Magnetic Monopole Searches

MAGNETIC MONOPOLE SEARCHES

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Although the usual formulation of Maxwell's equations suggests magnetic monopoles, no observed phenomenon requires them for explanation [1]. A monopole anywhere in the universe results in electric charge quantization everywhere, and leads to the prediction of a least magnetic charge $G = e/2\alpha$, the Dirac charge [2]. Recently monopoles have become indispensable in many gauge theories, which endow them with a variety of extraordinarily large masses.

Monopole detectors have predominantly used either induction or ionization. Induction experiments measure the monopole magnetic charge and are independent of monopole electric charge, mass, and velocity. Monopole candidate events (CABRERA 82, CAPLIN 86) in single semiconductor loops have been detected by this method, but no two-loop coincidence has been observed. Ionization experiments rely on a magnetic charge producing more ionization than an electrical charge with the same velocity. However, the ability to distinguish a monopole by ionization diminishes with velocity.

Cosmic rays are the most likely source of massive monopoles, since accelerator energies are insufficient to produce them. Evidence for such monopoles may also be obtained from astrophysical observations.

This compilation is only a guide to the literature, since the quoted experimental limits are often only indicative.

References

1. J.D. Jackson, CERN-77-17 (1977).
2. P.A.M. Dirac, Proc. Royal Soc. London **A133**, 60 (1931).

Monopole Production Cross Section — Accelerator Searches

X-SECT (cm^2)	MASS (GeV)	CHG (g)	ENERGY (GeV)	BEAM	EVTS	DOCUMENT ID		TECN
	<510			e^+e^-		[1] ACCIARRI	95C	L3
<3.E−37	<45.0	1.0	88–94	e^+e^-	0	PINFOLD	93	PLAS
<3.E−37	<41.6	2.0	88–94	e^+e^-	0	PINFOLD	93	PLAS
<7.E−35	<44.9	0.2–1.0	89–93	e^+e^-	0	KINOSHITA	92	PLAS
<2.E−34	<850	≥ 0.5	1800	$p\overline{p}$	0	BERTANI	90	PLAS
<1.2E−33	<800	≥ 1	1800	$p\overline{p}$	0	PRICE	90	PLAS
<1.E−37	<29	1	50–61	e^+e^-	0	KINOSHITA	89	PLAS
<1.E−37	<18	2	50–61	e^+e^-	0	KINOSHITA	89	PLAS
<1.E−38	<17	<1	35	e^+e^-	0	BRAUNSCH...	88B	CNTR
<8.E−37	<24	1	50–52	e^+e^-	0	KINOSHITA	88	PLAS
<1.3E−35	<22	2	50–52	e^+e^-	0	KINOSHITA	88	PLAS
<9.E−37	<4	<0.15	10.6	e^+e^-	0	GENTILE	87	CLEO

<3.E−32	<800	≥ 1	1800	$p\overline{p}$	0	PRICE	87	PLAS
<3.E−38		<3	29	$e^+ e^-$	0	FRYBERGER	84	PLAS
<1.E−31		1,3	540	$p\overline{p}$	0	AUBERT	83B	PLAS
<4.E−38	<10	<6	34	$e^+ e^-$	0	MUSSET	83	PLAS
<8.E−36	<20		52	$p p$	0	[2] DELL	82	CNTR
<9.E−37	<30	<3	29	$e^+ e^-$	0	KINOSHITA	82	PLAS
<1.E−37	<20	<24	63	$p p$	0	CARRIGAN	78	CNTR
<1.E−37	<30	<3	56	$p p$	0	HOFFMANN	78	PLAS
			62	$p p$	0	[2] DELL	76	SPRK
<4.E−33			300	p	0	[2] STEVENS	76B	SPRK
<1.E−40	<5	<2	70	p	0	[3] ZRELOV	76	CNTR
<2.E−30			300	n	0	[2] BURKE	75	OSPK
<1.E−38			8	ν	0	[4] CARRIGAN	75	HLBC
<5.E−43	<12	<10	400	p	0	EBERHARD	75B	INDU
<2.E−36	<30	<3	60	$p p$	0	GIACOMELLI	75	PLAS
<5.E−42	<13	<24	400	p	0	CARRIGAN	74	CNTR
<6.E−42	<12	<24	300	p	0	CARRIGAN	73	CNTR
<2.E−36		1	.001	γ	0	[3] BARTLETT	72	CNTR
<1.E−41	<5		70	p	0	GUREVICH	72	EMUL
<1.E−40	<3	<2	28	p	0	AMALDI	63	EMUL
<2.E−40	<3	<2	30	p	0	PURCELL	63	CNTR
<1.E−35	<3	<4	28	p	0	FIDECARO	61	CNTR
<2.E−35	<1	1	6	p	0	BRADNER	59	EMUL

[1] ACCIARRI 95C finds a limit B($Z \to \gamma\gamma\gamma$) $< 0.8 \times 10^{-5}$ (which is possible via a monopole loop) at 95% CL and sets the mass limit via a cross section model.

[2] Multiphoton events.

[3] Cherenkov radiation polarization.

[4] Re-examines CERN neutrino experiments.

Monopole Flux — Cosmic Ray Searches

FLUX (cm^{-2}sr^{-1}s^{-1})	*MASS* (GeV)	*CHG* (g)	*COMMENTS* ($\beta = v/c$)	*EVTS*	*DOCUMENT ID*		*TECN*
<5.6E−15		1	1.8E−4 < β <3.E−3	0	[5] AHLEN	94	MCRO
<2.7E−15		1	$\beta \sim 1 \times 10^{-3}$	0	[6] BECKER-SZ...	94	IMB
<8.7E−15		1	>2.E−3	0	THRON	92	SOUD
<4.4E−12		1	all β	0	GARDNER	91	INDU
<7.2E−13		1	all β	0	HUBER	91	INDU
<3.7E−15	>E12	1	β=1.E−4	0	[7] ORITO	91	PLAS
<3.2E−16	>E10	1	β > 0.05	0	[7] ORITO	91	PLAS
<3.2E−16	>E10–E12	2,3		0	[7] ORITO	91	PLAS
<3.8E−13		1	all β	0	BERMON	90	INDU
<5.E−16		1	β <1.E−3	0	[6] BEZRUKOV	90	CHER
<1.8E−14		1	β >1.1E−4	0	[8] BUCKLAND	90	HEPT
<1E−18			3.E−4 < β <1.5E−3	0	[9] GHOSH	90	MICA
<7.2E−13		1	all β	0	HUBER	90	INDU
<5.E−12	>E7	1	3.E−4 < β <5.E−3	0	BARISH	87	CNTR
<1.E−13			1.E−5 < β <1	0	[6] BARTELT	87	SOUD
<1.E−10		1	all β	0	EBISU	87	INDU
<2.E−13			1.E−4 < β <6.E−4	0	MASEK	87	HEPT
<2.E−14			4.E−5 < β <2.E−4	0	NAKAMURA	87	PLAS
<2.E−14			1.E−3 < β <1	0	NAKAMURA	87	PLAS
<5.E−14			9.E−4 < β <1.E−2	0	SHEPKO	87	CNTR
<2.E−13			4.E−4 < β <1	0	TSUKAMOTO	87	CNTR
<5.E−14		1	all β	1	[10] CAPLIN	86	INDU
<5.E−12		1		0	CROMAR	86	INDU
<1.E−13		1	7.E−4 < β	0	HARA	86	CNTR
<7.E−11		1	all β	0	INCANDELA	86	INDU
<1.E−18			4.E−4 < β <1.E−3	0	[9] PRICE	86	MICA
<5.E−12		1		0	BERMON	85	INDU
<6.E−12		1		0	CAPLIN	85	INDU
<6.E−10		1		0	EBISU	85	INDU
<3.E−15			5.E−5 ≤ β ≤ 1.E−3	0	[6] KAJITA	85	KAMI
<2.E−21			β <1.E−3	0	[6,11] KAJITA	85	KAMI
<3.E−15			1.E−3 < β <1.E−1	0	[6] PARK	85B	CNTR
<5.E−12		1	1.E−4 < β <1	0	BATTISTONI	84	NUSX

<7.E−12		1		0	INCANDELA	84	INDU
<7.E−13		1	3.E−4 < β	0	[8] KAJINO	84	CNTR
<2.E−12		1	3.E−4 < β <1.E−1	0	KAJINO	84B	CNTR
<6.E−13		1	5.E−4 < β <1	0	KAWAGOE	84	CNTR
<2.E−14			1.E−3 < β	0	[6] KRISHNA...	84	CNTR
<4.E−13		1	6.E−4 < β <2.E−3	0	LISS	84	CNTR
<1.E−16			3.E−4 < β <1.E−3	0	[9] PRICE	84	MICA
<1.E−13		1	1.E−4 < β	0	PRICE	84B	PLAS
<4.E−13		1	6.E−4 < β <2.E−3	0	TARLE	84	CNTR
				7	[12] ANDERSON	83	EMUL
<4.E−13		1	1.E−2 < β <1.E−3	0	BARTELT	83B	CNTR
<1.E−12		1	7.E−3 < β <1	0	BARWICK	83	PLAS
<3.E−13		1	1.E−3 < β <4.E−1	0	BONARELLI	83	CNTR
<3.E−12			5.E−4 < β <5.E−2	0	[6] BOSETTI	83	CNTR
<4.E−11		1		0	CABRERA	83	INDU
<5.E−15		1	1.E−2 < β <1	0	DOKE	83	PLAS
<8.E−15			1.E−4 < β <1.E−1	0	[6] ERREDE	83	IMB
<5.E−12		1	1.E−4 < β <3.E−2	0	GROOM	83	CNTR
<2.E−12			6.E−4 < β <1	0	MASHIMO	83	CNTR
<1.E−13		1	β=3.E−3	0	ALEXEYEV	82	CNTR
<2.E−12		1	7.E−3 < β <6.E−1	0	BONARELLI	82	CNTR
6.E−10		1	all β	1	[13] CABRERA	82	INDU
<2.E−11			1.E−2 < β <1.E−1	0	MASHIMO	82	CNTR
<2.E−15			concentrator	0	BARTLETT	81	PLAS
<1.E−13	>1		1.E−3 < β	0	KINOSHITA	81B	PLAS
<5.E−11	<E17		3.E−4 < β <1.E−3	0	ULLMAN	81	CNTR
<2.E−11			concentrator	0	BARTLETT	78	PLAS
1.E−1	>200	2		1	[14] PRICE	75	PLAS
<2.E−13		>2		0	FLEISCHER	71	PLAS
<1.E−19		>2	obsidian, mica	0	FLEISCHER	69C	PLAS
<5.E−15	<15	<3	concentrator	0	CARITHERS	66	ELEC
<2.E−11		<1–3	concentrator	0	MALKUS	51	EMUL

[5] AHLEN 94 limit for dyons extends down to β=0.9E−4 and a limit of 1.3E−14 extends to β = 0.8E−4. Aso see comment by PRICE 94 and reply of BARISH 94. One loophole in the AHLEN 94 result is that in the case of monopoles catalyzing nucleon decay, relativisitic particles could veto the events. New electronics will remove this possibility.

[6] Catalysis of nucleon decay; sensitive to assumed catalysis cross section.

[7] ORITO 91 limits are functions of velocity. Lowest limits are given here.

[8] Used DKMPR mechanism and Penning effect.

[9] Assumes monopole attaches fermion nucleus.

[10] Limit from combining data of CAPLIN 86, BERMON 85, INCANDELA 84, and CABRERA 83. For a discussion of controversy about CAPLIN 86 observed event, see GUY 87. Also see SCHOUTEN 87.

[11] Based on lack of high- energy solar neutrinos from catalysis in the sun.

[12] Anomalous long-range α (^{4}He) tracks.

[13] CABRERA 82 candidate event has single Dirac charge within ±5%.

[14] ALVAREZ 75, FLEISCHER 75, and FRIEDLANDER 75 explain as fragmenting nucleus. EBERHARD 75 and ROSS 76 discuss conflict with other experiments. HAGSTROM 77 reinterprets as antinucleus. PRICE 78 reassesses.

Monopole Flux — Astrophysics

FLUX ($cm^{-2}sr^{-1}s^{-1}$)	*MASS* (GeV)	*CHG* (g)	*COMMENTS* ($\beta = v/c$)	*EVTS*	*DOCUMENT ID*		*TECN*
<1.E−16	E17	1	galactic field	0	[15] ADAMS	93	COSM
<1.E−23			Jovian planets		[16] ARAFUNE	85	COSM
<1.E−16	E15		solar trapping	0	BRACCI	85B	COSM
<1.E−18		1		0	[16] HARVEY	84	COSM
<3.E−23			neutron stars		KOLB	84	COSM
<7.E−22			pulsars	0	[16] FREESE	83B	COSM
<1.E−18	<E18	1	intergalactic field	0	[16] REPHAELI	83	COSM
<1.E−23			neutron stars	0	[16] DIMOPOUL...	82	COSM
<5.E−22			neutron stars	0	[16] KOLB	82	COSM
<5.E−15	>E21		galactic halo		SALPETER	82	COSM
<1.E−12	E19	1	β=3.E−3	0	[17] TURNER	82	COSM
<1.E−16		1	galactic field	0	PARKER	70	COSM

[15] ADAMS 93 limit based on "survival and growth of a small galactic seed field" is 10^{-16} ($m/10^{17}$ GeV) $cm^{-2}\,s^{-1}\,sr^{-1}$. Above 10^{17} GeV, limit 10^{-16} (10^{17} GeV$/m$) $cm^{-2}\,s^{-1}\,sr^{-1}$ (from requirement that monopole density does not overclose the universe) is more stringent.

[16] Catalysis of nucleon decay.
[17] Re-evaluates PARKER 70 limit for GUT monopoles.

Monopole Density — Matter Searches

DENSITY	CHG (g)	MATERIAL	EVTS	DOCUMENT ID		TECN
<6.9E−6/gram	>1/3	Meteorites and other	0	JEON	95	INDU
<2.E−7/gram	>0.6	Fe ore	0	[18] EBISU	87	INDU
>1.E−14/gram	>1/3	iron aerosols	>1	MIKHAILOV	83	SPEC
<6.E−4/gram		air, seawater	0	CARRIGAN	76	CNTR
<5.E−1/gram	>0.04	11 materials	0	CABRERA	75	INDU
<2.E−4/gram	>0.05	moon rock	0	ROSS	73	INDU
<6.E−7/gram	<140	seawater	0	KOLM	71	CNTR
<1.E−2/gram	<120	manganese nodules	0	FLEISCHER	69	PLAS
<1.E−4/gram	>0	manganese	0	FLEISCHER	69B	PLAS
<2.E−3/gram	<1–3	magnetite, meteor	0	GOTO	63	EMUL
<2.E−2/gram		meteorite	0	PETUKHOV	63	CNTR

[18] Mass 1×10^{14}–1×10^{17} GeV.

Monopole Density — Astrophysics

DENSITY	CHG (g)	MATERIAL	EVTS	DOCUMENT ID		TECN
<1.E−9/gram	1	sun, catalysis	0	[19] ARAFUNE	83	COSM
<6.E−33/nucl	1	moon wake	0	SCHATTEN	83	ELEC
<2.E−28/nucl		earth heat	0	CARRIGAN	80	COSM
<2.E−4/prot		42cm absorption	0	BRODERICK	79	COSM
<2.E−13/m^3		moon wake	0	SCHATTEN	70	ELEC

[19] Catalysis of nucleon decay.

REFERENCES FOR Magnetic Monopole Searches

ACCIARRI	95C	PL B345 609	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)
JEON	95	PRL 75 1443	Jeon, Longo	(MICH)
AHLEN	94	PRL 72 608	+Ambrosio, Antolini, Auriemma+	(MACRO Collab.)
BARISH	94	PRL 73 1306	+Giacomelli, Hong	(CIT, BGNA, BOST)
BECKER-SZ...	94	PR D49 2169	Becker-Szendy, Bratton, Breault, Casper+	(IMB Collab.)
PRICE	94	PRL 73 1305		(UCB)
ADAMS	93	PRL 70 2511	+Fatuzzo, Freese, Tarle+	(MICH, FNAL)
PINFOLD	93	PL B316 407	+Du, Kinoshita, Lorazo+	(ALBE, HARV, MONT, UCB)
KINOSHITA	92	PR D46 R881	+Du, Giacomelli, Patriziili+	(HARV, BGNA, REHO)
THRON	92	PR D46 4846	+Allison, Alner, Ambats+	(SOUDAN-2 Collab.)
GARDNER	91	PR D44 622	+Cabrera, Huber, Taber	(STAN)
HUBER	91	PR D44 636	+Cabrera, Taber, Gardner	(STAN)
ORITO	91	PRL 66 1951	+Ichinose, Nakamura+	(ICEPP, WASCR, NIHO, ICRR)
BERMON	90	PRL 64 839	+Chi, Tsuei+	(IBM, BNL)
BERTANI	90	EPL 12 613	+Giacomelli, Mondardini, Pal+	(BGNA, INFN)
BEZRUKOV	90	SJNP 52 54	+Belolaptikov, Bugaev, Budnev+	(INRM)
		Translated from YAF 52 86.		
BUCKLAND	90	PR D41 2726	+Masek, Vernon, Knapp, Stronsi	(UCSD)
GHOSH	90	EPL 12 25	+Chatterjea	(JADA)
HUBER	90	PRL 64 835	+Cabrera, Tabor, Gardner	(STAN)
PRICE	90	PRL 65 149	+Guiru, Kinoshita	(UCB, HARV)
KINOSHITA	89	PL B228 543	+Fujii, Nakajima+	(HARV, TISA, KEK, UCB, GIFU)
BRAUNSCH...	88B	ZPHY C38 543	Braunschweig, Gerhards, Kirschfink+	(TASSO Collab.)
KINOSHITA	88	PRL 60 1610	+Fujii, Nakajima+	(HARV, TISA, KEK, UCB, GIFU)
BARISH	87	PR D36 2641	+Liu, Lane	(CIT)
BARTELT	87	PR D36 1990	+Courant, Heller+	(Soudan Collab.)
Also	89	PR D40 1701 erratum	Bartelt, Courant, Heller+	(Soudan Collab.)
EBISU	87	PR D36 3359	+Watanabe	(KOBE)
Also	85	JPG 11 883	Ebisu, Watanabe	(KOBE)
GENTILE	87	PR D35 1081	+Haas, Hempstead+	(CLEO Collab.)
GUY	87	Nature 325 463		(LOIC)
MASEK	87	PR D35 2758	+Knapp, Miller, Stronski, Vernon, White	(UCSD)
NAKAMURA	87	PL B183 395	+Kawagoe, Yamamoto+	(INUS, WASCR, NIHO)
PRICE	87	PRL 59 2523	+Guoxiao, Kinoshita	(UCB, HARV)
SCHOUTEN	87	JPE 20 850	+Caplin, Guy, Hardiman+	(LOIC)
SHEPKO	87	PR D35 2917	+Gagliardi, Green, McIntyre+	(TAMU)
TSUKAMOTO	87	EPL 3 39	+Nagano, Anraku+	(ICRR)
CAPLIN	86	Nature 321 402	+Hardiman, Koratzinos, Schouten	(LOIC)
Also	87	JPE 20 850	Schouten, Caplin, Guy, Hardiman+	(LOIC)
Also	87	Nature 325 463	Guy	(LOIC)
CROMAR	86	PRL 56 2561	+Clark, Fickett	(NBSB)
HARA	86	PRL 56 553	+Honda, Ohno+	(ICRR, KYOT, KEK, KOBE, ICEPP)
INCANDELA	86	PR D34 2637	+Frisch, Somalwar, Kuchnir+	(CHIC, FNAL, MICH)
PRICE	86	PRL 56 1226	+Salamon	(UCB)
ARAFUNE	85	PR D32 2586	+Fukugita, Yanagita	(ICRR, KYOTY, IBAR)
BERMON	85	PRL 55 1850	+Chaudhari, Chi, Tesche, Tsuei	(IBM)
BRACCI	85B	NP B258 726	+Fiorentini, Mezzorani	(PISA, CAGL, INFN)
Also	85	LNC 42 123	Bracci, Fiorentini	(PISA)
CAPLIN	85	Nature 317 234	+Guy, Hardiman, Park, Schouten	(LOIC)
EBISU	85	JPG 11 883	+Watanabe	(KOBE)
KAJITA	85	JPSJ 54 4065	+Arisaka, Koshiba, Nakahata+	(ICRR, KEK, NIIG)

PARK	85B	NP B252 261	+Blewitt, Cortez, Foster+	(IMB Collab.)
BATTISTONI	84	PL 133B 454	+Bellotti, Bologna, Campana+	(NUSEX Collab.)
FRYBERGER	84	PR D29 1524	+Coan, Kinoshita, Price	(SLAC, UCB)
HARVEY	84	NP B236 255		(PRIN)
INCANDELA	84	PRL 53 2067	+Campbell, Frisch+	(CHIC, FNAL, MICH)
KAJINO	84	PRL 52 1373	+Matsuno, Yuan, Kitamura	(ICRR)
KAJINO	84B	JPG 10 447	+Matsuno, Kitamura, Aoki, Yuan, Mitsui+	(ICRR)
KAWAGOE	84	LNC 41 315	+Mashimo, Nakamura, Nozaki, Orito	(TOKY)
KOLB	84	APJ 286 702	+Turner	(FNAL, CHIC)
KRISHNA...	84	PL 142B 99	Krishnaswamy, Menon+	(TATA, OSKC, INUS)
LISS	84	PR D30 884	+Ahlen, Tarle	(UCB, IND, MICH)
PRICE	84	PRL 52 1265	+Guo, Ahlen, Fleischer	(ROMA, UCB, IND, GESC)
PRICE	84B	PL 140B 112		(CERN)
TARLE	84	PRL 52 90	+Ahlen, Liss	(UCB, MICH, IND)
ANDERSON	83	PR D28 2308	+Lord, Strausz, Wilkes	(WASH)
ARAFUNE	83	PL 133B 380	+Fukugita	(ICRR, KYOTY)
AUBERT	83B	PL 120B 465	+Musset, Price, Vialle	(CERN, LAPP)
BARTELT	83B	PRL 50 655	+Courant, Heller, Joyce, Marshak+	(MINN, ANL)
BARWICK	83	PR D28 2338	+Kinoshita, Price	(UCB)
BONARELLI	83	PL 126B 137	+Capiluppi, Dantone	(BGNA)
BOSETTI	83	PL 133B 265	+Gorham, Harris, Learned+	(AACH3, HAWA, TOKY)
CABRERA	83	PRL 51 1933	+Taber, Gardner, Bourg	(STAN)
DOKE	83	PL 129B 370	+Hayashi, Hamasaki+	(WASU, RIKK, TTAM, RIKEN)
ERREDE	83	PRL 51 245	+Stone, Vander Velde, Bionta+	(IMB Collab.)
FREESE	83B	PRL 51 1625	+Turner, Schramm	(CHIC)
GROOM	83	PRL 50 573	+Loh, Nelson, Ritson	(UTAH, STAN)
MASHIMO	83	PL 128B 327	+Orito, Kawagoe, Nakamura, Nozaki	(ICEPP)
MIKHAILOV	83	PL 130B 331		(KAZA)
MUSSET	83	PL 128B 333	+Price, Lohrmann	(CERN, HAMB)
REPHAELI	83	PL 121B 115	+Turner	(CHIC)
SCHATTEN	83	PR D27 1525		(NASA)
ALEXEYEV	82	LNC 35 413	+Boliev, Chudakov, Makoev, Mikheyev+	(INRM)
BONARELLI	82	PL 112B 100	+Capiluppi, Dantone+	(BGNA)
CABRERA	82	PRL 48 1378		(STAN)
DELL	82	NP B209 45	+Yuan, Roberts, Dooher+	(BNL, ADEL, ROMA)
DIMOPOUL...	82	PL 119B 320	Dimopoulos, Preskill, Wilczek	(HARV, UCSBT)
KINOSHITA	82	PRL 48 77	+Price, Fryberger	(UCB, SLAC)
KOLB	82	PRL 49 1373	+Colgate, Harvey	(LASL, PRIN)
MASHIMO	82	JPSJ 51 3067	+Kawagoe, Koshiba	(INUS)
SALPETER	82	PRL 49 1114	+Shapiro, Wasserman	(CORN)
TURNER	82	PR D26 1296	+Parker, Bogdan	(CHIC)
BARTLETT	81	PR D24 612	+Soo, Fleischer, Hart+	(COLO, GESC)
KINOSHITA	81B	PR D24 1707	+Price	(UCB)
ULLMAN	81	PRL 47 289		(LEHM, BNL)
CARRIGAN	80	Nature 288 348		(FNAL)
BRODERICK	79	PR D19 1046	+Ficenec, Teplitz, Teplitz	(VPI)
BARTLETT	78	PR D18 2253	+Soo, White	(COLO, PRIN)
CARRIGAN	78	PR D17 1754	+Strauss, Giacomelli	(FNAL, BGNA)
HOFFMANN	78	LNC 23 357	+Kantardjian, Diliberto, Meddi+	(CERN, ROMA)
PRICE	78	PR D18 1382	+Shirk, Osborne, Pinsky	(UCB, HOUS)
HAGSTROM	77	PRL 38 729		(LBL)
CARRIGAN	76	PR D13 1823	+Nezrick, Strauss	(FNAL)
DELL	76	LNC 15 269	+Uto, Yuan, Amaldi+	(CERN, BNL, ROMA, ADEL)
ROSS	76	LBL-4665		(LBL)
STEVENS	76B	PR D14 2207	+Collins, Ficenec, Trower, Fischer+	(VPI, BNL)
ZRELOV	76	CZJP B26 1306	+Kollarova, Kollar, Lupiltsev, Pavlovic+	(JINR)
ALVAREZ	75	LBL-4260		(LBL)
BURKE	75	PL 60B 113	+Gustafson, Jones, Longo	(MICH)
CABRERA	75	Thesis		(STAN)
CARRIGAN	75	NP B91 279	+Nezrick	(FNAL)
Also	71	PR D3 56	Carrigan, Nezrick	(FNAL)
EBERHARD	75	PR D11 3099	+Ross, Taylor, Alvarez, Oberlack	(LBL, MPIM)
EBERHARD	75B	LBL-4289		(LBL)
FLEISCHER	75	PRL 35 1412	+Walker	(GESC, WUSL)
FRIEDLANDER	75	PRL 35 1167		(WUSL)
GIACOMELLI	75	NC 28A 21	+Rossi+	(BGNA, CERN, SACL, ROMA)
PRICE	75	PRL 35 487	+Shirk, Osborne, Pinsky	(UCB, HOUS)
CARRIGAN	74	PR D10 3867	+Nezrick, Strauss	(FNAL)
CARRIGAN	73	PR D8 3717	+Nezrick, Strauss	(FNAL)
ROSS	73	PR D8 698	+Eberhard, Alvarez, Watt	(LBL, SLAC)
Also	71	PR D4 3260	Eberhard, Ross, Alvarez, Watt	(LBL, SLAC)
Also	70	Science 167 701	Alvarez, Eberhard, Ross, Watt	(LBL, SLAC)
BARTLETT	72	PR D6 1817	+Lahana	(COLO)
GUREVICH	72	PL 38B 549	+Khakimov, Martemyanov+	(KIAE, NOVO, SERP)
Also	72B	JETP 34 917	Barkov, Gurevich, Zolotorev	(KIAE, NOVO, SERP)
		Translated from ZETF 61 1721.		
Also	70	PL 31B 394	Gurevich, Khakimov+	(KIAE, NOVO, SERP)
FLEISCHER	71	PR D4 24	+Hart, Nichols, Price	(GESC)
KOLM	71	PR D4 1285	+Villa, Odian	(MIT, SLAC)
PARKER	70	APJ 160 383		(CHIC)
SCHATTEN	70	PR D1 2245		(NASA)
FLEISCHER	69	PR 177 2029	+Jacobs, Schwartz, Price	(GESC, FSU)
FLEISCHER	69B	PR 184 1393	+Hart, Jacobs+	(GESC, UNCS, GSCO)
FLEISCHER	69C	PR 184 1398	+Price, Woods	(GESC)
Also	70C	JAP 41 958	Fleischer, Hart, Jacobs, Price+	(GESC)
CARITHERS	66	PR 149 1070	+Stefanski, Adair	(YALE, BNL)
AMALDI	63	NC 28 773	+Baroni, Manfredini+	(ROMA, UCSD, CERN)
GOTO	63	PR 132 387	+Kolm, Ford	(TOKY, MIT, BRAN)
PETUKHOV	63	NP 49 87	+Yakimenko	(LEBD)
PURCELL	63	PR 129 2326	+Collins, Fujii, Hornbostel, Turkot	(HARV, BNL)
FIDECARO	61	NC 22 657	+Finocchiaro, Giacomelli	(CERN)

BRADNER	59	PR 114 603	+Isbell	(LBL)
MALKUS	51	PR 83 899		(CHIC)

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