WIMPs and Other Particles Searches for

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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/cm^3 is assumed; see each paper for velocity distribution assumptions. In the papers the limit is given as a function of the X^0 mass. Here we list limits only for typical mass values of 20 GeV, 100 GeV, and 1 TeV. Specific limits on supersymmetric dark matter particles may be found in the Supersymmetry section.

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

Isoscalar coupling is assumed to extract the limits from those on X^0–nuclei cross section.

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. • • •					
$<1.5 \times 10^{-5}$	90	[1] ABE	13B	XMAS	Xe
$<1.2 \times 10^{-7}$	90	AKIMOV	12	ZEP3	Xe
		[2] ANGLOHER	12	CRES	$CaWO_4$
$<8 \times 10^{-6}$	90	[3] ANGLOHER	12	CRES	$CaWO_4$
$<7 \times 10^{-9}$	90	APRILE	12	X100	Xe
		[4] ARCHAMBAU...	12	PICA	F (C_4F_{10})
$<7 \times 10^{-7}$	90	[5] ARMENGAUD	12	EDE2	Ge
		[6] BARRETO	12	DMIC	CCD
$<1 \times 10^{-6}$	90	BEHNKE	12	COUP	CF_3I
$<7 \times 10^{-6}$		[7] FELIZARDO	12	SMPL	C_2ClF_5
$<1.5 \times 10^{-6}$	90	KIM	12	KIMS	CsI
$<5 \times 10^{-5}$	90	[8] AALSETH	11	CGNT	Ge
		[9] AALSETH	11A	CGNT	Ge
		[10] AHMED	11	CDM2	Ge, inelastic
$<2.7 \times 10^{-7}$	90	[11] AHMED	11A	RVUE	Ge
		[12] AHMED	11B	CDM2	Ge, low threshold
$<3 \times 10^{-6}$	90	[13] ANGLE	11	XE10	Xe
$<7 \times 10^{-8}$	90	[14] APRILE	11	X100	Xe
		[15] APRILE	11A	X100	Xe, inelastic
$<2 \times 10^{-8}$	90	APRILE	11B	X100	Xe
		[16] HORN	11	ZEP3	Xe
$<2 \times 10^{-7}$	90	AHMED	10	CDM2	Ge
$<1 \times 10^{-5}$	90	[17] 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	[18] AHMED	09	CDM2	Ge
$<2 \times 10^{-4}$	90	[19] LIN	09	TEXO	Ge
		[20] AALSETH	08	CGNT	Ge

[1] See their Fig. 8 for limits extending down to m_{X^0} = 7 GeV.
[2] ANGLOHER 12 observe excess events above the expected background which are consistent with X^0 with mass ∼ 25 GeV (or 12 GeV) and spin-independent X^0-nucleon cross section of 2×10^{-6} pb (or 4×10^{-5} pb).
[3] Reanalysis of ANGLOHER 09 data with all three nuclides. See also BROWN 12.
[4] See their Fig. 7 for cross section limits for m_{X^0} between 4 and 12 GeV.
[5] See their Fig. 4 for limits extending down to m_{X^0} = 7 GeV.
[6] See their Fig. 13 for cross section limits for m_{X^0} between 1.2 and 10 GeV.
[7] See also DAHL 12 for a criticism.
[8] See their Fig. 4 for limits extending to m_{X^0} = 3.5 GeV.
[9] AALSETH 11A find indications of annual modulation of the data, the energy spectrum being compatible with X^0 mass around 8 GeV.
[10] AHMED 11 search for X^0 inelastic scattering. See their Fig. 8–10 for limits.
[11] AHMED 11A combine CDMS and EDELWEISS data.
[12] AHMED 11B give limits on spin-independent X^0-nucleon cross section for m_{X^0} = 4–12 GeV in the range 10^{-3}–10^{-5} pb. See their Fig. 3.
[13] See their Fig. 3 for limits down to m_{X^0} = 4 GeV.
[14] APRILE 11 reanalyze APRILE 10 data.
[15] APRILE 11A search for X^0 inelastic scattering. See their Fig. 2 and 3 for limits.
[16] HORN 11 perform detector calibration by neutrons. Earlier results are only marginally affected.
[17] See their Fig. 10 and 12 for limits extending to X^0 mass of 1 GeV.
[18] Superseded by AHMED 10.
[19] See their Fig. 6(a) for cross section limits for m_{X^0} extending down to 2 GeV.
[20] See their Fig. 2 for cross section limits for m_{X^0} between 4 and 10 GeV.

For m_{X^0} = 100 GeV

VALUE (pb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<1.67 \times 10^{-6}$	90	[1,2] ABBASI	12	ICCB	H, solar ν
$<1.07 \times 10^{-4}$	90	[1,3] ABBASI	12	ICCB	H, solar ν
$<4 \times 10^{-8}$	90	AKIMOV	12	ZEP3	Xe
$<1.4 \times 10^{-6}$	90	[4] ANGLOHER	12	CRES	$CaWO_4$
$<3 \times 10^{-9}$	90	APRILE	12	X100	Xe
$<1.6 \times 10^{-7}$	90	BEHNKE	12	COUP	CF_3I
$<7 \times 10^{-6}$		FELIZARDO	12	SMPL	C_2ClF_5
$<2.5 \times 10^{-7}$	90	[5] KIM	12	KIMS	CsI
$<2 \times 10^{-4}$	90	AALSETH	11	CGNT	Ge
		[6] AHMED	11	CDM2	Ge, inelastic
$<3.3 \times 10^{-8}$	90	[7] AHMED	11A	RVUE	Ge
		[8] AJELLO	11	FLAT	
$<3 \times 10^{-8}$	90	[9] APRILE	11	X100	Xe
		[10] APRILE	11A	X100	Xe, inelastic
$<1 \times 10^{-8}$	90	APRILE	11B	X100	Xe
$<5 \times 10^{-8}$	90	[11] ARMENGAUD	11	EDE2	Ge
		[12] 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
		[13] 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_2ClF_3
$<5 \times 10^{-8}$	90	[14] AHMED	09	CDM2	Ge
		[15] ANGLE	09	XE10	Xe, inelastic
$<3 \times 10^{-4}$	90	LIN	09	TEXO	Ge
		[16] GIULIANI	05	RVUE	

[1] 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.
[2] The annihilation channel $X^0\overline{X}^0 \rightarrow W^+W^-$ is assumed.
[3] The annihilation channel $X^0\overline{X}^0 \rightarrow b\overline{b}$ is assumed.
[4] Reanalysis of ANGLOHER 09 data with all three nuclides. See also BROWN 12.
[5] See their Fig. 6 for a limit on inelastically scattering X^0 for m_{X^0} = 70 GeV.
[6] AHMED 11 search for X^0 inelastic scattering. See their Fig. 8–10 for limits.
[7] AHMED 11A combine CDMS and EDELWEISS data.
[8] AJELLO 11 search for $e^{\pm}$ flux from X^0 annihilations in the Sun. Models in which X^0 annihilates into an intermediate long-lived weakly interacting particles or X^0 scatters inelastically are constrained. See their Fig. 6–8 for limits.
[9] APRILE 11 reanalyze APRILE 10 data.
[10] APRILE 11A search for X^0 inelastic scattering. See their Fig. 2 and 3 for limits.
[11] Supersedes ARMENGAUD 10. A limit on inelastic cross section is also given.
[12] HORN 11 perform detector calibration by neutrons. Earlier results are only marginally affected.
[13] AKIMOV 10 give cross section limits for inelastically scattering dark matter. See their Fig. 4.
[14] Superseded by AHMED 10.
[15] ANGLE 09 search for X^0 inelastic scattering. See their Fig. 4 for limits.
[16] GIULIANI 05 analyzes the spin-independent X^0-nucleon cross section limits with both isoscalar and isovector couplings. See their Fig. 3 and 4 for limits on the couplings.

For m_{X^0} = 1 TeV

VALUE (pb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<2.12 \times 10^{-7}$	90	[1,2] ABBASI	12	ICCB	H, solar ν
$<6.56 \times 10^{-6}$	90	[1,3] ABBASI	12	ICCB	H, solar ν
$<4 \times 10^{-7}$	90	AKIMOV	12	ZEP3	Xe
$<1.1 \times 10^{-5}$	90	[4] ANGLOHER	12	CRES	$CaWO_4$
$<2 \times 10^{-8}$	90	APRILE	12	X100	Xe
$<1.2 \times 10^{-6}$	90	BEHNKE	12	COUP	CF_3I
$<4 \times 10^{-6}$		FELIZARDO	12	SMPL	C_2ClF_5
$<1.5 \times 10^{-6}$	90	KIM	12	KIMS	CsI
		[5] AHMED	11	CDM2	Ge, inelastic
$<1.5 \times 10^{-7}$	90	[6] AHMED	11A	RVUE	Ge
$<2 \times 10^{-7}$	90	[7] APRILE	11	X100	Xe
$<8 \times 10^{-8}$	90	APRILE	11B	X100	Xe
$<2 \times 10^{-7}$	90	[8] ARMENGAUD	11	EDE2	Ge

		[9] 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	[10] AHMED	09	CDM2	Ge

[1] 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.
[2] The annihilation channel $X^0 \overline{X}^0 \rightarrow W^+ W^-$ is assumed.
[3] The annihilation channel $X^0 \overline{X}^0 \rightarrow b \overline{b}$ is assumed.
[4] Reanalysis of ANGLOHER 09 data with all three nuclides. See also BROWN 12.
[5] AHMED 11 search for X^0 inelastic scattering. See their Fig. 8–10 for limits.
[6] AHMED 11A combine CDMS and EDELWEISS data.
[7] APRILE 11 reanalyze APRILE 10 data.
[8] Supersedes ARMENGAUD 10. A limit on inelastic cross section is also given.
[9] HORN 11 perform detector calibration by neutrons. Earlier results are only marginally affected.
[10] Superseded by AHMED 10.

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

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. • • •					
$< 3 \times 10^{-2}$	90	ARCHAMBAU..	12	PICA	F (C_4F_{10})
$< 2 \times 10^{-2}$	90	BEHNKE	12	COUP	CF_3I
< 20	90	DAW	12	DRFT	F (CF_4)
$< 7 \times 10^{-3}$		FELIZARDO	12	SMPL	C_2ClF_5
< 0.15	90	KIM	12	KIMS	CsI
$< 1 \times 10^{5}$	90	[1] AHLEN	11	DMTP	F (CF_4)
< 0.1	90	[1] BEHNKE	11	COUP	CF_3I
$< 1.5 \times 10^{-2}$	90	[2,3] TANAKA	11	SKAM	H, solar ν
< 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	CsI
< 20	90	[4] 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_4F_{10})
< 1.5	90	GIRARD	05	SMPL	F (C_2ClF_5)
< 35	90	MIUCHI	03	BOLO	LiF
< 30	90	TAKEDA	03	BOLO	NaF

[1] Use a direction-sensitive detector.
[2] The annihilation channel $X^0 \overline{X}^0 \rightarrow b \overline{b}$ is assumed.
[3] 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.
[4] See also AKERIB 05.

For m_{X^0} = 100 GeV

VALUE (pb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<7.07\times10^{-4}$	90	[1,2] ABBASI	12	ICCB	H, solar ν
$<4.53\times10^{-2}$	90	[1,3] ABBASI	12	ICCB	H, solar ν
$<7\times10^{-2}$	90	ARCHAMBAU...	12	PICA	F (C_4F_{10})
$<7\times10^{-3}$	90	BEHNKE	12	COUP	CF_3I
<1.8	90	DAW	12	DRFT	F (CF_4)
$<9\times10^{-3}$		FELIZARDO	12	SMPL	C_2ClF_5
$<2\times10^{-2}$	90	KIM	12	KIMS	CsI
$<2\times10^{3}$	90	[4] AHLEN	11	DMTP	F (CF_4)
$<7\times10^{-2}$	90	BEHNKE	11	COUP	CF_3I
$<2.7\times10^{-4}$	90	[2,5] TANAKA	11	SKAM	H, solar ν
$<4.5\times10^{-3}$	90	[3,5] TANAKA	11	SKAM	H, solar ν
		[6] FELIZARDO	10	SMPL	C_2ClF_3
$<6\times10^{3}$	90	[4] MIUCHI	10	NAGE	CF_4
<0.4	90	ARCHAMBAU...	09	PICA	F
<0.8	90	LEBEDENKO	09A	ZEP3	Xe
<1.0	90	ANGLE	08A	XE10	Xe
<15	90	ALNER	07	ZEP2	Xe
<0.2	90	LEE	07A	KIMS	CsI
$<1\times10^{4}$	90	[4] MIUCHI	07	NAGE	F (CF_4)
<5	90	[7] AKERIB	06	CDMS	^{73}Ge, ^{29}Si
<2	90	SHIMIZU	06A	CNTR	F (CaF_2)
<0.3	90	ALNER	05	NAIA	NaI
<2	90	BARNABE-HE...	05	PICA	F (C_4F_{10})
<100	90	BENOIT	05	EDEL	^{73}Ge
<1.5	90	GIRARD	05	SMPL	F (C_2ClF_5)
<0.7		[8] GIULIANI	05A	RVUE	
		[9] GIULIANI	04	RVUE	
		[10] GIULIANI	04A	RVUE	
<35	90	MIUCHI	03	BOLO	LiF
<40	90	TAKEDA	03	BOLO	NaF

[1] 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.
[2] The annihilation channel $X^0\overline{X}^0 \rightarrow W^+W^-$ is assumed.
[3] The annihilation channel $X^0\overline{X}^0 \rightarrow b\overline{b}$ is assumed.
[4] Use a direction-sensitive detector.
[5] 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.
[6] See their Fig. 3 for limits on spin-dependent proton couplings for X^0 mass of 50 GeV.
[7] See also AKERIB 05.
[8] GIULIANI 05A analyze available data and give combined limits.
[9] GIULIANI 04 reanalyze COLLAR 00 data and give limits for spin-dependent X^0-proton coupling.
[10] GIULIANI 04A give limits for spin-dependent X^0-proton couplings from existing data.

For m_{X^0} = 1 TeV

VALUE (pb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$< 2.50 \times 10^{-4}$	90	[1,2] ABBASI	12	ICCB	H, solar ν
$< 7.86 \times 10^{-3}$	90	[1,3] ABBASI	12	ICCB	H, solar ν
$< 4 \times 10^{-2}$	90	BEHNKE	12	COUP	CF_3I
< 8	90	DAW	12	DRFT	F (CF_4)
$< 6 \times 10^{-2}$		FELIZARDO	12	SMPL	C_2ClF_5
$< 8 \times 10^{-2}$	90	KIM	12	KIMS	CsI
$< 8 \times 10^{3}$	90	[4] AHLEN	11	DMTP	F (CF_4)
< 0.4	90	BEHNKE	11	COUP	CF_3I
$< 2 \times 10^{-3}$	90	[3,5] TANAKA	11	SKAM	H, solar ν
$< 2 \times 10^{-2}$	90	[2,5] TANAKA	11	SKAM	H, solar ν
$< 1 \times 10^{-3}$	90	[6] ABBASI	10	ICCB	KK dark matter
$< 2 \times 10^{4}$	90	[4] MIUCHI	10	NAGE	CF_4
$< 8.7 \times 10^{-4}$	90	[2] ABBASI	09B	ICCB	H, solar ν
$< 2.2 \times 10^{-2}$	90	[3] ABBASI	09B	ICCB	H, solar ν
< 3	90	ARCHAMBAU...	09	PICA	F
< 6	90	LEBEDENKO	09A	ZEP3	Xe
< 9	90	ANGLE	08A	XE10	Xe
<100	90	ALNER	07	ZEP2	Xe
< 0.8	90	LEE	07A	KIMS	CsI
$< 4 \times 10^{4}$	90	[4] MIUCHI	07	NAGE	F (CF_4)
< 30	90	[7] AKERIB	06	CDMS	^{73}Ge, ^{29}Si
< 1.5	90	ALNER	05	NAIA	NaI
< 15	90	BARNABE-HE...	05	PICA	F (C_4F_{10})
<600	90	BENOIT	05	EDEL	^{73}Ge
< 10	90	GIRARD	05	SMPL	F (C_2ClF_5)
<260	90	MIUCHI	03	BOLO	LiF
<150	90	TAKEDA	03	BOLO	NaF

[1] 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.
[2] The annihilation channel $X^0 \overline{X}^0 \rightarrow W^+ W^-$ is assumed.
[3] The annihilation channel $X^0 \overline{X}^0 \rightarrow b\overline{b}$ is assumed.
[4] Use a direction-sensitive detector.
[5] 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.
[6] ABBASI 10 search for ν_μ from annihilations of Kaluza-Klein photon dark matter in the Sun.
[7] See also AKERIB 05.

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

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. • • •					
< 0.02	90	AKIMOV	12	ZEP3	Xe
		[1] AHMED	11B	CDM2	Ge, low threshold
< 0.06	90	AHMED	09	CDM2	Ge
< 0.04	90	LEBEDENKO	09A	ZEP3	Xe

<50		[2] LIN	09	TEXO	Ge
$<6 \times 10^{-3}$	90	ANGLE	08A	XE10	Xe
<0.5	90	ALNER	07	ZEP2	Xe
<25	90	LEE	07A	KIMS	CsI
<0.3	90	[3] 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_4F_{10})
<10	90	BENOIT	05	EDEL	^{73}Ge
<4	90	KLAPDOR-K...	05	HDMS	^{73}Ge (enriched)
<600	90	TAKEDA	03	BOLO	NaF

[1] AHMED 11B give limits on spin-dependent X^0-neutron cross section for m_{X^0} = 4–12 GeV in the range 10^{-3}–10 pb. See their Fig. 3.
[2] See their Fig. 6(b) for cross section limits for m_{X^0} extending down to 2 GeV.
[3] See also AKERIB 05.

For m_{X^0} = 100 GeV

VALUE (pb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.01	90	AKIMOV	12	ZEP3	Xe
		[1] FELIZARDO	10	SMPL	C_2ClF_3
<0.02	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	[2] BEDNYAKOV	08	RVUE	Ge
<0.08	90	ALNER	07	ZEP2	Xe
<6	90	LEE	07A	KIMS	CsI
<0.07	90	[3] AKERIB	06	CDMS	^{73}Ge, ^{29}Si
<30	90	SHIMIZU	06A	CNTR	F (CaF_2)
<10	90	ALNER	05	NAIA	NaI
<30	90	BARNABE-HE...	05	PICA	F (C_4F_{10})
<0.7	90	BENOIT	05	EDEL	^{73}Ge
<0.2		[4] GIULIANI	05A	RVUE	
<1.5	90	KLAPDOR-K...	05	HDMS	^{73}Ge (enriched)
		[5] GIULIANI	04	RVUE	
		[6] GIULIANI	04A	RVUE	
		[7] MIUCHI	03	BOLO	LiF
<800	90	TAKEDA	03	BOLO	NaF

[1] See their Fig. 3 for limits on spin-dependent neutron couplings for X^0 mass of 50 GeV.
[2] BEDNYAKOV 08 reanalyze KLAPDOR-KLEINGROTHAUS 05 and BAUDIS 01 data.
[3] See also AKERIB 05.
[4] GIULIANI 05A analyze available data and give combined limits.
[5] GIULIANI 04 reanalyze COLLAR 00 data and give limits for spin-dependent X^0-neutron coupling.
[6] GIULIANI 04A give limits for spin-dependent X^0-neutron couplings from existing data.
[7] MIUCHI 03 give model-independent limit for spin-dependent X^0-proton and neutron cross sections. See their Fig. 5.

For m_{X^0} = 1 TeV

VALUE (pb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$< 8 \times 10^{-2}$	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	[1] BEDNYAKOV	08	RVUE	Ge
< 0.6	90	ALNER	07	ZEP2	Xe
< 30	90	LEE	07A	KIMS	CsI
< 0.5	90	[2] AKERIB	06	CDMS	^{73}Ge, ^{29}Si
< 40	90	ALNER	05	NAIA	NaI
< 200	90	BARNABE-HE...	05	PICA	F (C_4F_{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] BEDNYAKOV 08 reanalyze KLAPDOR-KLEINGROTHAUS 05 and BAUDIS 01 data.
[2] See also AKERIB 05.

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

For m_{X^0} = 20 GeV

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

[1] ANGLOHER 02 limit is for spin-dependent WIMP-Aluminum cross section.
[2] 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 NaI experiments.
[3] KLIMENKO 98 limit is for inelastic scattering $X^0\ ^{73}\mathrm{Ge} \rightarrow X^0\ ^{73}\mathrm{Ge}^*$ (13.26 keV).
[4] BELLI 96 limit for inelastic scattering $X^0\ ^{129}\mathrm{Xe} \rightarrow X^0\ ^{129}\mathrm{Xe}^*$(39.58 keV).

[5] 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.
[6] BERNABEI 96 use pulse shape discrimination to enhance the possible signal. The limit here is from R. Bernabei, private communication, September 19, 1997.
[7] 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.
[8] SMITH 96 use pulse shape discrimination to enhance the possible signal. A dark matter density of 0.4 GeV cm^{-3} is assumed.
[9] GARCIA 95 limit is from the event rate. A weaker limit is obtained from searches for diurnal and annual modulation.
[10] 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.
[11] REUSSER 91 limit here is changed from published (0.04) after reanalysis by authors. J.L. Vuilleumier, private communication, March 29, 1996.

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

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

[1] ANGLOHER 02 limit is for spin-dependent WIMP-Aluminum cross section.
[2] BELLI 02 discuss dependence of the extracted WIMP cross section on the assumptions of the galactic halo structure.
[3] BERNABEI 02C analyze the DAMA data in the scenario in which X^0 scatters into a slightly heavier state as discussed by SMITH 01.
[4] GREEN 02 discusses dependence of extracted WIMP cross section limits on the assumptions of the galactic halo structure.
[5] ULLIO 01 disfavor the possibility that the BERNABEI 99 signal is due to spin-dependent WIMP coupling.
[6] 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 NaI experiments.
[7] BERNABEI 00D limit is for inelastic scattering $X^0\,{}^{129}\mathrm{Xe} \rightarrow X^0\,{}^{129}\mathrm{Xe}$ (39.58 keV).
[8] AMBROSIO 99 search for upgoing muon events induced by neutrinos originating from WIMP annihilations in the Sun and Earth.
[9] BRHLIK 99 discuss the effect of astrophysical uncertainties on the WIMP interpretation of the BERNABEI 99 signal.
[10] KLIMENKO 98 limit is for inelastic scattering $X^0\,{}^{73}\mathrm{Ge} \rightarrow X^0\,{}^{73}\mathrm{Ge}^*$ (13.26 keV).
[11] KLIMENKO 98 limit is for inelastic scattering $X^0\,{}^{73}\mathrm{Ge} \rightarrow X^0\,{}^{73}\mathrm{Ge}^*$ (66.73 keV).
[12] BELLI 96 limit for inelastic scattering $X^0\,{}^{129}\mathrm{Xe} \rightarrow X^0\,{}^{129}\mathrm{Xe}^*$(39.58 keV).
[13] BELLI 96C use background subtraction and obtain $\sigma < 0.35$ pb (< 0.15 fb) (90% CL) for spin-dependent (independent) X^0-proton cross section. The confidence level is from R. Bernabei, private communication, May 20, 1999.
[14] BERNABEI 96 use pulse shape discrimination to enhance the possible signal. The limit here is from R. Bernabei, private communication, September 19, 1997.
[15] 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.
[16] SMITH 96 use pulse shape discrimination to enhance the possible signal. A dark matter density of 0.4 GeV cm^{-3} is assumed.
[17] GARCIA 95 limit is from the event rate. A weaker limit is obtained from searches for diurnal and annual modulation.
[18] 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.
[19] BECK 94 uses enriched ^{76}Ge (86% purity).
[20] REUSSER 91 limit here is changed from published (0.3) after reanalysis by authors. J.L. Vuilleumier, private communication, March 29, 1996.

For m_{X^0} = 1 TeV

VALUE (nb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<$ 3	90	[1] ANGLOHER	02	CRES	Al
		[2] BENOIT	00	EDEL	Ge
		[3] BERNABEI	99D	CNTR	SIMP
		[4] DERBIN	99	CNTR	SIMP
$<$ 0.06	95	[5] KLIMENKO	98	CNTR	^{73}Ge, inel.
$<$ 0.4	95	[6] KLIMENKO	98	CNTR	^{73}Ge, inel.
$<$ 40		ALESSAND...	96	CNTR	O
$<$700		ALESSAND...	96	CNTR	Te
$<$ 0.05	90	[7] BELLI	96	CNTR	^{129}Xe, inel.
$<$ 1.5	90	[8] BELLI	96	CNTR	^{129}Xe, inel.
		[9] BELLI	96C	CNTR	^{129}Xe
$<$ 0.01	90	[10] BERNABEI	96	CNTR	Na

$<\ 9$		90	[10] BERNABEI	96	CNTR	I
$<\ 7$		95	[11] SARSA	96	CNTR	Na
$<\ 0.3$		90	[12] SMITH	96	CNTR	Na
$<\ 6$		90	[12] SMITH	96	CNTR	I
$<\ 6$		95	[13] GARCIA	95	CNTR	Natural Ge
$<\ 8$		95	QUENBY	95	CNTR	Na
$<\ 50$		95	QUENBY	95	CNTR	I
<700		90	[14] SNOWDEN-...	95	MICA	^{16}O
$<\ 1$	$\times 10^3$	90	[14] SNOWDEN-...	95	MICA	^{39}K
$<\ 0.8$		90	[15] BECK	94	CNTR	^{76}Ge
$<\ 30$		90	BACCI	92	CNTR	Na
$<\ 30$		90	BACCI	92	CNTR	I
$<\ 15$		90	[16] REUSSER	91	CNTR	Natural Ge
$<\ 6$		95	CALDWELL	88	CNTR	Natural Ge

[1] ANGLOHER 02 limit is for spin-dependent WIMP-Aluminum cross section.

[2] 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 NaI experiments.

[3] 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.

[4] 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.

[5] KLIMENKO 98 limit is for inelastic scattering $X^0\ {}^{73}\text{Ge} \rightarrow X^0\ {}^{73}\text{Ge}^*$ (13.26 keV).

[6] KLIMENKO 98 limit is for inelastic scattering $X^0\ {}^{73}\text{Ge} \rightarrow X^0\ {}^{73}\text{Ge}^*$ (66.73 keV).

[7] BELLI 96 limit for inelastic scattering $X^0\ {}^{129}\text{Xe} \rightarrow X^0\ {}^{129}\text{Xe}^*$(39.58 keV).

[8] BELLI 96 limit for inelastic scattering $X^0\ {}^{129}\text{Xe} \rightarrow X^0\ {}^{129}\text{Xe}^*$(236.14 keV).

[9] BELLI 96C use background subtraction and obtain $\sigma < 0.7$ pb (< 0.7 fb) (90% CL) for spin-dependent (independent) X^0-proton cross section. The confidence level is from R. Bernabei, private communication, May 20, 1999.

[10] BERNABEI 96 use pulse shape discrimination to enhance the possible signal. The limit here is from R. Bernabei, private communication, September 19, 1997.

[11] 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.

[12] SMITH 96 use pulse shape discrimination to enhance the possible signal. A dark matter density of 0.4 GeV cm^{-3} is assumed.

[13] GARCIA 95 limit is from the event rate. A weaker limit is obtained from searches for diurnal and annual modulation.

[14] 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.

[15] BECK 94 uses enriched ^{76}Ge (86% purity).

[16] REUSSER 91 limit here is changed from published (5) after reanalysis by authors. J.L. Vuilleumier, private communication, March 29, 1996.

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. • • •					
		[1] ACKERMANN	12	FLAT	Galaxy

		[2] ACKERMANN	12	FLAT	Galaxy
$<10^{-22}$	90	[3] ABBASI	11C	ICCB	Galctic halo, m=1 TeV
$<3 \times 10^{-25}$	95	[4] ABRAMOWSKI	11	HESS	Near Galactic center, m=1 TeV
$<10^{-26}$	95	[5] ACKERMANN	11	FLAT	Satellite galaxy, m=10 GeV
$<10^{-25}$	95	[5] ACKERMANN	11	FLAT	Satellite galaxy, m=100 GeV
$<10^{-24}$	95	[5] ACKERMANN	11	FLAT	Satellite galaxy, m=1 TeV

[1] 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} cm^{-2}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.

[2] 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} cm^{-2}s^{-1} or larger is obtained for X^0 mass between 5 GeV and 10 TeV for various annihilation channels including W^+W^-, $b\overline{b}$, gg, 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.

[3] ABBASI 11C search for ν_μ 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.

[4] ABRAMOWSKI 11 search for γ from X^0 annihilation near the Galactic center. The limit assumes Einasto DM density profile.

[5] ACKERMANN 11 search for γ from X^0 annihilation in ten dwarf spheroidal satellite galaxies of the Milky Way. The limit for m = 10 GeV assumes annihilation into $b\overline{b}$, 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] AAD	13C	ATLS	$\gamma + \not{E}_T$
	[2] AALTONEN	12K	CDF	$t + \not{E}_T$
	[3] AALTONEN	12M	CDF	jet + $\not{E}_T$
	[4] CHATRCHYAN	12AP	CMS	jet + $\not{E}_T$
	[5] CHATRCHYAN	12T	CMS	$\gamma + \not{E}_T$

[1] AAD 13C search for events with a photon and missing $\not{E}_T$ in pp collisions at E_{cm} = 7 TeV with L = 4.6 fb^{-1}. See their Fig. 3 for translated limits on X^0-nucleon cross section for m = 1–1000 GeV.

[2] AALTONEN 12K search for events with a top quark and missing $\not{E}_T$ in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with L = 7.7 fb^{-1}. Upper limits on $\sigma(tX^0)$ in the range 0.4–2 pb (95% CL) is given for m_{X^0} = 0–150 GeV.

[3] AALTONEN 12M search for events with a jet and missing E_T in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with L = 6.7 fb^{-1}. Upper limits on the cross section in the range 2–10 pb (90% CL) is given for m_{X^0} = 1–300 GeV. See their Fig. 2 for translated limits on X^0-nucleon cross section.

[4] CHATRCHYAN 12AP search for events with a jet and missing E_T in pp collisions at E_{cm} = 7 TeV with L = 5.0 fb^{-1}. See their Fig. 4 for translated limits on X^0-nucleon cross section for m_{X^0} = 0.1–1000 GeV.

[5] CHATRCHYAN 12T search for events with a photon and missing $\not{E}_T$ in pp collisions at E_{cm} = 7 TeV with L = 5.0 fb^{-1}. Upper limits on the cross section in the range 13–15 fb (90% CL) is given for m_{X^0} = 1–1000 GeV. See their Fig. 2 for translated limits on X^0-nucleon cross section.

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=5–1600m_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 = 1000m_p
$<2 \times 10^{-21}$	90	[3] HEMMICK	90	SPEC	Water, M = 5000m_p
$<3 \times 10^{-20}$	90	[3] HEMMICK	90	SPEC	Water, M = 10000m_p
$<1. \times 10^{-29}$		SMITH	82B	SPEC	Water, M=30–400m_p
$<2. \times 10^{-28}$		SMITH	82B	SPEC	Water, M=12–1000m_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, ρ=0.3 GeV/cm^3, 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 = 100m_p
$<8 \times 10^{-20}$	90	[3] HEMMICK	90	SPEC	C, M = 1000m_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, $M = 1000 m_p$
$< 1.5 \times 10^{-13}$/nucleon	68	[4] NORMAN	89	SPEC	$^{206}\mathrm{Pb}X^-$
$< 1.2 \times 10^{-12}$/nucleon	68	[4] NORMAN	87	SPEC	$^{56,58}\mathrm{Fe}X^-$

[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.

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] AAD	13A	ATLS	$WW \rightarrow \ell\nu\ell'\nu$
	[2] AAD	13C	ATLS	$\gamma + \not\!\!E_T$
	[3] CHATRCHYAN	13	CMS	$\ell^+\ell^-$ + jets + $\not\!\!E_T$
	[4] AAD	12C	ATLS	$t\bar{t} + \not\!\!E_T$
	[5] AALTONEN	12M	CDF	jet + $\not\!\!E_T$
	[6] CHATRCHYAN	12AP	CMS	jet + $\not\!\!E_T$
	[7] CHATRCHYAN	12Q	CMS	Z + jets + $\not\!\!E_T$
	[8] CHATRCHYAN	12T	CMS	$\gamma + \not\!\!E_T$
	[9] AAD	11S	ATLS	jet + $\not\!\!E_T$
	[10] AALTONEN	11AF	CDF	$\ell^\pm\ell^\pm$
	[11] CHATRCHYAN	11C	CMS	$\ell^+\ell^-$ + jets + $\not\!\!E_T$
	[12] CHATRCHYAN	11U	CMS	jet + $\not\!\!E_T$
	[13] AALTONEN	10AF	CDF	$\gamma\gamma + \ell, \not\!\!E_T$
	[14] AALTONEN	09AF	CDF	$\ell\gamma b \not\!\!E_T$
	[15] AALTONEN	09G	CDF	$\ell\ell\ell \not\!\!E_T$

[1] AAD 13A search for resonant WW production in pp collisions at E_{cm} = 7 TeV with L = 4.7 fb^{-1}.

[2] AAD 13C search for events with a photon and missing $\not\!\!E_T$ in pp collisions at E_{cm} = 7 TeV with L = 4.6 fb^{-1}.

[3] CHATRCHYAN 13 search for events with an opposite-sign lepton pair, jets, and missing E_T in pp collisions at E_{cm} = 7 TeV with L = 4.98 fb^{-1}.

[4] AAD 12C search for events with a $t\overline{t}$ pair and missing $\not{E}_T$ in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 1.04 fb^{-1}.
[5] AALTONEN 12M search for events with a jet and missing E_T in $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV with L = 6.7 fb^{-1}.
[6] CHATRCHYAN 12AP search for events with a jet and missing E_T in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 5.0 fb^{-1}.
[7] CHATRCHYAN 12Q search for events with a Z, jets, and missing $\not{E}_T$ in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 4.98 fb^{-1}.
[8] CHATRCHYAN 12T search for events with a photon and missing $\not{E}_T$ in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 5.0 fb^{-1}.
[9] AAD 11S search for events with one jet and missing E_T in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 33 pb^{-1}.
[10] AALTONEN 11AF search for high-p_T like-sign dileptons in $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV with L = 6.1 fb^{-1}.
[11] CHATRCHYAN 11C search for events with an opposite-sign lepton pair, jets, and missing E_T in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 34 pb^{-1}.
[12] CHATRCHYAN 11U search for events with one jet and missing E_T in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 36 pb^{-1}.
[13] AALTONEN 10AF search for $\gamma\gamma$ events with e, μ, τ, or missing E_T in $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV with L = 1.1–2.0 fb^{-1}.
[14] AALTONEN 09AF search for $\ell\gamma b$ events with missing E_T in $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV with L = 1.9 fb^{-1}. The observed events are compatible with Standard Model expectation including $t\overline{t}\gamma$ production.
[15] AALTONEN 09G search for $\mu\mu\mu$ and $\mu\mu e$ events with missing E_T in $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV with L = 976 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] AAD	13D	ATLS	7 TeV $pp \to$ 2 jets
			[2] CHATRCHYAN	13A	CMS	7 TeV $pp \to$ 2 jets
			[3] CHATRCHYAN	13A	CMS	7 TeV $pp \to b\overline{b}X$
			[4] AAD	12S	ATLS	7 TeV $pp \to$ 2 jets
			[5] CHATRCHYAN	12BL	CMS	7 TeV $pp \to t\overline{t}X$
			[6] AAD	11AG	ATLS	7 TeV $pp \to$ 2 jets
			[7] AALTONEN	11M	CDF	1.96 TeV $p\overline{p} \to W+$ 2 jets
			[8] ABAZOV	11I	D0	1.96 TeV $p\overline{p} \to W+$ 2 jets
			[9] AAD	10	ATLS	7 TeV $pp \to$ 2 jets
			[10] KHACHATRY...	10	CMS	7 TeV $pp \to$ 2 jets
			[11] ABE	99F	CDF	1.8 TeV $p\overline{p} \to b\overline{b}+$ anything
			[12] ABE	97G	CDF	1.8 TeV $p\overline{p} \to$ 2 jets
<2603	95	200	[13] ABE	93G	CDF	1.8 TeV $p\overline{p} \to$ 2 jets
< 44	95	400	[13] ABE	93G	CDF	1.8 TeV $p\overline{p} \to$ 2 jets
< 7	95	600	[13] ABE	93G	CDF	1.8 TeV $p\overline{p} \to$ 2 jets

[1] AAD 13D search for dijet resonances in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 4.8 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 = 1.0–4.0 TeV.

[2] CHATRCHYAN 13A search for qq, qg, and gg resonances in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 4.8 fb^{-1}. See their Fig. 3 and Table 1 for limits on resonance cross section in the range m = 1.0–4.3 TeV.

[3] CHATRCHYAN 13A search for $b\overline{b}$ resonances in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 4.8 fb^{-1}. See their Fig. 8 and Table 4 for limits on resonance cross section in the range m = 1.0–4.0 TeV.

[4] AAD 12S search for dijet resonances in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 1.0 fb^{-1}. See their Fig. 3 and Table 2 for limits on resonance cross section in the range m = 0.9–4.0 TeV.

[5] CHATRCHYAN 12BL search for $t\overline{t}$ resonances in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 4.4 fb^{-1}. See their Fig. 4 for limits on resonance cross section in the range m = 0.5–3.0 TeV.

[6] AAD 11AG search for dijet resonances in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 36 pb^{-1}. Limits on number of events for m = 0.6–4 TeV are given in their Table 3.

[7] AALTONEN 11M find a peak in two jet invariant mass distribution around 140 GeV in W + 2 jet events in $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV with L = 4.3 fb^{-1}.

[8] ABAZOV 11I search for two-jet resonances in W + 2 jet events in $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV with L = 4.3 fb^{-1} and give limits $\sigma <$ (2.6–1.3) pb (95% CL) for m = 110–170 GeV. The result is incompatible with AALTONEN 11M.

[9] AAD 10 search for narrow dijet resonances in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 315 nb^{-1}. Limits on the cross section in the range 10–10^3 pb is given for m = 0.3–1.7 TeV.

[10] KHACHATRYAN 10 search for narrow dijet resonances in pp collisions at $E_{\rm cm}$ = 7 TeV with L = 2.9 pb^{-1}. Limits on the cross section in the range 1–300 pb is given for m = 0.5–2.6 TeV separately in the final states qq, qg, and gg.

[11] ABE 99F search for narrow $b\overline{b}$ resonances in $p\overline{p}$ collisions at $E_{\rm cm}$=1.8 TeV. Limits on $\sigma(p\overline{p} \rightarrow X+$ anything$)\times$B$(X \rightarrow b\overline{b})$ in the range 3–10^3 pb (95%CL) are given for m_X=200–750 GeV. See their Table I.

[12] ABE 97G search for narrow dijet resonances in $p\overline{p}$ collisions with 106 pb^{-1} of data at $E_{\rm cm}$ = 1.8 TeV. Limits on $\sigma(p\overline{p} \rightarrow X+$ anything$)\cdot$B$(X \rightarrow jj)$ in the range 10^4–10^{-1} pb (95%CL) are given for dijet mass m=200–1150 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.

[13] ABE 93G give cross section times branching ratio into light (d, u, s, c, b) quarks for Γ = 0.02 M. Their Table II gives limits for M = 200–900 GeV and Γ = (0.02–0.2) 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. • • •					
<(0.043–0.17)	95	[1] ABBIENDI	00D	OPAL	$e^+e^- \rightarrow X^0Y^0$, $X^0 \rightarrow Y^0\gamma$
<(0.05–0.8)	95	[2] ABBIENDI	00D	OPAL	$e^+e^- \rightarrow X^0X^0$, $X^0 \rightarrow Y^0\gamma$
<(2.5–0.5)	95	[3] ACKERSTAFF	97B	OPAL	$e^+e^- \rightarrow X^0Y^0$, $X^0 \rightarrow Y^0\gamma$
<(1.6–0.9)	95	[4] ACKERSTAFF	97B	OPAL	$e^+e^- \rightarrow X^0X^0$, $X^0 \rightarrow Y^0\gamma$

[1] ABBIENDI 00D associated production limit is for m_{X^0}= 90–188 GeV, m_{Y^0}=0 at E_{cm}=189 GeV. See also their Fig. 9.
[2] ABBIENDI 00D pair production limit is for m_{X^0} = 45–94 GeV, m_{Y^0}=0 at E_{cm}=189 GeV. See also their Fig. 12.
[3] ACKERSTAFF 97B associated production limit is for m_{X^0} = 80–160 GeV, m_{Y^0}=0 from 10.0 pb^{-1} at E_{cm} = 161 GeV. See their Fig. 3(a).
[4] ACKERSTAFF 97B pair production limit is for m_{X^0} = 40–80 GeV, m_{Y^0}=0 from 10.0 pb^{-1} at E_{cm} = 161 GeV. See their Fig. 3(b).

Heavy Particle Production Cross Section

VALUE (cm^2/N)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
			[1] ADAMS	97B	KTEV	m= 1.2–5 GeV
$< 10^{-36}$–10^{-33}	90		[2] GALLAS	95	TOF	m= 0.5–20 GeV
$<(4–0.3) \times 10^{-31}$	95		[3] AKESSON	91	CNTR	m = 0–5 GeV
$<2 \times 10^{-36}$	90	0	[4] BADIER	86	BDMP	$\tau = (0.05–1.) \times 10^{-8}$s
$<2.5 \times 10^{-35}$		0	[5] GUSTAFSON	76	CNTR	$\tau > 10^{-7}$ s

[1] ADAMS 97B search for a hadron-like neutral particle produced in pN interactions, which decays into a ρ^0 and a weakly interacting massive particle. Upper limits are given for the ratio to K_L production for the mass range 1.2–5 GeV and lifetime 10^{-9}–10^{-4} s. See also our Light Gluino Section.
[2] GALLAS 95 limit is for a weakly interacting neutral particle produced in 800 GeV/c pN interactions decaying with a lifetime of 10^{-4}–10^{-8} s. See their Figs. 8 and 9. Similar limits are obtained for a stable particle with interaction cross section 10^{-29}–10^{-33} cm^2. See Fig. 10.
[3] 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, $\sigma < 10^{-30}$ cm^{-2}/nucleon is obtained.
[4] 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, $\mu^+\pi^-$, $\mu^+\mu^-$, $\pi^+\pi^-$X, $\pi^+\pi^-\pi^\pm$ etc. See their figure 5 for the contours of limits in the mass-τ plane for each mode.
[5] 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 σ(production) $\times$ σ(interaction)$\times$acceptance $< 2.26 \times 10^{-71}$ cm^4/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%	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
			[1] ACKERSTAFF	98P	OPAL	Q=1,2/3, m=45–89.5 GeV
			[2] ABREU	97D	DLPH	Q=1,2/3, m=45–84 GeV
			[3] BARATE	97K	ALEP	Q=1, m=45–85 GeV
$<2 \times 10^{-5}$	95		[4] AKERS	95R	OPAL	Q=1, m= 5–45 GeV
$<1 \times 10^{-5}$	95		[4] AKERS	95R	OPAL	Q=2, m= 5–45 GeV
$<2 \times 10^{-3}$	90		[5] BUSKULIC	93C	ALEP	Q=1, m=32–72 GeV
$<(10^{-2}$–$1)$	95		[6] ADACHI	90C	TOPZ	Q = 1, m = 1–16, 18–27 GeV
$<7 \times 10^{-2}$	90		[7] ADACHI	90E	TOPZ	Q = 1, m = 5–25 GeV
$<1.6 \times 10^{-2}$	95	0	[8] KINOSHITA	82	PLAS	Q=3–180, m <14.5 GeV
$<5.0 \times 10^{-2}$	90	0	[9] BARTEL	80	JADE	Q=(3,4,5)/3 2–12 GeV

[1] ACKERSTAFF 98P search for pair production of long-lived charged particles at E_{cm} between 130 and 183 GeV and give limits σ <(0.05–0.2) pb (95%CL) for spin-0 and spin-1/2 particles with m=45–89.5 GeV, charge 1 and 2/3. The limit is translated to the cross section at E_{cm}=183 GeV with the s dependence described in the paper. See their Figs. 2–4.

[2] ABREU 97D search for pair production of long-lived particles and give limits σ <(0.4–2.3) pb (95%CL) for various center-of-mass energies E_{cm}=130–136, 161, and 172 GeV, assuming an almost flat production distribution in cosθ.

[3] BARATE 97K search for pair production of long-lived charged particles at E_{cm} = 130, 136, 161, and 172 GeV and give limits σ <(0.2–0.4) pb (95%CL) for spin-0 and spin-1/2 particles with m=45–85 GeV. The limit is translated to the cross section at E_{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.

[4] AKERS 95R is a CERN-LEP experiment with $W_{cm} \sim m_Z$. The limit is for the production of a stable particle in multihadron events normalized to $\sigma(e^+e^- \rightarrow$ hadrons). Constant phase space distribution is assumed. See their Fig. 3 for bounds for $Q = \pm2/3$, $\pm4/3$.

[5] BUSKULIC 93C is a CERN-LEP experiment with $W_{cm} = m_Z$. 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.

[6] ADACHI 90C is a KEK-TRISTAN experiment with W_{cm} = 52–60 GeV. The limit is for pair production of a scalar or spin-1/2 particle. See Figs. 3 and 4.

[7] ADACHI 90E is KEK-TRISTAN experiment with W_{cm} = 52–61.4 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 $\beta = (1-4m^2/W^2_{cm})^{1/2}$. See the paper for the assumption about the production mechanism.

[8] KINOSHITA 82 is SLAC PEP experiment at W_{cm} = 29 GeV using lexan and ^{39}Cr plastic sheets sensitive to highly ionizing particles.

[9] BARTEL 80 is DESY-PETRA experiment with W_{cm} = 27–35 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= 40.4–45.6 GeV
$<1 \times 10^{-3}$	95	AKRAWY	90O	OPAL	m = 29–40 GeV

[1] AKERS 95R give the 95% CL limit $\sigma(X\overline{X})/\sigma(\mu\mu) < 1.8\times10^{-4}$ 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 $Q = \pm2/3$, $\pm4/3$.

LIMITS ON CHARGED PARTICLES IN HADRONIC REACTIONS

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] AAD	11I	ATLS	$\lvert q\rvert$=10e, m=0.2–1 TeV
$<1.0 \times 10^{-5}$	95	[2,3] AALTONEN	09Z	CDF	m>100 GeV, noncolored
$<4.8 \times 10^{-5}$	95	[2,4] AALTONEN	09Z	CDF	m>100 GeV, colored
$< 0.31–0.04 \times 10^{-3}$	95	[5] ABAZOV	09M	D0	pair production
<0.19	95	[6] AKTAS	04C	H1	m=3–10 GeV
<0.05	95	[7] ABE	92J	CDF	m=50–200 GeV
<30–130		[8] CARROLL	78	SPEC	m=2–2.5 GeV
<100		[9] LEIPUNER	73	CNTR	m=3–11 GeV

[1] AAD 11I search for production of highly ionizing massive particles in pp collisions at E_{cm} = 7 TeV with L = 3.1 pb^{-1}. See their Table 5 for similar limits for $\lvert q\rvert$ = 6e and 17e, Table 6 for limits on pair production cross section.

[2] AALTONEN 09Z search for long-lived charged particles in $p\overline{p}$ collisions at E_{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 $\lvert\eta\rvert \lesssim 0.7$, $p_T > 40$ GeV, and $0.4 < \beta < 1.0$.

[3] Limit for weakly interacting charge-1 particle.

[4] Limit for up-quark like particle.

[5] ABAZOV 09M search for pair production of long-lived charged particles in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with L = 1.1 fb^{-1}. Limit on the cross section of (0.31–0.04) pb (95% CL) is given for the mass range of 60–300 GeV, assuming the kinematics of stau pair production.

[6] AKTAS 04C look for charged particle photoproduction at HERA with mean c.m. energy of 200 GeV.

[7] 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.

[8] 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_{lab} = 5.1–5.9 GeV/c.

[9] 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=2.1–9.4 GeV
$<2.2 \times 10^{-33}$	90	[2] ALBROW	75	SPEC	$\pm$	Q= $\pm$1, m=4–15 GeV
$<1.1 \times 10^{-33}$	90	[2] ALBROW	75	SPEC	$\pm$	Q= $\pm$2, m=6–27 GeV
$<8. \times 10^{-35}$	90	[3] JOVANOV...	75	CNTR	$\pm$	m=15–26 GeV
$<1.5 \times 10^{-34}$	90	[3] JOVANOV...	75	CNTR	$\pm$	Q= $\pm$2, m=3–10 GeV
$<6. \times 10^{-35}$	90	[3] JOVANOV...	75	CNTR	$\pm$	Q= $\pm$2, m=10–26 GeV
$<1. \times 10^{-31}$	90	[4] APPEL	74	CNTR	$\pm$	m=3.2–7.2 GeV
$<5.8 \times 10^{-34}$	90	[5] ALPER	73	SPEC	$\pm$	m=1.5–24 GeV
$<1.2 \times 10^{-35}$	90	[6] ANTIPOV	71B	CNTR	$-$	Q=$-$, m=2.2–2.8
$<2.4 \times 10^{-35}$	90	[7] ANTIPOV	71C	CNTR	$-$	Q=$-$, m=1.2–1.7, 2.1–4
$<2.4 \times 10^{-35}$	90	BINON	69	CNTR	$-$	Q=$-$, m=1–1.8 GeV
$<1.5 \times 10^{-36}$		[8] DORFAN	65	CNTR		Be target m=3–7 GeV
$<3.0 \times 10^{-36}$		[8] DORFAN	65	CNTR		Fe target m=3–7 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 (2.1–9.4 GeV) $\times$ $|(\text{charge})|$. Assumes stable particle interacting with matter as do antiprotons.

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

[3] JOVANOVICH 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 < β <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=4–12 GeV
$<1. \times 10^{-35}$	90	[2] THRON	85	CNTR	+	Q= 1, m=4–12 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=1.5–3.0 GeV
		[4] BOZZOLI	79	CNTR	$\pm$	Q = (2/3, 1, 4/3, 2)
$<1.1 \times 10^{-37}$	90	[5] CUTTS	78	CNTR		m=4–10 GeV
$<3.0 \times 10^{-37}$	90	[6] VIDAL	78	CNTR		m=4.5–6 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 = 1.5–7.5 GeV and $\tau = 10^{-8}$–2×10^{-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_{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 antideuterons.
[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 pBe 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 (σ(Heavy Particle) / $\sigma(\pi)$)

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	$\pm$	$Q = (-5/3,\pm2)$
	0	[2] BUSSIERE	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] BUSSIERE 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)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<20 to 800	0	[1] ALEKSEEV	76	ELEC	τ=5 ms to 1 day
<200 to 2000	0	[1] ALEKSEEV	76B	ELEC	τ=100 ms to 1 day
<1.4 to 9	0	[2] FRANKEL	75	CNTR	τ=50 ms to 10 hours
<0.1 to 9	0	[3] FRANKEL	74	CNTR	τ=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 Search at Hadron Collisions

Limits are for cross section times branching ratio.

VALUE (pb/nucleon)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<2	90	0	[1] BADIER	86	BDMP	$\tau = (0.05\text{–}1.) \times 10^{-8}$s

[1] 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, $\mu^+\pi^-$, $\mu^+\mu^-$, $\pi^+\pi^-$X, $\pi^+\pi^-\pi^\pm$ 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 $p p \rightarrow X^{++} n$. No candidate is found. The limit is for the cross section at 15° scattering angle at 460 MeV incident energy and applies for $\tau(X^{++}) \gg 0.1\,\mu$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	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$\sim 6 \times 10^{-9}$		2	[1] SAITO	90			$Q \simeq 14$, $m \simeq 370 m_p$
$< 1.4 \times 10^{-12}$	90	0	[2] MINCER	85	CALO		$m \geq 1$ TeV
			[3] SAKUYAMA	83B	PLAS		$m \sim 1$ TeV
$< 1.7 \times 10^{-11}$	99	0	[4] BHAT	82	CC		
$< 1. \times 10^{-9}$	90	0	[5] MARINI	82	CNTR	±	$Q = 1$, $m \sim 4.5 m_p$
$2. \times 10^{-9}$		3	[6] YOCK	81	SPRK	±	$Q = 1$, $m \sim 4.5 m_p$
		3	[6] YOCK	81	SPRK		Fractionally charged
3.0×10^{-9}		3	[7] 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		[8] 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 $< -7e$
$> 6. \times 10^{-9}$		5	[9] 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=5–15 GeV

[1] SAITO 90 candidates carry about 450 MeV/nucleon. Cannot be accounted for by conventional backgrounds. Consistent with strange quark matter hypothesis.

[2] 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.

[3] 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.

[4] 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.

[5] 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.

[6] YOCK 81 saw another 3 events with $Q = \pm1$ and m about $4.5m_p$ as well as 2 events with $m > 5.3m_p$, $Q = \pm0.75 \pm 0.05$ and $m > 2.8m_p$, $Q = \pm0.70 \pm 0.05$ and 1 event with $m = (9.3 \pm 3.)m_p$, $Q = \pm0.89 \pm 0.06$ as possible heavy candidates.

[7] YOCK 80 events are with charge exactly or approximately equal to unity.

[8] BHAT 78 is at Kolar gold fields. Limit is for $\tau > 10^{-6}$ s.

[9] YOCK 74 events could be tritons.

Superheavy Particle (Quark Matter) Flux in Cosmic Rays

VALUE ($\mathrm{cm^{-2}sr^{-1}s^{-1}}$)	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$<5 \times 10^{-16}$	90		[1] AMBROSIO	00B	MCRO	$m > 5 \times 10^{14}$ GeV
$<1.8 \times 10^{-12}$	90		[2] ASTONE	93	CNTR	$m \geq 1.5 \times 10^{-13}$gram
$<1.1 \times 10^{-14}$	90		[3] AHLEN	92	MCRO	$10^{-10} < m < 0.1$ gram
$<2.2 \times 10^{-14}$	90	0	[4] NAKAMURA	91	PLAS	$m > 10^{11}$ GeV
$<6.4 \times 10^{-16}$	90	0	[5] ORITO	91	PLAS	$m > 10^{12}$ GeV
$<2.0 \times 10^{-11}$	90		[6] LIU	88	BOLO	$m > 1.5 \times 10^{-13}$ gram
$<4.7 \times 10^{-12}$	90		[7] BARISH	87	CNTR	$1.4 \times 10^{8} < m < 10^{12}$ GeV
$<3.2 \times 10^{-11}$	90	0	[8] NAKAMURA	85	CNTR	$m > 1.5 \times 10^{-13}$gram
$<3.5 \times 10^{-11}$	90	0	[9] ULLMAN	81	CNTR	Planck-mass 10^{19}GeV
$<7. \times 10^{-11}$	90	0	[9] ULLMAN	81	CNTR	$m \leq 10^{16}$ GeV

[1] AMBROSIO 00B searched for quark matter ("nuclearites") in the velocity range $(10^{-5}$–$1)$ c. The listed limit is for 2×10^{-3} c.

[2] ASTONE 93 searched for quark matter ("nuclearites") in the velocity range $(10^{-3}$–$1)$ c. Their Table 1 gives a compilation of searches for nuclearites.

[3] 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.

[4] NAKAMURA 91 searched for quark matter in the velocity range $(4 \times 10^{-5}$–$1)$ c.

[5] ORITO 91 searched for quark matter. The limit is for the velocity range $(10^{-4}$–$10^{-3})$ c.

[6] 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 $(1$–$2.5) \times 10^{-3}c$.

[7] BARISH 87 searched for quark matter ("nuclearites") in the velocity range $(2.7 \times 10^{-4}$–$5 \times 10^{-3})c$.

[8] 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.

[9] ULLMAN 81 is sensitive for heavy slow singly charge particle reaching earth with vertical velocity 100–350 km/s.

Highly Ionizing Particle Flux

VALUE ($\mathrm{m^{-2}yr^{-1}}$)	*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 QUANTUM BLACK HOLE PRODUCTION

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[1] AAD	13D	ATLS	7 TeV $pp \to$ 2 jets
	[2] CHATRCHYAN	13A	CMS	7 TeV $pp \to$ 2 jets
	[3] CHATRCHYAN	12W	CMS	7 TeV $pp \to$ multijets
	[4] AAD	11AG	ATLS	7 TeV $pp \to$ 2 jets

[1] AAD 13D search for quantum black hole formation followed by its decay to two jets, in pp collisions at E_{cm} = 7 TeV with L = 4.8 fb^{-1}. See their Fig. 8 and Table 3 for limits.

[2] CHATRCHYAN 13A search for quantum black hole formation followed by its decay to two jets, in pp collisions at E_{cm} = 7 TeV with L = 5 fb^{-1}. See their Figs. 5 and 6 for limits.

[3] CHATRCHYAN 12W search for quantum black hole formation followed by its evapolation to multiparticle final states, in multijet (including γ, ℓ) events in pp collisions at E_{cm} = 7 TeV with L = 4.7 fb^{-1}. See their Figs. 5–8 for limits.

[4] AAD 11AG search for quantum black hole formation followed by its decay to two jets, in pp collisions at E_{cm} = 7 TeV with L = 36 pb^{-1}. See their Fig. 11 and Table 4 for limits.

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ALEKSEEV	76	SJNP 22 531	G.D. Alekseev *et al.*	(JINR)
		Translated from YAF 22 1021.		
ALEKSEEV	76B	SJNP 23 633	G.D. Alekseev *et al.*	(JINR)
		Translated from YAF 23 1190.		
BALDIN	76	SJNP 22 264	B.Y. Baldin *et al.*	(JINR)
		Translated from YAF 22 512.		
BRIATORE	76	NC 31A 553	L. Briatore *et al.*	(LCGT, FRAS, FREIB)
GUSTAFSON	76	PRL 37 474	H.R. Gustafson *et al.*	(MICH)
ALBROW	75	NP B97 189	M.G. Albrow *et al.*	(CERN, DARE, FOM+)
FRANKEL	75	PR D12 2561	S. Frankel *et al.*	(PENN, FNAL)
JOVANOV...	75	PL 56B 105	J.V. Jovanovich *et al.*	(MANI, AACH, CERN+)
YOCK	75	NP B86 216	P.C.M. Yock	(AUCK, SLAC)
APPEL	74	PRL 32 428	J.A. Appel *et al.*	(COLU, FNAL)
FRANKEL	74	PR D9 1932	S. Frankel *et al.*	(PENN, FNAL)
YOCK	74	NP B76 175	P.C.M. Yock	(AUCK)
ALPER	73	PL 46B 265	B. Alper *et al.*	(CERN, LIVP, LUND, BOHR+)
LEIPUNER	73	PRL 31 1226	L.B. Leipuner *et al.*	(BNL, YALE)
DARDO	72	NC 9A 319	M. Dardo *et al.*	(TORI)
TONWAR	72	JPA 5 569	S.C. Tonwar, S. Naranan, B.V. Sreekantan	(TATA)
ANTIPOV	71B	NP B31 235	Y.M. Antipov *et al.*	(SERP)
ANTIPOV	71C	PL 34B 164	Y.M. Antipov *et al.*	(SERP)
BINON	69	PL 30B 510	F.G. Binon *et al.*	(SERP)
BJORNBOE	68	NC B53 241	J. Bjornboe *et al.*	(BOHR, TATA, BERN+)
JONES	67	PR 164 1584	L.W. Jones	(MICH, WISC, LBL, UCLA, MINN+)
DORFAN	65	PRL 14 999	D.E. Dorfan *et al.*	(COLU)