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, axigluons), 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=5–1600m_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, $M = 1000 m_p$

$<2 \times 10^{-21}$	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=30–400m_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, $M = 100 m_p$
$<8 \times 10^{-20}$	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, $M = 1000 m_p$
$< 1.5 \times 10^{-13}$/nucleon	68	[4] NORMAN	89	SPEC	$^{206}\text{Pb}X^-$
$< 1.2 \times 10^{-12}$/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.

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	15AT	ATLS	$t + \not\!\!E_T$
	[2] KHACHATRY...	15F	CMS	$t + \not\!\!E_T$
	[3] AALTONEN	14J	CDF	W + 2 jets
	[4] AAD	13A	ATLS	$W W \rightarrow \ell \nu \ell' \nu$
	[5] AAD	13C	ATLS	$\gamma + \not\!\!E_T$
	[6] AALTONEN	13I	CDF	Delayed $\gamma + \not\!\!E_T$
	[7] CHATRCHYAN	13	CMS	$\ell^+ \ell^-$ + jets + $\not\!\!E_T$
	[8] AAD	12C	ATLS	$t \overline{t} + \not\!\!E_T$
	[9] AALTONEN	12M	CDF	jet + $\not\!\!E_T$
	[10] CHATRCHYAN	12AP	CMS	jet + $\not\!\!E_T$
	[11] CHATRCHYAN	12Q	CMS	Z + jets + $\not\!\!E_T$
	[12] CHATRCHYAN	12T	CMS	$\gamma + \not\!\!E_T$
	[13] AAD	11S	ATLS	jet + $\not\!\!E_T$
	[14] AALTONEN	11AF	CDF	$\ell^\pm \ell^\pm$
	[15] CHATRCHYAN	11C	CMS	$\ell^+ \ell^-$ + jets + $\not\!\!E_T$
	[16] CHATRCHYAN	11U	CMS	jet + $\not\!\!E_T$
	[17] AALTONEN	10AF	CDF	$\gamma\gamma + \ell, \not\!\!E_T$
	[18] AALTONEN	09AF	CDF	$\ell \gamma b \not\!\!E_T$
	[19] AALTONEN	09G	CDF	$\ell \ell \ell \not\!\!E_T$

[1] AAD 15AT search for events with a top quark and mssing E_T in pp collisions at E_{cm} = 8 TeV with L = 20.3 fb^{-1}.

[2] KHACHATRYAN 15F search for events with a top quark and mssing E_T in pp collisions at E_{cm} = 8 TeV with L = 19.7 fb^{-1}.

[3] AALTONEN 14J examine events with a W and two jets in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with L = 8.9 fb^{-1}. Invariant mass distributions of the two jets are consistent with the Standard Model expectation.

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

[5] 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}.

[6] AALTONEN 13I search for events with a photon and missing E_T, where the photon is detected after the expected timing, in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with L = 6.3 fb^{-1}. The data are consistent with the Standard Model expectation.

[7] 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}.

[8] AAD 12C search for events with a $t\overline{t}$ pair and missing $\not\!\!E_T$ in pp collisions at E_{cm} = 7 TeV with L = 1.04 fb^{-1}.

[9] 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}.

[10] 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}.
[11] CHATRCHYAN 12Q search for events with a Z, jets, and missing $\not\!E_T$ in pp collisions at E_{cm} = 7 TeV with L = 4.98 fb^{-1}.
[12] 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}.
[13] AAD 11S search for events with one jet and missing E_T in pp collisions at E_{cm} = 7 TeV with L = 33 pb^{-1}.
[14] AALTONEN 11AF search for high-p_T like-sign dileptons in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with L = 6.1 fb^{-1}.
[15] CHATRCHYAN 11C search for events with an opposite-sign lepton pair, jets, and missing E_T in pp collisions at E_{cm} = 7 TeV with L = 34 pb^{-1}.
[16] CHATRCHYAN 11U search for events with one jet and missing E_T in pp collisions at E_{cm} = 7 TeV with L = 36 pb^{-1}.
[17] AALTONEN 10AF search for $\gamma\gamma$ events with e, μ, τ, or missing E_T in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with L = 1.1–2.0 fb^{-1}.
[18] AALTONEN 09AF search for $\ell\gamma b$ events with missing E_T in $p\overline{p}$ collisions at E_{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.
[19] AALTONEN 09G search for $\mu\mu\mu$ and $\mu\mu e$ events with missing E_T in $p\overline{p}$ collisions at E_{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] KHACHATRY...	17W	CMS	$pp \to jj$ resonance
			[2] KHACHATRY...	17Y	CMS	$pp \to$ (8–10) $j+\not\!E_T$
			[3] SIRUNYAN	17F	CMS	$pp \to jj$ angular distribution
			[4] AABOUD	16	ATLS	$pp \to b$ + jet
			[5] AAD	16N	ATLS	$pp \to$ 3 high E_T jets
			[6] AAD	16S	ATLS	$pp \to jj$ resonance
			[7] KHACHATRY...	16K	CMS	$pp \to jj$ resonance
			[8] KHACHATRY...	16L	CMS	$pp \to jj$ resonance
			[9] AAD	13D	ATLS	7 TeV $pp \to$ 2 jets
			[10] AALTONEN	13R	CDF	1.96 TeV $p\overline{p} \to$ 4 jets
			[11] CHATRCHYAN	13A	CMS	7 TeV $pp \to$ 2 jets
			[12] CHATRCHYAN	13A	CMS	7 TeV $pp \to b\overline{b}X$
			[13] AAD	12S	ATLS	7 TeV $pp \to$ 2 jets
			[14] CHATRCHYAN	12BL	CMS	7 TeV $pp \to t\overline{t}X$
			[15] AAD	11AG	ATLS	7 TeV $pp \to$ 2 jets
			[16] AALTONEN	11M	CDF	1.96 TeV $p\overline{p} \to W+$ 2 jets
			[17] ABAZOV	11I	D0	1.96 TeV $p\overline{p} \to W+$ 2 jets
			[18] AAD	10	ATLS	7 TeV $pp \to$ 2 jets

			[19] KHACHATRY...	10	CMS	7 TeV $pp \to 2$ jets
			[20] ABE	99F	CDF	1.8 TeV $p\overline{p} \to b\overline{b}+$ anything
			[21] ABE	97G	CDF	1.8 TeV $p\overline{p} \to 2$ jets
<2603	95	200	[22] ABE	93G	CDF	1.8 TeV $p\overline{p} \to 2$ jets
< 44	95	400	[22] ABE	93G	CDF	1.8 TeV $p\overline{p} \to 2$ jets
< 7	95	600	[22] ABE	93G	CDF	1.8 TeV $p\overline{p} \to 2$ jets

[1] 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.

[2] KHACHATRYAN 17Y search for $pp \to$ (8–10) j in 19.7 fb^{-1} at 8 TeV. No signal seen. Limits set on colorons, axigluons, RPV, and SUSY.

[3] SIRUNYAN 17F measure $pp \to jj$ angular distribution in 2.6 fb^{-1} at 13 TeV; limits set on LEDs and quantum black holes.

[4] 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.

[5] 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).

[6] 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.

[7] KHACHATRYAN 16K search for dijet resonance in 2.4 fb^{-1} data at 13 TeV; see Fig. 3 for limits on axigluons, diquarks etc.

[8] 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 between 500–800 GeV.

[9] AAD 13D search for dijet resonances in pp collisions at $E_{cm} = 7$ 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.

[10] AALTONEN 13R search for production of a pair of jet-jet resonances in $p\overline{p}$ collisions at $E_{cm} = 1.96$ TeV with $L = 6.6$ fb^{-1}. See their Fig. 5 and Tables I, II for cross section limits.

[11] CHATRCHYAN 13A search for qq, qg, and gg resonances in pp collisions at $E_{cm} =$ 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.

[12] CHATRCHYAN 13A search for $b\overline{b}$ resonances in pp collisions at $E_{cm} = 7$ 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.

[13] AAD 12S search for dijet resonances in pp collisions at $E_{cm} = 7$ 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.

[14] CHATRCHYAN 12BL search for $t\overline{t}$ resonances in pp collisions at $E_{cm} = 7$ 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.

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

[16] 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 $E_{cm} = 1.96$ TeV with L = 4.3 fb^{-1}.

[17] ABAZOV 11I search for two-jet resonances in $W + 2$ jet events in $p\overline{p}$ collisions at E_{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.

[18] AAD 10 search for narrow dijet resonances in pp collisions at $E_{cm} = 7$ 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.

[19] KHACHATRYAN 10 search for narrow dijet resonances in pp collisions at $E_{cm} = 7$ 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.

[20] ABE 99F search for narrow $b\overline{b}$ resonances in $p\overline{p}$ collisions at E_{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.

[21] ABE 97G search for narrow dijet resonances in $p\overline{p}$ collisions with 106 pb^{-1} of data at E_{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.

[22] 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. • • •					
		[1] KHACHATRY...	17D	CMS	$Z\gamma$ resonance
<0.0008	95	[2] AAD	16AI	ATLS	$pp \rightarrow \gamma +$ jet
		[3] KHACHATRY...	16M	CMS	$pp \rightarrow \gamma\gamma$ resonance
<(0.043–0.17)	95	[4] ABBIENDI	00D	OPAL	$e^+e^- \rightarrow X^0 Y^0$, $X^0 \rightarrow Y^0\gamma$
<(0.05–0.8)	95	[5] ABBIENDI	00D	OPAL	$e^+e^- \rightarrow X^0 X^0$, $X^0 \rightarrow Y^0\gamma$
<(2.5–0.5)	95	[6] ACKERSTAFF	97B	OPAL	$e^+e^- \rightarrow X^0 Y^0$, $X^0 \rightarrow Y^0\gamma$
<(1.6–0.9)	95	[7] ACKERSTAFF	97B	OPAL	$e^+e^- \rightarrow X^0 X^0$, $X^0 \rightarrow Y^0\gamma$

[1] 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.

[2] 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 σ_G/M_G = 2%.

[3] 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.

[4] 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.

[5] 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.

[6] 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).

[7] 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%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[1] AABOUD	17B	ATLS	WH, ZH resonance
		[2] AAIJ	17BR	LHCB	$pp \to \pi_V \pi_V$, $\pi_V \to jj$
		[3] AAD	16O	ATLS	ℓ + (ℓs or jets)
		[4] AAD	16R	ATLS	WW, WZ, ZZ resonance
		[5] LEES	15E	BABR	$e^+ e^-$ collisions
		[6] ADAMS	97B	KTEV	m= 1.2–5 GeV
$< 10^{-36}$–10^{-33}	90	[7] GALLAS	95	TOF	m= 0.5–20 GeV
$<$(4–0.3) $\times 10^{-31}$	95	[8] AKESSON	91	CNTR	m = 0–5 GeV
$<2 \times 10^{-36}$	90	[9] BADIER	86	BDMP	τ = (0.05–1.) $\times 10^{-8}$s
$<2.5 \times 10^{-35}$		[10] GUSTAFSON	76	CNTR	$\tau > 10^{-7}$ s

[1] AABOUD 17B exclude m(W', Z') $<$ 1.49–2.31 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.

[2] 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.

[3] AAD 16O search for high E_T ℓ + (ℓs 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.

[4] 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).

[5] LEES 15E search for long-lived neutral particles produced in $e^+ e^-$ collisions in the Upsilon region, which decays into $e^+ e^-$, $\mu^+ \mu^-$, $e^\pm \mu^\mp$, $\pi^+ \pi^-$, $K^+ K^-$, or $\pi^\pm K^\mp$. See their Fig. 2 for cross section limits.

[6] 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.

[7] 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.

[8] 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.

[9] 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.

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

[1] ABLIKIM 17AA search for dark photon $A \rightarrow \ell\overline{\ell}$ at 3.773 GeV with 2.93 fb^{-1}. Limits are set in ϵ vs m(A) plane.

[2] 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.

[3] 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.

[4] 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.

[5] 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 $Q = \pm 2/3$, $\pm 4/3$.

[6] 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.

[7] 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.

[8] 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.

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

[10] 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 $Q = \pm 2/3$, $\pm 4/3$.

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	$\lvert Q\rvert = 2$
>200	95	[2] CHATRCHYAN	13AB	CMS	$\lvert Q\rvert = 1/3$
>480	95	[2] CHATRCHYAN	13AB	CMS	$\lvert Q\rvert = 2/3$
>574	95	[2] CHATRCHYAN	13AB	CMS	$\lvert Q\rvert = 1$
>685	95	[2] CHATRCHYAN	13AB	CMS	$\lvert Q\rvert = 2$
>140	95	[3] CHATRCHYAN	13AR	CMS	$\lvert Q\rvert = 1/3$
>310	95	[3] CHATRCHYAN	13AR	CMS	$\lvert Q\rvert = 2/3$

[1] AAD 15BJ use 20.3 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See paper for limits for $\lvert Q\rvert$ = 3, 4, 5, 6.

[2] CHATRCHYAN 13AB use 5.0 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 18.8 fb^{-1} at E_{cm} = 8 TeV. See paper for limits for $\lvert Q\rvert$ = 3, 4,. . ., 8.

[3] CHATRCHYAN 13AR use 5.0 fb^{-1} of pp collisions at E_{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] AABOUD	17D	ATLS	anomalous $WWjj$, $WZjj$
		[2] AABOUD	17L	ATLS	m>870 GeV, $Z(\rightarrow \nu\nu)tX$
		[3] SIRUNYAN	17B	CMS	tH
		[4] SIRUNYAN	17C	CMS	$Z + (t$ or $b)$

		[5] SIRUNYAN	17J	CMS	$X_{5/3} \to tW$
		[6] AAIJ	15BD	LHCB	m=124–309 GeV
		[7] AAD	13AH	ATLS	$\lvert q\rvert$=(2–6)e, m=50–600 GeV
$<1.2 \times 10^{-3}$	95	[8] AAD	11I	ATLS	$\lvert q\rvert$=10e, m=0.2–1 TeV
$<1.0 \times 10^{-5}$	95	[9,10] AALTONEN	09Z	CDF	$m>$100 GeV, noncolored
$<4.8 \times 10^{-5}$	95	[9,11] AALTONEN	09Z	CDF	$m>$100 GeV, colored
$<$ 0.31–0.04 $\times 10^{-3}$	95	[12] ABAZOV	09M	D0	pair production
$<$0.19	95	[13] AKTAS	04C	H1	m=3–10 GeV
$<$0.05	95	[14] ABE	92J	CDF	m=50–200 GeV
$<$30–130		[15] CARROLL	78	SPEC	m=2–2.5 GeV
$<$100		[16] LEIPUNER	73	CNTR	m=3–11 GeV

[1] AABOUD 17D search for $WWjj$, $WZjj$ in pp collisions at 8 TeV with 3.2 fb^{-1}; set limits on anomalous couplings.

[2] AABOUD 17L search for the pair production of heavy vector-like T quarks in the $Z(\to \nu\nu)tX$ final state.

[3] SIRUNYAN 17B search for vector-like quark $pp \to TX \to tHX$ in 2.3 fb^{-1} at 13 TeV; no signal seen; limits placed.

[4] SIRUNYAN 17C search for vector-like quark $pp \to TX \to Z + (t$ or $b)$ in 2.3 fb^{-1} at 13 TeV; no signal seen; limits placed.

[5] SIRUNYAN 17J search for $pp \to X_{5/3}X_{5/3} \to tWtW$ with 2.3 fb^{-1} at 13 TeV. No signal seen: m(X) $>$ 1020 (990) GeV for RH (LH) new charge 5/3 quark.

[6] AAIJ 15BD search for production of long-lived particles in pp collisions at E_{cm} = 7 and 8 TeV. See their Table 6 for cross section limits.

[7] AAD 13AH search for production of long-lived particles with $\lvert q\rvert$=(2–6)e in pp collisions at E_{cm} = 7 TeV with 4.4 fb^{-1}. See their Fig. 8 for cross section limits.

[8] 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.

[9] 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 $0.4 < \beta < 1.0$.

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

[11] Limit for up-quark like particle.

[12] 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.

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

[14] 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.

[15] CARROLL 78 look for neutral, $S = -2$ dihyperon resonance in $pp \to 2K^+$X. Cross section varies within above limits over mass range and p_{lab} = 5.1–5.9 GeV/c.

[16] 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	±	Q= ±1, m=4–15 GeV
$<1.1 \times 10^{-33}$	90	[2] ALBROW	75	SPEC	±	Q= ±2, m=6–27 GeV
$<8. \times 10^{-35}$	90	[3] JOVANOV...	75	CNTR	±	m=15–26 GeV
$<1.5 \times 10^{-34}$	90	[3] JOVANOV...	75	CNTR	±	Q= ±2, m=3–10 GeV
$<6. \times 10^{-35}$	90	[3] JOVANOV...	75	CNTR	±	Q= ±2, m=10–26 GeV
$<1. \times 10^{-31}$	90	[4] APPEL	74	CNTR	±	m=3.2–7.2 GeV
$<5.8 \times 10^{-34}$	90	[5] ALPER	73	SPEC	±	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. • • •						
$< 5–700 \times 10^{-35}$	90	[1] BERNSTEIN	88	CNTR		
$< 5–700 \times 10^{-37}$	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	±	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	±	$Q = (-5/3, \pm 2)$
	0	[2] BUSSIERE	80	CNTR	±	$Q = (2/3, 1, 4/3, 2)$

[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)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<20 to 800	[1] ALEKSEEV	76	ELEC	τ=5 ms to 1 day
<200 to 2000	[1] ALEKSEEV	76B	ELEC	τ=100 ms to 1 day
<1.4 to 9	[2] FRANKEL	75	CNTR	τ=50 ms to 10 hours
<0.1 to 9	[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%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[1] AAIJ	16AR	LHCB	$H \to XX$ long-lived particles
		[2] KHACHATRY...	16BW	CMS	direct production: HSCPs
<2	90	[3] BADIER	86	BDMP	$\tau = (0.05$–$1.) \times 10^{-8}$s

[1] AAIJ 16AR search for long lived particles from $H \to XX$ with displaced X decay vertex using 0.62 fb^{-1} at 7 TeV; limits set in Fig. 7.
[2] KHACHATRYAN 16BW search for heavy stable charged particles via ToF with 2.5 fb^{-1} at 13 TeV; require stable m(gluinoball) > 1610 GeV.
[3] 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 $pp \to X^{++} n$. 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 ($\text{cm}^{-2}\text{sr}^{-1}\text{s}^{-1}$)		CL%	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •								
< 1	$\times 10^{-8}$	90	0	[1] AGNESE	15	CDM2		$Q = 1/6$
∼ 6	$\times 10^{-9}$		2	[2] SAITO	90			$Q \simeq 14$, $m \simeq 370 m_p$
< 1.4	$\times 10^{-12}$	90	0	[3] MINCER	85	CALO		$m \geq 1$ TeV
				[4] SAKUYAMA	83B	PLAS		$m \sim 1$ TeV
< 1.7	$\times 10^{-11}$	99	0	[5] BHAT	82	CC		
< 1.	$\times 10^{-9}$	90	0	[6] MARINI	82	CNTR	±	Q= 1, $m \sim 4.5 m_p$
2.	$\times 10^{-9}$		3	[7] YOCK	81	SPRK	±	Q= 1, $m \sim 4.5 m_p$
			3	[7] YOCK	81	SPRK		Fractionally charged
3.0	$\times 10^{-9}$		3	[8] YOCK	80	SPRK		$m \sim 4.5\ m_p$
(4 ±1)	$\times 10^{-11}$		3	GOODMAN	79	ELEC		$m \geq 5$ GeV
< 1.3	$\times 10^{-9}$	90		[9] 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	[10] 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] See AGNESE 15 Fig. 6 for limits extending down to Q = 1/200.

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

[3] 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.

[4] 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.

[5] BHAT 82 observed 12 events with delay $> 2.\times10^{-8}$ 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.

[6] 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.

[7] 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.

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

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

[10] YOCK 74 events could be tritons.

Superheavy Particle (Quark Matter) Flux in Cosmic Rays

VALUE ($cm^{-2}sr^{-1}s^{-1}$)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[1] ADRIANI	15	PMLA	$4 < m < 1.2 \times 10^5$ m_p
$<5 \times 10^{-16}$	90	[2] AMBROSIO	00B	MCRO	$m > 5 \times 10^{14}$ GeV
$<1.8 \times 10^{-12}$	90	[3] ASTONE	93	CNTR	$m \geq 1.5 \times 10^{-13}$ gram
$<1.1 \times 10^{-14}$	90	[4] AHLEN	92	MCRO	$10^{-10} < m < 0.1$ gram
$<2.2 \times 10^{-14}$	90	[5] NAKAMURA	91	PLAS	$m > 10^{11}$ GeV
$<6.4 \times 10^{-16}$	90	[6] ORITO	91	PLAS	$m > 10^{12}$ GeV
$<2.0 \times 10^{-11}$	90	[7] LIU	88	BOLO	$m > 1.5 \times 10^{-13}$ gram
$<4.7 \times 10^{-12}$	90	[8] BARISH	87	CNTR	$1.4 \times 10^8 < m < 10^{12}$ GeV
$<3.2 \times 10^{-11}$	90	[9] NAKAMURA	85	CNTR	$m > 1.5 \times 10^{-13}$ gram
$<3.5 \times 10^{-11}$	90	[10] ULLMAN	81	CNTR	Planck-mass 10^{19} GeV
$<7. \times 10^{-11}$	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 Table 1 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 (2.7×10^{-4}–5×10^{-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 ($m^{-2}yr^{-1}$)	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 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 $pp \rightarrow \gamma +$ jet
	[4] AAD	14AL	ATLS	8 TeV $pp \rightarrow \ell +$ jet
	[5] AAD	14C	ATLS	8 TeV $pp \rightarrow \ell + (\ell$ or jets)
	[6] AAD	13D	ATLS	7 TeV $pp \rightarrow$ 2 jets
	[7] CHATRCHYAN	13A	CMS	7 TeV $pp \rightarrow$ 2 jets
	[8] CHATRCHYAN	13AD	CMS	8 TeV $pp \rightarrow$ multijets
	[9] AAD	12AK	ATLS	7 TeV $pp \rightarrow \ell + (\ell$ or jets)
	[10] CHATRCHYAN	12W	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_{cm} = 8 TeV with L = 20.3 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_{cm} = 8 TeV with L = 20 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_{cm} = 8 TeV with L = 20.3 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 $\geq$ 2 (leptons or jets), in pp collisions at E_{cm} = 8 TeV with L = 20.3 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_{cm} = 7 TeV with L = 4.8 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_{cm} = 7 TeV with L = 5 fb^{-1}. See their Figs. 5 and 6 for limits.
[8] CHATRCHYAN 13AD search for microscopic (semiclassical) black hole formation followed by its evapolation to multiparticle final states, in multijet (including γ, ℓ) events in pp collisions at E_{cm} = 8 TeV with L = 12 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 $\geq$ 2 (leptons or jets), in pp collisions at E_{cm} = 7 TeV with L = 1.04 fb^{-1}. See their Fig. 4 and 5 for limits.

[10] CHATRCHYAN 12W search for microscopic (semiclassical) 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.

[11] 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.

REFERENCES FOR Other Particle Searches

AABOUD	17B	PL B765 32	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	17D	PR D95 032001	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	17L	JHEP 1708 052	M. Aaboud *et al.*	(ATLAS Collab.)
AAIJ	17BR	EPJ C77 812	R. Aaij *et al.*	(LHCb Collab.)
ABLIKIM	17AA	PL B774 252	M. Ablikim *et al.*	(BES III Collab.)
KHACHATRY...	17D	JHEP 1701 076	V. Khachatryan *et al.*	(CMS Collab.)
KHACHATRY...	17W	PL B769 520	V. Khachatryan *et al.*	(CMS Collab.)
KHACHATRY...	17Y	PL B770 257	V. Khachatryan *et al.*	(CMS Collab.)
SIRUNYAN	17B	JHEP 1704 136	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	17C	JHEP 1705 029	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	17F	JHEP 1707 013	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	17J	JHEP 1708 073	A.M. Sirunyan *et al.*	(CMS Collab.)
AABOUD	16	PL B759 229	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	16P	EPJ C76 541	M. Aaboud *et al.*	(ATLAS Collab.)
AAD	16AI	JHEP 1603 041	G. Aad *et al.*	(ATLAS Collab.)
AAD	16N	JHEP 1603 026	G. Aad *et al.*	(ATLAS Collab.)
AAD	16O	PL B760 520	G. Aad *et al.*	(ATLAS Collab.)
AAD	16R	PL B755 285	G. Aad *et al.*	(ATLAS Collab.)
AAD	16S	PL B754 302	G. Aad *et al.*	(ATLAS Collab.)
AAIJ	16AR	EPJ C76 664	R. Aaij *et al.*	(LHCb Collab.)
KHACHATRY...	16BW	PR D94 112004	V. Khachatryan *et al.*	(CMS Collab.)
KHACHATRY...	16K	PRL 116 071801	V. Khachatryan *et al.*	(CMS Collab.)
KHACHATRY...	16L	PRL 117 031802	V. Khachatryan *et al.*	(CMS Collab.)
KHACHATRY...	16M	PRL 117 051802	V. Khachatryan *et al.*	(CMS Collab.)
AAD	15AN	JHEP 1507 032	G. Aad *et al.*	(ATLAS Collab.)
AAD	15AT	EPJ C75 79	G. Aad *et al.*	(ATLAS Collab.)
AAD	15BJ	EPJ C75 362	G. Aad *et al.*	(ATLAS Collab.)
AAIJ	15BD	EPJ C75 595	R. Aaij *et al.*	(LHCb Collab.)
ADRIANI	15	PRL 115 111101	O. Adriani *et al.*	(PAMELA Collab.)
AGNESE	15	PRL 114 111302	R. Agnese *et al.*	(CDMS Collab.)
KHACHATRY...	15F	PRL 114 101801	V. Khachatryan *et al.*	(CMS Collab.)
LEES	15E	PRL 114 171801	J.P. Lees *et al.*	(BABAR Collab.)
AAD	14A	PL B728 562	G. Aad *et al.*	(ATLAS Collab.)
AAD	14AL	PRL 112 091804	G. Aad *et al.*	(ATLAS Collab.)
AAD	14C	JHEP 1408 103	G. Aad *et al.*	(ATLAS Collab.)
AALTONEN	14J	PR D89 092001	T. Aaltonen *et al.*	(CDF Collab.)
AAD	13A	PL B718 860	G. Aad *et al.*	(ATLAS Collab.)
AAD	13AH	PL B722 305	G. Aad *et al.*	(ATLAS Collab.)
AAD	13C	PRL 110 011802	G. Aad *et al.*	(ATLAS Collab.)
AAD	13D	JHEP 1301 029	G. Aad *et al.*	(ATLAS Collab.)
AALTONEN	13I	PR D88 031103	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	13R	PRL 111 031802	T. Aaltonen *et al.*	(CDF Collab.)
CHATRCHYAN	13	PL B718 815	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	13A	JHEP 1301 013	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	13AB	JHEP 1307 122	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	13AD	JHEP 1307 178	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	13AR	PR D87 092008	S. Chatrchyan *et al.*	(CMS Collab.)
AAD	12AK	PL B716 122	G. Aad *et al.*	(ATLAS Collab.)
AAD	12C	PRL 108 041805	G. Aad *et al.*	(ATLAS Collab.)
AAD	12S	PL B708 37	G. Aad *et al.*	(ATLAS Collab.)
AALTONEN	12M	PRL 108 211804	T. Aaltonen *et al.*	(CDF Collab.)
CHATRCHYAN	12AP	JHEP 1209 094	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12BL	JHEP 1212 015	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12Q	PL B716 260	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12T	PRL 108 261803	S. Chatrchyan *et al.*	(CMS Collab.)

CHATRCHYAN	12W	JHEP 1204 061	S. Chatrchyan *et al.*	(CMS Collab.)
AAD	11AG	NJP 13 053044	G. Aad *et al.*	(ATLAS Collab.)
AAD	11I	PL B698 353	G. Aad *et al.*	(ATLAS Collab.)
AAD	11S	PL B705 294	G. Aad *et al.*	(ATLAS Collab.)
AALTONEN	11AF	PRL 107 181801	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	11M	PRL 106 171801	T. Aaltonen *et al.*	(CDF Collab.)
ABAZOV	11I	PRL 107 011804	V.M. Abazov *et al.*	(D0 Collab.)
CHATRCHYAN	11C	JHEP 1106 026	S. Chatychyan *et al.*	(CMS Collab.)
CHATRCHYAN	11U	PRL 107 201804	S. Chatychyan *et al.*	(CMS Collab.)
AAD	10	PRL 105 161801	G. Aad *et al.*	(ATLAS Collab.)
AALTONEN	10AF	PR D82 052005	T. Aaltonen *et al.*	(CDF Collab.)
KHACHATRY...	10	PRL 105 211801	V. Khachatryan *et al.*	(CMS Collab.)
Also		PRL 106 029902	V. Khachatryan *et al.*	(CMS Collab.)
AALTONEN	09AF	PR D80 011102	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	09G	PR D79 052004	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	09Z	PRL 103 021802	T. Aaltonen *et al.*	(CDF Collab.)
ABAZOV	09M	PRL 102 161802	V.M. Abazov *et al.*	(D0 Collab.)
AKTAS	04C	EPJ C36 413	A. Atkas *et al.*	(H1 Collab.)
JAVORSEK	02	PR D65 072003	D. Javorsek II *et al.*	
JAVORSEK	01	PR D64 012005	D. Javorsek II *et al.*	
JAVORSEK	01B	PRL 87 231804	D. Javorsek II *et al.*	
ABBIENDI	00D	EPJ C13 197	G. Abbiendi *et al.*	(OPAL Collab.)
AMBROSIO	00B	EPJ C13 453	M. Ambrosio *et al.*	(MACRO Collab.)
ABE	99F	PRL 82 2038	F. Abe *et al.*	(CDF Collab.)
ACKERSTAFF	98P	PL B433 195	K. Ackerstaff *et al.*	(OPAL Collab.)
ABE	97G	PR D55 5263	F. Abe *et al.*	(CDF Collab.)
ABREU	97D	PL B396 315	P. Abreu *et al.*	(DELPHI Collab.)
ACKERSTAFF	97B	PL B391 210	K. Ackerstaff *et al.*	(OPAL Collab.)
ADAMS	97B	PRL 79 4083	J. Adams *et al.*	(FNAL KTeV Collab.)
BARATE	97K	PL B405 379	R. Barate *et al.*	(ALEPH Collab.)
AKERS	95R	ZPHY C67 203	R. Akers *et al.*	(OPAL Collab.)
GALLAS	95	PR D52 6	E. Gallas *et al.*	(MSU, FNAL, MIT, FLOR)
RAM	94	PR D49 3120	S. Ram *et al.*	(TELA, TRIU)
ABE	93G	PRL 71 2542	F. Abe *et al.*	(CDF Collab.)
ASTONE	93	PR D47 4770	P. Astone *et al.*	(ROMA, ROMAI, CATA, FRAS)
BUSKULIC	93C	PL B303 198	D. Buskulic *et al.*	(ALEPH Collab.)
YAMAGATA	93	PR D47 1231	T. Yamagata, Y. Takamori, H. Utsunomiya	(KONAN)
ABE	92J	PR D46 1889	F. Abe *et al.*	(CDF Collab.)
AHLEN	92	PRL 69 1860	S.P. Ahlen *et al.*	(MACRO Collab.)
VERKERK	92	PRL 68 1116	P. Verkerk *et al.*	(ENSP, SACL, PAST)
AKESSON	91	ZPHY C52 219	T. Akesson *et al.*	(HELIOS Collab.)
NAKAMURA	91	PL B263 529	S. Nakamura *et al.*	
ORITO	91	PRL 66 1951	S. Orito *et al.*	(ICEPP, WASCR, NIHO, ICRR)
ADACHI	90C	PL B244 352	I. Adachi *et al.*	(TOPAZ Collab.)
ADACHI	90E	PL B249 336	I. Adachi *et al.*	(TOPAZ Collab.)
AKRAWY	90O	PL B252 290	M.Z. Akrawy *et al.*	(OPAL Collab.)
HEMMICK	90	PR D41 2074	T.K. Hemmick *et al.*	(ROCH, MICH, OHIO+)
SAITO	90	PRL 65 2094	T. Saito *et al.*	(ICRR, KOBE)
NAKAMURA	89	PR D39 1261	T.T. Nakamura *et al.*	(KYOT, TMTC)
NORMAN	89	PR D39 2499	E.B. Norman *et al.*	(LBL)
BERNSTEIN	88	PR D37 3103	R.M. Bernstein *et al.*	(STAN, WISC)
LIU	88	PRL 61 271	G. Liu, B. Barish	
BARISH	87	PR D36 2641	B.C. Barish, G. Liu, C. Lane	(CIT)
NORMAN	87	PRL 58 1403	E.B. Norman, S.B. Gazes, D.A. Bennett	(LBL)
BADIER	86	ZPHY C31 21	J. Badier *et al.*	(NA3 Collab.)
MINCER	85	PR D32 541	A. Mincer *et al.*	(UMD, GMAS, NSF)
NAKAMURA	85	PL 161B 417	K. Nakamura *et al.*	(KEK, INUS)
THRON	85	PR D31 451	J.L. Thron *et al.*	(YALE, FNAL, IOWA)
SAKUYAMA	83B	LNC 37 17	H. Sakuyama, N. Suzuki	(MEIS)
Also		LNC 36 389	H. Sakuyama, K. Watanabe	(MEIS)
Also		NC 78A 147	H. Sakuyama, K. Watanabe	(MEIS)
Also		NC 6C 371	H. Sakuyama, K. Watanabe	(MEIS)
BHAT	82	PR D25 2820	P.N. Bhat *et al.*	(TATA)
KINOSHITA	82	PRL 48 77	K. Kinoshita, P.B. Price, D. Fryberger	(UCB+)
MARINI	82	PR D26 1777	A. Marini *et al.*	(FRAS, LBL, NWES, STAN+)
SMITH	82B	NP B206 333	P.F. Smith *et al.*	(RAL)
KINOSHITA	81B	PR D24 1707	K. Kinoshita, P.B. Price	(UCB)
LOSECCO	81	PL 102B 209	J.M. LoSecco *et al.*	(MICH, PENN, BNL)
ULLMAN	81	PRL 47 289	J.D. Ullman	(LEHM, BNL)
YOCK	81	PR D23 1207	P.C.M. Yock	(AUCK)
BARTEL	80	ZPHY C6 295	W. Bartel *et al.*	(JADE Collab.)

BUSSIERE	80	NP B174 1	A. Bussiere *et al.*	(BGNA, SACL, LAPP)
YOCK	80	PR D22 61	P.C.M. Yock	(AUCK)
ARMITAGE	79	NP B150 87	J.C.M. Armitage *et al.*	(CERN, DARE, FOM+)
BOZZOLI	79	NP B159 363	W. Bozzoli *et al.*	(BGNA, LAPP, SACL+)
GOODMAN	79	PR D19 2572	J.A. Goodman *et al.*	(UMD)
SMITH	79	NP B149 525	P.F. Smith, J.R.J. Bennett	(RHEL)
BHAT	78	PRAM 10 115	P.N. Bhat, P.V. Ramana Murthy	(TATA)
CARROLL	78	PRL 41 777	A.S. Carroll *et al.*	(BNL, PRIN)
CUTTS	78	PRL 41 363	D. Cutts *et al.*	(BROW, FNAL, ILL, BARI+)
VIDAL	78	PL 77B 344	R.A. Vidal *et al.*	(COLU, FNAL, STON+)
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	JP A5 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)