

Magnetic Monopole Searches

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Monopole Production Cross Section — Accelerator Searches

<i>X-SECT</i> (cm^2)	<i>MASS</i> (GeV)	<i>CHG</i> (g)	<i>ENERGY</i> (GeV)	<i>BEAM</i>	<i>DOCUMENT ID</i>	<i>TECN</i>
$<1.6\text{E}-38$	200–1200	1	7000	pp	¹ AAD	12CS ATLS
$<5\text{E}-38$	45–102	1	206	e^+e^-	² ABBIENDI	08 OPAL
$<0.2\text{E}-36$	200–700	1	1960	$p\bar{p}$	³ ABULENCIA	06K CNTR
$<2\text{E}-36$		1	300	e^+p	^{4,5} AKTAS	05A INDU
$<0.2\text{E}-36$		2	300	e^+p	^{4,5} AKTAS	05A INDU
$<0.09\text{E}-36$		3	300	e^+p	^{4,5} AKTAS	05A INDU
$<0.05\text{E}-36$		≥ 6	300	e^+p	^{4,5} AKTAS	05A INDU
$<2\text{E}-36$		1	300	e^+p	^{4,6} AKTAS	05A INDU
$<0.2\text{E}-36$		2	300	e^+p	^{4,6} AKTAS	05A INDU
$<0.07\text{E}-36$		3	300	e^+p	^{4,6} AKTAS	05A INDU
$<0.06\text{E}-36$		≥ 6	300	e^+p	^{4,6} AKTAS	05A INDU
$<0.6\text{E}-36$	>265	1	1800	$p\bar{p}$	⁷ KALBFLEISCH 04	INDU
$<0.2\text{E}-36$	>355	2	1800	$p\bar{p}$	⁷ KALBFLEISCH 04	INDU
$<0.07\text{E}-36$	>410	3	1800	$p\bar{p}$	⁷ KALBFLEISCH 04	INDU
$<0.2\text{E}-36$	>375	6	1800	$p\bar{p}$	⁷ KALBFLEISCH 04	INDU
$<0.7\text{E}-36$	>295	1	1800	$p\bar{p}$	^{8,9} KALBFLEISCH 00	INDU
$<7.8\text{E}-36$	>260	2	1800	$p\bar{p}$	^{8,9} KALBFLEISCH 00	INDU
$<2.3\text{E}-36$	>325	3	1800	$p\bar{p}$	^{8,10} KALBFLEISCH 00	INDU
$<0.11\text{E}-36$	>420	6	1800	$p\bar{p}$	^{8,10} KALBFLEISCH 00	INDU
$<0.65\text{E}-33$	<3.3	≥ 2	11A	¹⁹⁷ Au	¹¹ HE	97
$<1.90\text{E}-33$	<8.1	≥ 2	160A	²⁰⁸ Pb	¹¹ HE	97
$<3\text{E}-37$	<45.0	1.0	88–94	e^+e^-	PINFOLD	93 PLAS
$<3\text{E}-37$	<41.6	2.0	88–94	e^+e^-	PINFOLD	93 PLAS
$<7\text{E}-35$	<44.9	0.2–1.0	89–93	e^+e^-	KINOSHITA	92 PLAS
$<2\text{E}-34$	<850	≥ 0.5	1800	$p\bar{p}$	BERTANI	90 PLAS
$<1.2\text{E}-33$	<800	≥ 1	1800	$p\bar{p}$	PRICE	90 PLAS
$<1\text{E}-37$	<29	1	50–61	e^+e^-	KINOSHITA	89 PLAS
$<1\text{E}-37$	<18	2	50–61	e^+e^-	KINOSHITA	89 PLAS
$<1\text{E}-38$	<17	<1	35	e^+e^-	BRAUNSCH...	88B CNTR
$<8\text{E}-37$	<24	1	50–52	e^+e^-	KINOSHITA	88 PLAS
$<1.3\text{E}-35$	<22	2	50–52	e^+e^-	KINOSHITA	88 PLAS
$<9\text{E}-37$	<4	<0.15	10.6	e^+e^-	GENTILE	87 CLEO
$<3\text{E}-32$	<800	≥ 1	1800	$p\bar{p}$	PRICE	87 PLAS
$<3\text{E}-38$		<3	29	e^+e^-	FRYBERGER	84 PLAS
$<1\text{E}-31$		1,3	540	$p\bar{p}$	AUBERT	83B PLAS
$<4\text{E}-38$	<10	<6	34	e^+e^-	MUSSET	83 PLAS
$<8\text{E}-36$	<20		52	pp	¹² DELL	82 CNTR
$<9\text{E}-37$	<30	<3	29	e^+e^-	KINOSHITA	82 PLAS
$<1\text{E}-37$	<20	<24	63	pp	CARRIGAN	78 CNTR
$<1\text{E}-37$	<30	<3	56	pp	HOFFMANN	78 PLAS
			62	pp	¹² DELL	76 SPRK

<4.E-33			300	p	¹² STEVENS	76B	SPRK
<1.E-40	<5	<2	70	p	¹³ ZRELOV	76	CNTR
<2.E-30			300	n	¹² BURKE	75	OSPK
<1.E-38			8	ν	¹⁴ CARRIGAN	75	HLBC
<5.E-43	<12	<10	400	p	EBERHARD	75B	INDU
<2.E-36	<30	<3	60	pp	GIACOMELLI	75	PLAS
<5.E-42	<13	<24	400	p	CARRIGAN	74	CNTR
<6.E-42	<12	<24	300	p	CARRIGAN	73	CNTR
<2.E-36		1	0.001	γ	¹³ BARTLETT	72	CNTR
<1.E-41	<5		70	p	GUREVICH	72	EMUL
<1.E-40	<3	<2	28	p	AMALDI	63	EMUL
<2.E-40	<3	<2	30	p	PURCELL	63	CNTR
<1.E-35	<3	<4	28	p	FIDECARO	61	CNTR
<2.E-35	<1	1	6	p	BRADNER	59	EMUL

¹ AAD 12CS searched for monopoles as highly ionising objects. The cross section limits are based on an assumed Drell Yan-like production process for spin 1/2 monopoles. The limits are mass- and scenario-dependent.

² ABBIENDI 08 assume production of spin 1/2 monopoles with effective charge $g\beta$ ($n=1$), via $e^+e^- \rightarrow \gamma^* \rightarrow M\bar{M}$, so that the cross section is proportional to $(1 + \cos^2\theta)$. There is no z information for such highly saturated tracks, so a parabolic track in the jet chamber is projected onto the xy plane. Charge per hit in the chamber produces a clean separation of signal and background.

³ ABULENCIA 06K searches for high-ionizing signals in CDF central outer tracker and time-of-flight detector. For Drell-Yan $M\bar{M}$ production, the cross section limit implies $M > 360$ GeV at 95% CL.

⁴ AKTAS 05A model-dependent limits as a function of monopole mass shown for arbitrary mass of 60 GeV. Based on search for stopped monopoles in the H1 Al beam pipe.

⁵ AKTAS 05A limits with assumed elastic spin 0 monopole pair production.

⁶ AKTAS 05A limits with assumed inelastic spin 1/2 monopole pair production.

⁷ KALBFLEISCH 04 reports searches for stopped magnetic monopoles in Be, Al, and Pb samples obtained from discarded material from the upgrading of DØ and CDF. A large-aperture warm-bore cryogenic detector was used. The approach was an extension of the methods of KALBFLEISCH 00. Cross section results moderately model dependent; interpretation as a mass lower limit depends on possibly invalid perturbation expansion.

⁸ KALBFLEISCH 00 used an induction method to search for stopped monopoles in pieces of the DØ (FNAL) beryllium beam pipe and in extensions to the drift chamber aluminum support cylinder. Results are model dependent.

⁹ KALBFLEISCH 00 result is for aluminum.

¹⁰ KALBFLEISCH 00 result is for beryllium.

¹¹ HE 97 used a lead target and barium phosphate glass detectors. Cross-section limits are well below those predicted via the Drell-Yan mechanism.

¹² Multiphoton events.

¹³ Cherenkov radiation polarization.

¹⁴ Re-examines CERN neutrino experiments.

Monopole Production — Other Accelerator Searches

MASS (GeV)	CHG (g)	SPIN	ENERGY (GeV)	BEAM	DOCUMENT ID	TECN
> 610	≥ 1	0	1800	$p\bar{p}$	¹⁵ ABBOTT 98K	D0
> 870	≥ 1	1/2	1800	$p\bar{p}$	¹⁵ ABBOTT 98K	D0
>1580	≥ 1	1	1800	$p\bar{p}$	¹⁵ ABBOTT 98K	D0
> 510			88-94	e^+e^-	¹⁶ ACCIARRI 95C	L3

- ¹⁵ ABBOTT 98K search for heavy pointlike Dirac monopoles via central production of a pair of photons with high transverse energies.
¹⁶ ACCIARRI 95C finds a limit $B(Z \rightarrow \gamma\gamma) < 0.8 \times 10^{-5}$ (which is possible via a monopole loop) at 95% CL and sets the mass limit via a cross section model.

Monopole Flux — Cosmic Ray Searches

“Caty” in the charge column indicates a search for monopole-catalyzed nucleon decay.

<u>FLUX</u> ($\text{cm}^{-2}\text{sr}^{-1}\text{s}^{-1}$)	<u>MASS</u> (GeV)	<u>CHG</u> (g)	<u>COMMENTS</u> ($\beta = v/c$)	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<1.3E-17		1	$\beta > 0.625$	0	17 ADRIAN-MAR..12A	ANTR
<6E-28	<1E17	Caty	$1E-5 < \beta < 0.04$	0	18 UENO	12 SKAM
<1E-19		1	$\gamma > 1E10$	0	19 DETRIXHE	11 ANIT
<3.8E-17		1	$\beta > 0.76$	0	20 ABBASI	10A AMND
<1.3E-15	$1E4 < M < 5E13$	1	$\beta > 0.05$	0	21 BALESTRA	08 PLAS
<0.65E-15	>5E13	1	$\beta > 0.05$	0	21 BALESTRA	08 PLAS
<1E-18		1	$\gamma > 1 E8$	0	19 HOGAN	08 RICE
<1.4E-16		1	$1.1E-4 < \beta < 1$	0	22 AMBROSIO	02B MCRO
<3E-16		Caty	$1.1E-4 < \beta < 5E-3$	0	23 AMBROSIO	02C MCRO
<1.5E-15		1	$5E-3 < \beta < 0.99$	0	24 AMBROSIO	02D MCRO
<1E-15		1	$1.1 \times 10^{-4} - 0.1$	0	25 AMBROSIO	97 MCRO
<5.6E-15		1	$(0.18-3.0)E-3$	0	26 AHLEN	94 MCRO
<2.7E-15		Caty	$\beta \sim 1 \times 10^{-3}$	0	27 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	$\beta = 1.E-4$	0	28 ORITO	91 PLAS
<3.2E-16	>E10	1	$\beta > 0.05$	0	28 ORITO	91 PLAS
<3.2E-16	>E10-E12	2,3		0	28 ORITO	91 PLAS
<3.8E-13		1	all β	0	BERMON	90 INDU
<5.E-16		Caty	$\beta < 1.E-3$	0	27 BEZRUKOV	90 CHER
<1.8E-14		1	$\beta > 1.1E-4$	0	29 BUCKLAND	90 HEPT
<1E-18			$3.E-4 < \beta < 1.5E-3$	0	30 GHOSH	90 MICA
<7.2E-13		1	all β	0	HUBER	90 INDU
<5.E-12	>E7	1	$3.E-4 < \beta < 5.E-3$	0	BARISH	87 CNTR
<1.E-13		Caty	$1.E-5 < \beta < 1$	0	27 BARTELT	87 SOUD
<1.E-10		1	all β	0	EBISU	87 INDU
<2.E-13			$1.E-4 < \beta < 6.E-4$	0	MASEK	87 HEPT
<2.E-14			$4.E-5 < \beta < 2.E-4$	0	NAKAMURA	87 PLAS
<2.E-14			$1.E-3 < \beta < 1$	0	NAKAMURA	87 PLAS
<5.E-14			$9.E-4 < \beta < 1.E-2$	0	SHEPKO	87 CNTR
<2.E-13			$4.E-4 < \beta < 1$	0	TSUKAMOTO	87 CNTR
<5.E-14		1	all β	1	31 CAPLIN	86 INDU
<5.E-12		1		0	CROMAR	86 INDU
<1.E-13		1	$7.E-4 < \beta$	0	HARA	86 CNTR
<7.E-11		1	all β	0	INCANDELA	86 INDU
<1.E-18			$4.E-4 < \beta < 1.E-3$	0	30 PRICE	86 MICA
<5.E-12		1		0	BERMON	85 INDU
<6.E-12		1		0	CAPLIN	85 INDU
<6.E-10		1		0	EBISU	85 INDU
<3.E-15		Caty	$5.E-5 \leq \beta \leq 1.E-3$	0	27 KAJITA	85 KAMI

<2.E-21		Caty $\beta < 1.E-3$	0	^{27,32} KAJITA	85	KAMI
<3.E-15		Caty $1.E-3 < \beta < 1.E-1$	0	²⁷ PARK	85B	CNTR
<5.E-12		1 $1.E-4 < \beta < 1$	0	BATTISTONI	84	NUSX
<7.E-12		1	0	INCANDELA	84	INDU
<7.E-13		1 $3.E-4 < \beta$	0	²⁹ KAJINO	84	CNTR
<2.E-12		1 $3.E-4 < \beta < 1.E-1$	0	KAJINO	84B	CNTR
<6.E-13		1 $5.E-4 < \beta < 1$	0	KAWAGOE	84	CNTR
<2.E-14		1 $1.E-3 < \beta$	0	²⁷ KRISHNA...	84	CNTR
<4.E-13		1 $6.E-4 < \beta < 2.E-3$	0	LISS	84	CNTR
<1.E-16		1 $3.E-4 < \beta < 1.E-3$	0	³⁰ PRICE	84	MICA
<1.E-13		1 $1.E-4 < \beta$	0	PRICE	84B	PLAS
<4.E-13		1 $6.E-4 < \beta < 2.E-3$	0	TARLE	84	CNTR
			7	³³ ANDERSON	83	EMUL
<4.E-13		1 $1.E-2 < \beta < 1.E-3$	0	BARTELT	83B	CNTR
<1.E-12		1 $7.E-3 < \beta < 1$	0	BARWICK	83	PLAS
<3.E-13		1 $1.E-3 < \beta < 4.E-1$	0	BONARELLI	83	CNTR
<3.E-12		Caty $5.E-4 < \beta < 5.E-2$	0	²⁷ BOSETTI	83	CNTR
<4.E-11		1	0	CABRERA	83	INDU
<5.E-15		1 $1.E-2 < \beta < 1$	0	DOKE	83	PLAS
<8.E-15		Caty $1.E-4 < \beta < 1.E-1$	0	²⁷ ERREDE	83	IMB
<5.E-12		1 $1.E-4 < \beta < 3.E-2$	0	GROOM	83	CNTR
<2.E-12		1 $6.E-4 < \beta < 1$	0	MASHIMO	83	CNTR
<1.E-13		1 $\beta = 3.E-3$	0	ALEXEYEV	82	CNTR
<2.E-12		1 $7.E-3 < \beta < 6.E-1$	0	BONARELLI	82	CNTR
6.E-10		1 all β	1	³⁴ CABRERA	82	INDU
<2.E-11		1 $1.E-2 < \beta < 1.E-1$	0	MASHIMO	82	CNTR
<2.E-15		concentrator	0	BARTLETT	81	PLAS
<1.E-13	>1	1 $1.E-3 < \beta$	0	KINOSHITA	81B	PLAS
<5.E-11	<E17	1 $3.E-4 < \beta < 1.E-3$	0	ULLMAN	81	CNTR
<2.E-11		concentrator	0	BARTLETT	78	PLAS
1.E-1	>200	2	1	³⁵ 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

¹⁷ ADRIAN-MARTINEZ 12A measurements were based on a Cherenkov signature in an underwater telescope in the Western Mediterranean Sea. Limits are speed-dependent.

¹⁸ The limits from UENO 12 depend on the monopole speed and are also sensitive to assumed values of monopole mass and the catalysis cross section.

¹⁹ HOGAN 08 and DETRIXHE 11 limits on relativistic monopoles are based on nonobservation of radio Cherenkov signals at the South Pole. Limits are speed-dependent.

²⁰ ABBASI 10A was based on a Cherenkov signature in an array of optical modules which were sunk in the Antarctic ice cap. Limits are speed-dependent.

²¹ BALESTRA 08 exposed of nuclear track detector modules totaling 400 m² for 4 years at the Chacaltaya Laboratory (5230 m) in search for intermediate-mass monopoles with $\beta > 0.05$. The analysis is mainly based on three CR39 modules. For $M > 5 \times 10^{13}$ GeV there can be upward-going monopoles as well, hence the flux limit is half that obtained for less massive monopoles. Previous experiments (e.g. MACRO and OHYA (ORITO 91)) had set limits only for $M > 1 \times 10^9$ GeV.

²² AMBROSIO 02B direct search final result for $m \geq 10^{17}$ GeV, based upon 4.2 to 9.5 years of running, depending upon the subsystem. Limit with CR39 track-etch detector extends the limit from $\beta = 4 \times 10^{-5}$ (3.1×10^{-16} cm⁻² sr⁻¹ s⁻¹) to $\beta = 1 \times 10^{-4}$

- ($2.1 \times 10^{-16} \text{ cm}^{-2} \text{ sr}^{-1} \text{ s}^{-1}$). Limit curve in paper is piecewise continuous due to different detection techniques for different β ranges.
- 23 AMBROSIO 02C limit for catalysis of nucleon decay with catalysis cross section of $\approx 1 \text{ mb}$. The flux limit increases by ~ 3 at the higher β limit, and increases to $1 \times 10^{-14} \text{ cm}^{-2} \text{ sr}^{-1} \text{ s}^{-1}$ if the catalysis cross section is 0.01 mb. Based upon 71193 hr of data with the streamer detector, with an acceptance of $4250 \text{ m}^2 \text{ sr}$.
- 24 AMBROSIO 02D result for "more than two years of data." Ionization search using several subsystems. Limit curve as a function of β not given. Included in AMBROSIO 02B.
- 25 AMBROSIO 97 global MACRO 90%CL is 0.78×10^{-15} at $\beta=1.1 \times 10^{-4}$, goes through a minimum at 0.61×10^{-15} near $\beta=(1.1-2.7) \times 10^{-3}$, then rises to 0.84×10^{-15} at $\beta=0.1$. The global limit in this region is below the Parker bound at 10^{-15} . Less stringent limits are established for $4 \times 10^{-5} < \beta < 1 \times 10^{-4}$. Limits set by various triggers and different subdetectors are given in the paper. All limits assume a catalysis cross section smaller than a few mb.
- 26 AHLEN 94 limit for dyons extends down to $\beta=0.9\text{E}-4$ and a limit of $1.3\text{E}-14$ extends to $\beta = 0.8\text{E}-4$. Also see comment by PRICE 94 and reply of BARISH 94. One loophole in the AHLEN 94 result is that in the case of monopoles catalyzing nucleon decay, relativistic particles could veto the events. See AMBROSIO 97 for additional results.
- 27 Catalysis of nucleon decay; sensitive to assumed catalysis cross section.
- 28 ORITO 91 limits are functions of velocity. Lowest limits are given here.
- 29 Used DKMPR mechanism and Penning effect.
- 30 Assumes monopole attaches fermion nucleus.
- 31 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.
- 32 Based on lack of high- energy solar neutrinos from catalysis in the sun.
- 33 Anomalous long-range α (^4He) tracks.
- 34 CABRERA 82 candidate event has single Dirac charge within $\pm 5\%$.
- 35 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

<i>FLUX</i> ($\text{cm}^{-2}\text{sr}^{-1}\text{s}^{-1}$)	<i>MASS</i> (GeV)	<i>CHG</i> (g)	<i>COMMENTS</i> ($\beta = v/c$)	<i>EVTS</i>	<i>DOCUMENT ID</i>	<i>TECN</i>
<1.3E-20			faint white dwarf		36 FREESE 99	ASTR
<1.E-16	E17	1	galactic field	0	37 ADAMS 93	COSM
<1.E-23			Jovian planets		36 ARAFUNE 85	ASTR
<1.E-16	E15		solar trapping	0	BRACCI 85B	ASTR
<1.E-18		1		0	36 HARVEY 84	COSM
<3.E-23			neutron stars		KOLB 84	ASTR
<7.E-22			pulsars	0	36 FREESE 83B	ASTR
<1.E-18	<E18	1	intergalactic field	0	36 REPHAELI 83	COSM
<1.E-23			neutron stars	0	36 DIMOPOUL... 82	COSM
<5.E-22			neutron stars	0	36 KOLB 82	COSM
<5.E-15	>E21		galactic halo		SALPETER 82	COSM
<1.E-12	E19	1	$\beta=3.\text{E}-3$	0	38 TURNER 82	COSM
<1.E-16		1	galactic field	0	PARKER 70	COSM

³⁶ Catalysis of nucleon decay.

³⁷ ADAMS 93 limit based on “survival and growth of a small galactic seed field” is $10^{-16} (m/10^{17} \text{ GeV}) \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$. Above 10^{17} GeV , limit $10^{-16} (10^{17} \text{ GeV}/m) \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$ (from requirement that monopole density does not overclose the universe) is more stringent.

³⁸ Re-evaluates PARKER 70 limit for GUT monopoles.

Monopole Density — Matter Searches

<u>DENSITY</u>	<u>CHG (g)</u>	<u>MATERIAL</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<6.9E−6/gram	>1/3	Meteorites and other	0	JEON 95	INDU
<2.E−7/gram	>0.6	Fe ore	0	³⁹ EBISU 87	INDU
<4.6E−6/gram	> 0.5	deep schist	0	KOVALIK 86	INDU
<1.6E−6/gram	> 0.5	manganese nodules	0	⁴⁰ KOVALIK 86	INDU
<1.3E−6/gram	> 0.5	seawater	0	KOVALIK 86	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

³⁹ Mass 1×10^{14} – $1 \times 10^{17} \text{ GeV}$.

⁴⁰ KOVALIK 86 examined 498 kg of schist from two sites which exhibited clear mineralogical evidence of having been buried at least 20 km deep and held below the Curie temperature.

Monopole Density — Astrophysics

<u>DENSITY</u>	<u>CHG (g)</u>	<u>MATERIAL</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<1.E−9/gram	1	sun, catalysis	0	⁴¹ 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

⁴¹ Catalysis of nucleon decay.

REFERENCES FOR Magnetic Monopole Searches

AAD	12CS	PRL 109 261803	G. Aad <i>et al.</i>	(ATLAS Collab.)
ADRIAN-MAR...	12A	ASP 35 634	S. Adrian-Martinez <i>et al.</i>	(ANTARES Collab.)
UENO	12	ASP 36 131	K. Ueno <i>et al.</i>	(Super-Kamiokande Collab.)
DETRIXHE	11	PR D83 023513	M. Detrixhe <i>et al.</i>	(ANITA Collab.)
ABBASI	10A	EPJ C69 361	R. Abbasi <i>et al.</i>	(IceCube Collab.)
ABBIENDI	08	PL B663 37	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
BALESTRA	08	EPJ C55 57	S. Balestra <i>et al.</i>	(SLIM Collab.)
HOGAN	08	PR D78 075031	D.P. Hogan <i>et al.</i>	(KANS, NEBR, DELA)
ABULENCIA	06K	PRL 96 201801	A. Abulencia <i>et al.</i>	(CDF Collab.)
AKTAS	05A	EPJ C41 133	A. Aktas <i>et al.</i>	(H1 Collab.)
KALBFLEISCH	04	PR D69 052002	G.R. Kalbfleisch <i>et al.</i>	(OKLA)
AMBROSIO	02B	EPJ C25 511	M. Ambrosio <i>et al.</i>	(MACRO Collab.)
AMBROSIO	02C	EPJ C26 163	M. Ambrosio <i>et al.</i>	(MACRO Collab.)
AMBROSIO	02D	ASP 18 27	M. Ambrosio <i>et al.</i>	(MACRO Collab.)

KALBFLEISCH	00	PRL 85 5292	G.R. Kalbfleisch <i>et al.</i>
FREESE	99	PR D59 063007	K. Freese, E. Krasteva
ABBOTT	98K	PRL 81 524	B. Abbott <i>et al.</i> (D0 Collab.)
AMBROSIO	97	PL B406 249	M. Ambrosio <i>et al.</i> (MACRO Collab.)
HE	97	PRL 79 3134	Y.D. He (UCB)
ACCIARRI	95C	PL B345 609	M. Acciari <i>et al.</i> (L3 Collab.)
JEON	95	PRL 75 1443	H. Jeon, M.J. Longo (MICH)
Also		PRL 76 159 (erratum)	H. Jeon, M.J. Longo
AHLEN	94	PRL 72 608	S.P. Ahlen <i>et al.</i> (MACRO Collab.)
BARISH	94	PRL 73 1306	B.C. Barish, G. Giacomelli, J.T. Hong (CIT+)
BECKER-SZ...	94	PR D49 2169	R.A. Becker-Szendy <i>et al.</i> (IMB Collab.)
PRICE	94	PRL 73 1305	P.B. Price (UCB)
ADAMS	93	PRL 70 2511	F.C. Adams <i>et al.</i> (MICH, FNAL)
PINFOLD	93	PL B316 407	J.L. Pinfold <i>et al.</i> (ALBE, HARV, MONT+)
KINOSHITA	92	PR D46 R881	K. Kinoshita <i>et al.</i> (HARV, BGNA, REHO)
THRON	92	PR D46 4846	J.L. Thron <i>et al.</i> (SOUDAN-2 Collab.)
GARDNER	91	PR D44 622	R.D. Gardner <i>et al.</i> (STAN)
HUBER	91	PR D44 636	M.E. Huber <i>et al.</i> (STAN)
ORITO	91	PRL 66 1951	S. Orito <i>et al.</i> (ICEPP, WASCR, NIHO, ICRR)
BERMON	90	PRL 64 839	S. Berman <i>et al.</i> (IBM, BNL)
BERTANI	90	EPL 12 613	M. Bertani <i>et al.</i> (BGNA, INFN)
BEZRUKOV	90	SJNP 52 54	L.B. Bezrukov <i>et al.</i> (INRM)
		Translated from YAF 52 86.	
BUCKLAND	90	PR D41 2726	K.N. Buckland <i>et al.</i> (UCSD)
GHOSH	90	EPL 12 25	D.C. Ghosh, S. Chatterjea (JADA)
HUBER	90	PRL 64 835	M.E. Huber <i>et al.</i> (STAN)
PRICE	90	PRL 65 149	P.B. Price, J. Guiru, K. Kinoshita (UCB, HARV)
KINOSHITA	89	PL B228 543	K. Kinoshita <i>et al.</i> (HARV, TISA, KEK+)
BRAUNSCH...	88B	ZPHY C38 543	R. Braunschweig <i>et al.</i> (TASSO Collab.)
KINOSHITA	88	PRL 60 1610	K. Kinoshita <i>et al.</i> (HARV, TISA, KEK+)
BARISH	87	PR D36 2641	B.C. Barish, G. Liu, C. Lane (CIT)
BARTELT	87	PR D36 1990	J.E. Bartelt <i>et al.</i> (Soudan Collab.)
Also		PR D40 1701 (erratum)	J.E. Bartelt <i>et al.</i> (Soudan Collab.)
EBISU	87	PR D36 3359	T. Ebisu, T. Watanabe (KOBE)
Also		JPG 11 883	T. Ebisu, T. Watanabe (KOBE)
GENTILE	87	PR D35 1081	T. Gentile <i>et al.</i> (CLEO Collab.)
GUY	87	NAT 325 463	J. Guy (LOIC)
MASEK	87	PR D35 2758	G.E. Masek <i>et al.</i> (UCSD)
NAKAMURA	87	PL B183 395	S. Nakamura <i>et al.</i> (INUS, WASCR, NIHO)
PRICE	87	PRL 59 2523	P.B. Price, R. Guoxiao, K. Kinoshita (UCB, HARV)
SCHOUTEN	87	JPE 20 850	J.C. Schouten <i>et al.</i> (LOIC)
SHEPKO	87	PR D35 2917	M.J. Shepko <i>et al.</i> (TAMU)
TSUKAMOTO	87	EPL 3 39	T. Tsukamoto <i>et al.</i> (ICRR)
CAPLIN	86	NAT 321 402	A.D. Caplin <i>et al.</i> (LOIC)
Also		JPE 20 850	J.C. Schouten <i>et al.</i> (LOIC)
Also		NAT 325 463	J. Guy (LOIC)
CROMAR	86	PRL 56 2561	M.W. Cromar, A.F. Clark, F.R. Fickett (NBSB)
HARA	86	PRL 56 553	T. Hara <i>et al.</i> (ICRR, KYOT, KEK, KOBE+)
INCANDELA	86	PR D34 2637	J. Incandela <i>et al.</i> (CHIC, FNAL, MICH)
KOVALIK	86	PR A33 1183	J.M. Kovalik, J.L. Kirschwink (CIT)
PRICE	86	PRL 56 1226	P.B. Price, M.H. Salamon (UCB)
ARAFUNE	85	PR D32 2586	J. Arafune, M. Fukugita, S. Yanagita (ICRR, KYOTU+)
BERMON	85	PRL 55 1850	S. Berman <i>et al.</i> (IBM)
BRACCI	85B	NP B258 726	L. Bracci, G. Fiorentini, G. Mezzorani (PISA+)
Also		LNC 42 123	L. Bracci, G. Fiorentini (PISA)
CAPLIN	85	NAT 317 234	A.D. Caplin <i>et al.</i> (LOIC)
EBISU	85	JPG 11 883	T. Ebisu, T. Watanabe (KOBE)
KAJITA	85	JPSJ 54 4065	T. Kajita <i>et al.</i> (ICRR, KEK, NIIG)
PARK	85B	NP B252 261	H.S. Park <i>et al.</i> (IMB Collab.)
BATTISTONI	84	PL 133B 454	G. Battistoni <i>et al.</i> (NUSEX Collab.)
FRYBERGER	84	PR D29 1524	D. Fryberger <i>et al.</i> (SLAC, UCB)
HARVEY	84	NP B236 255	J.A. Harvey (PRIN)
INCANDELA	84	PRL 53 2067	J. Incandela <i>et al.</i> (CHIC, FNAL, MICH)
KAJINO	84	PRL 52 1373	F. Kajino <i>et al.</i> (ICRR)
KAJINO	84B	JPG 10 447	F. Kajino <i>et al.</i> (ICRR)
KAWAGOE	84	LNC 41 315	K. Kawagoe <i>et al.</i> (TOKY)
KOLB	84	APJ 286 702	E.W. Kolb, M.S. Turner (FNAL, CHIC)
KRISHNA...	84	PL 142B 99	M.R. Krishnaswamy <i>et al.</i> (TATA, OSKC+)
LISS	84	PR D30 884	T.M. Liss, S.P. Ahlen, G. Tarle (UCB, IND+)
PRICE	84	PRL 52 1265	P.B. Price <i>et al.</i> (ROMA, UCB, IND+)
PRICE	84B	PL 140B 112	P.B. Price (CERN)

TARLE	84	PRL 52 90	G. Tarle, S.P. Ahlen, T.M. Liss	(UCB, MICH+)
ANDERSON	83	PR D28 2308	S.N. Anderson <i>et al.</i>	(WASH)
ARAFUNE	83	PL 133B 380	J. Arafune, M. Fukugita	(ICRR, KYOTU)
AUBERT	83B	PL 120B 465	B. Aubert <i>et al.</i>	(CERN, LAPP)
BARTELT	83B	PRL 50 655	J.E. Bartelt <i>et al.</i>	(MINN, ANL)
BARWICK	83	PR D28 2338	S.W. Barwick, K. Kinoshita, P.B. Price	(UCB)
BONARELLI	83	PL 126B 137	R. Bonarelli, P. Capiluppi, I. d'Antone	(BGNA)
BOSETTI	83	PL 133B 265	P.C. Bosetti <i>et al.</i>	(AACH3, HAWA, TOKY)
CABRERA	83	PRL 51 1933	B. Cabrera <i>et al.</i>	(STAN)
DOKE	83	PL 129B 370	T. Doke <i>et al.</i>	(WASU, RIKK, TTAM, RIKEN)
ERREDE	83	PRL 51 245	S.M. Errede <i>et al.</i>	(IMB Collab.)
FREESE	83B	PRL 51 1625	K. Freese, M.S. Turner, D.N. Schramm	(CHIC)
GROOM	83	PRL 50 573	D.E. Groom <i>et al.</i>	(UTAH, STAN)
MASHIMO	83	PL 128B 327	T. Mashimo <i>et al.</i>	(ICEPP)
MIKHAILOV	83	PL 130B 331	V.F. Mikhailov	(KAZA)
MUSSET	83	PL 128B 333	P. Musset, M. Price, E. Lohrmann	(CERN, HAMB)
REPHAELI	83	PL 121B 115	Y. Rephaeli, M.S. Turner	(CHIC)
SCHATTEN	83	PR D27 1525	K.H. Schatten	(NASA)
ALEXEYEV	82	LNC 35 413	E.N. Alekseev <i>et al.</i>	(INRM)
BONARELLI	82	PL 112B 100	R. Bonarelli <i>et al.</i>	(BGNA)
CABRERA	82	PRL 48 1378	B. Cabrera	(STAN)
DELL	82	NP B209 45	G.F. Dell <i>et al.</i>	(BNL, ADEL, ROMA)
DIMOPOUL...	82	PL 119B 320	S. Dimopoulos, J. Preskill, F. Wilczek	(HARV+)
KINOSHITA	82	PRL 48 77	K. Kinoshita, P.B. Price, D. Fryberger	(UCB+)
KOLB	82	PRL 49 1373	E.W. Kolb, S.A. Colgate, J.A. Harvey	(LASL, PRIN)
MASHIMO	82	JPSJ 51 3067	T. Mashimo, K. Kawagoe, M. Koshihira	(INUS)
SALPETER	82	PRL 49 1114	E.E. Salpeter, S.L. Shapiro, I. Wasserman	(CORN)
TURNER	82	PR D26 1296	M.S. Turner, E.N. Parker, T.J. Bogdan	(CHIC)
BARTLETT	81	PR D24 612	D.F. Bartlett <i>et al.</i>	(COLO, GESC)
KINOSHITA	81B	PR D24 1707	K. Kinoshita, P.B. Price	(UCB)
ULLMAN	81	PRL 47 289	J.D. Ullman	(LEHM, BNL)
CARRIGAN	80	NAT 288 348	R.A. Carrigan	(FNAL)
BRODERICK	79	PR D19 1046	J.J. Broderick <i>et al.</i>	(VPI)
BARTLETT	78	PR D18 2253	D.F. Bartlett, D. Soo, M.G. White	(COLO, PRIN)
CARRIGAN	78	PR D17 1754	R.A. Carrigan, B.P. Strauss, G. Giacomelli	(FNAL+)
HOFFMANN	78	LNC 23 357	H. Hoffmann <i>et al.</i>	(CERN, ROMA)
PRICE	78	PR D18 1382	P.B. Price <i>et al.</i>	(UCB, HOUS)
HAGSTROM	77	PRL 38 729	R. Hagstrom	(LBL)
CARRIGAN	76	PR D13 1823	R.A. Carrigan, F.A. Nezrick, B.P. Strauss	(FNAL)
DELL	76	LNC 15 269	G.F. Dell <i>et al.</i>	(CERN, BNL, ROMA, ADEL)
ROSS	76	LBL-4665	R.R. Ross	(LBL)
STEVENS	76B	PR D14 2207	D.M. Stevens <i>et al.</i>	(VPI, BNL)
ZRELOV	76	CZJP B26 1306	V.P. Zrelov <i>et al.</i>	(JINR)
ALVAREZ	75	LBL-4260	L.W. Alvarez	(LBL)
BURKE	75	PL 60B 113	D.L. Burke <i>et al.</i>	(MICH)
CABRERA	75	Thesis	B. Cabrera	(STAN)
CARRIGAN	75	NP B91 279	R.A. Carrigan, F.A. Nezrick	(FNAL)
Also		PR D3 56	R.A. Carrigan, F.A. Nezrick	(FNAL)
EBERHARD	75	PR D11 3099	P.H. Eberhard <i>et al.</i>	(LBL, MPIM)
EBERHARD	75B	LBL-4289	P.H. Eberhard	(LBL)
FLEISCHER	75	PRL 35 1412	R.L. Fleischer, R.N.F. Walker	(GESC, WUSL)
FRIEDLANDER	75	PRL 35 1167	M.W. Friedlander	(WUSL)
GIACOMELLI	75	NC 28A 21	G. Giacomelli <i>et al.</i>	(BGNA, CERN, SACL+)
PRICE	75	PRL 35 487	P.B. Price <i>et al.</i>	(UCB, HOUS)
CARRIGAN	74	PR D10 3867	R.A. Carrigan, F.A. Nezrick, B.P. Strauss	(FNAL)
CARRIGAN	73	PR D8 3717	R.A. Carrigan, F.A. Nezrick, B.P. Strauss	(FNAL)
ROSS	73	PR D8 698	R.R. Ross <i>et al.</i>	(LBL, SLAC)
Also		PR D4 3260	P.H. Eberhard <i>et al.</i>	(LBL, SLAC)
Also		SCI 167 701	L.W. Alvarez <i>et al.</i>	(LBL, SLAC)
BARTLETT	72	PR D6 1817	D.F. Bartlett, M.D. Lahana	(COLO)
GUREVICH	72	PL 38B 549	I.I. Gurevich <i>et al.</i>	(KIAE, NOVO, SERP)
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Also		Translated from ZETF 61		
Also		PL 31B 394	I.I. Gurevich <i>et al.</i>	(KIAE, NOVO, SERP)
FLEISCHER	71	PR D4 24	R.L. Fleischer <i>et al.</i>	(GESC)
KOLM	71	PR D4 1285	H.H. Kolm, F. Villa, A. Odian	(MIT, SLAC)
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SCHATTEN	70	PR D1 2245	K.H. Schatten	(NASA)
FLEISCHER	69	PR 177 2029	R.L. Fleischer <i>et al.</i>	(GESC, FSU)
FLEISCHER	69B	PR 184 1393	R.L. Fleischer <i>et al.</i>	(GESC, UNCS, GSCO)

FLEISCHER	69C	PR 184 1398	R.L. Fleischer, P.B. Price, R.T. Woods	(GESC)
Also		JAP 41 958	R.L. Fleischer <i>et al.</i>	(GESC)
CARITHERS	66	PR 149 1070	W.C.J. Carithers, R.J. Stefanski, R.K. Adair	
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