WIMPs and Other Particle Searches

OMITTED FROM SUMMARY TABLE

WIMPS AND OTHER PARTICLE SEARCHES

Revised October 1997 by K. Hikasa (Tohoku University).

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

1. Galactic WIMP (weakly-interacting massive particle) searches
2. Concentration of stable particles in matter
3. Limits on neutral particle production at accelerators
4. Limits on jet-jet resonance in hadron collisions
5. Limits on charged particles in e^+e^- collisions
6. Limits on charged particles in hadron reactions
7. Limits on charged particles in cosmic rays

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), heavy leptons, heavy neutrinos, free quarks, monopoles, supersymmetric particles, and compositeness. We include specific WIMP searches in the appropriate sections when they yield limits on hypothetical particles such as supersymmetric particles, axions, massive neutrinos, monopoles, *etc.*

We omit papers on CHAMP's, millicharged particles, and other exotic particles. We no longer list for limits on tachyons and centauros. See our 1994 edition for these limits.

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

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.

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. • • •					
		[1] BERNABEI	97	CNTR	F
< 0.8		ALESSAND...	96	CNTR	O
< 6		ALESSAND...	96	CNTR	Te
< 0.02	90	[2] BELLI	96	CNTR	^{129}Xe, inel.
		[3] BELLI	96C	CNTR	^{129}Xe
< 0.004	90	[4] BERNABEI	96	CNTR	Na
< 0.3	90	[4] BERNABEI	96	CNTR	I
< 0.2	95	[5] SARSA	96	CNTR	Na
< 0.015	90	[6] SMITH	96	CNTR	Na
< 0.05	95	[7] GARCIA	95	CNTR	Natural Ge
< 0.1	95	QUENBY	95	CNTR	Na
<90	90	[8] SNOWDEN-...	95	MICA	^{16}O
< 4 $\times 10^3$	90	[8] SNOWDEN-...	95	MICA	^{39}K
< 0.7	90	BACCI	92	CNTR	Na
< 0.12	90	[9] REUSSER	91	CNTR	Natural Ge
< 0.06	95	CALDWELL	88	CNTR	Natural Ge

[1] BERNABEI 97 give $\sigma < 12$ pb (90%CL) for the spin-dependent X^0-proton cross section.

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

[3] BELLI 96C use background subtraction and obtain $\sigma < 150$ pb (< 1.5 fb) (?%CL) for spin-dependent (independent) X^0-proton cross section.

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

[5] 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.

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

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

[8] 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.

[9] 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. • • •				
		[10] BERNABEI 97	CNTR	F
$<$ 4		ALESSAND... 96	CNTR	O
$<$25		ALESSAND... 96	CNTR	Te
$<$ 0.006	90	[11] BELLI 96	CNTR	^{129}Xe, inel.
		[12] BELLI 96C	CNTR	^{129}Xe
$<$ 0.001	90	[13] BERNABEI 96	CNTR	Na
$<$ 0.3	90	[13] BERNABEI 96	CNTR	I
$<$ 0.7	95	[14] SARSA 96	CNTR	Na
$<$ 0.03	90	[15] SMITH 96	CNTR	Na
$<$ 0.8	90	[15] SMITH 96	CNTR	I
$<$ 0.35	95	[16] GARCIA 95	CNTR	Natural Ge
$<$ 0.6	95	QUENBY 95	CNTR	Na
$<$ 3	95	QUENBY 95	CNTR	I
$<$ 1.5 $\times 10^2$	90	[17] SNOWDEN-... 95	MICA	^{16}O
$<$ 4 $\times 10^2$	90	[17] SNOWDEN-... 95	MICA	^{39}K
$<$ 0.08	90	[18] BECK 94	CNTR	^{76}Ge
$<$ 2.5	90	BACCI 92	CNTR	Na
$<$ 3	90	BACCI 92	CNTR	I
$<$ 0.9	90	[19] REUSSER 91	CNTR	Natural Ge
$<$ 0.7	95	CALDWELL 88	CNTR	Natural Ge

[10] BERNABEI 97 give $\sigma < 5$ pb (90%CL) for the spin-dependent X^0-proton cross section.

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

[12] BELLI 96C use background subtraction and obtain $\sigma < 0.35$ pb ($<$ 0.15 fb) (?%CL) for spin-dependent (independent) X^0-proton cross section.

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

[14] 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.

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

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

[17] 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.

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

[19] 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. • • •				
		[20] BERNABEI 97	CNTR	F
$<$ 40		ALESSAND... 96	CNTR	O
$<$700		ALESSAND... 96	CNTR	Te
$<$ 0.05	90	[21] BELLI 96	CNTR	^{129}Xe, inel.
$<$ 1.5	90	[22] BELLI 96	CNTR	^{129}Xe, inel.

			[23] BELLI	96C	CNTR	^{129}Xe
$<$ 0.01		90	[24] BERNABEI	96	CNTR	Na
$<$ 9		90	[24] BERNABEI	96	CNTR	I
$<$ 7		95	[25] SARSA	96	CNTR	Na
$<$ 0.3		90	[26] SMITH	96	CNTR	Na
$<$ 6		90	[26] SMITH	96	CNTR	I
$<$ 6		95	[27] GARCIA	95	CNTR	Natural Ge
$<$ 8		95	QUENBY	95	CNTR	Na
$<$ 50		95	QUENBY	95	CNTR	I
$<$ 7	$\times 10^2$	90	[28] SNOWDEN-...	95	MICA	^{16}O
$<$ 1	$\times 10^3$	90	[28] SNOWDEN-...	95	MICA	^{39}K
$<$ 0.8		90	[29] BECK	94	CNTR	^{76}Ge
$<$ 30		90	BACCI	92	CNTR	Na
$<$ 30		90	BACCI	92	CNTR	I
$<$ 15		90	[30] REUSSER	91	CNTR	Natural Ge
$<$ 6		95	CALDWELL	88	CNTR	Natural Ge

[20] BERNABEI 97 give $\sigma < 32$ pb (90%CL) for the spin-dependent X^0-proton cross section.

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

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

[23] BELLI 96C use background subtraction and obtain $\sigma < 0.7$ pb (< 0.7 fb) (?%CL) for spin-dependent (independent) X^0-proton cross section.

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

[25] 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.

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

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

[28] 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.

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

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

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	[31] YAMAGATA	93	SPEC	Deep sea water, m=5–1600m_p
$<6 \times 10^{-15}$	95	[32] VERKERK	92	SPEC	Water, $m= 10^5$ to 3×10^7 GeV
$<7 \times 10^{-15}$	95	[32] VERKERK	92	SPEC	Water, $m= 10^4$, 6×10^7 GeV
$<9 \times 10^{-15}$	95	[32] VERKERK	92	SPEC	Water, $m= 10^8$ GeV
$<3 \times 10^{-23}$	90	[33] HEMMICK	90	SPEC	Water, $m = 1000m_p$
$<2 \times 10^{-21}$	90	[33] HEMMICK	90	SPEC	Water, $m = 5000m_p$
$<3 \times 10^{-20}$	90	[33] 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

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

[32] 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.

[33] See HEMMICK 90 Fig. 7 for other masses 100–10000 m_p.

Concentration of Heavy (Charge −1) Stable Particles

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<4 \times 10^{-20}$	90	[34] HEMMICK	90	SPEC	C, $M = 100m_p$
$<8 \times 10^{-20}$	90	[34] HEMMICK	90	SPEC	C, $M = 1000m_p$
$<2 \times 10^{-16}$	90	[34] HEMMICK	90	SPEC	C, $M = 10000m_p$
$<6 \times 10^{-13}$	90	[34] HEMMICK	90	SPEC	Li, $M = 1000m_p$
$<1 \times 10^{-11}$	90	[34] HEMMICK	90	SPEC	Be, $M = 1000m_p$
$<6 \times 10^{-14}$	90	[34] HEMMICK	90	SPEC	B, $M = 1000m_p$
$<4 \times 10^{-17}$	90	[34] HEMMICK	90	SPEC	O, $M = 1000m_p$
$<4 \times 10^{-15}$	90	[34] HEMMICK	90	SPEC	F, $M = 1000m_p$
$< 1.5 \times 10^{-13}$/nucleon	68	[35] NORMAN	89	SPEC	^{206}PbX^-
$< 1.2 \times 10^{-12}$/nucleon	68	[35] NORMAN	87	SPEC	^{56,58}FeX^-

[34] See HEMMICK 90 Fig. 7 for other masses 100–10000 m_p.

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

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. • • •					
<(2.5–0.5)	95	[36] ACKERSTAFF	97B	OPAL	$e^+e^- \rightarrow X^0 Y^0$, $X^0 \rightarrow Y^0\gamma$
<(1.6–0.9)	95	[37] ACKERSTAFF	97B	OPAL	$e^+e^- \rightarrow X^0 X^0$, $X^0 \rightarrow Y^0\gamma$

[36] ACKERSTAFF 97B associated production limit is for m_{X^0} = 80–160 GeV, m_{Y^0}=0 from 10.0 pb^{-1} at $\sqrt{s}$ = 161 GeV. See their Fig. 3(a).

[37] ACKERSTAFF 97B pair production limit is for m_{X^0} = 40–80 GeV, m_{Y^0}=0 from 10.0 pb^{-1} at $\sqrt{s}$ = 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. • • •						
$< 10^{-36}$–10^{-33}	90		[38] GALLAS	95	TOF	m= 0.5–20 GeV
$<(4$–$0.3)\times 10^{-31}$	95		[39] AKESSON	91	CNTR	m = 0–5 GeV
$<2 \times 10^{-36}$	90	0	[40] BADIER	86	BDMP	$\tau = (0.05$–$1.) \times 10^{-8}$s
$<2.5 \times 10^{-35}$		0	[41] GUSTAFSON	76	CNTR	$\tau > 10^{-7}$ s

[38] 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.

[39] 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.

[40] 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.

[41] 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. • • •				
	[42] LOSECCO	81	CALO	28 GeV protons

[42] 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 JET-JET RESONANCES

Heavy Particle Production Cross Section in $p\overline{p}$

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. • • •						
			[43] ABE	97G	CDF	1.8 TeV $p\overline{p} \to$ 2 jets
<2603	95	200	[44] ABE	93G	CDF	1.8 TeV $p\overline{p} \to$ 2jets
< 44	95	400	[44] ABE	93G	CDF	1.8 TeV $p\overline{p} \to$ 2jets
< 7	95	600	[44] ABE	93G	CDF	1.8 TeV $p\overline{p} \to$ 2jets

[43] ABE 97G search for narrow dijet resonances in $p\overline{p}$ collisions with 106 pb^{-1} of data at $\sqrt{s} = 1.8$ TeV. Limits on $\sigma(p\overline{p} \to X+\text{anything})\cdot B(X \to jj)$ 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.

[44] ABE 93G gives cross section times branching ratio into light (d, u, s, c, b) quarks for $\Gamma = 0.02\,M$. Their Table II gives limits for M = 200–900 GeV and Γ = (0.02–0.2) M.

LIMITS ON CHARGED PARTICLES IN e^+e^-

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

Ratio to $\sigma(e^+e^- \to \mu^+\mu^-)$ 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. • • •						
			[45] ABREU	97D	DLPH	Q=1,2/3, m=45–84 GeV
			[46] BARATE	97K	ALEP	Q=1, m=45–85 GeV
$<2 \times 10^{-5}$	95		[47] AKERS	95R	OPAL	Q=1, m= 5–45 GeV
$<1 \times 10^{-5}$	95		[47] AKERS	95R	OPAL	Q=2, m= 5–45 GeV
$<2 \times 10^{-3}$	90		[48] BUSKULIC	93C	ALEP	Q=1, m=32–72 GeV
$<(10^{-2}$–$1)$	95		[49] ADACHI	90C	TOPZ	$Q = 1$, m = 1–16, 18–27 GeV
$<7 \times 10^{-2}$	90		[50] ADACHI	90E	TOPZ	$Q = 1$, m = 5–25 GeV
$<1.6 \times 10^{-2}$	95	0	[51] KINOSHITA	82	PLAS	Q=3–180, m <14.5 GeV
$<5.0 \times 10^{-2}$	90	0	[52] BARTEL	80	JADE	Q=(3,4,5)/3 2–12 GeV

[45] ABREU 97D search for pair production of long-lived particles and give limits $\sigma <$(0.4–2.3) pb (95%CL) for various center-of-mass energies $\sqrt{s}$=130–136, 161, and 172 GeV, assuming an almost flat production distribution in $\cos\theta$.

[46] BARATE 97K search for pair production of long-lived charged particles at $\sqrt{s}$ = 130, 136, 161, and 172 GeV and give limits $\sigma <$(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 $\sqrt{s}$=172 GeV with the $\sqrt{s}$ dependence described in the paper. See their Figs. 2 and 3 for limits on $J = 1/2$ and $J = 0$ cases.

[47] 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 $\sigma(e^+e^- \to \text{hadrons})$. Constant phase space distribution is assumed. See their Fig. 3 for bounds for $Q = \pm 2/3$, $\pm 4/3$.

[48] 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.

[49] 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.

[50] 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.

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

[52] 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	[53] AKERS	95R	OPAL	m= 40.4–45.6 GeV
$<1 \times 10^{-3}$	95	AKRAWY	90O	OPAL	m = 29–40 GeV

[53] 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%*	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<0.05	95		[54] ABE	92J	CDF	m=50–200 GeV
<30–130			[55] CARROLL	78	SPEC	m=2–2.5 GeV
<100		0	[56] LEIPUNER	73	CNTR	m=3–11 GeV

[54] 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.

[55] 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.

[56] 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%*	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$<2.6 \times 10^{-36}$	90	0	[57] BALDIN	76	CNTR	−	Q= 1, m=2.1–9.4 GeV
$<2.2 \times 10^{-33}$	90	0	[58] ALBROW	75	SPEC	±	Q= ±1, m=4–15 GeV
$<1.1 \times 10^{-33}$	90	0	[58] ALBROW	75	SPEC	±	Q= ±2, m=6–27 GeV
$<8. \times 10^{-35}$	90	0	[59] JOVANOV...	75	CNTR	±	m=15–26 GeV
$<1.5 \times 10^{-34}$	90	0	[59] JOVANOV...	75	CNTR	±	Q= ±2, m=3–10 GeV
$<6. \times 10^{-35}$	90	0	[59] JOVANOV...	75	CNTR	±	Q= ±2, m=10–26 GeV
$<1. \times 10^{-31}$	90	0	[60] APPEL	74	CNTR	±	m=3.2–7.2 GeV

$<5.8 \times 10^{-34}$	90	0	[61] ALPER	73	SPEC	$\pm$	m=1.5–24 GeV
$<1.2 \times 10^{-35}$	90	0	[62] ANTIPOV	71B	CNTR	$-$	Q=$-$, m=2.2–2.8
$<2.4 \times 10^{-35}$	90	0	[63] ANTIPOV	71C	CNTR	$-$	Q=$-$, m=1.2–1.7, 2.1–4
$<2.4 \times 10^{-35}$	90	0	BINON	69	CNTR	$-$	Q=$-$, m=1–1.8 GeV
$<1.5 \times 10^{-36}$		0	[64] DORFAN	65	CNTR		Be target m=3–7 GeV
$<3.0 \times 10^{-36}$		0	[64] DORFAN	65	CNTR		Fe target m=3–7 GeV

[57] 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.

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

[59] 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.

[60] 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.

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

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

[63] ANTIPOV 71C limit inferred from flux ratio. 70 GeV p experiment.

[64] 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 ($\text{cm}^2/\text{GeV}^2/N$)	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$< 5 \times 10^{-35}$–7×10^{-33}	90	0	[65] BERNSTEIN	88	CNTR		
$< 5 \times 10^{-37}$–7×10^{-35}	90	0	[65] BERNSTEIN	88	CNTR		
$<2.5 \times 10^{-36}$	90	0	[66] THRON	85	CNTR	$-$	Q= 1, m=4–12 GeV
$<1. \times 10^{-35}$	90	1	[66] THRON	85	CNTR	$+$	Q= 1, m=4–12 GeV
$<6. \times 10^{-33}$	90	0	[67] ARMITAGE	79	SPEC		m=1.87 GeV
$<1.5 \times 10^{-33}$	90	0	[67] ARMITAGE	79	SPEC		m=1.5–3.0 GeV
		0	[68] BOZZOLI	79	CNTR	$\pm$	$Q = (2/3, 1, 4/3, 2)$
$<1.1 \times 10^{-37}$	90	0	[69] CUTTS	78	CNTR		m=4–10 GeV
$<3.0 \times 10^{-37}$	90	0	[70] VIDAL	78	CNTR		m=4.5–6 GeV

[65] 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.

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

[67] 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.
[68] 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.
[69] 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 $p_T = 0.175$.
[70] 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. • • •						
$<10^{-8}$		[71] NAKAMURA	89	SPEC	$\pm$	$Q = (-5/3, \pm 2)$
	0	[72] BUSSIERE	80	CNTR	$\pm$	$Q = (2/3, 1, 4/3, 2)$

[71] 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.
[72] 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	[73] ALEKSEEV	76	ELEC	τ=5 ms to 1 day
<200 to 2000	0	[73] ALEKSEEV	76B	ELEC	τ=100 ms to 1 day
<1.4 to 9	0	[74] FRANKEL	75	CNTR	τ=50 ms to 10 hours
<0.1 to 9	0	[75] FRANKEL	74	CNTR	τ=1 to 1000 hours

[73] ALEKSEEV 76 and ALEKSEEV 76B are 61–70 GeV p Serpukhov experiment. Cross section is per Pb nucleus.
[74] FRANKEL 75 is extension of FRANKEL 74.
[75] 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	[76] BADIER	86	BDMP	$\tau = (0.05\text{–}1.) \times 10^{-8}$s

[76] 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	[77] RAM	94	SPEC	$1015 < m_{X^{++}} < 1085$ MeV
<75	95	[77] RAM	94	SPEC	$920 < m_{X^{++}} < 1025$ MeV

[77] RAM 94 search for a long-lived doubly-charged fermion X^{++} with mass between m_N and $m_N + m_\pi$ and baryon number +1 in the reaction $pp \rightarrow X^{++} n$. No candidate is found. The limit is for the cross section at 15° scattering angle at 460 MeV incident energy and applies for $\tau(X^{++}) \gg 0.1\,\mu$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	[78] SAITO	90			$Q \simeq 14$, $m \simeq 370 m_p$
$< 1.4 \times 10^{-12}$	90	0	[79] MINCER	85	CALO		$m \geq 1$ TeV
			[80] SAKUYAMA	83B	PLAS		$m \sim 1$ TeV
$< 1.7 \times 10^{-11}$	99	0	[81] BHAT	82	CC		
$< 1. \times 10^{-9}$	90	0	[82] MARINI	82	CNTR	±	$Q = 1$, $m \sim 4.5 m_p$
$2. \times 10^{-9}$		3	[83] YOCK	81	SPRK	±	$Q = 1$, $m \sim 4.5 m_p$
		3	[83] YOCK	81	SPRK		Fractionally charged
3.0×10^{-9}		3	[84] 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		[85] 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	[86] 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

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

[79] 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.

[80] 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.

[81] 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.
[82] 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.
[83] YOCK 81 saw another 3 events with $Q = \pm 1$ and m about $4.5 m_p$ as well as 2 events with $m > 5.3 m_p$, $Q = \pm 0.75 \pm 0.05$ and $m > 2.8 m_p$, $Q = \pm 0.70 \pm 0.05$ and 1 event with $m = (9.3 \pm 3.) m_p$, $Q = \pm 0.89 \pm 0.06$ as possible heavy candidates.
[84] YOCK 80 events are with charge exactly or approximately equal to unity.
[85] BHAT 78 is at Kolar gold fields. Limit is for $\tau > 10^{-6}$ s.
[86] YOCK 74 events could be tritons.

Superheavy Particle (Quark Matter) Flux in Cosmic Rays

VALUE ($cm^{-2}sr^{-1}s^{-1}$)	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$<1.8 \times 10^{-12}$	90		[87] ASTONE	93	CNTR	$m \geq 1.5 \times 10^{-13}$gram
$<1.1 \times 10^{-14}$	90		[88] AHLEN	92	MCRO	$10^{-10} < m < 0.1$ gram
$<3.2 \times 10^{-11}$	90	0	[89] NAKAMURA	85	CNTR	$m > 1.5 \times 10^{-13}$gram
$<3.5 \times 10^{-11}$	90	0	[90] ULLMAN	81	CNTR	Planck-mass 10^{19}GeV
$<7. \times 10^{-11}$	90	0	[90] ULLMAN	81	CNTR	$m \leq 10^{16}$ GeV

[87] ASTONE 93 searched for quark matter ("nuclearites") in the velocity/c range = 10^{-3}–1. Their Table 1 gives a compilation of searches for nuclearites.
[88] AHLEN 92 searched for quark matter ("nuclearites"). The bound applies to velocity/c $< 2.5 \times 10^{-3}$. See their Fig. 3 for other velocity/c and heavier mass range.
[89] 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/c of 10^{-4}–10^{-3}.
[90] 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

REFERENCES FOR WIMPs and Other Particle Searches

ABE 97G PR D55 R5263 +Akimoto, Akopian, Albrow, Amendolia+ (CDF Collab.)
ABREU 97D PL B396 315 P. Abreu+ (DELPHI Collab.)
ACKERSTAFF 97B PL B391 210 K. Ackerstaff+ (OPAL Collab.)
BARATE 97K PL B405 379 R. Barate+ (ALEPH Collab.)
BERNABEI 97 ASP 7 73 R. Bernabei+
SARSA 97 PR D56 1856 M.L. Sarsa+ (ZARA)
ALESSAND... 96 PL B384 316 Alessandrello, Brofferio, Camin+ (MILA, MILAI, SASSO)
BELLI 96 PL B387 222 + (ROMA2, ROMAI, ROMA, ROMA3, BHEP)
Also 96B PL B389 783 (erratum) P. Belli+
BELLI 96C NC 19C 537 P. Belli+ (ROMA2, ROMAI, ROMA3, SASSO, BHEP)
BERNABEI 96 PL B389 757 + (ROMA2, ROMAI, ROMA, ROMA3, BHEP+)
COLLAR 96 PRL 76 331 (SCUC)
SARSA 96 PL B386 458 +Morales, Morales, Garcia+ (ZARA)
Also 97 PR D56 1856 M.L. Sarsa+ (ZARA)
SMITH 96 PL B379 299 +Arnison+ (RAL, SHEF, LOIC, BIRK, NOTT)
SNOWDEN-... 96 PRL 76 332 Snowden-Ifft, Freeman, Price (UCB)
AKERS 95R ZPHY C67 203 +Alexander, Allison, Ametewee, Anderson+ (OPAL Collab.)
GALLAS 95 PR D52 6 +Abolins, Brock, Cobau+ (MSU, FNAL, MIT, FLOR)
GARCIA 95 PR D51 1458 +Morales, Morales, Sarsa+ (ZARA, SCUC, PNL)
QUENBY 95 PL B351 70 +Sumner+ (LOIC, RAL, SHEF, BIRK, NOTT, RHBL)
SNOWDEN-... 95 PRL 74 4133 Snowden-Ifft, Freeman, Price (UCB)
Also 96 PRL 76 331 Collar (SCUC)
Also 96 PRL 76 332 Snowden-Ifft, Freeman, Price (UCB)
BECK 94 PL B336 141 +Bensch, Bockholt+ (MPIH, KIAE, SASSO)
RAM 94 PR D49 3120 +Abegg, Ashery, Frekers, Helmer+ (TELA, TRIU)
ABE 93G PRL 71 2542 +Albrow, Akimoto, Amidei, Anway-Wiese+ (CDF Collab.)
ASTONE 93 PR D47 4770 +Bassan, Bonifazi, Coccia+(ROMA, ROMAI, CATA, FRAS)
BUSKULIC 93C PL B303 198 +Decamp, Goy, Lees, Minard+ (ALEPH Collab.)
YAMAGATA 93 PR D47 1231 +Takamori, Utsunomiya (KONAN)
ABE 92J PR D46 R1889 +Amidei, Anway-Weiss+ (CDF Collab.)
AHLEN 92 PRL 69 1860 +Ambrosio, Antolini, Auriemma, Baker+ (MACRO Collab.)
BACCI 92 PL B293 460 +Belli, Bernabei+ (Beijing-Roma-Saclay Collab.)
VERKERK 92 PRL 68 1116 +Grynberg, Pichard, Spiro, Zylberajch+(ENSP, SACL, PAST)
AKESSON 91 ZPHY C52 219 +Almehed, Angelis, Atherton, Aubry+ (HELIOS Collab.)
REUSSER 91 PL B255 143 +Treichel, Boehm, Broggini+ (NEUC, CIT, PSI)
ADACHI 90C PL B244 352 +Aihara, Doser, Enomoto+ (TOPAZ Collab.)
ADACHI 90E PL B249 336 +Anazawa, Doser, Enomoto, Fujii+ (TOPAZ Collab.)
AKRAWY 90O PL B252 290 +Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
HEMMICK 90 PR D41 2074 +Elmore+ (ROCH, MICH, OHIO, RAL, LANL, STON)
SAITO 90 PRL 65 2094 +Hatano, Fukada, Oda (ICRR, KOBE)
NAKAMURA 89 PR D39 1261 +Kobayashi, Konaka, Imai, Masaike+ (KYOT, TMTC)
NORMAN 89 PR D39 2499 +Chadwick, Lesko, Larimer, Hoffman (LBL)
BERNSTEIN 88 PR D37 3103 +Shea, Winstein, Cousins, Greenhalgh+ (STAN, WISC)
CALDWELL 88 PRL 61 510 +Eisberg, Grumm, Witherell+ (UCSB, UCB, LBL)
NORMAN 87 PRL 58 1403 +Gazes, Bennett (LBL)
BADIER 86 ZPHY C31 21 +Bemporad, Boucrot, Callot+ (NA3 Collab.)
MINCER 85 PR D32 541 +Freudenreich, Goodman+ (UMD, GMAS, NSF)
NAKAMURA 85 PL 161B 417 +Horie, Takahashi, Tanimori (KEK, INUS)
THRON 85 PR D31 451 +Cardello, Cooper, Teig+ (YALE, FNAL, IOWA)
SAKUYAMA 83B LNC 37 17 +Nuzuki (MEIS)
Also 83 LNC 36 389 Sakuyama, Watanabe (MEIS)
Also 83D NC 78A 147 Sakuyama, Watanabe (MEIS)
Also 83C NC 6C 371 Sakuyama, Watanabe (MEIS)
BHAT 82 PR D25 2820 +Gupta, Murthy, Sreekantan+ (TATA)
KINOSHITA 82 PRL 48 77 +Price, Fryberger (UCB, SLAC)
MARINI 82 PR D26 1777 +Peruzzi, Piccolo+ (FRAS, LBL, NWES, STAN, HAWA)
SMITH 82B NP B206 333 +Bennett, Homer, Lewin, Walford, Smith (RAL)
KINOSHITA 81B PR D24 1707 +Price (UCB)
LOSECCO 81 PL 102B 209 +Sulak, Galik, Horstkotte+ (MICH, PENN, BNL)
ULLMAN 81 PRL 47 289 (LEHM, BNL)
YOCK 81 PR D23 1207 (AUCK)
BARTEL 80 ZPHY C6 295 +Canzler, Lords, Drumm+ (JADE Collab.)
BUSSIERE 80 NP B174 1 +Giacomelli, Lesquoy+ (BGNA, SACL, LAPP)
YOCK 80 PR D22 61 (AUCK)
ARMITAGE 79 NP B150 87 +Benz, Bobbink+ (CERN, DARE, FOM, MCHS, UTRE)

BOZZOLI	79	NP B159 363	+Bussiere, Giacomelli+	(BGNA, LAPP, SACL, CERN)
GOODMAN	79	PR D19 2572	+Ellsworth, Ito, Macfall, Siohan+	(UMD)
SMITH	79	NP B149 525	+Bennett	(RHEL)
BHAT	78	Pramana 10 115	+Murthy	(TATA)
CARROLL	78	PRL 41 777	+Chiang, Johnson, Kycia, Ki+	(BNL, PRIN)
CUTTS	78	PRL 41 363	+Dulude+	(BROW, FNAL, ILL, BARI, MIT, WARS)
VIDAL	78	PL 77B 344	+Herb, Lederman+	(COLU, FNAL, STON, UCB)
ALEKSEEV	76	SJNP 22 531	+Zaitsev, Kalinina, Kruglov+	(JINR)
		Translated from YAF 22 1021.		
ALEKSEEV	76B	SJNP 23 633	+Zaitsev, Kalinina, Kruglov+	(JINR)
		Translated from YAF 23 1190.		
BALDIN	76	SJNP 22 264	+Vertogradov, Vishnevsky, Grishkevich+	(JINR)
		Translated from YAF 22 512.		
BRIATORE	76	NC 31A 553	+Dardo, Piazzoli, Mannocchi+	(LCGT, FRAS, FREIB)
GUSTAFSON	76	PRL 37 474	+Ayre, Jones, Longo, Murthy	(MICH)
ALBROW	75	NP B97 189	+Barber+	(CERN, DARE, FOM, LANC, MCHS, UTRE)
FRANKEL	75	PR D12 2561	+Frati, Resvanis, Yang, Nezrick	(PENN, FNAL)
JOVANOV...	75	PL 56B 105	Jovanovich+	(MANI, AACH, CERN, GENO, HARV+)
YOCK	75	NP B86 216		(AUCK, SLAC)
APPEL	74	PRL 32 428	+Bourquin, Gaines, Lederman+	(COLU, FNAL)
FRANKEL	74	PR D9 1932	+Frati, Resvanis, Yang, Nezrick	(PENN, FNAL)
YOCK	74	NP B76 175		(AUCK)
ALPER	73	PL 46B 265	+	(CERN, LIVP, LUND, BOHR, RHEL, STOH, BERG+)
LEIPUNER	73	PRL 31 1226	+Larsen, Sessoms, Smith, Williams+	(BNL, YALE)
DARDO	72	NC 9A 319	+Navarra, Penengo, Sitte	(TORI)
TONWAR	72	JPA 5 569	+Naranan, Sreekantan	(TATA)
ANTIPOV	71B	NP B31 235	+Denisov, Donskov, Gorin, Kachanov+	(SERP)
ANTIPOV	71C	PL 34B 164	+Denisov, Donskov, Gorin, Kachanov+	(SERP)
BINON	69	PL 30B 510	+Duteil, Kachanov, Khromov, Kutyin+	(SERP)
BJORNBOE	68	NC B53 241	+Damgard, Hansen+	(BOHR, TATA, BERN, BERG)
JONES	67	PR 164 1584		(MICH, WISC, LBL, UCLA, MINN, COSU, COLO+)
DORFAN	65	PRL 14 999	+Eades, Lederman, Lee, Ting	(COLU)