1.75 \times 10^{-24}$	95	40,42 ACKERMANN 14	FLAT	Satellite galaxy, $m = 1$ TeV
$<4.52 \times 10^{-24}$	95	43 ALEKSIK 14	MGIC	Segue 1, $m = 1.35$ TeV
		44 AARTSEN 13c	ICCB	Galaxies
		45 ABRAMOWSKI13	HESS	Central Galactic Halo
		46 ACKERMANN 13a	FLAT	Galaxy
		47 ABRAMOWSKI12	HESS	Fornax Cluster
		48 ACKERMANN 12	FLAT	Galaxy
		49 ACKERMANN 12	FLAT	Galaxy
		50 ALIU 12	VRTS	Segue 1
$<1 \times 10^{-22}$	90	51 ABBASI 11c	ICCB	Galactic halo, $m=1$ TeV
$<3 \times 10^{-25}$	95	52 ABRAMOWSKI11	HESS	Near Galactic center, $m=1$ TeV
$<1 \times 10^{-26}$	95	53 ACKERMANN 11	FLAT	Satellite galaxy, $m=10$ GeV
$<1 \times 10^{-25}$	95	53 ACKERMANN 11	FLAT	Satellite galaxy, $m=100$ GeV
$<1 \times 10^{-24}$	95	53 ACKERMANN 11	FLAT	Satellite galaxy, $m=1$ TeV

- 1 ABEYSEKARA 19 search for γ s from DM annihilation in galactic substructures with HAWC; no signal, limits placed in $J(\sigma v)$ vs. declination plane for $m(\text{DM}) \sim 1$ –108 TeV.
- 2 ALBERT 19b search for DM signal from M31 galaxy in μ, τ, t, b, W channels using HAWC for $m(\text{DM}) \sim 1$ –100 TeV; no signal, limits placed in $\langle\sigma v\rangle$ vs. $m(\text{DM})$ plane.
- 3 CHEUNG 19 derive model-dependent bounds on $\langle\sigma v\rangle$ from EDGES data: $< 4 \times 10^{-26}$ cm³/s for $e^+ e^-$ and $b\bar{b}$ for $m(\chi) = 100$ GeV (including boost factor).
- 4 DI-MAURO 19 place limits on WIMP annihilation via Fermi-LAT observation of M31 and M33 galaxies: $\langle\sigma v\rangle < 7 \times 10^{-27}$ cm³/s for $m(\chi) = 20$ GeV from M31.
- 5 JOHNSON 19 search for γ -rays, 10–600 GeV energy, from P-wave annihilating DM around SgrA* BH using Fermi-LAT; limits set for various models.
- 6 LI 19d search for $\chi\chi \rightarrow \gamma$ in Fermi-LAT data; no signal, require $\langle\sigma v\rangle < 2 \times 10^{-26}$ cm³/s for $m(\chi) = 100$ GeV.
- 7 NG 19 search for X-ray line from sterile ν decay/annihilation using NuStar M-31; no signal: limits placed in $m(\nu)$ vs mixing angle and $\langle\sigma v\rangle$ vs $m(\nu)$.
- 8 QUEIROZ 19 examine $\chi\chi \rightarrow \chi SM$ semi-annihilation of DM reaction; limits placed for various assumed SM particles in $\langle\sigma v\rangle$ vs. $m(\chi)$ plane.
- 9 ABDALLAH 18 search for WIMP WIMP $\rightarrow \gamma X$ in central galactic halo, 10 years of data; limits placed in $\langle\sigma v\rangle$ vs. $m(\text{WIMP})$ plane for $m(\text{WIMP})$: 0.3–70 TeV.
- 10 AHNEN 18 search for WIMP WIMP $\rightarrow \gamma X$ from Ursa Major II; limits set in $\langle\sigma v\rangle$ vs. $m(\text{WIMP})$ plane for $b\bar{b}, W^+ W^-, \tau^+ \tau^-,$ and $\mu^+ \mu^-$ annihilation modes.
- 11 ALBERT 18b search for TeV-scale WIMPs with WIMP WIMP $\rightarrow \gamma X$ in Andromeda galaxy using HAWC Observatory; limits set in $\langle\sigma v\rangle$ vs $m(\text{WIMP})$ plane.
- 12 CHANG 18a examine $\chi\chi \rightarrow b\bar{b} \rightarrow \gamma$ using Fermi Pass 8 data; no signal; require $\langle\sigma v\rangle < 10^{-26}$ cm³/s for $m(\chi) = 50$ GeV.
- 13 LISANTI 18 examine Fermi Pass 8 γ -ray data from galaxy groups; report $m(\text{WIMP}) > 30$ GeV for annihilation in $b\bar{b}$ channel.
- 14 MAZZIOTTA 18 examine Fermi-LAT electron and positron spectra searching for features originating from DM particles annihilation into $e^+ e^-$ pairs, from 45 GeV to 2 TeV; no signal found, limits are obtained.
- 15 AARTSEN 17c use 1005 days of IceCube data to search for $\chi\chi \rightarrow$ neutrinos via various annihilation channels. Limits set.
- 16 ALBERT 17a search for DM annihilation to ν s using ANTARES data from 2007–2015. No signal. Limits set in $\langle\sigma v\rangle$ vs. $m(\text{DM})$ plane for $m(\text{DM}) \sim 10$ – 10^5 GeV. The listed limit is for $m(\text{DM}) = 100$ TeV.
- 17 ARCHAMBAULT 17 set limits for WIMP mass between 100 GeV and 1 TeV on $\langle\sigma v\rangle$ for $W^+ W^-, ZZ, b\bar{b}, s\bar{s}, u\bar{u}, d\bar{d}, t\bar{t}, e^+ e^-, gg, c\bar{c}, hh, \gamma\gamma, \mu^+ \mu^-, \tau^+ \tau^-$ annihilation channels.
- 18 AVROIRIN 17 find upper limits for the annihilation cross section in various channels for DM particle mass between 30 GeV and 10 TeV. Strongest upper limits coming from the two neutrino channel require $\langle\sigma v\rangle < 6 \times 10^{-20}$ cm³/s in dwarf galaxies and $\langle\sigma v\rangle < 7 \times 10^{-21}$ cm³/s in LMC for 5 TeV WIMP mass.

Searches Particle Listings

WIMP and Dark Matter Searches

- ¹⁹ BOUDAUD 17 use data from the spacecraft Voyager 1, beyond the heliopause, and from AMS02 on $\chi\chi \rightarrow e^+e^-$ to require $\langle\sigma v\rangle < 1. \times 10^{-28} \text{ cm}^3/\text{s}$ for $m(\chi) = 10 \text{ MeV}$.
- ²⁰ AARTSEN 16d search for GeV ν s from WIMP annihilation in galaxy; limits set on $\langle\sigma v\rangle$ in Fig. 6, 7.
- ²¹ ABDALLAH 16 require $\langle\sigma v\rangle < 6 \times 10^{-26} \text{ cm}^3/\text{s}$ for $m(\text{WIMP}) = 1.5 \text{ TeV}$ from 254 hours observation (WW channel) and $< 2 \times 10^{-26} \text{ cm}^3/\text{s}$ for $m(\text{WIMP}) = 1.0 \text{ TeV}$ in $\tau^+\tau^-$ channel.
- ²² ABDALLAH 16A search for line spectra from $WIMP + WIMP \rightarrow \gamma\gamma$ in 18 hr HESS data; rule out previous 130 GeV WIMP hint from Fermi-LAT data.
- ²³ AHNEN 16 require $\langle\sigma v\rangle < 3 \times 10^{-26} \text{ cm}^3/\text{s}$ for $m(\text{WIMP}) = 100 \text{ GeV}$ (WW channel).
- ²⁴ AVORIN 16 require $\langle\sigma v\rangle < 1.91 \times 10^{-21} \text{ cm}^3/\text{s}$ from WIMP annihilation to ν s via WW channel for $m(\text{WIMP}) = 1 \text{ TeV}$.
- ²⁵ CAPUTO 16 place limits on WIMPs from annihilation to gamma rays in Small Magellanic Cloud using Fermi-LAT data: $\langle\sigma v\rangle < 3 \times 10^{-26} \text{ cm}^3/\text{s}$ for $m(\text{WIMP}) = 10 \text{ GeV}$.
- ²⁶ FORNASE 16 use anisotropies in the γ -ray diffuse emission detected by Fermi-LAT to bound $\langle\sigma v\rangle < 10^{-25} \text{ cm}^3/\text{s}$ for $m(\text{WIMP}) = 100 \text{ GeV}$ in $b\bar{b}$ channel: see Fig. 28. The limit is driven by dark-matter subhalos in the Milky Way and it refers to their Most Constraining Scenario.
- ²⁷ LEITE 16 constrain WIMP annihilation via search for radio emissions from Smith cloud; $\langle\sigma v\rangle < 5 \times 10^{-27} \text{ cm}^3/\text{s}$ in ee channel for $m(\text{WIMP}) = 5 \text{ GeV}$.
- ²⁸ LI 16 re-analyze Fermi-LAT data on 8 dwarf spheroidal; set limit $\langle\sigma v\rangle < 2 \times 10^{-26} \text{ cm}^3/\text{s}$ for $m(\text{WIMP}) = 100 \text{ GeV}$ in $b\bar{b}$ mode with substructures included.
- ²⁹ LI 16A constrain $\langle\sigma v\rangle < 10^{-25} \text{ cm}^3/\text{s}$ in $b\bar{b}$ channel for $m(\text{WIMP}) = 100 \text{ GeV}$ using Fermi-LAT data from M31; see Fig. 6.
- ³⁰ LIANG 16 search dwarf spheroidal galaxies, Large Magellanic Cloud, and Small Magellanic Cloud for γ -line in Fermi-LAT data.
- ³¹ LU 16 re-analyze Fermi-LAT and AMS-02 data; require $\langle\sigma v\rangle < 10^{-25} \text{ cm}^3/\text{s}$ for $m(\text{WIMP}) = 1 \text{ TeV}$ in $b\bar{b}$ channel.
- ³² SHIRASAKI 16 re-analyze Fermi-LAT extra-galactic data; require $\langle\sigma v\rangle < 10^{-23} \text{ cm}^3/\text{s}$ for $m(\text{WIMP}) = 1 \text{ TeV}$ in $b\bar{b}$ channel; see Fig. 8.
- ³³ AARTSEN 15c search for neutrinos from X^0 annihilation in the Galactic halo. See their Figs. 16 and 17, and Table 5 for limits on $\sigma \cdot v$ for X^0 mass between 100 GeV and 100 TeV.
- ³⁴ AARTSEN 15E search for neutrinos from X^0 annihilation in the Galactic center. See their Figs. 7 and 9, and Table 3 for limits on $\sigma \cdot v$ for X^0 mass between 30 GeV and 10 TeV.
- ³⁵ ABRAMOWSKI 15 search for γ from X^0 annihilation in the Galactic center. See their Fig. 4 for limits on $\sigma \cdot v$ for X^0 mass between 250 GeV and 10 TeV.
- ³⁶ ACKERMANN 15 search for monochromatic γ from X^0 annihilation in the Galactic halo. See their Fig. 8 and Tables 2–4 for limits on $\sigma \cdot v$ for X^0 mass between 0.2 GeV and 500 GeV.
- ³⁷ ACKERMANN 15A search for γ from X^0 annihilation (both Galactic and extragalactic) in the isotropic γ background. See their Fig. 7 for limits on $\sigma \cdot v$ for X^0 mass between 10 GeV and 30 TeV.
- ³⁸ ACKERMANN 15B search for γ from X^0 annihilation in 15 dwarf spheroidal satellite galaxies of the Milky Way. See their Figs. 1 and 2 for limits on $\sigma \cdot v$ for X^0 mass between 2 GeV and 10 TeV.
- ³⁹ ADRIAN-MARTINEZ 15 search for neutrinos from X^0 annihilation in the Galactic center. See their Figs. 10 and 11 and Tables 1 and 2 for limits on $\sigma \cdot v$ for X^0 mass between 25 GeV and 10 TeV.
- ⁴⁰ ACKERMANN 14 search for γ from X^0 annihilation in 25 dwarf spheroidal satellite galaxies of the Milky Way. See their Tables II–VII for limits assuming annihilation into e^+e^- , $\mu^+\mu^-$, $\tau^+\tau^-$, $u\bar{u}$, $b\bar{b}$, and W^+W^- , for X^0 mass ranging from 2 GeV to 10 TeV.
- ⁴¹ Limit assuming X^0 pair annihilation into $b\bar{b}$.
- ⁴² Limit assuming X^0 pair annihilation into W^+W^- .
- ⁴³ ALEKSIC 14 search for γ from X^0 annihilation in the dwarf spheroidal galaxy Segue 1. The listed limit assumes annihilation into W^+W^- . See their Figs. 6, 7, and 16 for limits on $\sigma \cdot v$ for annihilation channels $\mu^+\mu^-$, $\tau^+\tau^-$, $b\bar{b}$, $t\bar{t}$, $\gamma\gamma$, γZ , W^+W^- , ZZ for X^0 mass between 10^2 and 10^4 GeV .
- ⁴⁴ AARTSEN 13c search for neutrinos from X^0 annihilation in nearby galaxies and galaxy clusters. See their Figs. 5–7 for limits on $\sigma \cdot v$ for $X^0 X^0 \rightarrow \nu\bar{\nu}$, $\mu^+\mu^-$, $\tau^+\tau^-$, and W^+W^- for X^0 mass between 300 GeV and 100 TeV.
- ⁴⁵ ABRAMOWSKI 13 search for monochromatic γ from X^0 annihilation in the Milky Way halo in the central region. Limit on $\sigma \cdot v$ between 10^{-28} and $10^{-25} \text{ cm}^3 \text{ s}^{-1}$ (95% CL) is obtained for X^0 mass between 500 GeV and 20 TeV for $X^0 X^0 \rightarrow \gamma\gamma$. X^0 density distribution in the Galaxy by Einasto is assumed. See their Fig. 4.
- ⁴⁶ ACKERMANN 13A search for monochromatic γ from X^0 annihilation in the Milky Way. Limit on $\sigma \cdot v$ for the process $X^0 X^0 \rightarrow \gamma\gamma$ in the range 10^{-29} – $10^{-27} \text{ cm}^3 \text{ s}^{-1}$ (95% CL) is obtained for X^0 mass between 5 and 300 GeV. The limit depends slightly on the assumed density profile of X^0 in the Galaxy. See their Tables VII–X and Fig. 10. Supersedes ACKERMANN 12.
- ⁴⁷ ABRAMOWSKI 12 search for γ s from X^0 annihilation in the Fornax galaxy cluster. See their Fig. 7 for limits on $\sigma \cdot v$ for X^0 mass between 0.1 and 100 TeV for the annihilation channels $\tau^+\tau^-$, $b\bar{b}$, and W^+W^- .
- ⁴⁸ ACKERMANN 12 search for monochromatic γ from X^0 annihilation in the Milky Way. Limit on $\sigma \cdot v$ in the range 10^{-28} – $10^{-26} \text{ cm}^3 \text{ s}^{-1}$ (95% CL) is obtained for X^0 mass between 7 and 200 GeV if X^0 annihilates into $\gamma\gamma$. The limit depends slightly on the assumed density profile of X^0 in the Galaxy. See their Table III and Fig. 15.
- ⁴⁹ ACKERMANN 12 search for γ from X^0 annihilation in the Milky Way in the diffuse γ background. Limit on $\sigma \cdot v$ of $10^{-24} \text{ cm}^3 \text{ s}^{-1}$ or larger is obtained for X^0 mass between 5 GeV and 10 TeV for various annihilation channels including W^+W^- , $b\bar{b}$, $g\bar{g}$, e^+e^- , $\mu^+\mu^-$, $\tau^+\tau^-$. The limit depends slightly on the assumed density profile of X^0 in the Galaxy. See their Figs. 17–20.
- ⁵⁰ ALIU 12 search for γ s from X^0 annihilation in the dwarf spheroidal galaxy Segue 1. Limit on $\sigma \cdot v$ in the range 10^{-24} – $10^{-20} \text{ cm}^3 \text{ s}^{-1}$ (95% CL) is obtained for X^0 mass between 10 GeV and 2 TeV for annihilation channels e^+e^- , $\mu^+\mu^-$, $\tau^+\tau^-$, $b\bar{b}$, and W^+W^- . See their Fig. 3.

- ⁵¹ ABBASI 11c search for $\nu\mu$ from X^0 annihilation in the outer halo of the Milky Way. The limit assumes annihilation into $\nu\nu$. See their Fig. 9 for limits with other annihilation channels.
- ⁵² ABRAMOWSKI 11 search for γ from X^0 annihilation near the Galactic center. The limit assumes Einasto DM density profile.
- ⁵³ ACKERMANN 11 search for γ from X^0 annihilation in ten dwarf spheroidal satellite galaxies of the Milky Way. The limit for $m = 10 \text{ GeV}$ assumes annihilation into $b\bar{b}$, the others W^+W^- . See their Fig. 2 for limits with other final states. See also GERINGER-SAMETH 11 for a different analysis of the same data.

Dark Matter Particle (X^0) Production in Hadron Collisions

Searches for X^0 production in association with observable particles (γ , jets, ...) in high energy hadron collisions. If a specific form of effective interaction Lagrangian is assumed, the limits may be translated into limits on X^0 -nucleon scattering cross section.

VALUE	DOCUMENT ID	TECN	COMMENT
• • •	We do not use the following data for averages, fits, limits, etc. • • •		
1	AABOUD	19AA ATLS	multi-channel BSM search
2	AABOUD	19AI ATLS	$H \rightarrow \chi\chi$
3	AABOUD	19AL ATLS	$H \rightarrow \chi\chi$
4	AABOUD	19Q ATLS	single $t\bar{t}E_T$
5	AABOUD	19V ATLS	review mediator based DM searches
6	BANERJEE	19 NA64	$eN \rightarrow eN + E$
7	SIRUNYAN	19AN CMS	$H\chi\chi \rightarrow b\bar{b}E_T$
8	SIRUNYAN	19BC CMS	$LQ LQ \rightarrow \mu j E_T$
9	SIRUNYAN	19BO CMS	$VV \rightarrow Hqq; H \rightarrow \text{DM}$
10	SIRUNYAN	19C CMS	$pp \rightarrow t\bar{t}\chi\chi$
11	SIRUNYAN	19O CMS	$pp \rightarrow \gamma E_T$
12	SIRUNYAN	19X CMS	$pp \rightarrow t\bar{t} + \cancel{p}_T; pp \rightarrow t(\bar{t}) + \cancel{p}_T$
13	AABOUD	18 ATLS	$pp \rightarrow Z\chi\chi; Z \rightarrow \ell\ell$
14	AABOUD	18A ATLS	$pp \rightarrow t\bar{t}E_T; pp \rightarrow b\bar{b}E_T$
15	AABOUD	18CA ATLS	$pp \rightarrow V\chi\chi; V \rightarrow jj$
16	AABOUD	18I ATLS	$pp \rightarrow \text{jet}(s) + E_T$
17	AGUILAR-AR...	18B MBNE	$pN \rightarrow \chi\chi, \chi = e, \pi, \text{ or } N$
18	KHACHATRY...	18 CMS	$pp \rightarrow Z(\ell\ell) + E_T$
19	SIRUNYAN	18BF CMS	$pp \rightarrow tE_T$
20	SIRUNYAN	18BO CMS	dijet resonance search
21	SIRUNYAN	18BV CMS	$pp \rightarrow Z E_T$
22	SIRUNYAN	18C CMS	$pp \rightarrow t\bar{t}E_T$
23	SIRUNYAN	18CU CMS	$pp \rightarrow Z E_T$
24	SIRUNYAN	18DH CMS	$pp \rightarrow \chi\chi h; h \rightarrow \gamma\gamma \text{ or } \tau\tau$
25	SIRUNYAN	18S CMS	$pp \rightarrow \text{jets } E_T$
26	AABOUD	17A ATLS	$pp (H \rightarrow b\bar{b} + \text{WIMP pair})$
27	AABOUD	17AM ATLS	$pp \rightarrow Z' \rightarrow Ah \rightarrow h(b\bar{b}) + E_T$
28	AABOUD	17AQ ATLS	$pp \rightarrow h(\gamma\gamma) + E_T$
29	AABOUD	17BD ATLS	$pp \rightarrow \text{jet}(s) + E_T$
30	AABOUD	17R ATLS	$pp \rightarrow \gamma E_T$
31	AGUILAR-AR...	17A MBNE	$pN \rightarrow \chi\chi X; \chi N \rightarrow \chi N$
32	BANERJEE	17 NA64	$eN \rightarrow eN\gamma'$
33	KHACHATRY...	17A CMS	forward jets + E_T
34	KHACHATRY...	17F CMS	$H \rightarrow \text{invisibles}$
35	SIRUNYAN	17 CMS	$Z + E_T$
36	SIRUNYAN	17AP CMS	$pp \rightarrow Z' \rightarrow Ah \rightarrow h + \text{MET}$
37	SIRUNYAN	17AQ CMS	$pp \rightarrow \gamma + \text{MET}$
38	SIRUNYAN	17BB CMS	$pp \rightarrow t\bar{t} + E_T; pp \rightarrow b\bar{b} + E_T$
39	SIRUNYAN	17G CMS	$pp \rightarrow j + E_T$
40	SIRUNYAN	17U CMS	$pp \rightarrow Z\chi\chi; Z \rightarrow \ell\bar{\ell}$
41	AABOUD	16AD ATLS	(W or Z \rightarrow jets) + E_T
42	AAD	16AF ATLS	$VV \rightarrow \text{forward jets} + E_T$
43	AAD	16AG ATLS	$\ell + \text{jets}$
44	AAD	16M ATLS	$pp \rightarrow H + E_T, H \rightarrow b\bar{b}$
45	KHACHATRY...	16BZ CMS	$\text{jet}(s) + E_T$
46	KHACHATRY...	16CA CMS	$\text{jets} + E_T$
47	KHACHATRY...	16N CMS	$pp \rightarrow \gamma + E_T$
48	AAD	15AS ATLS	$b(\bar{b}) + E_T, t\bar{t} + E_T$
49	AAD	15BH ATLS	$\text{jet} + E_T$
50	AAD	15CF ATLS	$H^0 + E_T$
51	AAD	15CS ATLS	$\gamma + E_T$
52	KHACHATRY...	15AG CMS	$t\bar{t} + E_T$
53	KHACHATRY...	15AL CMS	$\text{jet} + E_T$
54	KHACHATRY...	15T CMS	$\ell + E_T$
55	AAD	14AI ATLS	$W + E_T$
56	AAD	14BK ATLS	$W, Z + E_T$
57	AAD	14K ATLS	$Z + E_T$
58	AAD	14O ATLS	$Z + E_T$
59	AAD	13AD ATLS	$\text{jet} + E_T$
60	AAD	13C ATLS	$\gamma + E_T$
61	AALTONEN	12K CDF	$t + E_T$
62	AALTONEN	12M CDF	$\text{jet} + E_T$
63	CHATRCHYAN12AP	CMS	$\text{jet} + E_T$
64	CHATRCHYAN12T	CMS	$\gamma + E_T$

- 1 AABOUD 19AA searches for BSM physics in more than 700 event classes with more than 10^5 regions at 13 TeV with 3.2 fb^{-1} ; no significant signal.
- 2 AABOUD 19AI searches for vector boson fusion $pp \rightarrow Hq\bar{q}$, $H \rightarrow \text{invisible}$ at 13 TeV with 36.1 fb^{-1} ; no signal: require $B(H \rightarrow \text{invisible}) < 0.37$ (0.28 expected).
- 3 AABOUD 19AL perform search in three different channels for $H \rightarrow \chi\chi$ at 7, 8 and 13 TeV; combined result $\text{BF}(H \rightarrow \text{invisible}) < 0.26$ (0.17 expected).
- 4 AABOUD 19Q search for single $t + \cancel{E}_T$ at 13 TeV with 36.1 fb^{-1} of data; no signal; limits set in σ or coupling vs. mass plane for simplified models.
- 5 AABOUD 19V review ATLAS results from 7, 8 and 13 TeV searches for mediator-based DM and DE scalar which couples to gravity; no signal: limits set for large variety of simplified models.
- 6 BANERJEE 19 search for dark photon via $eN \rightarrow eN + \cancel{E}$ in NA64; no signal, limits placed in kinetic mixing ϵ vs. $m(\text{DM})$ plane for $m(\text{DM}) \sim 0.001\text{--}1 \text{ GeV}$.
- 7 SIRUNYAN 19AN search at 13 TeV with 35.9 fb^{-1} for $pp \rightarrow H\chi\chi \rightarrow b\bar{b}\cancel{E}_T$; no signal: limits set in the context of a 2HDM + pseudoscalar (a) model and a baryonic Z' model.
- 8 SIRUNYAN 19BC search for DM via LeptoQuark pair annihilation $LQ LQ \rightarrow \mu j \chi\chi \rightarrow \mu j \cancel{E}_T$ with 77.4 fb^{-1} , 13 TeV; no signal: limits placed in $m(\chi)$ vs. $m(LQ)$ plane. Model dependent limits on DM mass up to 600 GeV depending on $m(LQ)$ placed.
- 9 SIRUNYAN 19BO search for vector boson fusion $VV \rightarrow qqH$ with $H \rightarrow \chi\chi$ at 13 TeV with 38.2 fb^{-1} ; no signal: limits placed for several models. Also search for $H \rightarrow \text{invisible}$ at 7, 8, and 13 TeV; no signal: limit placed on $\text{BF} < 0.19$.
- 10 SIRUNYAN 19C search for DM via $pp \rightarrow t\bar{t}\chi\chi$ at 13 TeV, 35.9 fb^{-1} ; no signal; limits placed on coupling vs. mediator mass for various simplified models.
- 11 SIRUNYAN 19O search for $pp \rightarrow \gamma$ at 13 TeV with 35.9 fb^{-1} ; no signal: limits placed on parameters of various models.
- 12 SIRUNYAN 19X search for $pp \rightarrow t\bar{t}\cancel{E}_T$ and $pp \rightarrow t\cancel{E}_T + \dots$ at 13 TeV with 35.9 fb^{-1} ; no signal: limits placed on χ production σ for various simplified models with $m(\chi) = 1 \text{ GeV}$.
- 13 AABOUD 18 search for $pp \rightarrow Z + \cancel{E}_T$ with $Z \rightarrow \ell\ell$ at 13 TeV with 36.1 fb^{-1} of data. Limits set for simplified models.
- 14 AABOUD 18A search for $pp \rightarrow t\bar{t}\cancel{E}_T$ or $pp \rightarrow b\bar{b}\cancel{E}_T$ at 13 TeV, 36.1 fb^{-1} of data. Limits set for simplified models.
- 15 AABOUD 18CA search for $pp \rightarrow V\chi\chi$ with $V \rightarrow jj$ at 13 TeV, 36.1 fb^{-1} ; no signal; limits set in $m(\text{DM})$ vs $m(\text{mediator})$ simplified model plane.
- 16 AABOUD 18I search for $pp \rightarrow j + \cancel{E}_T$ at 13 TeV with 36.1 fb^{-1} of data. Limits set for simplified models with pair-produced weakly interacting dark-matter candidates.
- 17 AGUILAR-AREVALO 18B search for WIMP production in MiniBooNE p beam dump; no signal; limits set for $m(\chi) \sim 5\text{--}50 \text{ MeV}$ in vector portal DM model.
- 18 KHACHATRYAN 18 search for $pp \rightarrow Z(\ell\ell) + \cancel{E}_T$; no signal; limits set on effective dark matter interactions and other exotic physics models.
- 19 SIRUNYAN 18BF search for $pp \rightarrow t\cancel{E}_T$ at 13 TeV and 36 fb^{-1} ; no signal; limits placed on DM models involving a flavor changing neutral current, scalar resonance decaying to top quark and DM.
- 20 SIRUNYAN 18BO search for high mass dijet resonances at 13 TeV and 36 fb^{-1} ; no signal: limits placed on various models, including simplified DM models involving a spin = 1 Z' mediator.
- 21 SIRUNYAN 18BV search for $pp \rightarrow Z\cancel{E}_T$ at 13 TeV; no signal, limits placed for various exotic physics models including DM.
- 22 SIRUNYAN 18C search for new physics in $pp \rightarrow$ final states with two oppositely charged leptons at 13 TeV with 35.9 fb^{-1} . Limits placed on $m(\text{mediator})$ and top squark for various simplified models.
- 23 SIRUNYAN 18CU search for $pp \rightarrow Z\cancel{E}_T$ at 13 TeV and 2.3 fb^{-1} ; no signal: limits placed for various exotic models including DM.
- 24 SIRUNYAN 18BH search for $pp \rightarrow \chi\chi h$; $h \rightarrow \gamma\gamma$ or $\tau\tau$ at 13 TeV, 35.9 fb^{-1} ; no signal; limits placed on massive boson mediator Z' in the context of $Z' + 2\text{HDM}$ and baryonic Z' models. Limits also cast in terms of spin-independent WIMP-nucleon cross section for masses 1–200 GeV.
- 25 SIRUNYAN 18S search for $pp \rightarrow$ jets \cancel{E}_T at 13 TeV; no signal: limits placed on simplified dark matter models, on the branching ratio of the Higgs boson to invisible particles, and on several other exotic physics models including fermion portal DM.
- 26 AABOUD 17A search for $H \rightarrow b\bar{b} + \cancel{E}_T$. See Fig. 4b for limits set on VB mediator vs WIMP mass.
- 27 AABOUD 17AM search for $pp \rightarrow Z' \rightarrow Ah \rightarrow h(b\bar{b}) + \cancel{E}_T$ at 13 TeV. Limits set in $m(Z')$ vs. $m(A)$ plane and on the visible cross section of $h(b\bar{b}) + \cancel{E}_T$ events in bins of \cancel{E}_T .
- 28 AABOUD 17AQ search for WIMP in $pp \rightarrow h(\gamma\gamma) + \cancel{E}_T$ in 36.1 fb^{-1} of data. Limits on the visible cross section are also provided. Model dependent limits on spin independent DM - Nucleon cross-section are also presented, which are more stringent than those from direct searches for DM mass smaller than 2.5 GeV.
- 29 AABOUD 17BD search for $pp \rightarrow \text{jet}(s) + \cancel{E}_T$ at 13 TeV with 3.2 fb^{-1} of data. Limits set for simplified models. Observables corrected for detector effects can be used to constrain other models.
- 30 AABOUD 17R, for an axial vector mediator in the s-channel, excludes $m(\text{mediator}) < 750\text{--}1200 \text{ GeV}$ for $m(\text{DM}) < 230\text{--}480 \text{ GeV}$, depending on the couplings.
- 31 AGUILAR-AREVALO 17A search for DM produced in 8 GeV proton collisions with steel beam dump followed by DM-nucleon scattering in MiniBooNE detector. Limit placed on DM cross section parameter $Y < 2 \times 10^{-8}$ for $\alpha_D = 0.5$ and for $0.01 < m(\text{DM}) < 0.3 \text{ GeV}$.
- 32 BANERJEE 17 search for dark photon invisible decay via eN scattering; exclude $m(\gamma')$ < 100 MeV as an explanation of $(g_\mu - 2)$ muon anomaly.
- 33 KHACHATRYAN 17A search for WIMPs in forward jets $+\cancel{E}_T$ channel with 18.5 fb^{-1} at 8 TeV; limits set in effective theory model, Fig. 3.
- 34 KHACHATRYAN 17F search for $H \rightarrow \text{invisibles}$ in pp collisions at 7, 8, and 13 TeV; place limits on Higgs portal DM.
- 35 SIRUNYAN 17 search for $pp \rightarrow Z + \cancel{E}_T$ with 2.3 fb^{-1} at 13 TeV; no signal seen; limits placed on WIMPs and unparticles.
- 36 SIRUNYAN 17AP search for $pp \rightarrow Z' \rightarrow Ah \rightarrow h + \text{MET}$ with $h \rightarrow b\bar{b}$ or $\gamma\gamma$ and $A \rightarrow \chi\chi$ with 2.3 fb^{-1} at 13 TeV. Limits set in $m(Z')$ vs. $m(A)$ plane.
- 37 SIRUNYAN 17AQ search for $pp \rightarrow \gamma + \text{MET}$ at 13 TeV with 12.9 fb^{-1} . Limits derived for simplified DM models, effective electroweak-DM interaction and Extra Dimensions models.
- 38 SIRUNYAN 17BB search for WIMPs via $pp \rightarrow t\bar{t} + \cancel{E}_T$, $pp \rightarrow b\bar{b} + \cancel{E}_T$ at 13 TeV with 2.2 fb^{-1} . Limits derived for various simplified models.
- 39 SIRUNYAN 17G search for $pp \rightarrow j + \cancel{E}_T$ with 12.9 fb^{-1} at 13 TeV; limits placed on WIMP mass/mediators in DM simplified models.
- 40 SIRUNYAN 17U search for WIMPs/unparticles via $pp \rightarrow Z\chi\chi$, $Z \rightarrow \ell\bar{\ell}$ at 13 TeV with 2.3 fb^{-1} . Limits derived for various simplified models.
- 41 AABOUD 16AD place limits on $VVXX$ effective theory via search for hadronic W or Z plus WIMP pair production. See Fig. 5.
- 42 AAD 16AF search for $VV \rightarrow (H \rightarrow \text{WIMP pair}) +$ forward jets with 20.3 fb^{-1} at 8 TeV; set limits in Higgs portal model, Fig. 8.
- 43 AAD 16AG search for lepton jets with 20.3 fb^{-1} of data at 8 TeV; Fig. 13 excludes dark photons around 0.1–1 GeV for kinetic mixing $10^{-6}\text{--}10^{-2}$.
- 44 AAD 16M search with 20.3 fb^{-1} of data at 8 TeV pp collisions; limits placed on EFT model (Fig. 7) and simplified Z' model (Fig. 6).
- 45 KHACHATRYAN 16BZ search for jet(s) $+\cancel{E}_T$ in 19.7 fb^{-1} at 8 TeV; limits set for variety of simplified models.
- 46 KHACHATRYAN 16CA search for WIMPs via jet(s) $+\cancel{E}_T$ using razor variable; require mediator scale $> 1 \text{ TeV}$ for various effective theories.
- 47 KHACHATRYAN 16N search for $\gamma +$ WIMPs in 19.6 fb^{-1} at 8 TeV; limits set on SI and SD WIMP- p scattering in Fig. 3.
- 48 AAD 15AS search for events with one or more bottom quark and missing \cancel{E}_T , and also events with a top quark pair and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 8 \text{ TeV}$ with $L = 20.3 \text{ fb}^{-1}$. See their Figs. 5 and 6 for translated limits on X^0 -nucleon cross section for $m = 1\text{--}700 \text{ GeV}$.
- 49 AAD 15BH search for events with a jet and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 8 \text{ TeV}$ with $L = 20.3 \text{ fb}^{-1}$. See their Fig. 12 for translated limits on X^0 -nucleon cross section for $m = 1\text{--}1200 \text{ GeV}$.
- 50 AAD 15CF search for events with a $H^0 (\rightarrow \gamma\gamma)$ and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 8 \text{ TeV}$ with $L = 20.3 \text{ fb}^{-1}$. See paper for limits on the strength of some contact interactions containing X^0 and the Higgs fields.
- 51 AAD 15CS search for events with a photon and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 8 \text{ TeV}$ with $L = 20.3 \text{ fb}^{-1}$. See their Fig. 13 (see also erratum) for translated limits on X^0 -nucleon cross section for $m = 1\text{--}1000 \text{ GeV}$.
- 52 KHACHATRYAN 15AG search for events with a top quark pair and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 8 \text{ TeV}$ with $L = 19.7 \text{ fb}^{-1}$. See their Fig. 8 for translated limits on X^0 -nucleon cross section for $m = 1\text{--}200 \text{ GeV}$.
- 53 KHACHATRYAN 15AL search for events with a jet and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 8 \text{ TeV}$ with $L = 19.7 \text{ fb}^{-1}$. See their Fig. 5 and Tables 4–6 for translated limits on X^0 -nucleon cross section for $m = 1\text{--}1000 \text{ GeV}$.
- 54 KHACHATRYAN 15T search for events with a lepton and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 8 \text{ TeV}$ with $L = 19.7 \text{ fb}^{-1}$. See their Fig. 17 for translated limits on X^0 -proton cross section for $m = 1\text{--}1000 \text{ GeV}$.
- 55 AAD 14AI search for events with a W and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 8 \text{ TeV}$ with $L = 20.3 \text{ fb}^{-1}$. See their Fig. 4 for translated limits on X^0 -nucleon cross section for $m = 1\text{--}1500 \text{ GeV}$.
- 56 AAD 14BK search for hadronically decaying W, Z in association with \cancel{E}_T in 20.3 fb^{-1} at 8 TeV pp collisions. Fig. 5 presents exclusion results for SI and SD scattering cross section. In addition, cross section limits on the anomalous production of W or Z bosons with large missing transverse momentum are also set in two fiducial regions.
- 57 AAD 14K search for events with a Z and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 8 \text{ TeV}$ with $L = 20.3 \text{ fb}^{-1}$. See their Fig. 5 and 6 for translated limits on X^0 -nucleon cross section for $m = 1\text{--}10^3 \text{ GeV}$.
- 58 AAD 14O search for ZH^0 production with H^0 decaying to invisible final states. See their Fig. 4 for translated limits on X^0 -nucleon cross section for $m = 1\text{--}60 \text{ GeV}$ in Higgs-portal X^0 scenario.
- 59 AAD 13AD search for events with a jet and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 7 \text{ TeV}$ with $L = 4.7 \text{ fb}^{-1}$. See their Figs. 5 and 6 for translated limits on X^0 -nucleon cross section for $m = 1\text{--}1300 \text{ GeV}$.
- 60 AAD 13C search for events with a photon and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 7 \text{ TeV}$ with $L = 4.6 \text{ fb}^{-1}$. See their Fig. 3 for translated limits on X^0 -nucleon cross section for $m = 1\text{--}1000 \text{ GeV}$.
- 61 AALTONEN 12K search for events with a top quark and missing \cancel{E}_T in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96 \text{ TeV}$ with $L = 7.7 \text{ fb}^{-1}$. Upper limits on $\sigma(tX^0)$ in the range 0.4–2 pb (95% CL) is given for $m_{X^0} = 0\text{--}150 \text{ GeV}$.
- 62 AALTONEN 12M search for events with a jet and missing \cancel{E}_T in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96 \text{ TeV}$ with $L = 6.7 \text{ fb}^{-1}$. Upper limits on the cross section in the range 2–10 pb (90% CL) is given for $m_{X^0} = 1\text{--}300 \text{ GeV}$. See their Fig. 2 for translated limits on X^0 -nucleon cross section.
- 63 CHATRCHYAN 12AP search for events with a jet and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 7 \text{ TeV}$ with $L = 5.0 \text{ fb}^{-1}$. See their Fig. 4 for translated limits on X^0 -nucleon cross section for $m_{X^0} = 0.1\text{--}1000 \text{ GeV}$.
- 64 CHATRCHYAN 12T search for events with a photon and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 7 \text{ TeV}$ with $L = 5.0 \text{ fb}^{-1}$. Upper limits on the cross section in the range 13–15 fb (90% CL) is given for $m_{X^0} = 1\text{--}1000 \text{ GeV}$. See their Fig. 2 for translated limits on X^0 -nucleon cross section.

REFERENCES FOR WIMP and Dark Matter Searches

AKERIB	20	PR D101 012003	D.S. Akerib et al.	(LUX Collab.)
AABOUD	19AA	EPJ C79 120	M. Aaboud et al.	(ATLAS Collab.)
AABOUD	19AI	PL B793 499	M. Aaboud et al.	(ATLAS Collab.)
AABOUD	19AL	PRL 122 231801	M. Aaboud et al.	(ATLAS Collab.)
AABOUD	19Q	JHEP 1905 041	M. Aaboud et al.	(ATLAS Collab.)
AABOUD	19V	JHEP 1905 142	M. Aaboud et al.	(ATLAS Collab.)
ABDELHAMEED	19	EPJ C79 630	A.H. Abdelhameed et al.	(CREST Collab.)
ABDELHAMEED	19A	PR D100 102002	A.H. Abdelhameed et al.	(CREST Collab.)
ABE	19	PL B789 45	K. Abe et al.	(XMASS Collab.)
ABEYSEKARA	19	JCAP 1907 022	A.U. Abeysekara et al.	(HAWC Collab.)
ABRAMOFF	19	PRL 122 161801	O. Abramoff et al.	(SENSEI Collab.)
ADHIKARI	19	PRL 123 031302	G. Adhikari et al.	(COSINE-100 Collab.)
AGNESE	19A	PR D99 062003	R. Agnese et al.	(CDMS Collab.)
AGUILAR-AR.	19A	PRL 123 181802	A. Aguilar-Arevalo et al.	(DAMIC Collab.)

Searches Particle Listings

WIMP and Dark Matter Searches

AJAJ	19	PR D100 022004	R. Ajaj <i>et al.</i>	(DEAP-3600 Collab.)	AABOUD	16F	JHEP 1606 059	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AKERIB	19	PRL 122 131301	D.S. Akerib <i>et al.</i>	(LUX Collab.)	AAD	16AF	JHEP 1601 172	G. Aad <i>et al.</i>	(ATLAS Collab.)
ALBERT	19B	JCAP 1904 E01	A. Albert <i>et al.</i>	(HAWC Collab.)	AAD	16AG	JHEP 1602 062	G. Aad <i>et al.</i>	(ATLAS Collab.)
AMARE	19	PRL 123 031301	J. Amare <i>et al.</i>	(ANAIS Collab.)	AAD	16M	PR D93 072007	G. Aad <i>et al.</i>	(ATLAS Collab.)
AMOLE	19	PR D100 022001	C. Amole <i>et al.</i>	(PICO Collab.)	AARTSEN	16C	JCAP 1604 022	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)
ANGLOHER	19	EPJ C79 43	G. Angloher <i>et al.</i>	(CREST-II Collab.)	AARTSEN	16D	EPJ C76 531	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)
APRILE	19	PRL 122 071301	E. Aprile <i>et al.</i>	(XENON1T Collab.)	ABDALLAH	16	PRL 117 111301	H. Abdallah <i>et al.</i>	(H.E.S.S. Collab.)
APRILE	19A	PRL 122 141301	E. Aprile <i>et al.</i>	(XENON1T Collab.)	ABDALLAH	16A	PRL 117 151302	H. Abdallah <i>et al.</i>	(H.E.S.S. Collab.)
APRILE	19C	PRL 123 241803	E. Aprile <i>et al.</i>	(XENON1T Collab.)	ADRIAN-MAR...	16	PL B759 69	S. Adrian-Martinez <i>et al.</i>	(ANTARES Collab.)
APRILE	19D	PRL 123 251801	E. Aprile <i>et al.</i>	(XENON1T Collab.)	ADRIAN-MAR...	16B	JCAP 1605 016	S. Adrian-Martinez <i>et al.</i>	(ANTARES Collab.)
ARMENGAUD	19	PR D99 082003	E. Armengaud <i>et al.</i>	(EDELWEISS Collab.)	AGNES	16	PR D93 081101	P. Agnes <i>et al.</i>	(DarkSide-50 Collab.)
BANERJEE	19	PRL 123 121801	D. Banerjee <i>et al.</i>	(NA64 Collab.)	AGNESE	16	PRL 116 071301	R. Agnese <i>et al.</i>	(SuperCDMS Collab.)
BRINGMANN	19	PRL 122 171801	T. Bringmann, M. Pospelov	(OSLO, VICT)	AGUILAR-AR...	16	PR D94 082006	A. Aguilar-Arevalo <i>et al.</i>	(DAMIC Collab.)
BRUNE	19	PR D99 096005	T. Brune, H. Pas	(DORT)	AHNEN	16	JCAP 1602 039	M.L. Ahnen <i>et al.</i>	(MAGIC and Fermi-LAT Collab.)
CHEUNG	19	PL B789 137	K. Cheung <i>et al.</i>	(SUNG)	AKERIB	16	PRL 116 161301	D.S. Akerib <i>et al.</i>	(LUX Collab.)
CHOI	19	PR D99 083018	K.-Y. Choi, J. Kim, C. Rott	(SUNG)	AKERIB	16A	PRL 116 161302	D.S. Akerib <i>et al.</i>	(LUX Collab.)
DI-MAURO	19	PR D99 123027	M. Di Mauro <i>et al.</i>	(COSINE-100 Collab.)	AMOLE	16	PR D93 052014	C. Amole <i>et al.</i>	(PICO Collab.)
HA	19	PRL 122 131802	C. Ha <i>et al.</i>	(COSINE-100 Collab.)	AMOLE	16A	PR D93 061101	C. Amole <i>et al.</i>	(PICO Collab.)
JOHNSON	19	PR D99 103007	C. Johnson <i>et al.</i>	(KIMS Collab.)	ANGLOHER	16	EPJ C76 25	G. Angloher <i>et al.</i>	(CREST-II Collab.)
KIM	19A	JHEP 1903 194	K.W. Kim <i>et al.</i>	(KIMS Collab.)	ANGLOHER	16A	PRL 117 021303	G. Angloher <i>et al.</i>	(CREST-II Collab.)
KLOPF	19	PRL 122 222503	M. Klopff <i>et al.</i>	(PERKEO II Collab.)	APRILE	16	PR D94 092001	E. Aprile <i>et al.</i>	(XENON100 Collab.)
KOBAYASHI	19	PL B795 308	M. Kobayashi <i>et al.</i>	(XMASS Collab.)	APRILE	16B	PR D94 122001	E. Aprile <i>et al.</i>	(XENON100 Collab.)
LI	19D	PR D99 123519	S. Li <i>et al.</i>	(CDX Collab.)	ARMENGAUD	16	JCAP 1605 019	E. Armengaud <i>et al.</i>	(EDELWEISS-III Collab.)
LIU	19B	PRL 123 161301	Z.Z. Liu <i>et al.</i>	(CDX Collab.)	AVRORIN	16	ASP 81 12	A.D. Avrorin <i>et al.</i>	(BAIKAL Collab.)
NG	19	PR D99 083005	K.C.Y. Ng <i>et al.</i>	(CDX Collab.)	CAPUTO	16	PR D93 062004	R. Caputo <i>et al.</i>	(Fermi-LAT Collab.)
QUEIROZ	19	JCAP 1904 048	F.S. Queiroz, C. Siqueira	(BELLE Collab.)	FORNASE	16	PR D94 123005	M. Fornasa <i>et al.</i>	(EDELWEISS-III Collab.)
SEONG	19	PRL 122 011801	I.S. Seong <i>et al.</i>	(BELLE Collab.)	HEHN	16	EPJ C76 548	L. Hehn <i>et al.</i>	(EDELWEISS-III Collab.)
SIRUNYAN	19AN	EPJ C79 280	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	KHACHATRY...	16AJ	PR D93 052011	V. Khachatryan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19BC	PL B795 76	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	KHACHATRY...	16BZ	JHEP 1612 083	V. Khachatryan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19BO	PL B793 520	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	Also	16	JHEP 1708 035 (err.)	V. Khachatryan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19C	PRL 122 011803	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	KHACHATRY...	16CA	JHEP 1612 086	V. Khachatryan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19D	JHEP 1902 074	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	KHACHATRY...	16N	PL B755 102	V. Khachatryan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19X	JHEP 1903 141	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	LEITE	16	JCAP 1611 021	N. Leite <i>et al.</i>	(PICO Collab.)
SUZUKI	19	ASP 110 1	T. Suzuki <i>et al.</i>	(XMASS Collab.)	LI	16	PR D93 043518	S. Li <i>et al.</i>	(CDX Collab.)
XIA	19A	PL B792 193	J. Xia <i>et al.</i>	(PandaX-II Collab.)	LI	16A	JCAP 1612 028	Z. Li <i>et al.</i>	(CDX Collab.)
YAGUNA	19	JCAP 1904 041	C. Yaguna	(CDX Collab.)	LIANG	16	PR D94 103502	Y.-F. Liang <i>et al.</i>	(PandaX Collab.)
YANG	19	PRL 123 221301	L.T. Yang <i>et al.</i>	(CDX Collab.)	LU	16	PR D93 103517	B.-Q. Lu, H.-S. Zong	(PandaX Collab.)
AABOUD	18	PL B776 318	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	SHIRASAKI	16	PR D94 063522	M. Shirasaki <i>et al.</i>	(PandaX Collab.)
AABOUD	18A	EPJ C78 18	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	TAN	16	PR D93 122009	T.H. Tan <i>et al.</i>	(PandaX Collab.)
AABOUD	18CA	JHEP 1810 180	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	TAN	16B	PRL 117 121303	A. Tan <i>et al.</i>	(PandaX Collab.)
AABOUD	18I	JHEP 1801 126	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	ZHAO	16	PR D93 092003	W. Zhao <i>et al.</i>	(CDF Collab.)
AARTSEN	18D	EPJ C78 831	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)	AAD	15AS	EPJ C75 92	G. Aad <i>et al.</i>	(ATLAS Collab.)
ABDALLAH	18	PRL 120 201101	H. Abdallah <i>et al.</i>	(H.E.S.S. Collab.)	AAD	15BH	EPJ C75 299	G. Aad <i>et al.</i>	(ATLAS Collab.)
ABE	18C	PR D97 102006	K. Abe <i>et al.</i>	(XMASS Collab.)	Also	15	EPJ C75 408 (err.)	G. Aad <i>et al.</i>	(ATLAS Collab.)
ABE	18F	PL B787 153	K. Abe <i>et al.</i>	(XMASS Collab.)	AAD	15CF	PRL 115 131801	G. Aad <i>et al.</i>	(ATLAS Collab.)
ADHIKARI	18	NAT 564 83	G. Adhikari <i>et al.</i>	(COSINE-100 Collab.)	AAD	15CS	PR D91 012008	G. Aad <i>et al.</i>	(ATLAS Collab.)
AGNES	18	PRL 121 081307	P. Agnes <i>et al.</i>	(DarkSide-50 Collab.)	Also	15	PR D92 059903 (err.)	G. Aad <i>et al.</i>	(ATLAS Collab.)
AGNES	18A	PR D98 102006	P. Agnes <i>et al.</i>	(DarkSide-50 Collab.)	AARTSEN	15C	EPJ C75 20	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)
AGNES	18B	PRL 121 111303	P. Agnes <i>et al.</i>	(DarkSide-50 Collab.)	AARTSEN	15E	EPJ C75 492	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)
AGNESE	18	PR D97 022002	R. Agnese <i>et al.</i>	(SuperCDMS Collab.)	ABRAMOWSKI	15	PRL 114 081301	A. Abramowski <i>et al.</i>	(H.E.S.S. Collab.)
AGNESE	18A	PRL 120 061802	R. Agnese <i>et al.</i>	(SuperCDMS Collab.)	ACKERMANN	15	PR D91 122002	M. Ackermann <i>et al.</i>	(Fermi-LAT Collab.)
AGNESE	18B	PRL 121 051301	R. Agnese <i>et al.</i>	(SuperCDMS Collab.)	ACKERMANN	15A	JCAP 1509 008	M. Ackermann <i>et al.</i>	(Fermi-LAT Collab.)
Also	18	PRL 122 041301 (err.)	A. Aguilar-Arevalo	(SuperCDMS Collab.)	ACKERMANN	15B	PRL 115 231301	M. Ackermann <i>et al.</i>	(Fermi-LAT Collab.)
AGUILAR-AR...	18B	PR D98 112004	A.A. Aguilar-Arevalo	(MiniBooNE Collab.)	ADRIAN-MAR...	15	JCAP 1510 068	S. Adrian-Martinez <i>et al.</i>	(ANTARES Collab.)
AHNEN	18	JCAP 1803 009	M.L. Ahnen <i>et al.</i>	(MAGIC Collab.)	AGNES	15	PL B743 456	P. Agnes <i>et al.</i>	(DarkSide-50 Collab.)
AKERIB	18A	PR D98 062005	D.S. Akerib <i>et al.</i>	(LUX Collab.)	AGNESE	15A	PR D91 052021	R. Agnese <i>et al.</i>	(SuperCDMS Collab.)
ALBERT	18B	JCAP 1806 043	A. Albert <i>et al.</i>	(HAWC Collab.)	AGNESE	15B	PR D92 072003	R. Agnese <i>et al.</i>	(SuperCDMS Collab.)
ALBERT	18C	PR D98 123012	A. Albert <i>et al.</i>	(HAWC Collab.)	AMOLE	15	PRL 114 231302	C. Amole <i>et al.</i>	(PICO Collab.)
AMAUDRUZ	18	PRL 121 071801	P.A. Amaudruz <i>et al.</i>	(DEAP-3600 Collab.)	APRILE	15	PRL 115 091302	E. Aprile <i>et al.</i>	(XENON Collab.)
APRILE	18	PRL 121 111302	E. Aprile <i>et al.</i>	(XENON1T Collab.)	APRILE	15A	SCI 349 851	E. Aprile <i>et al.</i>	(XENON Collab.)
ARMENGAUD	18	PR D98 082004	E. Armengaud <i>et al.</i>	(EDELWEISS-III Collab.)	CHOI	15	PRL 114 141301	K. Choi <i>et al.</i>	(Super-Kamiokande Collab.)
ARNAUD	18	ASP 97 54	Q. Arnaud <i>et al.</i>	(NEWS-G Collab.)	KHACHATRY...	15AG	JHEP 1506 121	V. Khachatryan <i>et al.</i>	(CMS Collab.)
CHANG	18A	PR D98 123004	L.J. Chang, M. Lisanti, S. Mishra-Sharma	(PRIN Collab.)	KHACHATRY...	15AL	EPJ C75 235	V. Khachatryan <i>et al.</i>	(CMS Collab.)
CRISLER	18	PRL 121 061803	M. Crisler <i>et al.</i>	(SENSEI Collab.)	KHACHATRY...	15T	PR D91 029005	V. Khachatryan <i>et al.</i>	(CMS Collab.)
JIANG	18	PRL 120 241301	H. Jiang <i>et al.</i>	(CDX Collab.)	NAKAMURA	15	PTEP 2015 4 043F01	K. Nakamura <i>et al.</i>	(NEWAGE Collab.)
KACHULIS	18	PRL 120 221301	C. Kachulis <i>et al.</i>	(Super-Kamiokande Collab.)	XIAO	15	PR D92 052004	X. Xiao <i>et al.</i>	(PandaX Collab.)
KHACHATRY...	18	PR D97 099903	V. Khachatryan <i>et al.</i>	(CMS Collab.)	AAD	14AI	JHEP 1409 037	G. Aad <i>et al.</i>	(ATLAS Collab.)
LISANTI	18	PRL 120 101101	M. Lisanti <i>et al.</i>	(PRIN, MIT, MICH)	AAD	14BK	PRL 112 041802	G. Aad <i>et al.</i>	(ATLAS Collab.)
MAZZIOTTA	18	PR D98 022006	M. Mazziotta <i>et al.</i>	(Fermi-LAT Collab.)	AAD	14K	PR D90 012004	G. Aad <i>et al.</i>	(ATLAS Collab.)
REN	18	PRL 121 021304	X. Ren <i>et al.</i>	(PandaX-II Collab.)	AAD	14O	PRL 112 201802	G. Aad <i>et al.</i>	(ATLAS Collab.)
SIRUNYAN	18BF	JHEP 1806 027	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	ACKERMANN	14	PR D89 042001	M. Ackermann <i>et al.</i>	(Fermi-LAT Collab.)
SIRUNYAN	18BO	JHEP 1808 130	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AGNESE	14	PRL 112 241302	R. Agnese <i>et al.</i>	(SuperCDMS Collab.)
SIRUNYAN	18BV	EPJ C78 291	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AGNESE	14A	PRL 112 041302	R. Agnese <i>et al.</i>	(SuperCDMS Collab.)
SIRUNYAN	18C	PR D97 032009	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AKERIB	14	PRL 112 091303	D.S. Akerib <i>et al.</i>	(LUX Collab.)
SIRUNYAN	18CU	JHEP 1801 056	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	AKERIB	14B	JCAP 1402 008	J. Akerib <i>et al.</i>	(MAGIC Collab.)
SIRUNYAN	18DH	JHEP 1809 046	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	ANGLOHER	14	EPJ C74 3184	G. Angloher <i>et al.</i>	(CREST-II Collab.)
SIRUNYAN	18S	PR D97 092005	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)	APRILE	14A	ASP 54 11	E. Aprile <i>et al.</i>	(XENON100 Collab.)
YANG	18	CP C42 032002	L.T. Yang <i>et al.</i>	(CDX Collab.)	AVRORIN	14	ASP 62 12	A.D. Avrorin <i>et al.</i>	(BAIKAL Collab.)
AABOUD	17A	PL B765 11	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	FELIZARDO	14	PR D89 072013	M. Felizardo <i>et al.</i>	(SIMPLE Collab.)
AABOUD	17AM	PRL 119 181804	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	LEE	14A	PR D90 052006	H.S. Lee <i>et al.</i>	(KIMS Collab.)
AABOUD	17AQ	PR D96 112004	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	LIU	14A	PR D90 032003	S.K. Liu <i>et al.</i>	(CDX Collab.)
AABOUD	17BD	EPJ C77 765	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	UCHIDA	14	PTEP 2014 063C01	H. Uchida <i>et al.</i>	(XMASS Collab.)
AABOUD	17R	EPJ C77 393	M. Aaboud <i>et al.</i>	(ATLAS Collab.)	YUE	14	PR D90 091701	Q. Yue <i>et al.</i>	(CDX Collab.)
AARTSEN	17	EPJ C77 82	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)	AAD	13AD	JHEP 1304 075	G. Aad <i>et al.</i>	(ATLAS Collab.)
AARTSEN	17A	EPJ C77 146	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)	AAD	13C	PRL 110 011802	G. Aad <i>et al.</i>	(ATLAS Collab.)
Also	17	EPJ C79 214 (err.)	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)	ALSETH	13	PR D88 012002	C.E. Aalseth <i>et al.</i>	(COGENT Collab.)
AARTSEN	17C	EPJ C77 627	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)	AARTSEN	13	PRL 110 131302	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)
AGUILAR-AR...	17	PRL 118 141803	A. Aguilar-Arevalo <i>et al.</i>	(DAMIC Collab.)	AARTSEN	13B	PR D88 122001	M.G. Aartsen <i>et al.</i>	(IceCube Collab.)
AGUILAR-AR...	17A	PRL 118 221803	A.A. Aguilar-Arevalo <i>et al.</i>	(MiniBooNE Collab.)	ABE	13C	PL B719 78	K. Abe <i>et al.</i>	(XMASS Collab.)
AKERIB	17	PRL 118 021303	D.S. Akerib <i>et al.</i>	(LUX Collab.)	ABRAMOWSKI	13	PRL 110 041301	A. Abramowski <i>et al.</i>	(H.E.S.S. Collab.)
AKERIB	17A	PRL 118 251302	D.S. Akerib <i>et al.</i>	(LUX Collab.)	ACKERMANN	13A	PR D88 082002	M. Ackermann <i>et al.</i>	(Fermi-LAT Collab.)
ALBERT	17A	PL B769 249	A. Albert <i>et al.</i>	(ANTARES Collab.)	ADRIAN-MAR...	13	JCAP 1311 032	S. Adrian-Martinez <i>et al.</i>	(ANTARES Collab.)
Also	17	PL B796 253 (err.)	A. Albert <i>et al.</i>	(ANTARES Collab.)	AGNESE	13	PR D88 031104	R. Agnese <i>et al.</i>	(CDMS Collab.)
AMOLE	17	PRL 118 251301	C. Amole <i>et al.</i>	(PICO Collab.)	AGNESE	13A	PRL 111 251301	R. Agnese <i>et al.</i>	(CDMS Collab.)
ANGLOHER	17A	EPJ C77 637	G. Angloher <i>et al.</i>	(CREST-II Collab.)	APRILE	13	PRL 111 021301	E. Aprile <i>et al.</i>	(XENON100 Collab.)
APRILE	17	PRL 118 101101	E. Aprile <i>et al.</i>	(XENON100 Collab.)	BERNABEI	13A	EPJ C73 2648	R. Bernabei <i>et al.</i>	(DAMA Collab.)
APRILE	17A	PR D96 022008	E. Aprile <i>et al.</i>	(XENON100 Collab.)	BOLIV	13	JCAP 1309 019	B. Bolivar <i>et al.</i>	(TEXONO Collab.)
APRILE	17D	PR D96 042004	E. Aprile <i>et al.</i>	(XENON100 Collab.)	LI	13B	PRL 110 261301	H.B. Li <i>et al.</i>	(INRM Collab.)
APRILE	17G	PRL 119 181301	E. Aprile <i>et al.</i>	(XENON Collab.)	SUVOROVA	13	PAN 76 1367	O.V. Suvorova <i>et al.</i>	(INRM Collab.)
APRILE	17H	PR D96 122002	E. Aprile <i>et al.</i>	(XENON100 Collab.)	Translated from YAF 76 1433				
APRILE	17K	JCAP 1710 039	E. Aprile <i>et al.</i>	(XENON100 Collab.)	ZHAO	13	PR D88 052004	W. Zhao <i>et al.</i>	(CDX Collab.)
ARCHAMBAU...	17	PR D95 082001	S. Archambault <i>et al.</i>	(VERITAS Collab.)	AALTONEN	12K	PRL 108 201802	T. Aaltonen <i>et al.</i>	(CDF Collab.)
AVRORIN									

AALSETH	11	PRL 106 131301	C.E. Aalseth <i>et al.</i>	(CoGeNT Collab.)
AALSETH	11A	PRL 107 141301	C.E. Aalseth <i>et al.</i>	(CoGeNT Collab.)
ABBASI	11C	PR D84 022004	R. Abbasi <i>et al.</i>	(IceCube Collab.)
ABRAMOWSKI	11	PRL 106 161301	A. Abramowski <i>et al.</i>	(H.E.S.S. Collab.)
ACKERMANN	11	PRL 107 241302	M. Ackermann <i>et al.</i>	(Fermi-LAT Collab.)
AHLEN	11	PL B695 124	S. Ahlen <i>et al.</i>	(DMTPC Collab.)
AHMED	11	PR D83 112002	Z. Ahmed <i>et al.</i>	(CDMS Collab.)
AHMED	11A	PR D84 011102	Z. Ahmed <i>et al.</i>	(CDMS and EDELWEISS Collabs.)
AHMED	11B	PRL 106 131302	Z. Ahmed <i>et al.</i>	(CDMS Collab.)
AJELLO	11	PR D84 032007	M. Ajello <i>et al.</i>	(Fermi-LAT Collab.)
ANGLE	11	PRL 107 051301	J. Angle <i>et al.</i>	(XENON10 Collab.)
Also		PRL 110 249901 (errat.)	J. Angle <i>et al.</i>	(XENON10 Collab.)
APRILE	11	PR D84 052003	E. Aprile <i>et al.</i>	(XENON100 Collab.)
APRILE	11A	PR D84 061101	E. Aprile <i>et al.</i>	(XENON100 Collab.)
APRILE	11B	PRL 107 131302	E. Aprile <i>et al.</i>	(XENON100 Collab.)
ARMENGAUD	11	PL B702 329	E. Armengaud <i>et al.</i>	(EDELWEISS-II Collab.)
BEHNKE	11	PRL 106 021303	E. Behnke <i>et al.</i>	(COUPP Collab.)
GERINGER-SAMETH	11	PRL 107 241303	A. Gerlinger-Sameth, S.M. Koushiappas	(ZEPLIN-III Collab.)
HORN	11	PL B705 471	M. Horn <i>et al.</i>	(Super-Kamiokande Collab.)
TANAKA	11	APJ 7402 78	T. Tanaka <i>et al.</i>	(IceCube Collab.)
ABBASI	10	PR D81 057101	R. Abbasi <i>et al.</i>	(IceCube Collab.)
AHMED	10	SCI 327 1619	Z. Ahmed <i>et al.</i>	(CDMS II Collab.)
AKERIB	10	PR D82 122004	D.S. Akerib <i>et al.</i>	(CDMS II Collab.)
AKIMOV	10	PL B692 180	D.Yu. Akimov <i>et al.</i>	(ZEPLIN-III Collab.)
APRILE	10	PRL 105 131302	E. Aprile <i>et al.</i>	(XENON100 Collab.)
ARMENGAUD	10	PL B687 294	E. Armengaud <i>et al.</i>	(EDELWEISS-II Collab.)
FELIZARDO	10	PRL 105 211301	M. Felizardo <i>et al.</i>	(The SIMPLE Collab.)
MIUCHI	10	PL B686 11	K. Miuchi <i>et al.</i>	(NEWAGE Collab.)
ABBASI	09B	PRL 102 201302	R. Abbasi <i>et al.</i>	(IceCube Collab.)
AHMED	09	PRL 102 011301	Z. Ahmed <i>et al.</i>	(CDMS Collab.)
ANGLE	09	PR D80 115005	J. Angle <i>et al.</i>	(XENON10 Collab.)
ANGLOHER	09	ASP 31 270	G. Angloher <i>et al.</i>	(CREST Collab.)
ARCHAMBAUD	09	PL B682 185	S. Archambault <i>et al.</i>	(PICASSO Collab.)
LEBEDENKO	09A	PRL 103 151302	V.N. Lebedenko <i>et al.</i>	(ZEPLIN-III Collab.)
LIN	09	PR D79 061101	S.T. Lin <i>et al.</i>	(TEXONO Collab.)
AALSETH	08	PRL 101 251301	C.E. Aalseth <i>et al.</i>	(CoGeNT Collab.)
Also		PRL 102 109903 (errat.)	C.E. Aalseth <i>et al.</i>	(CoGeNT Collab.)
ANGLE	08A	PRL 101 091301	J. Angle <i>et al.</i>	(XENON10 Collab.)
BEDNYAKOV	08	PAN 71 111	V.A. Bednyakov, H.P. Klapdor-Kleingrothaus, I.V. Krivosheina	
Also		Translated from YAF 71 112		
ALNER	07	PL B653 161	G.J. Alner <i>et al.</i>	(ZEPLIN-II Collab.)
MIUCHI	07A	PRL 99 091301	H.S. Lee <i>et al.</i>	(KIMS Collab.)
MIUCHI	07	PL B654 58	K. Miuchi <i>et al.</i>	(CDMS Collab.)
AKERIB	06	PR D73 011102	D.S. Akerib <i>et al.</i>	(CDMS Collab.)
SHIMIZU	06A	PL B633 195	Y. Shimizu <i>et al.</i>	(CDMS Collab.)
AKERIB	05	PR D72 052009	D.S. Akerib <i>et al.</i>	(CDMS Collab.)
ALNER	05	PL B616 17	G.J. Alner <i>et al.</i>	(UK Dark Matter Collab.)
BARNABE-HE.	05	PL B624 186	M. Barnabe-Heider <i>et al.</i>	(PICASSO Collab.)
BENOIT	05	PL B616 25	A. Benoit <i>et al.</i>	(EDELWEISS Collab.)
GIRARD	05	PL B621 233	T.A. Girard <i>et al.</i>	(SIMPLE Collab.)
GIULIANI	05	PRL 95 101301	F. Giuliani	
GIULIANI	05A	PR D71 123503	F. Giuliani, T.A. Girard	
KLAPDOR-K...	05	PL B609 226	H.V. Klapdor-Kleingrothaus, I.V. Krivosheina, C. Tomei	
GIULIANI	04	PL B588 151	F. Giuliani, T.A. Girard	
GIULIANI	04A	PRL 93 161301	F. Giuliani	
MIUCHI	03	ASP 19 135	K. Miuchi <i>et al.</i>	
TAKEDA	03	PL B572 145	A. Takeda <i>et al.</i>	(CREST Collab.)
ANGLOHER	02	ASP 18 43	G. Angloher <i>et al.</i>	(CREST Collab.)
BELLI	02	PR D66 043503	P. Belli <i>et al.</i>	(DAMA Collab.)
BERNABE	02C	EPJ C23 61	R. Bernabei <i>et al.</i>	(DAMA Collab.)
GREEN	02	PR D66 083003	A.M. Green	
BAUDIS	01	PR D63 022001	L. Baudis <i>et al.</i>	(Heidelberg-Moscow Collab.)
SMITH	01	PR D64 043502	D. Smith, N. Weiner	
ULLIO	01	JHEP 0107 044	P. Ullio, M. Kamionkowski, P. Vogel	
BENOIT	00	PL B479 8	A. Benoit <i>et al.</i>	(EDELWEISS Collab.)
BERNABE	00D	NJP 2 15	R. Bernabei <i>et al.</i>	(DAMA Collab.)
COLLAR	00	PRL 85 3083	J.J. Collar <i>et al.</i>	(SIMPLE Collab.)
AMBROSIO	99	PR D60 082002	M. Ambrosio <i>et al.</i>	(Macro Collab.)
BERNABE	99	PL B450 448	R. Bernabei <i>et al.</i>	(DAMA Collab.)
BERNABE	99D	PRL 83 4918	R. Bernabei <i>et al.</i>	(DAMA Collab.)
BRHLIK	99	PL B464 303	M. Brhlik, L. Roszkowski	
DERBIN	99	PAN 62 188	A.V. Derbin <i>et al.</i>	
Also		Translated from YAF 62 2034		
KLIMENKO	98	JETPL 67 875	A.A. Klimenko <i>et al.</i>	
Also		Translated from ZETFP 67 835		
SARSA	97	PR D56 1856	M.L. Sarsa <i>et al.</i>	(ZARA Collab.)
ALESSAND...	96	PL B384 316	A. Alessandrello <i>et al.</i>	(MILA, MILAI, SASSO Collab.)
BELLI	96	PL B387 222	P. Belli <i>et al.</i>	(DAMA Collab.)
Also		PL B389 783 (erratum)	P. Belli <i>et al.</i>	(DAMA Collab.)
BELLI	96C	NC C19 537	P. Belli <i>et al.</i>	(DAMA Collab.)
BERNABE	96	PL B389 757	R. Bernabei <i>et al.</i>	(DAMA Collab.)
COLLAR	96	PRL 76 331	J.J. Collar	(SCUC Collab.)
SARSA	96	PL B386 458	M.L. Sarsa <i>et al.</i>	(ZARA Collab.)
Also		PR D56 1856	M.L. Sarsa <i>et al.</i>	(ZARA Collab.)
SMITH	96	PL B379 299	P.F. Smith <i>et al.</i>	(RAL, SHEF, LOIC+ Collab.)
SNOWDEN-...	96	PRL 76 332	D.P. Snowden-Hift, E.S. Freeman, P.B. Price	(UCB Collab.)
GARCIA	95	PR D51 1458	E. Garcia <i>et al.</i>	(ZARA, SCUC, PNL Collab.)
QUENBY	95	PL B351 70	J.J. Quenby <i>et al.</i>	(LOIC, RAL, SHEF+ Collab.)
SNOWDEN-...	95	PRL 74 4133	D.P. Snowden-Hift, E.S. Freeman, P.B. Price	(UCB Collab.)
Also		PRL 76 331	J.J. Collar	(SCUC Collab.)
Also		PRL 76 332	D.P. Snowden-Hift, E.S. Freeman, P.B. Price	(UCB Collab.)
BECK	94	PL B336 141	M. Beck <i>et al.</i>	(MPIH, KIAE, SASSO Collab.)
BACCI	92	PL B293 460	C. Bacci <i>et al.</i>	(Beijing-Roma-Saclay Collab.)
REUSSER	91	PL B255 143	D. Reusser <i>et al.</i>	(NEUC, CIT, PSI Collab.)
CALDWELL	88	PRL 61 510	D.O. Caldwell <i>et al.</i>	(UCSB, UCB, LBL Collab.)

Other Particle Searches

OMITTED FROM SUMMARY TABLE
OTHER PARTICLE SEARCHES

Revised February 2018 by K. Hikasa (Tohoku University).

We collect here those searches which do not appear in any other search categories. These are listed in the following order:

- Concentration of stable particles in matter
- General new physics searches
- Limits on jet-jet resonance in hadron collisions
- Limits on neutral particle production at accelerators

- Limits on charged particles in e^+e^- collisions
- Limits on charged particles in hadron reactions
- Limits on charged particles in cosmic rays
- Searches for quantum black hole production

Note that searches appear in separate sections elsewhere for Higgs bosons (and technipions), other heavy bosons (including W_R , W' , Z' , leptoquarks, axiglons), axions (including pseudo-Goldstone bosons, Majorons, familons), WIMPs, heavy leptons, heavy neutrinos, free quarks, monopoles, supersymmetric particles, and compositeness.

We no longer list for limits on tachyons and centauros. See our 1994 edition for these limits.

CONCENTRATION OF STABLE PARTICLES IN MATTER

Concentration of Heavy (Charge +1) Stable Particles in Matter

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<4 \times 10^{-17}$	95	1 YAMAGATA	93	SPEC Deep sea water, $M=5-1600 m_p$
$<6 \times 10^{-15}$	95	2 VERKERK	92	SPEC Water, $M=10^5$ to 3×10^7 GeV
$<7 \times 10^{-15}$	95	2 VERKERK	92	SPEC Water, $M=10^4$, 6×10^7 GeV
$<9 \times 10^{-15}$	95	2 VERKERK	92	SPEC Water, $M=10^8$ GeV
$<3 \times 10^{-23}$	90	3 HEMMICK	90	SPEC Water, $M=1000 m_p$
$<2 \times 10^{-21}$	90	3 HEMMICK	90	SPEC Water, $M=5000 m_p$
$<3 \times 10^{-20}$	90	3 HEMMICK	90	SPEC Water, $M=10000 m_p$
$<1 \times 10^{-29}$		SMITH	82B	SPEC Water, $M=30-400 m_p$
$<2 \times 10^{-28}$		SMITH	82B	SPEC Water, $M=12-1000 m_p$
$<1 \times 10^{-14}$		SMITH	82B	SPEC Water, $M>1000 m_p$
$<(0.2-1) \times 10^{-21}$		SMITH	79	SPEC Water, $M=6-350 m_p$

1 YAMAGATA 93 used deep sea water at 4000 m since the concentration is enhanced in deep sea due to gravity.

2 VERKERK 92 looked for heavy isotopes in sea water and put a bound on concentration of stable charged massive particle in sea water. The above bound can be translated into into a bound on charged dark matter particle (5×10^6 GeV), assuming the local density, $\rho=0.3$ GeV/cm³, and the mean velocity $\langle v \rangle=300$ km/s.

3 See HEMMICK 90 Fig. 7 for other masses 100-10000 m_p .

Concentration of Heavy Stable Particles Bound to Nuclei

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<1.2 \times 10^{-11}$	95	1 JAVORSEK	01	SPEC Au, $M=3$ GeV
$<6.9 \times 10^{-10}$	95	1 JAVORSEK	01	SPEC Au, $M=144$ GeV
$<1 \times 10^{-11}$	95	2 JAVORSEK	01B	SPEC Au, $M=188$ GeV
$<1 \times 10^{-8}$	95	2 JAVORSEK	01B	SPEC Au, $M=1669$ GeV
$<6 \times 10^{-9}$	95	2 JAVORSEK	01B	SPEC Fe, $M=188$ GeV
$<1 \times 10^{-8}$	95	2 JAVORSEK	01B	SPEC Fe, $M=647$ GeV
$<4 \times 10^{-20}$	90	3 HEMMICK	90	SPEC C, $M=100 m_p$
$<8 \times 10^{-20}$	90	3 HEMMICK	90	SPEC C, $M=1000 m_p$
$<2 \times 10^{-16}$	90	3 HEMMICK	90	SPEC C, $M=10000 m_p$
$<6 \times 10^{-13}$	90	3 HEMMICK	90	SPEC Li, $M=1000 m_p$
$<1 \times 10^{-11}$	90	3 HEMMICK	90	SPEC Be, $M=1000 m_p$
$<6 \times 10^{-14}$	90	3 HEMMICK	90	SPEC B, $M=1000 m_p$
$<4 \times 10^{-17}$	90	3 HEMMICK	90	SPEC O, $M=1000 m_p$
$<4 \times 10^{-15}$	90	3 HEMMICK	90	SPEC F, $M=1000 m_p$
$<1.5 \times 10^{-13}/\text{nucleon}$	68	4 NORMAN	89	SPEC $^{206}\text{Pb} X^-$
$<1.2 \times 10^{-12}/\text{nucleon}$	68	4 NORMAN	87	SPEC $^{56,58}\text{Fe} X^-$

1 JAVORSEK 01 search for (neutral) SIMPs (strongly interacting massive particles) bound to Au nuclei. Here M is the effective SIMP mass.

2 JAVORSEK 01B search for (neutral) SIMPs (strongly interacting massive particles) bound to Au and Fe nuclei from various origins with exposures on the earth's surface, in a satellite, heavy ion collisions, etc. Here M is the mass of the anomalous nucleus. See also JAVORSEK 02.

3 See HEMMICK 90 Fig. 7 for other masses 100-10000 m_p .

4 Bound valid up to $m_{X^-} \sim 100$ TeV.

Searches Particle Listings
Other Particle Searches

GENERAL NEW PHYSICS SEARCHES

This subsection lists some of the search experiments which look for general signatures characteristic of new physics, independent of the framework of a specific model.

The observed events are compatible with Standard Model expectation, unless noted otherwise.

VALUE	DOCUMENT ID	TECN	COMMENT
• • •	We do not use the following data for averages, fits, limits, etc. • • •		
1	SIRUNYAN 20A	CMS	SUSY/LQ search with mT2 or long-lived charged particles
2	ALCANTARA 19		Auger, superheavy DM
3	PORAYKO 18	PPTA	pulsar timing fuzzy DM search
4	AAD 15AT	ATLS	$t + \cancel{E}_T$
5	KHACHATRYAN 15F	CMS	$t + \cancel{E}_T$
6	AALTONEN 14J	CDF	$W + 2$ jets
7	AAD 13A	ATLS	$WW \rightarrow \ell \nu \ell' \nu$
8	AAD 13C	ATLS	$\gamma + \cancel{E}_T$
9	AALTONEN 13I	CDF	Delayed $\gamma + \cancel{E}_T$
10	CHATRCHYAN 13	CMS	$\ell^+ \ell^- +$ jets + \cancel{E}_T
11	AAD 12C	ATLS	$t\bar{t} + \cancel{E}_T$
12	AALTONEN 12M	CDF	jet + \cancel{E}_T
13	CHATRCHYAN 12AP	CMS	jet + \cancel{E}_T
14	CHATRCHYAN 12Q	CMS	$Z +$ jets + \cancel{E}_T
15	CHATRCHYAN 12T	CMS	$\gamma + \cancel{E}_T$
16	AAD 11S	ATLS	jet + \cancel{E}_T
17	AALTONEN 11AF	CDF	$\ell^\pm \ell^\pm$
18	CHATRCHYAN 11C	CMS	$\ell^+ \ell^- +$ jets + \cancel{E}_T
19	CHATRCHYAN 11U	CMS	jet + \cancel{E}_T
20	AALTONEN 10AF	CDF	$\gamma\gamma + \ell, \cancel{E}_T$
21	AALTONEN 09AF	CDF	$\ell\gamma b \cancel{E}_T$
22	AALTONEN 09G	CDF	$\ell\ell\ell \cancel{E}_T$
1	SIRUNYAN 20A search for SUSY and LQ production using mT2 or presence of long-lived charged particle; no signal, limits placed in various mass planes for different BSM scenarios and various assumed lifetimes.		
2	ALCANTARA 19 place limits on m(WIMPzilla=X) vs lifetime from upper bound on ultra high energy cosmic rays at Auger experiment: e.g. $\tau(X) < 4 \times 10^{22}$ yr for $m(X) = 10^{16}$ GeV.		
3	PORAYKO 18 search for deviations in the residuals of pulsar timing data using PPTA. No signal observed. Limits set on fuzzy DM with $3 \times 10^{-24} < m(\text{DM}) < 2 \times 10^{-22}$ eV.		
4	AAD 15AT search for events with a top quark and mssing E_T in pp collisions at $E_{\text{cm}} = 8$ TeV with $L = 20.3 \text{ fb}^{-1}$.		
5	KHACHATRYAN 15F search for events with a top quark and mssing E_T in pp collisions at $E_{\text{cm}} = 8$ TeV with $L = 19.7 \text{ fb}^{-1}$.		
6	AALTONEN 14J examine events with a W and two jets in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 8.9 \text{ fb}^{-1}$. Invariant mass distributions of the two jets are consistent with the Standard Model expectation.		
7	AAD 13A search for resonant WW production in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 4.7 \text{ fb}^{-1}$.		
8	AAD 13C search for events with a photon and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 4.6 \text{ fb}^{-1}$.		
9	AALTONEN 13I search for events with a photon and missing E_T , where the photon is detected after the expected timing, in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 6.3 \text{ fb}^{-1}$. The data are consistent with the Standard Model expectation.		
10	CHATRCHYAN 13 search for events with an opposite-sign lepton pair, jets, and missing E_T in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 4.98 \text{ fb}^{-1}$.		
11	AAD 12C search for events with a $t\bar{t}$ pair and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 1.04 \text{ fb}^{-1}$.		
12	AALTONEN 12M search for events with a jet and missing E_T in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 6.7 \text{ fb}^{-1}$.		
13	CHATRCHYAN 12AP search for events with a jet and missing E_T in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 5.0 \text{ fb}^{-1}$.		
14	CHATRCHYAN 12Q search for events with a Z , jets, and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 4.98 \text{ fb}^{-1}$.		
15	CHATRCHYAN 12T search for events with a photon and missing \cancel{E}_T in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 5.0 \text{ fb}^{-1}$.		
16	AAD 11S search for events with one jet and missing E_T in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 33 \text{ pb}^{-1}$.		
17	AALTONEN 11AF search for high- p_T like-sign dileptons in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 6.1 \text{ fb}^{-1}$.		
18	CHATRCHYAN 11C search for events with an opposite-sign lepton pair, jets, and missing E_T in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 34 \text{ pb}^{-1}$.		
19	CHATRCHYAN 11U search for events with one jet and missing E_T in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 36 \text{ pb}^{-1}$.		
20	AALTONEN 10AF search for $\gamma\gamma$ events with e, μ, τ , or missing E_T in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 1.1\text{--}2.0 \text{ fb}^{-1}$.		
21	AALTONEN 09AF search for $\ell\gamma b$ events with missing E_T in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 1.9 \text{ fb}^{-1}$. The observed events are compatible with Standard Model expectation including $t\bar{t}\gamma$ production.		
22	AALTONEN 09G search for $\mu\mu\mu$ and $\mu\mu e$ events with missing E_T in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 976 \text{ pb}^{-1}$.		

LIMITS ON JET-JET RESONANCES

Heavy Particle Production Cross Section

Limits are for a particle decaying to two hadronic jets.

Units(pb)	CL%	Mass(GeV)	DOCUMENT ID	TECN	COMMENT
• • •	We do not use the following data for averages, fits, limits, etc. • • •				
1	AABOUD	19AJ	ATLS	$pp \rightarrow \gamma X, X \rightarrow jj$	
2	SIRUNYAN	19B	CMS	$pp \rightarrow jA, A \rightarrow b\bar{b}$	
3	SIRUNYAN	19CD	CMS	$pp \rightarrow Z'\gamma, Z' \rightarrow jj$	
4	AABOUD	18AD	ATLS	$pp \rightarrow Y \rightarrow HX \rightarrow (bb) + (qq)$	
5	AABOUD	18CK	ATLS	$pp \rightarrow bbb + \cancel{E}_T$	
6	AABOUD	18CL	ATLS	$pp \rightarrow$ vector-like quarks	
7	AABOUD	18N	ATLS	$pp \rightarrow jj$ resonance	
8	SIRUNYAN	18DJ	CMS	$pp \rightarrow ZZ$ or $WZ \rightarrow \ell\bar{\ell}jj$	
9	SIRUNYAN	18DY	CMS	$pp \rightarrow RR; R \rightarrow jj$	
10	KHACHATRYAN	17W	CMS	$pp \rightarrow jj$ resonance	
11	KHACHATRYAN	17Y	CMS	$pp \rightarrow (8\text{--}10) j + \cancel{E}_T$	
12	SIRUNYAN	17F	CMS	$pp \rightarrow jj$ angular distribution	
13	AABOUD	16	ATLS	$pp \rightarrow b + \text{jet}$	
14	AAD	16N	ATLS	$pp \rightarrow 3$ high E_T jets	
15	AAD	16S	ATLS	$pp \rightarrow jj$ resonance	
16	KHACHATRYAN	16K	CMS	$pp \rightarrow jj$ resonance	
17	KHACHATRYAN	16L	CMS	$pp \rightarrow jj$ resonance	
18	AAD	13D	ATLS	$7 \text{ TeV } p\bar{p} \rightarrow 2$ jets	
19	AALTONEN	13R	CDF	$1.96 \text{ TeV } p\bar{p} \rightarrow 4$ jets	
20	CHATRCHYAN	13A	CMS	$7 \text{ TeV } p\bar{p} \rightarrow 2$ jets	
21	CHATRCHYAN	13A	CMS	$7 \text{ TeV } p\bar{p} \rightarrow b\bar{b}X$	
22	AAD	12S	ATLS	$7 \text{ TeV } p\bar{p} \rightarrow 2$ jets	
23	CHATRCHYAN	12BL	CMS	$7 \text{ TeV } p\bar{p} \rightarrow t\bar{t}X$	
24	AAD	11AG	ATLS	$7 \text{ TeV } p\bar{p} \rightarrow 2$ jets	
25	AALTONEN	11M	CDF	$1.96 \text{ TeV } p\bar{p} \rightarrow W + 2$ jets	
26	ABAZOV	11I	D0	$1.96 \text{ TeV } p\bar{p} \rightarrow W + 2$ jets	
27	AAD	10	ATLS	$7 \text{ TeV } p\bar{p} \rightarrow 2$ jets	
28	KHACHATRYAN	10	CMS	$7 \text{ TeV } p\bar{p} \rightarrow 2$ jets	
29	ABE	99F	CDF	$1.8 \text{ TeV } p\bar{p} \rightarrow b\bar{b} + \text{anything}$	
30	ABE	97G	CDF	$1.8 \text{ TeV } p\bar{p} \rightarrow 2$ jets	
31	ABE	93G	CDF	$1.8 \text{ TeV } p\bar{p} \rightarrow 2$ jets	
31	ABE	93G	CDF	$1.8 \text{ TeV } p\bar{p} \rightarrow 2$ jets	
31	ABE	93G	CDF	$1.8 \text{ TeV } p\bar{p} \rightarrow 2$ jets	
1	AABOUD 19AJ search for low mass dijet resonance in $pp \rightarrow \gamma X, X \rightarrow jj$ at 13 TeV with 79.8 fb ⁻¹ of data; no signal found; limits placed on Z' model in coupling vs. $m(Z')$ plane.				
2	SIRUNYAN 19B search for low mass resonance $pp \rightarrow jA, A \rightarrow b\bar{b}$ at 13 TeV using 35.9 fb ⁻¹ ; no signal; exclude resonances 50–350 GeV depending on production and decay.				
3	SIRUNYAN 19CD search for $pp \rightarrow Z'\gamma, Z' \rightarrow jj$ with fat jet (jj); no signal, limits placed in $m(Z')$ vs. coupling plane for Z' masses from 10 to 125 GeV.				
4	AABOUD 18AD search for new heavy particle $Y \rightarrow HX \rightarrow (bb) + (qq)$. No signal observed. Limits set on $m(Y)$ vs. $m(X)$ in the ranges of $m(Y)$ in 1–4 TeV and $m(X)$ in 50–1000 GeV.				
5	AABOUD 18CK search for SUSY Higgsinos in gauge-mediation via $pp \rightarrow bbb + \cancel{E}_T$ at 13 TeV using two complementary analyses with 24.3/36.1 fb ⁻¹ ; no signal is found and Higgsinos with masses between 130 and 230 GeV and between 290 and 880 GeV are excluded at the 95% confidence level.				
6	AABOUD 18CL search for $pp \rightarrow$ vector-like quarks \rightarrow jets at 13 TeV with 36 fb ⁻¹ ; no signal seen; limits set on various VLQ scenarios. For pure $B \rightarrow Hb$ or $T \rightarrow Ht$, set the mass limit $m > 1010$ GeV.				
7	AABOUD 18N search for dijet resonance at Atlas with 13 TeV and 29.3 fb ⁻¹ ; limits set on $m(Z')$ in the mass range of 450–1800 GeV.				
8	SIRUNYAN 18DJ search for $pp \rightarrow ZZ$ or $WZ \rightarrow \ell\bar{\ell}jj$ resonance at 13 TeV, 35.9 fb ⁻¹ ; no signal; limits set in the 400–4500 GeV mass range, exclusion of W' up to 2270 GeV in the HVT model A, and up to 2330 GeV for HVT model B. WED bulk graviton exclusion up to 925 GeV.				
9	SIRUNYAN 18DY search for $pp \rightarrow RR; R \rightarrow jj$ two dijet resonances at 13 TeV 35.9 fb ⁻¹ ; no signal; limits placed on RPV top-squark pair production.				
10	KHACHATRYAN 17W search for dijet resonance in 12.9 fb ⁻¹ data at 13 TeV; see Fig. 2 for limits on axigluons, diquarks, dark matter mediators etc.				
11	KHACHATRYAN 17Y search for $pp \rightarrow (8\text{--}10) j$ in 19.7 fb ⁻¹ at 8 TeV. No signal seen. Limits set on colorons, axigluons, RPV, and SUSY.				
12	SIRUNYAN 17F measure $pp \rightarrow jj$ angular distribution in 2.6 fb ⁻¹ at 13 TeV; limits set on LEDs and quantum black holes.				
13	AABOUD 16 search for resonant dijets including one or two b -jets with 3.2 fb ⁻¹ at 13 TeV; exclude excited b^* quark from 1.1–2.1 TeV; exclude leptophilic Z' with SM couplings from 1.1–1.5 TeV.				
14	AAD 16N search for ≥ 3 jets with 3.6 fb ⁻¹ at 13 TeV; limits placed on micro black holes (Fig. 10) and string balls (Fig. 11).				
15	AAD 16S search for high mass jet-jet resonance with 3.6 fb ⁻¹ at 13 TeV; exclude portions of excited quarks, W' , Z' and contact interaction parameter space.				
16	KHACHATRYAN 16K search for dijet resonance in 2.4 fb ⁻¹ data at 13 TeV; see Fig. 3 for limits on axigluons, diquarks etc.				
17	KHACHATRYAN 16L use data scouting technique to search for jj resonance on 18.8 fb ⁻¹ of data at 8 TeV. Limits on the coupling of a leptophobic Z' to quarks are set, improving on the results by other experiments in the mass range from 500–800 GeV.				
18	AAD 13D search for dijet resonances in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 4.8 \text{ fb}^{-1}$. The observed events are compatible with Standard Model expectation. See their Fig. 6 and Table 2 for limits on resonance cross section in the range $m = 1.0\text{--}4.0$ TeV.				
19	AALTONEN 13R search for production of a pair of jet-jet resonances in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 6.6 \text{ fb}^{-1}$. See their Fig. 5 and Tables I, II for cross section limits.				

See key on page 999

Searches Particle Listings

Other Particle Searches

- ²⁰ CHATRCHYAN 13A search for $q\bar{q}$, qg , and $g\bar{g}$ resonances in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 4.8 \text{ fb}^{-1}$. See their Fig. 3 and Table 1 for limits on resonance cross section in the range $m = 1.0\text{--}4.3$ TeV.
- ²¹ CHATRCHYAN 13A search for $b\bar{b}$ resonances in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 4.8 \text{ fb}^{-1}$. See their Fig. 8 and Table 4 for limits on resonance cross section in the range $m = 1.0\text{--}4.0$ TeV.
- ²² AAD 12s search for dijet resonances in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 1.0 \text{ fb}^{-1}$. See their Fig. 3 and Table 2 for limits on resonance cross section in the range $m = 0.9\text{--}4.0$ TeV.
- ²³ CHATRCHYAN 12BL search for $t\bar{t}$ resonances in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 4.4 \text{ fb}^{-1}$. See their Fig. 4 for limits on resonance cross section in the range $m = 0.5\text{--}3.0$ TeV.
- ²⁴ AAD 11AG search for dijet resonances in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 36 \text{ pb}^{-1}$. Limits on number of events for $m = 0.6\text{--}4$ TeV are given in their Table 3.
- ²⁵ AALTONEN 11M find a peak in two jet invariant mass distribution around 140 GeV in $W + 2$ jet events in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 4.3 \text{ fb}^{-1}$.
- ²⁶ ABAZOV 11I search for two-jet resonances in $W + 2$ jet events in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 4.3 \text{ fb}^{-1}$ and give limits $\sigma < (2.6\text{--}1.3) \text{ pb}$ (95% CL) for $m = 110\text{--}170$ GeV. The result is incompatible with AALTONEN 11M.
- ²⁷ AAD 10 search for narrow dijet resonances in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 315 \text{ nb}^{-1}$. Limits on the cross section in the range $10\text{--}10^3 \text{ pb}$ is given for $m = 0.3\text{--}1.7$ TeV.
- ²⁸ KHACHATRYAN 10 search for narrow dijet resonances in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 2.9 \text{ pb}^{-1}$. Limits on the cross section in the range $1\text{--}300 \text{ pb}$ is given for $m = 0.5\text{--}2.6$ TeV separately in the final states $q\bar{q}$, qg , and $g\bar{g}$.
- ²⁹ ABE 99F search for narrow $b\bar{b}$ resonances in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.8$ TeV. Limits on $\sigma(p\bar{p} \rightarrow X + \text{anything}) \times B(X \rightarrow b\bar{b})$ in the range $3\text{--}10^3 \text{ pb}$ (95% CL) are given for $m_X = 200\text{--}750$ GeV. See their Table I.
- ³⁰ ABE 97G search for narrow dijet resonances in $p\bar{p}$ collisions with 106 pb^{-1} of data at $E_{\text{cm}} = 1.8$ TeV. Limits on $\sigma(p\bar{p} \rightarrow X + \text{anything}) \times B(X \rightarrow jj)$ in the range $10^4\text{--}10^{-1} \text{ pb}$ (95% CL) are given for dijet mass $m = 200\text{--}1150$ GeV with both jets having $|\eta| < 2.0$ and the dijet system having $|\cos\theta^*| < 0.67$. See their Table I for the list of limits. Supersedes ABE 93G.
- ³¹ ABE 93G give cross section times branching ratio into light (d, u, s, c, b) quarks for $\Gamma = 0.02 M$. Their Table II gives limits for $M = 200\text{--}900$ GeV and $\Gamma = (0.02\text{--}0.2) M$.

LIMITS ON NEUTRAL PARTICLE PRODUCTION

Production Cross Section of Radiatively-Decaying Neutral Particle

VALUE (pb)	CL%	DOCUMENT ID	TECN	COMMENT
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
<0.0008	95	1 ALBERT 18c	HAWC	γ from Sun
		2 KHACHATRYAN...17D	CMS	$Z\gamma$ resonance
		3 AAD 16AI	ATLS	$pp \rightarrow \gamma + \text{jet}$
<(0.043–0.17)	95	4 KHACHATRYAN...16M	CMS	$pp \rightarrow \gamma\gamma$ resonance
		5 ABBIENDI 00D	OPAL	$e^+e^- \rightarrow X^0 Y^0$, $X^0 \rightarrow Y^0 \gamma$
<(0.05–0.8)	95	6 ABBIENDI 00D	OPAL	$e^+e^- \rightarrow X^0 X^0$, $X^0 \rightarrow Y^0 \gamma$
<(2.5–0.5)	95	7 ACKERSTAFF 97B	OPAL	$e^+e^- \rightarrow X^0 Y^0$, $X^0 \rightarrow Y^0 \gamma$
<(1.6–0.9)	95	8 ACKERSTAFF 97B	OPAL	$e^+e^- \rightarrow X^0 X^0$, $X^0 \rightarrow Y^0 \gamma$
1 ALBERT 18c search for WIMP annihilation in Sun to long-lived, radiatively decaying mediator; no signal; limits set on $\sigma^{SD}(\chi p)$ assuming long-lived mediator.				
2 KHACHATRYAN 17D search for new scalar resonance decaying to $Z\gamma$ with $Z \rightarrow e^+e^-$, $\mu^+\mu^-$ in pp collisions at 8 and 13 TeV; no signal seen.				
3 AAD 16AI search for excited quarks (EQ) and quantum black holes (QBH) in 3.2 fb ⁻¹ at 13 TeV of data; exclude EQ below 4.4 TeV and QBH below 3.8 (6.2) TeV for RS1 (ADD) models. The visible cross section limit was obtained for 5 TeV resonance with $\sigma_G/M_G = 2\%$.				
4 KHACHATRYAN 16M search for $\gamma\gamma$ resonance using 19.7 fb ⁻¹ at 8 TeV and 3.3 fb ⁻¹ at 13 TeV; slight excess at 750 GeV noted; limit set on RS graviton.				
5 ABBIENDI 00D associated production limit is for $m_{X^0} = 90\text{--}188$ GeV, $m_{Y^0} = 0$ at $E_{\text{cm}} = 189$ GeV. See also their Fig. 9.				
6 ABBIENDI 00D pair production limit is for $m_{X^0} = 45\text{--}94$ GeV, $m_{Y^0} = 0$ at $E_{\text{cm}} = 189$ GeV. See also their Fig. 12.				
7 ACKERSTAFF 97B associated production limit is for $m_{X^0} = 80\text{--}160$ GeV, $m_{Y^0} = 0$ from 10.0 pb ⁻¹ at $E_{\text{cm}} = 161$ GeV. See their Fig. 3(a).				
8 ACKERSTAFF 97B pair production limit is for $m_{X^0} = 40\text{--}80$ GeV, $m_{Y^0} = 0$ from 10.0 pb ⁻¹ at $E_{\text{cm}} = 161$ GeV. See their Fig. 3(b).				

Heavy Particle Production Cross Section

VALUE (cm ² /N)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1	AABOUD 19H	ATLS		di-photon-jet resonance
2	AABOUD 19V	ATLS		ATLAS review, mediator-based DM
3	SIRUNYAN 19O	CMS		$pp \rightarrow \gamma E_T$
4	AABOUD 18CJ	ATLS		$pp \rightarrow VV/\ell\ell/\ell\nu, V = W, Z, h$
5	AABOUD 18CM	ATLS		$pp \rightarrow e\mu/e\tau/\mu\tau$
6	AAIJ 18AJ	LHCB		$pp \rightarrow A' \rightarrow \mu^+\mu^-$; dark photon
7	BANERJEE 18	NA64		$eZ \rightarrow eZX(A')$
8	BANERJEE 18A	NA64		$eZ \rightarrow eZA', A' \rightarrow \chi\chi$
9	MARSICANO 18	E137		$e^+e^- \rightarrow A'(\gamma)$ visible decay

10	SIRUNYAN 18BB	CMS		$pp \rightarrow Z' \rightarrow \ell^+\ell^-$ at 13 TeV
11	SIRUNYAN 18DA	CMS		$pp \rightarrow$ Black Hole, string ball, sphaleron
12	SIRUNYAN 18DD	CMS		$pp \rightarrow jj$
13	SIRUNYAN 18DR	CMS		$pp \rightarrow b\mu\bar{\mu}$
14	SIRUNYAN 18DU	CMS		$pp \rightarrow \gamma\gamma$
15	SIRUNYAN 18ED	CMS		$pp \rightarrow V \rightarrow Wh; h \rightarrow b\bar{b}; W \rightarrow \ell\nu$
16	AABOUD 17B	ATLS		WH, ZH resonance
17	AAIJ 17BR	LHCB		$pp \rightarrow \pi\nu\pi\nu, \pi\nu \rightarrow jj$
18	AAD 16O	ATLS		$\ell + (\ell s \text{ or jets})$
19	AAD 16R	ATLS		WW, WZ, ZZ resonance
20	KRASZNAHO...16			$p^7\text{Li} \rightarrow {}^8\text{Be} \rightarrow X(17)N, X(17) \rightarrow e^+e^-$
21	LEES 15E	BABR		e^+e^- collisions
22	ADAMS 97B	KTEV		$m = 1.2\text{--}5$ GeV
23	GALLAS 95	TOF		$m = 0.5\text{--}20$ GeV
24	AKESSON 91	CNTR		$m = 0\text{--}5$ GeV
25	BADIER 86	BDMP		$\tau = (0.05\text{--}1) \times 10^{-8}$ s
26	GUSTAFSON 76	CNTR		$\tau > 10^{-7}$ s

- ¹ AABOUD 19H searches for di-photon-jet resonance at 13 TeV and 36.7 fb⁻¹ of data; no signal found and limits placed on $\sigma \cdot \text{BR}$ vs. mass plane for various simplified models.
- ² AABOUD 19V review ATLAS searches for mediator-based DM at 7, 8, and 13 TeV with up to 37 fb⁻¹ of data; no signal found and limits set for wide variety of simplified models of dark matter.
- ³ SIRUNYAN 19O search for $pp \rightarrow \gamma E_T$ at 13 TeV with 36.1 fb⁻¹; no signal found and limits set for various simplified models.
- ⁴ AABOUD 18CJ make multichannel search for $pp \rightarrow VV/\ell\ell/\ell\nu, V = W, Z, h$ at 13 TeV, 36.1 fb⁻¹; no signal found; limits placed for several BSM models.
- ⁵ AABOUD 18CM search for lepton-flavor violating resonance in $pp \rightarrow e\mu/e\tau/\mu\tau$ at 13 TeV, 36.1 fb⁻¹; no signal is found and limits placed for various BSM models.
- ⁶ AAIJ 18AJ search for prompt and delayed dark photon decay $A' \rightarrow \mu^+\mu^-$ at LHCB detector using 1.6 fb⁻¹ of pp collisions at 13 TeV; limits on $m(A')$ vs. kinetic mixing are set.
- ⁷ BANERJEE 18 search for dark photon $A'/16.7$ MeV boson X at NA64 via $eZ \rightarrow eZX(A')$; no signal found and limits set on the $X\text{--}e^-$ coupling e_e in the range $1.3 \times 10^{-4} \leq e_e \leq 4.2 \times 10^{-4}$ excluding part of the allowed parameter space.
- ⁸ BANERJEE 18A search for invisibly decaying dark photons in $eZ \rightarrow eZA', A' \rightarrow$ invisible; no signal found and limits set on mixing for $m(A') < 1$ GeV.
- ⁹ MARSICANO 18 search for dark photon $e^+e^- \rightarrow A'(\gamma)$ visible decay in SLAC E137 e beam dump data. No signal observed and limits set in e coupling vs $m(A')$ plane, see their figure 7.
- ¹⁰ SIRUNYAN 18BB search for high mass dilepton resonance; no signal found and exclude portions of p -space of Z', KK graviton models.
- ¹¹ SIRUNYAN 18DA search for $pp \rightarrow$ Black Hole, string ball, sphaleron via high multiplicity events at 13 TeV, 35.9 fb⁻¹; no signal, require e.g. $m(\text{BH}) > 10.1$ TeV.
- ¹² SIRUNYAN 18DD search for $pp \rightarrow jj$ deviations in dijet angular distribution. No signal observed. Set limits on large extra dimensions, black holes and DM mediators e.g. $m(\text{BH}) > 5.9\text{--}8.2$ TeV.
- ¹³ SIRUNYAN 18DR search for dimuon resonance in $pp \rightarrow b\mu\bar{\mu}$ at 8 and 13 TeV. Slight excess seen at $m(\mu\bar{\mu}) \sim 28$ GeV in some channels.
- ¹⁴ SIRUNYAN 18DU search for high mass diphoton resonance in $pp \rightarrow \gamma\gamma$ at 13 TeV using 35.9 fb⁻¹; no signal; limits placed on RS Graviton, LED, and clockwork.
- ¹⁵ SIRUNYAN 18ED search for $pp \rightarrow V \rightarrow Wh; h \rightarrow b\bar{b}; W \rightarrow \ell\nu$ at 13 TeV with 35.9 fb⁻¹; no signal; limits set on $m(W')$ > 2.9 TeV.
- ¹⁶ AABOUD 17B exclude $m(W', Z') < 1.49\text{--}2.31$ TeV depending on the couplings and W'/Z' degeneracy assumptions via WH, ZH search in pp collisions at 13 TeV with 3.2 fb⁻¹ of data.
- ¹⁷ AAIJ 17BR search for long-lived hidden valley pions from Higgs decay. Limits are set on the signal strength as a function of the mass and lifetime of the long-lived particle in their Fig. 4 and Tab. 4.
- ¹⁸ AAD 16O search for high $E_T \ell + (\ell s \text{ or jets})$ with 3.2 fb⁻¹ at 13 TeV; exclude micro black holes mass < 8 TeV (Fig. 3) for models with two extra dimensions.
- ¹⁹ AAD 16R search for WW, WZ, ZZ resonance in 20.3 fb⁻¹ at 8 TeV data; limits placed on massive RS graviton (Fig. 4).
- ²⁰ KRASZNAHORKAY 16 report $p\text{Li} \rightarrow \text{Be} \rightarrow e\bar{e}N 5\sigma$ resonance at 16.7 MeV—possible evidence for nuclear interference or new light boson. However, such nuclear interference was ruled out already by ZANG 17.
- ²¹ LEES 15E search for long-lived neutral particles produced in e^+e^- collisions in the Upsilon region, which decays into $e^+\mu^-, \mu^+\mu^-, e^+\mu^\pm, \pi^+\pi^-, K^+K^-, \text{ or } \pi^\pm K^\pm$. See their Fig. 2 for cross section limits.
- ²² ADAMS 97B search for a hadron-like neutral particle produced in pN interactions, which decays into a p^0 and a weakly interacting massive particle. Upper limits are given for the ratio to K_S^0 production for the mass range 1.2–5 GeV and lifetime $10^{-9}\text{--}10^{-4}$ s. See also our Light Gluino Section.
- ²³ GALLAS 95 limit is for a weakly interacting neutral particle produced in 800 GeV/c pN interactions decaying with a lifetime of $10^{-4}\text{--}10^{-8}$ s. See their Figs. 8 and 9. Similar limits are obtained for a stable particle with interaction cross section $10\text{--}29\text{--}10\text{--}33 \text{ cm}^2$. See Fig. 10.
- ²⁴ AKESSON 91 limit is from weakly interacting neutral long-lived particles produced in pN reaction at 450 GeV/c performed at CERN SPS. Bourquin-Gaillard formula is used as the production model. The above limit is for $\tau > 10^{-7}$ s. For $\tau > 10^{-9}$ s, $\sigma < 10^{-30} \text{ cm}^2/\text{nucleon}$ is obtained.
- ²⁵ BADIER 86 looked for long-lived particles at 300 GeV π^- beam dump. The limit applies for nonstrongly interacting neutral or charged particles with mass > 2 GeV. The limit applies for particle modes, $\mu^+\pi^-, \mu^+\mu^-, \pi^+\pi^-, \pi^+\pi^+X, \pi^+\pi^-\pi^+$ etc. See their figure 5 for the contours of limits in the mass- τ plane for each mode.

Searches Particle Listings

Other Particle Searches

²⁶ GUSTAFSON 76 is a 300 GeV FNAL experiment looking for heavy ($m > 2$ GeV) long-lived neutral hadrons in the M4 neutral beam. The above typical value is for $m = 3$ GeV and assumes an interaction cross section of 1 mb. Values as a function of mass and interaction cross section are given in figure 2.

Production of New Penetrating Non- ν Like States in Beam Dump

VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
	¹ LOSECCO	81	CALO 28 GeV protons
¹ No excess neutral-current events leads to $\sigma(\text{production}) \times \sigma(\text{interaction}) \times \text{acceptance} < 2.26 \times 10^{-71} \text{ cm}^4/\text{nucleon}^2$ (CL = 90%) for light neutrals. Acceptance depends on models (0.1 to $4. \times 10^{-4}$).			

LIMITS ON CHARGED PARTICLES IN e^+e^-

Heavy Particle Production Cross Section in e^+e^-

Ratio to $\sigma(e^+e^- \rightarrow \mu^+\mu^-)$ unless noted. See also entries in Free Quark Search and Magnetic Monopole Searches.

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<1 $\times 10^{-3}$	90	¹ KILE	18	ALEP $e^+e^- \rightarrow 4$ jets
		² ABLIKIM	17AA	BES3 $e^+e^- \rightarrow \ell\bar{\ell}\gamma$
		³ ACKERSTAFF	98P	OPAL $Q=1,2/3, m=45\text{--}89.5$ GeV
		⁴ ABREU	97D	DLPH $Q=1,2/3, m=45\text{--}84$ GeV
		⁵ BARATE	97K	ALEP $Q=1, m=45\text{--}85$ GeV
<2 $\times 10^{-5}$	95	⁶ AKERS	95R	OPAL $Q=1, m=5\text{--}45$ GeV
		⁶ AKERS	95R	OPAL $Q=2, m=5\text{--}45$ GeV
<1 $\times 10^{-5}$	95	⁷ BUSKULIC	93C	ALEP $Q=1, m=32\text{--}72$ GeV
<2 $\times 10^{-3}$	90	⁸ ADACHI	90C	TOPZ $Q=1, m=1\text{--}16, 18\text{--}27$ GeV
<(10 ⁻² -1)	95	⁹ ADACHI	90E	TOPZ $Q=1, m=5\text{--}25$ GeV
<7 $\times 10^{-2}$	90	¹⁰ KINOSHITA	82	PLAS $Q=3\text{--}180, m < 14.5$ GeV
<1.6 $\times 10^{-2}$	95	¹¹ BARTEL	80	JADE $Q=(3,4,5)/3$ 2-12 GeV
<5.0 $\times 10^{-2}$	90			

- ¹ KILE 18 investigate archived ALEPH $e^+e^- \rightarrow 4$ jets data and see 4-5 σ excess at 110 GeV.
- ² ABLIKIM 17AA search for dark photon $A \rightarrow \ell\bar{\ell}$ at 3.773 GeV with 2.93 fb⁻¹. Limits are set in ϵ vs $m(A)$ plane.
- ³ ACKERSTAFF 98P search for pair production of long-lived charged particles at E_{cm} between 130 and 183 GeV and give limits $\sigma < (0.05\text{--}0.2)$ pb (95%CL) for spin-0 and spin-1/2 particles with $m=45\text{--}89.5$ GeV, charge 1 and 2/3. The limit is translated to the cross section at $E_{\text{cm}}=183$ GeV with the s dependence described in the paper. See their Figs. 2-4.
- ⁴ ABREU 97D search for pair production of long-lived particles and give limits $\sigma < (0.4\text{--}2.3)$ pb (95%CL) for various center-of-mass energies $E_{\text{cm}}=130\text{--}136, 161$, and 172 GeV, assuming an almost flat production distribution in $\cos\theta$.
- ⁵ BARATE 97K search for pair production of long-lived charged particles at $E_{\text{cm}} = 130, 136, 161$, and 172 GeV and give limits $\sigma < (0.2\text{--}0.4)$ pb (95%CL) for spin-0 and spin-1/2 particles with $m=45\text{--}85$ GeV. The limit is translated to the cross section at $E_{\text{cm}}=172$ GeV with the E_{cm} dependence described in the paper. See their Figs. 2 and 3 for limits on $J = 1/2$ and $J = 0$ cases.
- ⁶ AKERS 95R is a CERN-LEP experiment with $W_{\text{cm}} \sim m_Z$. The limit is for the production of a stable particle in multihadron events normalized to $\sigma(e^+e^- \rightarrow \text{hadrons})$. Constant phase space distribution is assumed. See their Fig. 3 for bounds for $Q = \pm 2/3, \pm 4/3$.
- ⁷ BUSKULIC 93C is a CERN-LEP experiment with $W_{\text{cm}} = m_Z$. The limit is for a pair or single production of heavy particles with unusual ionization loss in TPC. See their Fig. 5 and Table 1.
- ⁸ ADACHI 90C is a KEK-TRISTAN experiment with $W_{\text{cm}} = 52\text{--}60$ GeV. The limit is for pair production of a scalar or spin-1/2 particle. See Figs. 3 and 4.
- ⁹ ADACHI 90E is KEK-TRISTAN experiment with $W_{\text{cm}} = 52\text{--}61.4$ GeV. The above limit is for inclusive production cross section normalized to $\sigma(e^+e^- \rightarrow \mu^+\mu^-) \cdot \beta(3 - \beta^2)/2$, where $\beta = (1 - 4m^2/W_{\text{cm}}^2)^{1/2}$. See the paper for the assumption about the production mechanism.
- ¹⁰ KINOSHITA 82 is SLAC PEP experiment at $W_{\text{cm}} = 29$ GeV using lexan and ³⁹Cr plastic sheets sensitive to highly ionizing particles.
- ¹¹ BARTEL 80 is DESY-PETRA experiment with $W_{\text{cm}} = 27\text{--}35$ GeV. Above limit is for inclusive pair production and ranges between $1. \times 10^{-1}$ and $1. \times 10^{-2}$ depending on mass and production momentum distributions. (See their figures 9, 10, 11).

Branching Fraction of Z^0 to a Pair of Stable Charged Heavy Fermions

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<5 $\times 10^{-6}$	95	¹ AKERS	95R	OPAL $m = 40.4\text{--}45.6$ GeV
<1 $\times 10^{-3}$	95	AKRAWY	90O	OPAL $m = 29\text{--}40$ GeV
¹ AKERS 95R give the 95% CL limit $\sigma(X\bar{X})/\sigma(\mu\mu) < 1.8 \times 10^{-4}$ for the pair production of singly- or doubly-charged stable particles. The limit applies for the mass range 40.4-45.6 GeV for X^\pm and < 45.6 GeV for $X^{\pm\pm}$. See the paper for bounds for $Q = \pm 2/3, \pm 4/3$.				

LIMITS ON CHARGED PARTICLES IN HADRONIC REACTIONS

MASS LIMITS for Long-Lived Charged Heavy Fermions

Limits are for spin 1/2 particles with no color and $Su(2)_L$ charge. The electric charge Q of the particle (in the unit of e) is therefore equal to its weak hypercharge. Pair production by Drell-Yan like γ and Z exchange is assumed to derive the limits.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>660	95	¹ AAD	15BJ	ATLS $ Q = 2$
>200	95	² CHATRCHYAN	13AB	CMS $ Q = 1/3$
>480	95	² CHATRCHYAN	13AB	CMS $ Q = 2/3$
>574	95	² CHATRCHYAN	13AB	CMS $ Q = 1$
>685	95	² CHATRCHYAN	13AB	CMS $ Q = 2$
>140	95	³ CHATRCHYAN	13AR	CMS $ Q = 1/3$
>310	95	³ CHATRCHYAN	13AR	CMS $ Q = 2/3$

- ¹ AAD 15BJ use 20.3 fb⁻¹ of pp collisions at $E_{\text{cm}} = 8$ TeV. See paper for limits for $|Q| = 3, 4, 5, 6$.
- ² CHATRCHYAN 13AB use 5.0 fb⁻¹ of pp collisions at $E_{\text{cm}} = 7$ TeV and 18.8 fb⁻¹ at $E_{\text{cm}} = 8$ TeV. See paper for limits for $|Q| = 3, 4, \dots, 8$.
- ³ CHATRCHYAN 13AR use 5.0 fb⁻¹ of pp collisions at $E_{\text{cm}} = 7$ TeV.

Heavy Particle Production Cross Section

VALUE (nb)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<1.2 $\times 10^{-3}$	95	¹ AABOUD	19AA	ATLS BSM search
		² AABOUD	19Q	ATLS single top + MET
		³ AABOUD	17D	ATLS anomalous $WWjj, WZjj$
		⁴ AABOUD	17L	ATLS $m > 870$ GeV, $Z(\rightarrow \nu\nu)tX$
		⁵ SIRUNYAN	17B	CMS tH
		⁶ SIRUNYAN	17C	CMS $Z + (t \text{ or } b)$
		⁷ SIRUNYAN	17J	CMS $X_{5/3} \rightarrow tW$
		⁸ AAIJ	15BD	LHCB $m=124\text{--}309$ GeV
		⁹ AAD	13AH	ATLS $ q =(2-6)e, m=50\text{--}600$ GeV
		¹⁰ AAD	11I	ATLS $ q =10e, m=0.2\text{--}1$ TeV
<1.0 $\times 10^{-5}$	95	^{11,12} AALTONEN	09Z	CDF $m > 100$ GeV, noncolored
<4.8 $\times 10^{-5}$	95	^{11,13} AALTONEN	09Z	CDF $m > 100$ GeV, colored
<0.31-0.04 $\times 10^{-3}$	95	¹⁴ ABAZOV	09M	D0 pair production
<0.19	95	¹⁵ AKTAS	04c	H1 $m=3\text{--}10$ GeV
<0.05	95	¹⁶ ABE	92J	CDF $m=50\text{--}200$ GeV
<30-130		¹⁷ CARROLL	78	SPEC $m=2\text{--}2.5$ GeV
<100		¹⁸ LEIPUNER	73	CNTR $m=3\text{--}11$ GeV

- ¹ AABOUD 19AA search for BSM physics at 13 TeV with 3.2 fb⁻¹ in $> 10^5$ regions of > 700 event classes; no significant signal found.
- ² AABOUD 19Q search for single top+MET events at 13 TeV with 36.1 fb⁻¹ of data; no signal found and limits set in σ or coupling vs. mass plane for variety of simplified models including DM and vector-like top quark T .
- ³ AABOUD 17D search for $WWjj, WZjj$ in pp collisions at 8 TeV with 3.2 fb⁻¹; set limits on anomalous couplings.
- ⁴ AABOUD 17L search for the pair production of heavy vector-like T quarks in the $Z(\rightarrow \nu\nu)tX$ final state.
- ⁵ SIRUNYAN 17B search for vector-like quark $pp \rightarrow TX \rightarrow tHX$ in 2.3 fb⁻¹ at 13 TeV; no signal seen; limits placed.
- ⁶ SIRUNYAN 17C search for vector-like quark $pp \rightarrow TX \rightarrow Z + (t \text{ or } b)$ in 2.3 fb⁻¹ at 13 TeV; no signal seen; limits placed.
- ⁷ SIRUNYAN 17J search for $pp \rightarrow X_{5/3}X_{5/3} \rightarrow tWtW$ with 2.3 fb⁻¹ at 13 TeV. No signal seen: $m(X) > 1020$ (990) GeV for RH (LH) new charge 5/3 quark.
- ⁸ AAIJ 15BD search for production of long-lived particles in pp collisions at $E_{\text{cm}} = 7$ and 8 TeV. See their Table 6 for cross section limits.
- ⁹ AAD 13AH search for production of long-lived particles with $|q|=(2-6)e$ in pp collisions at $E_{\text{cm}} = 7$ TeV with 4.4 fb⁻¹. See their Fig. 8 for cross section limits.
- ¹⁰ AAD 11I search for production of highly ionizing massive particles in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 3.1$ pb⁻¹. See their Table 5 for similar limits for $|q| = 6e$ and 17e, Table 6 for limits on pair production cross section.
- ¹¹ AALTONEN 09Z search for long-lived charged particles in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 1.0$ fb⁻¹. The limits are on production cross section for a particle of mass above 100 GeV in the region $|\eta| \lesssim 0.7, p_T > 40$ GeV, and $0.4 < \beta < 1.0$.
- ¹² Limit for weakly interacting charge-1 particle.
- ¹³ Limit for up-quark like particle.
- ¹⁴ ABAZOV 09M search for pair production of long-lived charged particles in $p\bar{p}$ collisions at $E_{\text{cm}} = 1.96$ TeV with $L = 1.1$ fb⁻¹. Limit on the cross section of $(0.31\text{--}0.04)$ pb (95% CL) is given for the mass range of 60-300 GeV, assuming the kinematics of stau pair production.
- ¹⁵ AKTAS 04c look for charged particle photoproduction at HERA with mean c.m. energy of 200 GeV.
- ¹⁶ ABE 92J look for pair production of unit-charged particles which leave detector before decaying. Limit shown here is for $m=50$ GeV. See their Fig. 5 for different charges and stronger limits for higher mass.
- ¹⁷ CARROLL 78 look for neutral, $S = -2$ dihyperon resonance in $pp \rightarrow 2K^+X$. Cross section varies within above limits over mass range and $p_{\text{lab}} = 5.1\text{--}5.9$ GeV/c.
- ¹⁸ LEIPUNER 73 is an NAL 300 GeV p experiment. Would have detected particles with lifetime greater than 200 ns.

Heavy Particle Production Differential Cross Section

VALUE (cm ² sr ⁻¹ GeV ⁻¹)	CL%	DOCUMENT ID	TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<2.6 $\times 10^{-36}$	90	¹ BALDIN	76	CNTR	$-$ $Q=1, m=2.1\text{--}9.4$ GeV
<2.2 $\times 10^{-33}$	90	² ALBROW	75	SPEC	\pm $Q= \pm 1, m=4\text{--}15$ GeV
<1.1 $\times 10^{-33}$	90	² ALBROW	75	SPEC	\pm $Q= \pm 2, m=6\text{--}27$ GeV
<8. $\times 10^{-35}$	90	³ JOVANOVIĆ	75	CNTR	\pm $m=15\text{--}26$ GeV
<1.5 $\times 10^{-34}$	90	³ JOVANOVIĆ	75	CNTR	\pm $Q= \pm 2, m=3\text{--}10$ GeV
<6. $\times 10^{-35}$	90	³ JOVANOVIĆ	75	CNTR	\pm $Q= \pm 2, m=10\text{--}26$ GeV
<1. $\times 10^{-31}$	90	⁴ APPEL	74	CNTR	\pm $m=3.2\text{--}7.2$ GeV

See key on page 999

Searches Particle Listings

Other Particle Searches

$<5.8 \times 10^{-34}$	90	⁵ ALPER	73	SPEC	\pm	$m=1.5\text{--}24$ GeV
$<1.2 \times 10^{-35}$	90	⁶ ANTIPOV	71B	CNTR	$-$	$Q=-, m=2.2\text{--}2.8$
$<2.4 \times 10^{-35}$	90	⁷ ANTIPOV	71C	CNTR	$-$	$Q=-, m=1.2\text{--}1.7,$ 2.1–4
$<2.4 \times 10^{-35}$	90	BINON	69	CNTR	$-$	$Q=-, m=1\text{--}1.8$ GeV
$<1.5 \times 10^{-36}$		⁸ DORFAN	65	CNTR		Be target $m=3\text{--}7$ GeV
$<3.0 \times 10^{-36}$		⁸ DORFAN	65	CNTR		Fe target $m=3\text{--}7$ GeV

¹ BALDIN 76 is a 70 GeV Serpukhov experiment. Value is per Al nucleus at $\theta = 0$. For other charges in range -0.5 to -3.0 , CL = 90% limit is $(2.6 \times 10^{-36})/|(\text{charge})|$ for mass range $(2.1\text{--}9.4 \text{ GeV}) \times |(\text{charge})|$. Assumes stable particle interacting with matter as do antiprotons.

² ALBROW 75 is a CERN ISR experiment with $E_{\text{cm}} = 53$ GeV. $\theta = 40$ mr. See figure 5 for mass ranges up to 35 GeV.

³ JOVANOVIĆ 75 is a CERN ISR 26+26 and 15+15 GeV pp experiment. Figure 4 covers ranges $Q = 1/3$ to 2 and $m = 3$ to 26 GeV. Value is per GeV momentum.

⁴ APPEL 74 is NAL 300 GeV pW experiment. Studies forward production of heavy (up to 24 GeV) charged particles with momenta 24–200 GeV ($-$ charge) and 40–150 GeV ($+$ charge). Above typical value is for 75 GeV and is per GeV momentum per nucleon.

⁵ ALPER 73 is CERN ISR 26+26 GeV pp experiment. $p > 0.9$ GeV, $0.2 < \beta < 0.65$.

⁶ ANTIPOV 71B is from same 70 GeV p experiment as ANTIPOV 71C and BINON 69.

⁷ ANTIPOV 71C limit inferred from flux ratio. 70 GeV p experiment.

⁸ DORFAN 65 is a 30 GeV/c p experiment at BNL. Units are per GeV momentum per nucleus.

Long-Lived Heavy Particle Invariant Cross Section

VALUE (cm ² /GeV ² /N)	CL%	DOCUMENT ID	TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<5\text{--}700 \times 10^{-35}$	90	¹ BERNSTEIN	88	CNTR	
$<5\text{--}700 \times 10^{-37}$	90	¹ BERNSTEIN	88	CNTR	
$<2.5 \times 10^{-36}$	90	² THRON	85	CNTR	$-$ $Q = 1, m=4\text{--}12$ GeV
$<1. \times 10^{-35}$	90	² THRON	85	CNTR	$+$ $Q = 1, m=4\text{--}12$ GeV
$<6. \times 10^{-33}$	90	³ ARMITAGE	79	SPEC	$m=1.87$ GeV
$<1.5 \times 10^{-33}$	90	³ ARMITAGE	79	SPEC	$m=1.5\text{--}3.0$ GeV
		⁴ BOZZOLI	79	CNTR	\pm $Q = (2/3, 1, 4/3, 2)$
$<1.1 \times 10^{-37}$	90	⁵ CUTTS	78	CNTR	$m=4\text{--}10$ GeV
$<3.0 \times 10^{-37}$	90	⁶ VIDAL	78	CNTR	$m=4.5\text{--}6$ GeV

¹ BERNSTEIN 88 limits apply at $x = 0.2$ and $p_T = 0$. Mass and lifetime dependence of limits are shown in the regions: $m = 1.5\text{--}7.5$ GeV and $\tau = 10^{-8}\text{--}2 \times 10^{-6}$ s. First number is for hadrons; second is for weakly interacting particles.

² THRON 85 is FNAL 400 GeV proton experiment. Mass determined from measured velocity and momentum. Limits are for $\tau > 3 \times 10^{-9}$ s.

³ ARMITAGE 79 is CERN-ISR experiment at $E_{\text{cm}} = 53$ GeV. Value is for $x = 0.1$ and $p_T = 0.15$. Observed particles at $m = 1.87$ GeV are found all consistent with being antideuteron.

⁴ BOZZOLI 79 is CERN-SPS 200 GeV pN experiment. Looks for particle with τ larger than 10^{-8} s. See their figure 11–18 for production cross-section upper limits vs mass.

⁵ CUTTS 78 is p Be experiment at FNAL sensitive to particles of $\tau > 5 \times 10^{-8}$ s. Value is for $-0.3 < x < 0$ and $p_T = 0.175$.

⁶ VIDAL 78 is FNAL 400 GeV proton experiment. Value is for $x = 0$ and $p_T = 0$. Puts lifetime limit of $< 5 \times 10^{-8}$ s on particle in this mass range.

Long-Lived Heavy Particle Production

($\sigma(\text{Heavy Particle}) / \sigma(p)$)

VALUE	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<10^{-8}$		¹ NAKAMURA	89	SPEC	\pm $Q = (-5/3, \pm 2)$
	0	² BUSSIÈRE	80	CNTR	\pm $Q = (2/3, 1, 4/3, 2)$

¹ NAKAMURA 89 is KEK experiment with 12 GeV protons on Pt target. The limit applies for mass $\lesssim 1.6$ GeV and lifetime $\gtrsim 10^{-7}$ s.

² BUSSIÈRE 80 is CERN-SPS experiment with 200–240 GeV protons on Be and Al target. See their figures 6 and 7 for cross-section ratio vs mass.

Production and Capture of Long-Lived Massive Particles

VALUE (10 ⁻³⁶ cm ²)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
<20 to 800	¹ ALEKSEEV	76	ELEC $\tau=5$ ms to 1 day
<200 to 2000	¹ ALEKSEEV	76B	ELEC $\tau=100$ ms to 1 day
<1.4 to 9	² FRANKEL	75	CNTR $\tau=50$ ms to 100 hours
<0.1 to 9	³ FRANKEL	74	CNTR $\tau=1$ to 1000 hours

¹ ALEKSEEV 76 and ALEKSEEV 76B are 61–70 GeV p Serpukhov experiment. Cross section is per Pb nucleus.

² FRANKEL 75 is extension of FRANKEL 74.

³ FRANKEL 74 looks for particles produced in thick Al targets by 300–400 GeV/c protons.

Long-Lived Particle (LLP) Search at Hadron Collisions

Limits are for cross section times branching ratio.

VALUE (pb/nucleon)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
¹ AAD	20D	ATLS	$pp \rightarrow$ LLPs at 13 TeV
² AABOUD	19AE	ATLS	pp at 13 TeV
³ AABOUD	19AK	ATLS	$pp \rightarrow \Phi \rightarrow ZZ_d$
⁴ AABOUD	19AM	ATLS	DY multi-charged LLP production
⁵ AABOUD	19AO	ATLS	LLP via displaced jets
⁶ AABOUD	19AT	ATLS	heavy, charged long-lived particles
⁷ AABOUD	19G	ATLS	LLP decay to $\mu^+\mu^-$
⁸ SIRUNYAN	19BH	CMS	LLP via displaced jets

⁹ SIRUNYAN	19BT	CMS	LLP via displaced jets+MET
¹⁰ SIRUNYAN	19CA	CMS	LLP $\rightarrow \gamma$ search
¹¹ SIRUNYAN	19Q	CMS	$pp \rightarrow j$ + displaced dark quark jet
¹² SIRUNYAN	18AW	CMS	Long-lived particle search
¹³ AAIJ	16AR	LHCb	$H \rightarrow XX$ long-lived particles
¹⁴ KHACHATRYAN	16BW	CMS	direct production: HSCPs
¹⁵ BADIER	86	BDMP	$\tau = (0.05\text{--}1.) \times 10^{-8}$ s

< 2 at 90%CL

¹ AAD 20D search for opposite-sign dileptons originating from long-lived particles in pp collisions at 13 TeV with 32.8 fb⁻¹; limits placed in squark cross section vs. $c\tau$ plane for RPV SUSY.

² AABOUD 19AE search for long-lived particles via displaced jets using 10.8 fb⁻¹ or 33.0 fb⁻¹ data (depending on a trigger) at 13 TeV; no signal found and limits set in branching ratio vs. decay length plane.

³ AABOUD 19AK searches for long-lived particle Z_d via $pp \rightarrow \Phi \rightarrow ZZ_d$ at 13 TeV with 36.1 fb⁻¹; no signal found and limits set in $\sigma \times \text{BR}$ vs. lifetime plane for simplified model.

⁴ AABOUD 19AM search for Drell-Yan (DY) production of long-lived multi-charged particles at 13 TeV with 36.1 fb⁻¹ of data; no signal found and exclude 50 GeV $< m(\text{LLMCP}) < 980\text{--}1220$ GeV for electric charge $|q| = (2\text{--}7)$.

⁵ AABOUD 19AO search for neutral long-lived particles producing displaced jets at 13 TeV with 36.1 fb⁻¹ of data; no signal found and exclude regions of $\sigma \times \text{BR}$ vs. lifetime plane for various models.

⁶ AABOUD 19AT search for heavy, charged long-lived particles at 13 TeV with 36.1 fb⁻¹; no signal found and upper limits set on masses of various hypothetical particles.

⁷ AABOUD 19G search for long-lived particle with decay to $\mu^+\mu^-$ at 13 TeV with 32.9 fb⁻¹; no signal found and limits set in combinations of lifetime, mass and coupling planes for various simplified models.

⁸ SIRUNYAN 19BH search for long-lived SUSY particles via displaced jets at 13 TeV with 35.9 fb⁻¹; no signal found and limits placed in mass vs lifetime plane for various hypothetical models.

⁹ SIRUNYAN 19BT search for displaced jet(s)+ E_T at 13 TeV with 137 fb⁻¹; no signal found and limits placed in mass vs lifetime plane for gauge mediated SUSY breaking models.

¹⁰ SIRUNYAN 19CA search for gluino/squark decay to long-lived neutralino, decay to γ in GMSB; no signal, limits placed in $m(\chi)$ vs. lifetime plane for SPS8 GMSB benchmark point.

¹¹ SIRUNYAN 19Q search for $pp \rightarrow j$ + displaced jet via dark quark with 13 TeV at 16.1 fb⁻¹; no signal found and limits set in mass vs lifetime plane for dark quark/dark pion model.

¹² SIRUNYAN 18AW search for very long lived particles (LLPs) decaying hadronically or to $\mu\tau$ in CMS detector; none seen/limits set on lifetime vs. cross section.

¹³ AAIJ 16AR search for long lived particles from $H \rightarrow XX$ with displaced X decay vertex using 0.62 fb⁻¹ at 7 TeV; limits set in Fig. 7.

¹⁴ KHACHATRYAN 16BW search for heavy stable charged particles via ToF with 2.5 fb⁻¹ at 13 TeV; require stable $m(\text{gluino}) > 1610$ GeV.

¹⁵ BADIER 86 looked for long-lived particles at 300 GeV π^- beam dump. The limit applies for nonstrongly interacting neutral or charged particles with mass > 2 GeV. The limit applies for particle modes, $\mu^+\pi^-, \mu^+\mu^-, \pi^+\pi^-, \pi^+\pi^+\pi^+$ etc. See their figure 5 for the contours of limits in the mass- τ plane for each mode.

Long-Lived Heavy Particle Cross Section

VALUE (pb/sr)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<34	95	¹ RAM	94	SPEC $1015 < m_{X^{++}} < 1085$ MeV
<75	95	¹ RAM	94	SPEC $920 < m_{X^{++}} < 1025$ MeV

¹ RAM 94 search for a long-lived doubly-charged fermion X^{++} with mass between m_N and $m_N+m_{\pi^-}$ and baryon number $+1$ in the reaction $pp \rightarrow X^{++}n$. No candidate is found. The limit is for the cross section at 15° scattering angle at 460 MeV incident energy and applies for $\tau(X^{++}) \gtrsim 0.1 \mu\text{s}$.

LIMITS ON CHARGED PARTICLES IN COSMIC RAYS

Heavy Particle Flux in Cosmic Rays

VALUE (cm ⁻² sr ⁻¹ s ⁻¹)	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 1	$\times 10^{-8}$	90	¹ ALVIS	18	MAJD Fractionally charged
~ 6	$\times 10^{-9}$		² AGNESE	15	CDM2 $Q = 1/6$
		2	³ SAITO	90	$Q \approx 14, m \approx 370 m_p$
< 1.4	$\times 10^{-12}$	90	⁴ MINCER	85	CALO $m \geq 1$ TeV
			⁵ SAKUYAMA	83B	PLAS $m \sim 1$ TeV
< 1.7	$\times 10^{-11}$	99	⁶ BHAT	82	CC
$< 1.$	$\times 10^{-9}$	90	⁷ MARINI	82	CNTR $Q=1, m \sim 4.5 m_p$
$2.$	$\times 10^{-9}$		⁸ YOCK	81	SPRK $Q=1, m \sim 4.5 m_p$
		3	⁸ YOCK	81	SPRK Fractionally charged
3.0	$\times 10^{-9}$		⁹ YOCK	80	SPRK $m \sim 4.5 m_p$
$(4 \pm 1) \times 10^{-11}$			³ GOODMAN	79	ELEC $m \geq 5$ GeV
< 1.3	$\times 10^{-9}$	90	¹⁰ BHAT	78	CNTR $m > 1$ GeV
< 1.0	$\times 10^{-9}$		⁰ BRIATORE	76	ELEC
$< 7.$	$\times 10^{-10}$	90	⁰ YOCK	75	ELEC $Q > 7e$ or $< -7e$
$> 6.$	$\times 10^{-9}$		¹¹ YOCK	74	CNTR $m > 6$ GeV
< 3.0	$\times 10^{-8}$		⁰ DARDO	72	CNTR
< 1.5	$\times 10^{-9}$		⁰ TONWAR	72	CNTR $m > 10$ GeV
< 3.0	$\times 10^{-10}$		⁰ BJORNBOE	68	CNTR $m > 5$ GeV
< 5.0	$\times 10^{-11}$	90	⁰ JONES	67	ELEC $m=5\text{--}15$ GeV

Searches Particle Listings

Other Particle Searches

- ¹ ALVIS 18 search for fractional charged flux of cosmic matter at Majorana demonstrator; no signal observed and limits are set on the flux of lightly ionizing particles for charge as low as $e/1000$.
- ² See AGNESE 15 Fig. 6 for limits extending down to $Q = 1/200$.
- ³ SAITO 90 candidates carry about 450 MeV/nucleon. Cannot be accounted for by conventional backgrounds. Consistent with strange quark matter hypothesis.
- ⁴ MINCER 85 is high statistics study of calorimeter signals delayed by 20–200 ns. Calibration with AGS beam shows they can be accounted for by rare fluctuations in signals from low-energy hadrons in the shower. Claim that previous delayed signals including BJORNBOE 68, DARDO 72, BHAT 82, SAKUYAMA 83b below may be due to this fake effect.
- ⁵ SAKUYAMA 83b analyzed 6000 extended air shower events. Increase of delayed particles and change of lateral distribution above 10^{17} eV may indicate production of very heavy parent at top of atmosphere.
- ⁶ BHAT 82 observed 12 events with delay $> 2. \times 10^{-8}$ s and with more than 40 particles. 1 eV has good hadron shower. However all events are delayed in only one of two detectors in cloud chamber, and could not be due to strongly interacting massive particle.
- ⁷ MARINI 82 applied PEP-counter for TOF. Above limit is for velocity $= 0.54$ of light. Limit is inconsistent with YOCK 80 YOCK 81 events if isotropic dependence on zenith angle is assumed.
- ⁸ YOCK 81 saw another 3 events with $Q = \pm 1$ and m about $4.5 m_p$ as well as 2 events with $m > 5.3 m_p$, $Q = \pm 0.75 \pm 0.05$ and $m > 2.8 m_p$, $Q = \pm 0.70 \pm 0.05$ and 1 event with $m = (9.3 \pm 3.) m_p$, $Q = \pm 0.89 \pm 0.06$ as possible heavy candidates.
- ⁹ YOCK 80 events are with charge exactly or approximately equal to unity.
- ¹⁰ BHAT 78 is at Kolar gold fields. Limit is for $\tau > 10^{-6}$ s.
- ¹¹ YOCK 74 events could be tritons.

Superheavy Particle (Quark Matter) Flux in Cosmic Rays

VALUE ($\text{cm}^{-2}\text{s}^{-1}\text{s}^{-1}$)	CL%	DOCUMENT ID	TECN	COMMENT
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
$< 5 \times 10^{-16}$	90	¹ ADRIANI	15 PMLA	$4 < m < 1.2 \times 10^{15} m_p$
$< 1.8 \times 10^{-12}$	90	² AMBROSIO	00B MCRO	$m > 5 \times 10^{14}$ GeV
$< 1.1 \times 10^{-14}$	90	³ ASTONE	93 CNTR	$m \geq 1.5 \times 10^{-13}$ gram
$< 2.2 \times 10^{-14}$	90	⁴ AHLEN	92 MCRO	$10^{-10} < m < 0.1$ gram
$< 6.4 \times 10^{-16}$	90	⁵ NAKAMURA	91 PLAS	$m > 10^{11}$ GeV
$< 2.0 \times 10^{-11}$	90	⁶ ORITO	91 PLAS	$m > 10^{12}$ GeV
$< 4.7 \times 10^{-12}$	90	⁷ LIU	88 BOLO	$m > 1.5 \times 10^{-13}$ gram
$< 3.2 \times 10^{-11}$	90	⁸ BARISH	87 CNTR	$1.4 \times 10^8 < m < 10^{12}$ GeV
$< 3.5 \times 10^{-11}$	90	⁹ NAKAMURA	85 CNTR	$m > 1.5 \times 10^{-13}$ gram
$< 7. \times 10^{-11}$	90	¹⁰ ULLMAN	81 CNTR	Planck-mass 10^{19} GeV
	90	¹⁰ ULLMAN	81 CNTR	$m \leq 10^{16}$ GeV

- ¹ ADRIANI 15 search for relatively light quark matter with charge $Z = 1-8$. See their Figs. 2 and 3 for flux upper limits.
- ² AMBROSIO 00b searched for quark matter ("nuclearites") in the velocity range $(10^{-5}-1)$ c. The listed limit is for 2×10^{-3} c.
- ³ ASTONE 93 searched for quark matter ("nuclearites") in the velocity range $(10^{-3}-1)$ c. Their Table1 gives a compilation of searches for nuclearites.
- ⁴ AHLEN 92 searched for quark matter ("nuclearites"). The bound applies to velocity $< 2.5 \times 10^{-3}$ c. See their Fig. 3 for other velocity/c and heavier mass range.
- ⁵ NAKAMURA 91 searched for quark matter in the velocity range $(4 \times 10^{-5}-1)$ c.
- ⁶ ORITO 91 searched for quark matter. The limit is for the velocity range $(10^{-4}-10^{-3})$ c.
- ⁷ LIU 88 searched for quark matter ("nuclearites") in the velocity range $(2.5 \times 10^{-3}-1)$ c. A less stringent limit of 5.8×10^{-11} applies for $(1-2.5) \times 10^{-3}$ c.
- ⁸ BARISH 87 searched for quark matter ("nuclearites") in the velocity range $(2.7 \times 10^{-4}-5 \times 10^{-3})$ c.
- ⁹ NAKAMURA 85 at KEK searched for quark-matter. These might be lumps of strange quark matter with roughly equal numbers of u , d , s quarks. These lumps or nuclearites were assumed to have velocity of $(10^{-4}-10^{-3})$ c.
- ¹⁰ ULLMAN 81 is sensitive for heavy slow singly charge particle reaching earth with vertical velocity 100–350 km/s.

Highly Ionizing Particle Flux

VALUE ($\text{m}^{-2}\text{yr}^{-1}$)	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
< 0.4	95	0	KINOSHITA	81b PLAS	Z/β 30–100

SEARCHES FOR BLACK HOLE PRODUCTION

VALUE	DOCUMENT ID	TECN	COMMENT
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
not seen	¹ AABOUD	16P ATLS	13 TeV $pp \rightarrow e\mu, e\tau, \mu\tau$
	² AAD	15AN ATLS	8 TeV $pp \rightarrow$ multijets
	³ AAD	14A ATLS	8 TeV $pp \rightarrow \gamma + \text{jet}$
	⁴ AAD	14AL ATLS	8 TeV $pp \rightarrow \ell + \text{jet}$
	⁵ AAD	14C ATLS	8 TeV $pp \rightarrow \ell + (\ell \text{ or jets})$
	⁶ AAD	13D ATLS	7 TeV $pp \rightarrow 2$ jets
	⁷ CHATRCHYAN13A	CMS	7 TeV $pp \rightarrow 2$ jets
	⁸ CHATRCHYAN13AD	CMS	8 TeV $pp \rightarrow$ multijets
	⁹ AAD	12AK ATLS	7 TeV $pp \rightarrow \ell + (\ell \text{ or jets})$
	¹⁰ CHATRCHYAN12W	CMS	7 TeV $pp \rightarrow$ multijets
	¹¹ AAD	11AG ATLS	7 TeV $pp \rightarrow 2$ jets

- ¹ AABOUD 16P set limits on quantum BH production in $n = 6$ ADD or $n = 1$ RS models.
- ² AAD 15AN search for black hole or string ball formation followed by its decay to multijet final states, in pp collisions at $E_{\text{cm}} = 8$ TeV with $L = 20.3 \text{ fb}^{-1}$. See their Figs. 6–8 for limits.

- ³ AAD 14A search for quantum black hole formation followed by its decay to a γ and a jet, in pp collisions at $E_{\text{cm}} = 8$ TeV with $L = 20 \text{ fb}^{-1}$. See their Fig. 3 for limits.
- ⁴ AAD 14AL search for quantum black hole formation followed by its decay to a lepton and a jet, in pp collisions at $E_{\text{cm}} = 8$ TeV with $L = 20.3 \text{ fb}^{-1}$. See their Fig. 2 for limits.
- ⁵ AAD 14C search for microscopic (semiclassical) black hole formation followed by its decay to final states with a lepton and ≥ 2 (leptons or jets), in pp collisions at $E_{\text{cm}} = 8$ TeV with $L = 20.3 \text{ fb}^{-1}$. See their Figures 8–11, Tables 7, 8 for limits.
- ⁶ AAD 13D search for quantum black hole formation followed by its decay to two jets, in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 4.8 \text{ fb}^{-1}$. See their Fig. 8 and Table 3 for limits.
- ⁷ CHATRCHYAN 13A search for quantum black hole formation followed by its decay to two jets, in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 5 \text{ fb}^{-1}$. See their Figs. 5 and 6 for limits.
- ⁸ CHATRCHYAN 13AD search for microscopic (semiclassical) black hole formation followed by its evaporation to multiparticle final states, in multijet (including γ, ℓ) events in pp collisions at $E_{\text{cm}} = 8$ TeV with $L = 12 \text{ fb}^{-1}$. See their Figs. 5–7 for limits.
- ⁹ AAD 12AK search for microscopic (semiclassical) black hole formation followed by its decay to final states with a lepton and ≥ 2 (leptons or jets), in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 1.04 \text{ fb}^{-1}$. See their Fig. 4 and 5 for limits.
- ¹⁰ CHATRCHYAN 12W search for microscopic (semiclassical) black hole formation followed by its evaporation to multiparticle final states, in multijet (including γ, ℓ) events in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 4.7 \text{ fb}^{-1}$. See their Figs. 5–8 for limits.
- ¹¹ AAD 11AG search for quantum black hole formation followed by its decay to two jets, in pp collisions at $E_{\text{cm}} = 7$ TeV with $L = 36 \text{ pb}^{-1}$. See their Fig. 11 and Table 4 for limits.

REFERENCES FOR Other Partide Searches

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AABOUD	19AE	EPJ C79 481	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	19AJ	PL B795 56	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
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AABOUD	19AM	PR D99 052003	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
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AABOUD	19AT	PR D99 092007	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	19G	PR D99 012001	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	19H	PR D99 012008	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
AABOUD	19Q	JHEP 1905 041	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
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ALCANTARA	19	PR D99 103016	E. Alcantara, L.A. Anchordoqui, J.F. Soriano	
SIRUNYAN	19B	PR D99 012005	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19BH	PR D99 032011	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	19BT	PL B797 324876	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
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AABOUD	18CL	PR D98 092005	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
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MARSICANO	18	PR D98 015031	L. Marsicano <i>et al.</i>	
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SIRUNYAN	18DD	EPJ C78 789	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18DJ	JHEP 1809 101	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	18DR	JHEP 1811 161	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
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AABOUD	17D	PR D95 032001	M. Aaboud <i>et al.</i>	(ATLAS Collab.)
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SIRUNYAN	17C	JHEP 1705 029	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	17F	JHEP 1707 013	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
SIRUNYAN	17J	JHEP 1708 073	A.M. Sirunyan <i>et al.</i>	(CMS Collab.)
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AAD	16O	PL B760 520	G. Aad <i>et al.</i>	(ATLAS Collab.)
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ADRIANI	15	PRL 115 111101	O. Adriani <i>et al.</i>	(PAMELA Collab.)
AGNESE	15	PRL 114 111302	R. Agnese <i>et al.</i>	(CDMS Collab.)
KHACHATRYAN...	15F	PRL 114 101801	V. Khachatryan <i>et al.</i>	(CMS Collab.)
LEES	15E	PRL 114 171801	J.P. Lees <i>et al.</i>	(BABAR Collab.)
AAD	14A	PL B728 562	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	14AL	PRL 112 091804	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	14C	JHEP 1408 103	G. Aad <i>et al.</i>	(ATLAS Collab.)
AALTONEN	14J	PR D89 092001	T. Aaltonen <i>et al.</i>	(CDF Collab.)
AAD	13A	PL B718 860	G. Aad <i>et al.</i>	(ATLAS Collab.)
AAD	13AH	PL B722 305	G. Aad <i>et al.</i>	(ATLAS Collab.)

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Searches Particle Listings
Other Particle Searches

AAD	13C	PRL 110 011802	G. Aad <i>et al.</i>	(ATLAS Collab.)	AKRAWY	90O	PL B252 290	M.Z. Akrawy <i>et al.</i>	(OPAL Collab.)
AAD	13D	JHEP 1301 029	G. Aad <i>et al.</i>	(ATLAS Collab.)	HEMMICK	90	PR D41 2074	T.K. Hemmick <i>et al.</i>	(ROCH, MICH, OHIO+)
AALTONEN	13I	PR D88 031103	T. Aaltonen <i>et al.</i>	(CDF Collab.)	SAITO	90	PRL 65 2094	T. Saito <i>et al.</i>	(ICRR, KOBE)
AALTONEN	13R	PRL 111 031802	T. Aaltonen <i>et al.</i>	(CDF Collab.)	NAKAMURA	89	PR D39 1261	T.T. Nakamura <i>et al.</i>	(KYOT, TMTC)
CHATRCHYAN	13	PL B718 815	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	NORMAN	89	PR D39 2499	E.B. Norman <i>et al.</i>	(LBL)
CHATRCHYAN	13A	JHEP 1301 013	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	BERNSTEIN	88	PR D37 3103	R.M. Bernstein <i>et al.</i>	(STAN, WISC)
CHATRCHYAN	13AB	JHEP 1307 122	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	LIU	88	PRL 61 271	G. Liu, B. Barish	(CIT)
CHATRCHYAN	13AD	JHEP 1307 178	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	BARISH	87	PR D36 2641	B.C. Barish, G. Liu, C. Lane	(LBL)
CHATRCHYAN	13AR	PR D87 092008	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	NORMAN	87	PRL 58 1403	E.B. Norman, S.B. Gazes, D.A. Bennett	(NA3 Collab.)
AAD	12AK	PL B716 122	G. Aad <i>et al.</i>	(ATLAS Collab.)	BADIER	86	ZPHY C31 21	J. Badier <i>et al.</i>	(UMD, GMAS, NSF)
AAD	12C	PRL 108 041805	G. Aad <i>et al.</i>	(ATLAS Collab.)	MINCER	85	PR D32 541	A. Mincer <i>et al.</i>	(KEK, INUS)
AAD	12S	PL B708 37	G. Aad <i>et al.</i>	(ATLAS Collab.)	NAKAMURA	85	PL 161B 417	K. Nakamura <i>et al.</i>	(YALE, FNAL, IOWA)
AALTONEN	12M	PRL 108 211804	T. Aaltonen <i>et al.</i>	(CDF Collab.)	THRON	85	PR D31 451	J.L. Thron <i>et al.</i>	(MEIS)
CHATRCHYAN	12AP	JHEP 1209 094	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	SAKUYAMA	83B	LNC 37 17	H. Sakuyama, N. Suzuki	(MEIS)
CHATRCHYAN	12BL	JHEP 1212 015	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	Also		LNC 36 389	H. Sakuyama, K. Watanabe	(MEIS)
CHATRCHYAN	12Q	PL B716 260	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	Also		NC 78A 147	H. Sakuyama, K. Watanabe	(MEIS)
CHATRCHYAN	12T	PRL 108 261803	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	Also		NC 6C 371	H. Sakuyama, K. Watanabe	(MEIS)
CHATRCHYAN	12W	JHEP 1204 061	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	BHAT	82	PR D25 2820	P.N. Bhat <i>et al.</i>	(TATA)
AAD	11AG	NJP 13 053044	G. Aad <i>et al.</i>	(ATLAS Collab.)	KINOSHITA	82	PRL 48 77	K. Kinoshita, P.B. Price, D. Fryberger	(UCB+)
AAD	11I	PL B698 353	G. Aad <i>et al.</i>	(ATLAS Collab.)	MARINI	82	PR D26 1777	A. Marini <i>et al.</i>	(FRAS, LBL, NWES, STAN+)
AAD	11S	PL B705 294	G. Aad <i>et al.</i>	(ATLAS Collab.)	SMITH	82B	NP B206 333	P.F. Smith <i>et al.</i>	(RAL)
AALTONEN	11AF	PRL 107 181801	T. Aaltonen <i>et al.</i>	(CDF Collab.)	KINOSHITA	81B	PR D24 1707	K. Kinoshita, P.B. Price	(UCB)
AALTONEN	11M	PRL 106 171801	T. Aaltonen <i>et al.</i>	(CDF Collab.)	LOSECCO	81	PL 102B 209	J.M. LoSecco <i>et al.</i>	(MICH, PENN, BNL)
ABAZOV	11I	PRL 107 011804	V.M. Abazov <i>et al.</i>	(D0 Collab.)	ULLMAN	81	PRL 47 289	J.D. Ullman	(LEHM, BNL)
CHATRCHYAN	11C	JHEP 1106 026	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	YOCK	81	PR D23 1207	P.C.M. Yock	(AUCK)
CHATRCHYAN	11U	PRL 107 201804	S. Chatrchyan <i>et al.</i>	(CMS Collab.)	BARTEL	80	ZPHY C6 295	W. Bartel <i>et al.</i>	(JADE Collab.)
AAD	10	PRL 105 161801	G. Aad <i>et al.</i>	(ATLAS Collab.)	BUSSIERE	80	NP B174 1	A. Bussiere <i>et al.</i>	(BGNA, SACL, LAPP)
AALTONEN	10AF	PR D82 052005	T. Aaltonen <i>et al.</i>	(CDF Collab.)	YOCK	80	PR D22 61	P.C.M. Yock	(AUCK)
KHACHATRYAN	10	PRL 105 211801	V. Khachatryan <i>et al.</i>	(CMS Collab.)	ARMITAGE	79	NP B150 87	J.C.M. Armitage <i>et al.</i>	(CERN, DARE, FOM+)
Also		PRL 106 029902	V. Khachatryan <i>et al.</i>	(CMS Collab.)	BOZZOLI	79	NP B159 363	W. Bozzoli <i>et al.</i>	(BGNA, LAPP, SACL+)
AALTONEN	09AF	PR D80 011102	T. Aaltonen <i>et al.</i>	(CDF Collab.)	GOODMAN	79	PR D19 2572	J.A. Goodman <i>et al.</i>	(UMD)
AALTONEN	09G	PR D79 052004	T. Aaltonen <i>et al.</i>	(CDF Collab.)	SMITH	79	NP B149 525	P.F. Smith, J.R.J. Bennett	(RHEL)
AALTONEN	09Z	PRL 103 021802	T. Aaltonen <i>et al.</i>	(CDF Collab.)	BHAT	78	PRAM 10 115	P.N. Bhat, P.V. Ramana Murthy	(TATA)
ABAZOV	09M	PRL 102 161802	V.M. Abazov <i>et al.</i>	(D0 Collab.)	CARROLL	78	PRL 41 777	A.S. Carroll <i>et al.</i>	(BNL, PRIN)
AKTAS	04C	EPJ C36 413	A. Aktas <i>et al.</i>	(H1 Collab.)	CUTTS	78	PRL 41 363	D. Cutts <i>et al.</i>	(BROW, FNAL, ILL, BARI+)
JAVORSEK	02	PR D65 072003	D. Javorsek II <i>et al.</i>		VIDAL	78	PL 77B 344	R.A. Vidal <i>et al.</i>	(COLU, FNAL, STON+)
JAVORSEK	01	PR D64 012005	D. Javorsek II <i>et al.</i>		ALEKSEEV	76	SJNP 22 531	G.D. Alekseev <i>et al.</i>	(JINR)
JAVORSEK	01B	PRL 87 231804	D. Javorsek II <i>et al.</i>					Translated from YAF 22 1021.	
ABBIENDI	00D	EPJ C13 197	G. Abbiendi <i>et al.</i>	(OPAL Collab.)	ALEKSEEV	76B	SJNP 23 633	G.D. Alekseev <i>et al.</i>	(JINR)
AMBROSIO	00B	EPJ C13 453	M. Ambrosio <i>et al.</i>	(MACRO Collab.)	BALDIN	76	SJNP 22 264	B.Y. Baldin <i>et al.</i>	(JINR)
ABE	99F	PRL 82 2038	F. Abe <i>et al.</i>	(CDF Collab.)				Translated from YAF 23 1190.	
ACKERSTAFF	98P	PL B433 195	K. Ackerstaff <i>et al.</i>	(OPAL Collab.)				Translated from YAF 22 512.	
ABE	97G	PR D55 5263	F. Abe <i>et al.</i>	(CDF Collab.)	BRIATORE	76	NC 31A 553	L. Briatore <i>et al.</i>	(LCGT, FRAS, FREIB)
ABREU	97D	PL B396 315	P. Abreu <i>et al.</i>	(DELPHI Collab.)	GUSTAFSON	76	PRL 37 474	H.R. Gustafson <i>et al.</i>	(MICH)
ACKERSTAFF	97B	PL B391 210	K. Ackerstaff <i>et al.</i>	(OPAL Collab.)	ALBROW	75	NP B97 189	M.G. Albrow <i>et al.</i>	(CERN, DARE, FOM+)
ADAMS	97B	PRL 79 4083	J. Adams <i>et al.</i>	(FNAL KTeV Collab.)	FRANKEL	75	PR D12 2561	S. Frankel <i>et al.</i>	(PENN, FNAL)
BARATE	97K	PL B405 379	R. Barate <i>et al.</i>	(ALEPH Collab.)	JOVANOV...	75	PL 56B 105	J.V. Jovanovich <i>et al.</i>	(MANI, AACH, CERN+)
AKERS	95R	ZPHY C67 203	R. Akers <i>et al.</i>	(OPAL Collab.)	YOCK	75	NP B86 216	P.C.M. Yock	(AUCK, SLAC)
GALLAS	95	PR D52 6	E. Gallas <i>et al.</i>	(MSU, FNAL, MIT, FLOR)	APPEL	74	PRL 32 428	J.A. Appel <i>et al.</i>	(COLU, FNAL)
RAM	94	PR D49 3120	S. Ram <i>et al.</i>	(TELA, TRIU)	FRANKEL	74	PR D9 1932	S. Frankel <i>et al.</i>	(PENN, FNAL)
ABE	93G	PRL 71 2542	F. Abe <i>et al.</i>	(CDF Collab.)	YOCK	74	NP B76 175	P.C.M. Yock	(AUCK)
ASTONE	93	PR D47 4770	P. Astone <i>et al.</i>	(ROMA, ROMAI, CATA, FRAS)	ALPER	73	PL 46B 265	B. Alper <i>et al.</i>	(CERN, LIVP, LUND, BOHR+)
BUSKULIC	93C	PL B303 198	D. Buskulic <i>et al.</i>	(ALEPH Collab.)	LEIPUNER	73	PRL 31 1226	L.B. Leipuner <i>et al.</i>	(BNL, YALE)
YAMAGATA	93	PR D47 1231	T. Yamagata, Y. Takamori, H. Utsunomiya	(KONAN)	DARDO	72	NC 9A 319	M. Dardo <i>et al.</i>	(TORI)
ABE	92J	PR D46 1889	F. Abe <i>et al.</i>	(CDF Collab.)	TONWAR	72	JP A5 569	S.C. Tonwar, S. Naranan, B.V. Sreekantan	(TATA)
AHLEN	92	PRL 69 1860	S.P. Ahlen <i>et al.</i>	(MACRO Collab.)	ANTIPOV	71B	NP B31 235	Y.M. Antipov <i>et al.</i>	(SERP)
VERKERK	92	PRL 68 1116	P. Verkerk <i>et al.</i>	(ENSP, SACL, PAST)	ANTIPOV	71C	PL 34B 164	Y.M. Antipov <i>et al.</i>	(SERP)
AKESSON	91	ZPHY C52 219	T. Akeesson <i>et al.</i>	(HELIOS Collab.)	BINON	69	PL 30B 510	F.G. Binon <i>et al.</i>	(SERP)
NAKAMURA	91	PL B263 529	S. Nakamura <i>et al.</i>		BJORNBOE	68	NC B53 241	F. Bjornboe <i>et al.</i>	(BOHR, TATA, BERN+)
ORITO	91	PRL 66 1951	S. Orito <i>et al.</i>	(ICEPP, WASCR, NIHO, ICRR)	JONES	67	PR 164 1584	L.W. Jones	(MICH, WISC, LBL, UCLA, MINN+)
ADACHI	90C	PL B244 352	I. Adachi <i>et al.</i>	(TOPAZ Collab.)	DORFAN	65	PRL 14 999	D.E. Dorfman <i>et al.</i>	(COLU)
ADACHI	90E	PL B249 336	I. Adachi <i>et al.</i>	(TOPAZ Collab.)					

