p

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: ****

p MASS (atomic mass units u)

The mass is known much more precisely in u (atomic mass units) than in MeV. See the next data block.

VALUE (u)	DOCUMENT ID		TECN	COMMENT
1.00727646688±0.00000000013	MOHR	05	RVUE	2002 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.00727646688±0.00000000013	MOHR	99	RVUE	1998 CODATA value
1.007276470 ±0.000000012	COHEN	87	RVUE	1986 CODATA value

p MASS (MeV)

The mass is known much more precisely in u (atomic mass units) than in MeV. The conversion from u to MeV, 1 u = 931.494043±0.000080 MeV/c^2 (MOHR 05, the 2002 CODATA value), involves the relatively poorly known electronic charge.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
938.272029±0.000080	MOHR	05	RVUE	2002 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
938.271998±0.000038	MOHR	99	RVUE	1998 CODATA value
938.27231 ±0.00028	COHEN	87	RVUE	1986 CODATA value
938.2796 ±0.0027	COHEN	73	RVUE	1973 CODATA value

$|m_p - m_{\overline{p}}|/m_p$

A test of *CPT* invariance. Note that the comparison of the $\overline{p}$ and p charge-to-mass ratio, given in the next data block, is much better determined.

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<1.0 \times 10^{-8}$	90	[1] HORI	03	SPEC	$\overline{p}e^-$ ^{4}He and $\overline{p}e^-$ ^{3}He
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<6 \times 10^{-8}$	90	[1] HORI	01	SPEC	$\overline{p}e^-$He atom
$<5 \times 10^{-7}$		[2] TORII	99	SPEC	$\overline{p}e^-$He atom

[1] HORI 01 and HORI 03 use the more-precisely-known constraint on the $\overline{p}$ charge-to-mass ratio of GABRIELSE 99 (see below) to get their results. Their results are not independent of the HORI 01 and HORI 03 values for $|q_p + q_{\overline{p}}|/e$, below.

[2] TORII 99 uses the more-precisely-known constraint on the $\overline{p}$ charge-to-mass ratio of GABRIELSE 95 (see below) to get this result. This is not independent of the TORII 99 value for $|q_p + q_{\overline{p}}|/e$, below.

$\overline{p}/p$ CHARGE-TO-MASS RATIO, $\left|\frac{q_{\overline{p}}}{m_{\overline{p}}}\right|/(\frac{q_p}{m_p})$

A test of *CPT* invariance. Listed here are measurements involving the *inertial* masses. For a discussion of what may be inferred about the ratio of $\overline{p}$ and p *gravitational* masses, see ERICSON 90; they obtain an upper bound of 10^{-6}–10^{-7} for violation of the equivalence principle for $\overline{p}$'s.

VALUE	DOCUMENT ID		TECN	COMMENT
0.99999999991±0.00000000009	GABRIELSE	99	TRAP	Penning trap
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.0000000015 ±0.0000000011	[3] GABRIELSE	95	TRAP	Penning trap
1.000000023 ±0.000000042	[4] GABRIELSE	90	TRAP	Penning trap

[3] Equation (2) of GABRIELSE 95 should read $M(\overline{p})/M(p) = 0.999\,999\,99\underline{8}5\,(11)$ (G. Gabrielse, private communication).

[4] GABRIELSE 90 also measures $m_{\overline{p}}/m_{e^-} = 1836.152660 \pm 0.000083$ and $m_p/m_{e^-} = 1836.152680 \pm 0.000088$. Both are completely consistent with the 1986 CODATA (COHEN 87) value for m_p/m_{e^-} of 1836.152701 ± 0.000037.

$(\left|\frac{q_{\overline{p}}}{m_{\overline{p}}}\right| - \frac{q_p}{m_p})/\frac{q_p}{m_p}$

A test of *CPT* invariance. Taken from the $\overline{p}/p$ charge-to-mass ratio, above.

VALUE	DOCUMENT ID
$(-9\pm9)\times10^{-11}$ OUR EVALUATION	

$|q_p + q_{\overline{p}}|/e$

A test of *CPT* invariance. Note that the comparison of the $\overline{p}$ and p charge-to-mass ratios given above is much better determined. See also a similar test involving the electron.

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<1.0\times10^{-8}$	90	[5] HORI	03	SPEC	$\overline{p}e^-$ ^{4}He and $\overline{p}e^-$ ^{3}He
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<6\times10^{-8}$	90	[5] HORI	01	SPEC	$\overline{p}e^-$He atom
$<5\times10^{-7}$		[6] TORII	99	SPEC	$\overline{p}e^-$He atom
$<2\times10^{-5}$		[7] HUGHES	92	RVUE	

[5] HORI 01 and HORI 03 use the more-precisely-known constraint on the $\overline{p}$ charge-to-mass ratio of GABRIELSE 99 (see above) to get their results. Their results are not independent of the HORI 01 and HORI 03 values for $|m_p - m_{\overline{p}}|/m_p$, above.

[6] TORII 99 uses the more-precisely-known constraint on the $\overline{p}$ charge-to-mass ratio of GABRIELSE 95 (see above) to get this result. This is not independent of the TORII 99 value for $|m_p - m_{\overline{p}}|/m_p$, above.

[7] HUGHES 92 uses recent measurements of Rydberg-energy and cyclotron-frequency ratios.

$|q_p + q_e|/e$

See DYLLA 73 for a summary of experiments on the neutrality of matter.
See also "n CHARGE" in the neutron Listings.

VALUE	DOCUMENT ID		COMMENT
$<1.0 \times 10^{-21}$	[8] DYLLA	73	Neutrality of SF_6
• • • We do not use the following data for averages, fits, limits, etc. • • •			
$<3.2 \times 10^{-20}$	[9] SENGUPTA	00	binary pulsar
$<0.8 \times 10^{-21}$	MARINELLI	84	Magnetic levitation

[8] Assumes that $q_n = q_p + q_e$.

[9] SENGUPTA 00 uses the difference between the observed rate of of rotational energy loss by the binary pulsar PSR B1913+16 and the rate predicted by general relativity to set this limit. See the paper for assumptions.

p MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the Λ Listings.

VALUE (μ_N)	DOCUMENT ID		TECN	COMMENT
2.792847351±0.000000028	MOHR	05	RVUE	2002 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.792847337±0.000000029	MOHR	99	RVUE	1998 CODATA value
2.792847386±0.000000063	COHEN	87	RVUE	1986 CODATA value
2.7928456 ±0.0000011	COHEN	73	RVUE	1973 CODATA value

$\overline{p}$ MAGNETIC MOMENT

A few early results have been omitted.

VALUE (μ_N)	DOCUMENT ID		TECN	COMMENT
−2.800 ±0.008 OUR AVERAGE				
−2.8005±0.0090	KREISSL	88	CNTR	$\overline{p}$ ^{208}Pb 11→ 10 X-ray
−2.817 ±0.048	ROBERTS	78	CNTR	
−2.791 ±0.021	HU	75	CNTR	Exotic atoms

$(\mu_p + \mu_{\overline{p}}) / \mu_p$

A test of CPT invariance. Calculated from the p and $\overline{p}$ magnetic moments, above.

VALUE	DOCUMENT ID
$(-2.6\pm2.9) \times 10^{-3}$ OUR EVALUATION	

p ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both T invariance and P invariance.

VALUE (10^{-23} e cm)	EVTS	DOCUMENT ID		TECN	COMMENT
< 0.54		[10] DMITRIEV	03		Uses ^{199}Hg atom EDM
• • • We do not use the following data for averages, fits, limits, etc. • • •					
− 3.7 ± 6.3		CHO	89	NMR	Tl F molecules
< 400		DZUBA	85	THEO	Uses ^{129}Xe moment
130 ± 200		[11] WILKENING	84		
900 ±1400		[12] WILKENING	84		
700 ± 900	1G	HARRISON	69	MBR	Molecular beam

[10] DMITRIEV 03 calculates this limit from the limit on the electric dipole moment of the ^{199}Hg atom.

[11] This WILKENING 84 value includes a finite-size effect and a magnetic effect.

[12] This WILKENING 84 value is more cautious than the other and excludes the finite-size effect, which relies on uncertain nuclear integrals.

p ELECTRIC POLARIZABILITY α_p

For a very complete review of the "polarizability of the nucleon and Compton scattering," see SCHUMACHER 05. His recommended values for the proton are $\alpha_p = (12.0 \pm 0.6) \times 10^{-4}$ fm^3 and $\beta_p = (1.9 \mp 0.6) \times 10^{-4}$ fm^3, almost exactly our averages.

VALUE (10^{-4} fm^3)	DOCUMENT ID		TECN	COMMENT
12.0 ±0.6 OUR AVERAGE				
12.1 ±1.1 ±0.5	[13] BEANE	03		EFT + γp
$11.82 \pm 0.98^{+0.52}_{-0.98}$	[14] BLANPIED	01	LEGS	$p(\vec{\gamma},\gamma)$, $p(\vec{\gamma},\pi^0)$, $p(\vec{\gamma},\pi^+)$
11.9 ±0.5 ±1.3	[15] OLMOSDEL...	01	CNTR	γp Compton scattering
12.1 ±0.8 ±0.5	[16] MACGIBBON	95	RVUE	global average
• • • We do not use the following data for averages, fits, limits, etc. • • •				
11.7 ±0.8 ±0.7	[17] BARANOV	01	RVUE	Global average
12.5 ±0.6 ±0.9	MACGIBBON	95	CNTR	γp Compton scattering
9.8 ±0.4 ±1.1	HALLIN	93	CNTR	γp Compton scattering
$10.62^{+1.25}_{-1.19}{}^{+1.07}_{-1.03}$	ZIEGER	92	CNTR	γp Compton scattering
10.9 ±2.2 ±1.3	[18] FEDERSPIEL	91	CNTR	γp Compton scattering

[13] BEANE 03 uses effective field theory and low-energy γp and γd Compton-scattering data. It also gets for the isoscalar polarizabilities (see the erratum) $\alpha_N = (13.0 \pm 1.9^{+3.9}_{-1.5}) \times 10^{-4}$ fm^3 and $\beta_N = (-1.8 \pm 1.9^{+2.1}_{-0.9}) \times 10^{-4}$ fm^3.

[14] BLANPIED 01 gives $\alpha_p + \beta_p$ and $\alpha_p - \beta_p$. The separate α_p and β_p are provided to us by A. Sandorfi. The first error above is statistics plus systematics; the second is from the model.

[15] This OLMOSDELEON 01 result uses the TAPS data alone, and does not use the (re-evaluated) sum-rule constraint that $\alpha + \beta = (13.8 \pm 0.4) \times 10^{-4}$ fm^3. See the paper for a discussion.

[16] MACGIBBON 95 combine the results of ZIEGER 92, FEDERSPIEL 91, and their own experiment to get a "global average" in which model errors and systematic errors are treated in a consistent way. See MACGIBBON 95 for a discussion.

[17] BARANOV 01 combines the results of 10 experiments from 1958 through 1995 to get a global average that takes into account both systematic and model errors and does not use the theoretical constraint on the sum $\alpha_p + \beta_p$.

[18] FEDERSPIEL 91 obtains for the (static) electric polarizability α_p, defined in terms of the induced electric dipole moment by $\mathbf{D} = 4\pi\epsilon_0\alpha_p\mathbf{E}$, the value $(7.0\pm2.2\pm1.3)\times10^{-4}$ fm^3.

p MAGNETIC POLARIZABILITY β_p

The electric and magnetic polarizabilities are subject to a dispersion sum-rule constraint $\overline{\alpha} + \overline{\beta} = (14.2 \pm 0.5) \times 10^{-4}$ fm^3. Errors here are anticorrelated with those on $\overline{\alpha}_p$ due to this constraint.

VALUE (10^{-4} fm^3)	*DOCUMENT ID*		*TECN*	*COMMENT*
1.9 ±0.5 OUR AVERAGE				
3.4 ±1.1 ±0.1	[19] BEANE	03		EFT + γp
$1.43\pm0.98^{+0.52}_{-0.98}$	[20] BLANPIED	01	LEGS	$p(\vec{\gamma},\gamma)$, $p(\vec{\gamma},\pi^0)$, $p(\vec{\gamma},\pi^+)$
1.2 ±0.7 ±0.5	[21] OLMOSDEL...	01	CNTR	γp Compton scattering
2.1 ±0.8 ±0.5	[22] MACGIBBON	95	RVUE	global average
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.3 ±0.9 ±0.7	[23] BARANOV	01	RVUE	Global average
1.7 ±0.6 ±0.9	MACGIBBON	95	CNTR	γp Compton scattering
4.4 ±0.4 ±1.1	HALLIN	93	CNTR	γp Compton scattering
$3.58^{+1.19}_{-1.25}{}^{+1.03}_{-1.07}$	ZIEGER	92	CNTR	γp Compton scattering
3.3 ±2.2 ±1.3	FEDERSPIEL	91	CNTR	γp Compton scattering

[19] BEANE 03 uses effective field theory and low-energy γp and γd Compton-scattering data. It also gets for the isoscalar polarizabilities (see the erratum) $\alpha_N = (13.0 \pm 1.9^{+3.9}_{-1.5}) \times 10^{-4}$ fm^3 and $\beta_N = (-1.8 \pm 1.9^{+2.1}_{-0.9}) \times 10^{-4}$ fm^3.

[20] BLANPIED 01 gives $\alpha_p + \beta_p$ and $\alpha_p - \beta_p$. The separate α_p and β_p are provided to us by A. Sandorfi. The first error above is statistics plus systematics; the second is from the model.

[21] This OLMOSDELEON 01 result uses the TAPS data alone, and does not use the (re-evaluated) sum-rule constraint that $\alpha+\beta = (13.8 \pm 0.4) \times 10^{-4}$ fm^3. See the paper for a discussion.

[22] MACGIBBON 95 combine the results of ZIEGER 92, FEDERSPIEL 91, and their own experiment to get a "global average" in which model errors and systematic errors are treated in a consistent way. See MACGIBBON 95 for a discussion.

[23] BARANOV 01 combines the results of 10 experiments from 1958 through 1995 to get a global average that takes into account both systematic and model errors and does not use the theoretical constraint on the sum $\alpha_p + \beta_p$.

p CHARGE RADIUS

This is the rms charge radius, $\sqrt{\langle r^2 \rangle}$.

VALUE (fm)	*DOCUMENT ID*		*COMMENT*
0.8750±0.0068	MOHR	05	2002 CODATA value

• • • We do not use the following data for averages, fits, limits, etc. • • •

0.897 ±0.018		BLUNDEN	05	SICK 03 + 2γ correction
0.895 ±0.010 ±0.013		SICK	03	$ep \rightarrow ep$ reanalysis
0.830 ±0.040 ±0.040	[24]	ESCHRICH	01	$ep \rightarrow ep$
0.883 ±0.014		MELNIKOV	00	1S Lamb Shift in H
0.880 ±0.015		ROSENFELDR.	00	ep + Coul. corrections
0.847 ±0.008		MERGELL	96	ep + disp. relations
0.877 ±0.024		WONG	94	reanalysis of Mainz ep data
0.865 ±0.020		MCCORD	91	$ep \rightarrow ep$
0.862 ±0.012		SIMON	80	$ep \rightarrow ep$
0.880 ±0.030		BORKOWSKI	74	$ep \rightarrow ep$
0.810 ±0.020		AKIMOV	72	$ep \rightarrow ep$
0.800 ±0.025		FREREJACQ...	66	$ep \rightarrow ep$ (CH_2 tgt.)
0.805 ±0.011		HAND	63	$ep \rightarrow ep$

[24] ESCHRICH 01 actually gives $\langle r^2 \rangle = (0.69 \pm 0.06 \pm 0.06)$ fm^2.

p MEAN LIFE

A test of baryon conservation. See the "*p* Partial Mean Lives" section below for limits for identified final states. The limits here are to "anything" or are for "disappearance" modes of a bound proton (p) or (n). See also the 3ν modes in the "Partial Mean Lives" section. Table 1 of BACK 03 is a nice summary.

LIMIT (years)	PARTICLE	CL%		DOCUMENT ID		TECN	COMMENT
$>5.8 \times 10^{29}$	***n***	90	[25]	ARAKI	06	KLND	$n \rightarrow$ invisible
$>2.1 \times 10^{29}$	***p***	90	[26]	AHMED	04	SNO	$p \rightarrow$ invisible
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$>1.9 \times 10^{29}$	n	90	[26]	AHMED	04	SNO	$n \rightarrow$ invisible
$>1.8 \times 10^{25}$	n	90	[27]	BACK	03	BORX	
$>1.1 \times 10^{26}$	p	90	[27]	BACK	03	BORX	
$>3.5 \times 10^{28}$	p	90	[28]	ZDESENKO	03		$p \rightarrow$ invisible
$>1 \times 10^{28}$	p	90	[29]	AHMAD	02	SNO	$p \rightarrow$ invisible
$>4 \times 10^{23}$	p	95		TRETYAK	01		$d \rightarrow n$ + ?
$>1.9 \times 10^{24}$	p	90	[30]	BERNABEI	00B	DAMA	
$>1.6 \times 10^{25}$	p, n		[31,32]	EVANS	77		
$>3 \times 10^{23}$	p		[32]	DIX	70	CNTR	
$>3 \times 10^{23}$	p, n		[32,33]	FLEROV	58		

[25] ARAKI 06 looks for signs of de-excitation of the residual nucleus after disappearance of a neutron from the s shell of ^{12}C.

[26] AHMED 04 looks for γ rays from the de-excitation of a residual ^{15}O* or ^{15}N* following the disappearance of a neutron or proton in ^{16}O.

[27] BACK 03 looks for decays of unstable nuclides left after N decays of parent ^{12}C, ^{13}C, ^{16}O nuclei. These are "invisible channel" limits.

[28] ZDESENKO 03 gets this limit on proton disappearance in deuterium by analyzing SNO data in AHMAD 02.

[29] AHMAD 02 (see its footnote 7) looks for neutrons left behind after the disappearance of the proton in deuterons.

[30] BERNABEI 00B looks for the decay of a $^{128}_{53}$I nucleus following the disappearance of a proton in the otherwise-stable $^{129}_{54}$Xe nucleus.

[31] EVANS 77 looks for the daughter nuclide ^{129}Xe from possible ^{130}Te decays in ancient Te ore samples.

[32] This mean-life limit has been obtained from a half-life limit by dividing the latter by ln(2) = 0.693.

[33] FLEROV 58 looks for the spontaneous fission of a ^{232}Th nucleus after the disappearance of one of its nucleons.

$\overline{p}$ MEAN LIFE

Of the two astrophysical limits here, that of GEER 00D involves considerably more refinements in its modeling. The other limits come from direct observations of stored antiprotons. See also "$\overline{p}$ Partial Mean Lives" after "p Partial Mean Lives," below, for exclusive-mode limits. The best (lifetime/branching fraction) limit there is 7×10^5 years, for $\overline{p} \rightarrow e^- \gamma$. We advance only the exclusive-mode limits to our Summary Tables.

LIMIT (years)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$>8 \times 10^5$	90		[34] GEER	00D		$\overline{p}/p$ ratio, cosmic rays
>0.28			GABRIELSE	90	TRAP	Penning trap
>0.08	90	1	BELL	79	CNTR	Storage ring
$>1 \times 10^7$			GOLDEN	79	SPEC	$\overline{p}/p$ ratio, cosmic rays
$>3.7 \times 10^{-3}$			BREGMAN	78	CNTR	Storage ring

[34] GEER 00D uses agreement between a model of galactic $\overline{p}$ production and propagation and the observed $\overline{p}/p$ cosmic-ray spectrum to set this limit.

p DECAY MODES

See the "Note on Nucleon Decay" in our 1994 edition (Phys. Rev. **D50**, 1673) for a short review.

The "partial mean life" limits tabulated here are the limits on τ/B_i, where τ is the total mean life and B_i is the branching fraction for the mode in question. For N decays, p and n indicate proton and neutron partial lifetimes.

	Mode	Partial mean life (10^{30} years)	Confidence level
	Antilepton + meson		
τ_1	$N \rightarrow e^+ \pi$	> 158 (n), > 1600 (p)	90%
τ_2	$N \rightarrow \mu^+ \pi$	> 100 (n), > 473 (p)	90%
τ_3	$N \rightarrow \nu \pi$	> 112 (n), > 25 (p)	90%
τ_4	$p \rightarrow e^+ \eta$	> 313	90%
τ_5	$p \rightarrow \mu^+ \eta$	> 126	90%
τ_6	$n \rightarrow \nu \eta$	> 158	90%
τ_7	$N \rightarrow e^+ \rho$	> 217 (n), > 75 (p)	90%
τ_8	$N \rightarrow \mu^+ \rho$	> 228 (n), > 110 (p)	90%
τ_9	$N \rightarrow \nu \rho$	> 19 (n), > 162 (p)	90%
τ_{10}	$p \rightarrow e^+ \omega$	> 107	90%

τ_{11}	$p \rightarrow \mu^+ \omega$	> 117	90%
τ_{12}	$n \rightarrow \nu \omega$	> 108	90%
τ_{13}	$N \rightarrow e^+ K$	> 17 (n), > 150 (p)	90%
τ_{14}	$p \rightarrow e^+ K^0_S$	> 120	90%
τ_{15}	$p \rightarrow e^+ K^0_L$	> 51	90%
τ_{16}	$N \rightarrow \mu^+ K$	> 26 (n), > 120 (p)	90%
τ_{17}	$p \rightarrow \mu^+ K^0_S$	> 150	90%
τ_{18}	$p \rightarrow \mu^+ K^0_L$	> 83	90%
τ_{19}	$N \rightarrow \nu K$	> 86 (n), > 670 (p)	90%
τ_{20}	$n \rightarrow \nu K^0_S$	> 51	90%
τ_{21}	$p \rightarrow e^+ K^*(892)^0$	> 84	90%
τ_{22}	$N \rightarrow \nu K^*(892)$	> 78 (n), > 51 (p)	90%

Antilepton + mesons

τ_{23}	$p \rightarrow e^+ \pi^+ \pi^-$	> 82	90%
τ_{24}	$p \rightarrow e^+ \pi^0 \pi^0$	> 147	90%
τ_{25}	$n \rightarrow e^+ \pi^- \pi^0$	> 52	90%
τ_{26}	$p \rightarrow \mu^+ \pi^+ \pi^-$	> 133	90%
τ_{27}	$p \rightarrow \mu^+ \pi^0 \pi^0$	> 101	90%
τ_{28}	$n \rightarrow \mu^+ \pi^- \pi^0$	> 74	90%
τ_{29}	$n \rightarrow e^+ K^0 \pi^-$	> 18	90%

Lepton + meson

τ_{30}	$n \rightarrow e^- \pi^+$	> 65	90%
τ_{31}	$n \rightarrow \mu^- \pi^+$	> 49	90%
τ_{32}	$n \rightarrow e^- \rho^+$	> 62	90%
τ_{33}	$n \rightarrow \mu^- \rho^+$	> 7	90%
τ_{34}	$n \rightarrow e^- K^+$	> 32	90%
τ_{35}	$n \rightarrow \mu^- K^+$	> 57	90%

Lepton + mesons

τ_{36}	$p \rightarrow e^- \pi^+ \pi^+$	> 30	90%
τ_{37}	$n \rightarrow e^- \pi^+ \pi^0$	> 29	90%
τ_{38}	$p \rightarrow \mu^- \pi^+ \pi^+$	> 17	90%
τ_{39}	$n \rightarrow \mu^- \pi^+ \pi^0$	> 34	90%
τ_{40}	$p \rightarrow e^- \pi^+ K^+$	> 75	90%
τ_{41}	$p \rightarrow \mu^- \pi^+ K^+$	> 245	90%

Antilepton + photon(s)

τ_{42}	$p \rightarrow e^+ \gamma$	> 670	90%
τ_{43}	$p \rightarrow \mu^+ \gamma$	> 478	90%
τ_{44}	$n \rightarrow \nu \gamma$	> 28	90%
τ_{45}	$p \rightarrow e^+ \gamma \gamma$	> 100	90%
τ_{46}	$n \rightarrow \nu \gamma \gamma$	> 219	90%

Three (or more) leptons

τ_{47}	$p \rightarrow e^+ e^+ e^-$	> 793	90%
τ_{48}	$p \rightarrow e^+ \mu^+ \mu^-$	> 359	90%
τ_{49}	$p \rightarrow e^+ \nu \nu$	> 17	90%
τ_{50}	$n \rightarrow e^+ e^- \nu$	> 257	90%
τ_{51}	$n \rightarrow \mu^+ e^- \nu$	> 83	90%
τ_{52}	$n \rightarrow \mu^+ \mu^- \nu$	> 79	90%
τ_{53}	$p \rightarrow \mu^+ e^+ e^-$	> 529	90%
τ_{54}	$p \rightarrow \mu^+ \mu^+ \mu^-$	> 675	90%
τ_{55}	$p \rightarrow \mu^+ \nu \nu$	> 21	90%
τ_{56}	$p \rightarrow e^- \mu^+ \mu^+$	> 6	90%
τ_{57}	$n \rightarrow 3\nu$	> 0.0005	90%
τ_{58}	$n \rightarrow 5\nu$		

Inclusive modes

τ_{59}	$N \rightarrow e^+$ anything	> 0.6 (n, p)	90%
τ_{60}	$N \rightarrow \mu^+$ anything	> 12 (n, p)	90%
τ_{61}	$N \rightarrow \nu$ anything		
τ_{62}	$N \rightarrow e^+ \pi^0$ anything	> 0.6 (n, p)	90%
τ_{63}	$N \rightarrow$ 2 bodies, ν-free		

$\Delta B = 2$ dinucleon modes

The following are lifetime limits per iron nucleus.

τ_{64}	$p p \rightarrow \pi^+ \pi^+$	> 0.7	90%
τ_{65}	$p n \rightarrow \pi^+ \pi^0$	> 2	90%
τ_{66}	$n n \rightarrow \pi^+ \pi^-$	> 0.7	90%
τ_{67}	$n n \rightarrow \pi^0 \pi^0$	> 3.4	90%
τ_{68}	$p p \rightarrow e^+ e^+$	> 5.8	90%
τ_{69}	$p p \rightarrow e^+ \mu^+$	> 3.6	90%
τ_{70}	$p p \rightarrow \mu^+ \mu^+$	> 1.7	90%
τ_{71}	$p n \rightarrow e^+ \overline{\nu}$	> 2.8	90%
τ_{72}	$p n \rightarrow \mu^+ \overline{\nu}$	> 1.6	90%
τ_{73}	$n n \rightarrow \nu_e \overline{\nu}_e$	> 0.000049	90%
τ_{74}	$n n \rightarrow \nu_\mu \overline{\nu}_\mu$		
τ_{75}	$p n \rightarrow$ invisible	$>2.1 \times 10^{-5}$	90%
τ_{76}	$p p \rightarrow$ invisible	> 0.00005	90%

$\overline{p}$ DECAY MODES

	Mode	Partial mean life (years)	Confidence level
τ_{77}	$\overline{p} \rightarrow e^- \gamma$	$> 7 \times 10^5$	90%
τ_{78}	$\overline{p} \rightarrow \mu^- \gamma$	$> 5 \times 10^4$	90%
τ_{79}	$\overline{p} \rightarrow e^- \pi^0$	$> 4 \times 10^5$	90%
τ_{80}	$\overline{p} \rightarrow \mu^- \pi^0$	$> 5 \times 10^4$	90%

τ_{81}	$\overline{p} \rightarrow e^- \eta$	$> 2 \times 10^4$	90%
τ_{82}	$\overline{p} \rightarrow \mu^- \eta$	$> 8 \times 10^3$	90%
τ_{83}	$\overline{p} \rightarrow e^- K^0_S$	> 900	90%
τ_{84}	$\overline{p} \rightarrow \mu^- K^0_S$	$> 4 \times 10^3$	90%
τ_{85}	$\overline{p} \rightarrow e^- K^0_L$	$> 9 \times 10^3$	90%
τ_{86}	$\overline{p} \rightarrow \mu^- K^0_L$	$> 7 \times 10^3$	90%
τ_{87}	$\overline{p} \rightarrow e^- \gamma\gamma$	$> 2 \times 10^4$	90%
τ_{88}	$\overline{p} \rightarrow \mu^- \gamma\gamma$	$> 2 \times 10^4$	90%
τ_{89}	$\overline{p} \rightarrow e^- \rho$		
τ_{90}	$\overline{p} \rightarrow e^- \omega$	> 200	90%
τ_{91}	$\overline{p} \rightarrow e^- K^*(892)^0$		

p PARTIAL MEAN LIVES

The "partial mean life" limits tabulated here are the limits on τ/B_i, where τ is the total mean life for the proton and B_i is the branching fraction for the mode in question.

Decaying particle: p = proton, n = bound neutron. The same event may appear under more than one partial decay mode. Background estimates may be accurate to a factor of two.

Antilepton + meson

$\tau(N \rightarrow e^+ \pi)$ τ_1

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
> 158	***n***	**90**	**3**	**5**	MCGREW	99	IMB3
>1600	***p***	**90**	**0**	**0.1**	SHIOZAWA	98	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 540	*p*	90	0	0.2	MCGREW	99	IMB3
> 70	*p*	90	0	0.5	BERGER	91	FREJ
> 70	*n*	90	0	$\leq$ 0.1	BERGER	91	FREJ
> 550	*p*	90	0	0.7	[35] BECKER-SZ...	90	IMB3
> 260	*p*	90	0	<0.04	HIRATA	89C	KAMI
> 130	*n*	90	0	<0.2	HIRATA	89C	KAMI
> 310	*p*	90	0	0.6	SEIDEL	88	IMB
> 100	*n*	90	0	1.6	SEIDEL	88	IMB
> 1.3	*n*	90	0		BARTELT	87	SOUD
> 1.3	*p*	90	0		BARTELT	87	SOUD
> 250	*p*	90	0	0.3	HAINES	86	IMB
> 31	*n*	90	8	9	HAINES	86	IMB
> 64	*p*	90	0	<0.4	ARISAKA	85	KAMI
> 26	*n*	90	0	<0.7	ARISAKA	85	KAMI
> 82	*p* (free)	90	0	0.2	BLEWITT	85	IMB
> 250	*p*	90	0	0.2	BLEWITT	85	IMB
> 25	*n*	90	4	4	PARK	85	IMB

> 15	*p*, *n*	90	0		BATTISTONI	84	NUSX
> 0.5	*p*	90	1	0.3	[36] BARTELT	83	SOUD
> 0.5	*n*	90	1	0.3	[36] BARTELT	83	SOUD
> 5.8	*p*	90	2		[37] KRISHNA...	82	KOLR
> 5.8	*n*	90	2		[37] KRISHNA...	82	KOLR
> 0.1	*n*	90			[38] GURR	67	CNTR

[35] This BECKER-SZENDY 90 result includes data from SEIDEL 88.
[36] Limit based on zero events.
[37] We have calculated 90% CL limit from 1 confined event.
[38] We have converted half-life to 90% CL mean life.

$\tau(N \rightarrow \mu^+ \pi)$ τ_2

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>473	***p***	**90**	**0**	**0.6**	MCGREW	99	IMB3
>100	***n***	**90**	**0**	**<0.2**	HIRATA	89C	KAMI
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 90	*n*	90	1	1.9	MCGREW	99	IMB3
> 81	*p*	90	0	0.2	BERGER	91	FREJ
> 35	*n*	90	1	1.0	BERGER	91	FREJ
>230	*p*	90	0	<0.07	HIRATA	89C	KAMI
>270	*p*	90	0	0.5	SEIDEL	88	IMB
> 63	*n*	90	0	0.5	SEIDEL	88	IMB
> 76	*p*	90	2	1	HAINES	86	IMB
> 23	*n*	90	8	7	HAINES	86	IMB
> 46	*p*	90	0	<0.7	ARISAKA	85	KAMI
> 20	*n*	90	0	<0.4	ARISAKA	85	KAMI
> 59	*p* (free)	90	0	0.2	BLEWITT	85	IMB
>100	*p*	90	1	0.4	BLEWITT	85	IMB
> 38	*n*	90	1	4	PARK	85	IMB
> 10	*p*, *n*	90	0		BATTISTONI	84	NUSX
> 1.3	*p*, *n*	90	0		ALEKSEEV	81	BAKS

$\tau(N \rightarrow \nu \pi)$ τ_3

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
> 16	***p***	**90**	**6**	**6.7**	WALL	00B	SOU2
>112	***n***	**90**	**6**	**6.6**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 39	*n*	90	4	3.8	WALL	00B	SOU2
> 10	*p*	90	15	20.3	MCGREW	99	IMB3
> 13	*n*	90	1	1.2	BERGER	89	FREJ
> 10	*p*	90	11	14	BERGER	89	FREJ
> 25	*p*	90	32	32.8	[39] HIRATA	89C	KAMI
>100	*n*	90	1	3	HIRATA	89C	KAMI
> 6	*n*	90	73	60	HAINES	86	IMB
> 2	*p*	90	16	13	KAJITA	86	KAMI
> 40	*n*	90	0	1	KAJITA	86	KAMI

> 7	*n*	90	28	19	PARK	85	IMB
> 7	*n*	90	0		BATTISTONI	84	NUSX
> 2	*p*	90	≤ 3		BATTISTONI	84	NUSX
> 5.8	*p*	90	1		[40] KRISHNA...	82	KOLR
> 0.3	*p*	90	2		[41] CHERRY	81	HOME
> 0.1	*p*	90			[42] GURR	67	CNTR

[39] In estimating the background, this HIRATA 89C limit (as opposed to the later limits of WALL 00B and MCGREW 99) does not take into account present understanding that the flux of ν_μ originating in the upper atmosphere is depleted. Doing so would reduce the background and thus also would reduce the limit here.

[40] We have calculated 90% CL limit from 1 confined event.

[41] We have converted 2 possible events to 90% CL limit.

[42] We have converted half-life to 90% CL mean life.

$\tau(p \to e^+ \eta)$ — τ_4

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>313	***p***	**90**	**0**	**0.2**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 81	*p*	90	1	1.7	WALL	00B	SOU2
> 44	*p*	90	0	0.1	BERGER	91	FREJ
>140	*p*	90	0	<0.04	HIRATA	89C	KAMI
>100	*p*	90	0	0.6	SEIDEL	88	IMB
>200	*p*	90	5	3.3	HAINES	86	IMB
> 64	*p*	90	0	<0.8	ARISAKA	85	KAMI
> 64	*p* (free)	90	5	6.5	BLEWITT	85	IMB
>200	*p*	90	5	4.7	BLEWITT	85	IMB
> 1.2	*p*	90	2		[43] CHERRY	81	HOME

[43] We have converted 2 possible events to 90% CL limit.

$\tau(p \to \mu^+ \eta)$ — τ_5

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>126	***p***	**90**	**3**	**2.8**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 89	*p*	90	0	1.6	WALL	00B	SOU2
> 26	*p*	90	1	0.8	BERGER	91	FREJ
> 69	*p*	90	1	<0.08	HIRATA	89C	KAMI
> 1.3	*p*	90	0	0.7	PHILLIPS	89	HPW
> 34	*p*	90	1	1.5	SEIDEL	88	IMB
> 46	*p*	90	7	6	HAINES	86	IMB
> 26	*p*	90	1	<0.8	ARISAKA	85	KAMI
> 17	*p* (free)	90	6	6	BLEWITT	85	IMB
> 46	*p*	90	7	8	BLEWITT	85	IMB

$\tau(n \to \nu \eta)$ — τ_6

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>158	***n***	**90**	**0**	**1.2**	MCGREW	99	IMB3

• • • We do not use the following data for averages, fits, limits, etc. • • •

> 71	*n*	90	2	3.7	WALL	00B	SOU2
> 29	*n*	90	0	0.9	BERGER	89	FREJ
> 54	*n*	90	2	0.9	HIRATA	89C	KAMI
> 16	*n*	90	3	2.1	SEIDEL	88	IMB
> 25	*n*	90	7	6	HAINES	86	IMB
> 30	*n*	90	0	0.4	KAJITA	86	KAMI
> 18	*n*	90	4	3	PARK	85	IMB
> 0.6	*n*	90	2		[44] CHERRY	81	HOME

[44] We have converted 2 possible events to 90% CL limit.

$\tau(N \to e^+ \rho)$ — τ_7

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>217	***n***	**90**	**4**	**4.8**	MCGREW	99	IMB3
> 75	***p***	**90**	**2**	**2.7**	HIRATA	89C	KAMI

• • • We do not use the following data for averages, fits, limits, etc. • • •

> 29	*p*	90	0	2.2	BERGER	91	FREJ
> 41	*n*	90	0	1.4	BERGER	91	FREJ
> 58	*n*	90	0	1.9	HIRATA	89C	KAMI
> 38	*n*	90	2	4.1	SEIDEL	88	IMB
> 1.2	*p*	90	0		BARTELT	87	SOUD
> 1.5	*n*	90	0		BARTELT	87	SOUD
> 17	*p*	90	7	7	HAINES	86	IMB
> 14	*n*	90	9	4	HAINES	86	IMB
> 12	*p*	90	0	<1.2	ARISAKA	85	KAMI
> 6	*n*	90	2	<1	ARISAKA	85	KAMI
> 6.7	*p* (free)	90	6	6	BLEWITT	85	IMB
> 17	*p*	90	7	7	BLEWITT	85	IMB
> 12	*n*	90	4	2	PARK	85	IMB
> 0.6	*n*	90	1	0.3	[45] BARTELT	83	SOUD
> 0.5	*p*	90	1	0.3	[45] BARTELT	83	SOUD
> 9.8	*p*	90	1		[46] KRISHNA...	82	KOLR
> 0.8	*p*	90	2		[47] CHERRY	81	HOME

[45] Limit based on zero events.
[46] We have calculated 90% CL limit from 0 confined events.
[47] We have converted 2 possible events to 90% CL limit.

$\tau(N \to \mu^+ \rho)$ — τ_8

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>228	***n***	**90**	**3**	**9.5**	MCGREW	99	IMB3
>110	***p***	**90**	**0**	**1.7**	HIRATA	89C	KAMI

• • • We do not use the following data for averages, fits, limits, etc. • • •

> 12	*p*	90	0	0.5	BERGER	91	FREJ
> 22	*n*	90	0	1.1	BERGER	91	FREJ
> 23	*n*	90	1	1.8	HIRATA	89C	KAMI
> 4.3	*p*	90	0	0.7	PHILLIPS	89	HPW
> 30	*p*	90	0	0.5	SEIDEL	88	IMB
> 11	*n*	90	1	1.1	SEIDEL	88	IMB
> 16	*p*	90	4	4.5	HAINES	86	IMB

> 7	n	90	6	5	HAINES	86	IMB
> 12	p	90	0	<0.7	ARISAKA	85	KAMI
> 5	n	90	1	<1.2	ARISAKA	85	KAMI
> 5.5	p (free)	90	4	5	BLEWITT	85	IMB
> 16	p	90	4	5	BLEWITT	85	IMB
> 9	n	90	1	2	PARK	85	IMB

$\tau(N \rightarrow \nu\rho)$ τ_9

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>162	**p**	**90**	**18**	**21.7**	MCGREW	99	IMB3
> 19	**n**	**90**	**0**	**0.5**	SEIDEL	88	IMB
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 9	n	90	4	2.4	BERGER	89	FREJ
> 24	p	90	0	0.9	BERGER	89	FREJ
> 27	p	90	5	1.5	HIRATA	89C	KAMI
> 13	n	90	4	3.6	HIRATA	89C	KAMI
> 13	p	90	1	1.1	SEIDEL	88	IMB
> 8	p	90	6	5	HAINES	86	IMB
> 2	n	90	15	10	HAINES	86	IMB
> 11	p	90	2	1	KAJITA	86	KAMI
> 4	n	90	2	2	KAJITA	86	KAMI
> 4.1	p (free)	90	6	7	BLEWITT	85	IMB
> 8.4	p	90	6	5	BLEWITT	85	IMB
> 2	n	90	7	3	PARK	85	IMB
> 0.9	p	90	2		[48] CHERRY	81	HOME
> 0.6	n	90	2		[48] CHERRY	81	HOME

[48] We have converted 2 possible events to 90% CL limit.

$\tau(p \rightarrow e^+\omega)$ τ_{10}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>107	**p**	**90**	**7**	**10.8**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 17	p	90	0	1.1	BERGER	91	FREJ
> 45	p	90	2	1.45	HIRATA	89C	KAMI
> 26	p	90	1	1.0	SEIDEL	88	IMB
> 1.5	p	90	0		BARTELT	87	SOUD
> 37	p	90	6	5.3	HAINES	86	IMB
> 25	p	90	1	<1.4	ARISAKA	85	KAMI
> 12	p (free)	90	6	7.5	BLEWITT	85	IMB
> 37	p	90	6	5.7	BLEWITT	85	IMB
> 0.6	p	90	1	0.3	[49] BARTELT	83	SOUD
> 9.8	p	90	1		[50] KRISHNA...	82	KOLR
> 2.8	p	90	2		[51] CHERRY	81	HOME

[49] Limit based on zero events.
[50] We have calculated 90% CL limit from 0 confined events.
[51] We have converted 2 possible events to 90% CL limit.

$\tau(p \to \mu^+ \omega)$ τ_{11}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>117	***p***	**90**	**11**	**12.1**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 11	*p*	90	0	1.0	BERGER	91	FREJ
> 57	*p*	90	2	1.9	HIRATA	89C	KAMI
> 4.4	*p*	90	0	0.7	PHILLIPS	89	HPW
> 10	*p*	90	2	1.3	SEIDEL	88	IMB
> 23	*p*	90	2	1	HAINES	86	IMB
> 6.5	*p* (free)	90	9	8.7	BLEWITT	85	IMB
> 23	*p*	90	8	7	BLEWITT	85	IMB

$\tau(n \to \nu \omega)$ τ_{12}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>108	***n***	**90**	**12**	**22.5**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 17	*n*	90	1	0.7	BERGER	89	FREJ
> 43	*n*	90	3	2.7	HIRATA	89C	KAMI
> 6	*n*	90	2	1.3	SEIDEL	88	IMB
> 12	*n*	90	6	6	HAINES	86	IMB
> 18	*n*	90	2	2	KAJITA	86	KAMI
> 16	*n*	90	1	2	PARK	85	IMB
> 2.0	*n*	90	2		[52] CHERRY	81	HOME

[52] We have converted 2 possible events to 90% CL limit.

$\tau(N \to e^+ K)$ τ_{13}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
> 17	***n***	**90**	**35**	**29.4**	MCGREW	99	IMB3
>150	***p***	**90**	**0**	**<0.27**	HIRATA	89C	KAMI
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 85	*p*	90	3	4.9	WALL	00	SOU2
> 31	*p*	90	23	25.2	MCGREW	99	IMB3
> 60	*p*	90	0		BERGER	91	FREJ
> 70	*p*	90	0	1.8	SEIDEL	88	IMB
> 77	*p*	90	5	4.5	HAINES	86	IMB
> 38	*p*	90	0	<0.8	ARISAKA	85	KAMI
> 24	*p* (free)	90	7	8.5	BLEWITT	85	IMB
> 77	*p*	90	5	4	BLEWITT	85	IMB
> 1.3	*p*	90	0		ALEKSEEV	81	BAKS
> 1.3	*n*	90	0		ALEKSEEV	81	BAKS

$\tau(p \to e^+ K^0_S)$ τ_{14}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>2000	**p**	**90**	**6**	**4.7**	[53] KOBAYASHI	05	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 120	*p*	90	1	1.3	WALL	00	SOU2
> 76	*p*	90	0	0.5	BERGER	91	FREJ

[53] We have doubled the $p \rightarrow e^+ K^0$ limit given in KOBAYASHI 05 to obtain this $p \rightarrow e^+ K^0_S$ limit.

$\tau(p \rightarrow e^+ K^0_L)$ τ_{15}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>51	**p**	**90**	**2**	**3.5**	WALL	00	SOU2
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>44	p	90	0	≤ 0.1	BERGER	91	FREJ

$\tau(N \rightarrow \mu^+ K)$ τ_{16}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>120	**p**	**90**	**0**	**<1.2**	WALL	00	SOU2
>120	**p**	**90**	**4**	**7.2**	MCGREW	99	IMB3
> 26	**n**	**90**	**20**	**28.4**	MCGREW	99	IMB3
>120	**p**	**90**	**1**	**0.4**	HIRATA	89C	KAMI
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 54	p	90	0		BERGER	91	FREJ
> 3.0	p	90	0	0.7	PHILLIPS	89	HPW
> 19	p	90	3	2.5	SEIDEL	88	IMB
> 1.5	p	90	0		[54] BARTELT	87	SOUD
> 1.1	n	90	0		BARTELT	87	SOUD
> 40	p	90	7	6	HAINES	86	IMB
> 19	p	90	1	<1.1	ARISAKA	85	KAMI
> 6.7	p (free)	90	11	13	BLEWITT	85	IMB
> 40	p	90	7	8	BLEWITT	85	IMB
> 6	p	90	1		BATTISTONI	84	NUSX
> 0.6	p	90	0		[55] BARTELT	83	SOUD
> 0.4	n	90	0		[55] BARTELT	83	SOUD
> 5.8	p	90	2		[56] KRISHNA...	82	KOLR
> 2.0	p	90	0		CHERRY	81	HOME
> 0.2	n	90			[57] GURR	67	CNTR

[54] BARTELT 87 limit applies to $p \rightarrow \mu^+ K^0_S$.
[55] Limit based on zero events.
[56] We have calculated 90% CL limit from 1 confined event.
[57] We have converted half-life to 90% CL mean life.

$\tau(p \rightarrow \mu^+ K^0_S)$ τ_{17}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>2600	**p**	**90**	**3**	**3.9**	[58] KOBAYASHI	05	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 150	p	90	0	<0.8	WALL	00	SOU2
> 64	p	90	0	1.2	BERGER	91	FREJ

[58] We have doubled the $p \rightarrow \mu^+ K^0$ limit given in KOBAYASHI 05 to obtain this $p \rightarrow \mu^+ K^0_S$ limit.

$\tau(p \to \mu^+ K^0_L)$ τ_{18}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>83	**p**	**90**	**0**	**0.4**	WALL	00	SOU2
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>44	p	90	0	≤ 0.1	BERGER	91	FREJ

$\tau(N \to \nu K)$ τ_{19}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>2300	**p**	**90**	**0**	**1.3**	KOBAYASHI	05	SKAM
> 86	**n**	**90**	**0**	**2.4**	HIRATA	89C	KAMI
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 26	n	90	16	9.1	WALL	00	SOU2
> 670	p	90			HAYATO	99	SKAM
> 151	p	90	15	21.4	MCGREW	99	IMB3
> 30	n	90	34	34.1	MCGREW	99	IMB3
> 43	p	90	1	1.54	[59] ALLISON	98	SOU2
> 15	n	90	1	1.8	BERGER	89	FREJ
> 15	p	90	1	1.8	BERGER	89	FREJ
> 100	p	90	9	7.3	HIRATA	89C	KAMI
> 0.28	p	90	0	0.7	PHILLIPS	89	HPW
> 0.3	p	90	0		BARTELT	87	SOUD
> 0.75	n	90	0		[60] BARTELT	87	SOUD
> 10	p	90	6	5	HAINES	86	IMB
> 15	n	90	3	5	HAINES	86	IMB
> 28	p	90	3	3	KAJITA	86	KAMI
> 32	n	90	0	1.4	KAJITA	86	KAMI
> 1.8	p (free)	90	6	11	BLEWITT	85	IMB
> 9.6	p	90	6	5	BLEWITT	85	IMB
> 10	n	90	2	2	PARK	85	IMB
> 5	n	90	0		BATTISTONI	84	NUSX
> 2	p	90	0		BATTISTONI	84	NUSX
> 0.3	n	90	0		[61] BARTELT	83	SOUD
> 0.1	p	90	0		[61] BARTELT	83	SOUD
> 5.8	p	90	1		[62] KRISHNA...	82	KOLR
> 0.3	n	90	2		[63] CHERRY	81	HOME

[59] This ALLISON 98 limit is with no background subtraction; with subtraction the limit becomes $> 46 \times 10^{30}$ years.

[60] BARTELT 87 limit applies to $n \to \nu K^0_S$.

[61] Limit based on zero events.

[62] We have calculated 90% CL limit from 1 confined event.

[63] We have converted 2 possible events to 90% CL limit.

$\tau(n \to \nu K^0_S)$ τ_{20}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>260	**n**	**90**	**34**	**30**	[64] KOBAYASHI	05	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 51	n	90	16	9.1	WALL	00	SOU2

[64] We have doubled the $n \rightarrow \nu K^0$ limit given in KOBAYASHI 05 to obtain this $n \rightarrow \nu K^0_S$ limit.

$\tau(p \rightarrow e^+ K^*(892)^0)$ τ_{21}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>84	***p***	**90**	**38**	**52.0**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>10	*p*	90	0	0.8	BERGER	91	FREJ
>52	*p*	90	2	1.55	HIRATA	89C	KAMI
>10	*p*	90	1	<1	ARISAKA	85	KAMI

$\tau(N \rightarrow \nu K^*(892))$ τ_{22}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>51	***p***	**90**	**7**	**9.1**	MCGREW	99	IMB3
>78	***n***	**90**	**40**	**50**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>22	*n*	90	0	2.1	BERGER	89	FREJ
>17	*p*	90	0	2.4	BERGER	89	FREJ
>20	*p*	90	5	2.1	HIRATA	89C	KAMI
>21	*n*	90	4	2.4	HIRATA	89C	KAMI
>10	*p*	90	7	6	HAINES	86	IMB
> 5	*n*	90	8	7	HAINES	86	IMB
> 8	*p*	90	3	2	KAJITA	86	KAMI
> 6	*n*	90	2	1.6	KAJITA	86	KAMI
> 5.8	*p* (free)	90	10	16	BLEWITT	85	IMB
> 9.6	*p*	90	7	6	BLEWITT	85	IMB
> 7	*n*	90	1	4	PARK	85	IMB
> 2.1	*p*	90	1		[65] BATTISTONI	82	NUSX

[65] We have converted 1 possible event to 90% CL limit.

Antilepton + mesons

$\tau(p \rightarrow e^+ \pi^+ \pi^-)$ τ_{23}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>82	***p***	**90**	**16**	**23.1**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>21	*p*	90	0	2.2	BERGER	91	FREJ

$\tau(p \rightarrow e^+ \pi^0 \pi^0)$ τ_{24}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>147	***p***	**90**	**2**	**0.8**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 38	*p*	90	1	0.5	BERGER	91	FREJ

$\tau(n \to e^+ \pi^- \pi^0)$ τ_{25}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>52	***n***	**90**	**38**	**34.2**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>32	*n*	90	1	0.8	BERGER	91	FREJ

$\tau(p \to \mu^+ \pi^+ \pi^-)$ τ_{26}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>133	***p***	**90**	**25**	**38.0**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 17	*p*	90	1	2.6	BERGER	91	FREJ
> 3.3	*p*	90	0	0.7	PHILLIPS	89	HPW

$\tau(p \to \mu^+ \pi^0 \pi^0)$ τ_{27}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>101	***p***	**90**	**3**	**1.6**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 33	*p*	90	1	0.9	BERGER	91	FREJ

$\tau(n \to \mu^+ \pi^- \pi^0)$ τ_{28}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>74	***n***	**90**	**17**	**20.8**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>33	*n*	90	0	1.1	BERGER	91	FREJ

$\tau(n \to e^+ K^0 \pi^-)$ τ_{29}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>18	***n***	**90**	**1**	**0.2**	BERGER	91	FREJ

Lepton + meson

$\tau(n \to e^- \pi^+)$ τ_{30}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>65	***n***	**90**	**0**	**1.6**	SEIDEL	88	IMB
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>55	*n*	90	0	1.09	BERGER	91B	FREJ
>16	*n*	90	9	7	HAINES	86	IMB
>25	*n*	90	2	4	PARK	85	IMB

$\tau(n \to \mu^- \pi^+)$ τ_{31}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>49	***n***	**90**	**0**	**0.5**	SEIDEL	88	IMB
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>33	*n*	90	0	1.40	BERGER	91B	FREJ
> 2.7	*n*	90	0	0.7	PHILLIPS	89	HPW
>25	*n*	90	7	6	HAINES	86	IMB
>27	*n*	90	2	3	PARK	85	IMB

$\tau(n \to e^- \rho^+)$ τ_{32}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>62	***n***	**90**	**2**	**4.1**	SEIDEL	88	IMB
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>12	*n*	90	13	6	HAINES	86	IMB
>12	*n*	90	5	3	PARK	85	IMB

$\tau(n \to \mu^- \rho^+)$ τ_{33}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>7	***n***	**90**	**1**	**1.1**	SEIDEL	88	IMB
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>2.6	*n*	90	0	0.7	PHILLIPS	89	HPW
>9	*n*	90	7	5	HAINES	86	IMB
>9	*n*	90	2	2	PARK	85	IMB

$\tau(n \to e^- K^+)$ τ_{34}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>32	***n***	**90**	**3**	**2.96**	BERGER	91B	FREJ
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 0.23	*n*	90	0	0.7	PHILLIPS	89	HPW

$\tau(n \to \mu^- K^+)$ τ_{35}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>57	***n***	**90**	**0**	**2.18**	BERGER	91B	FREJ
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 4.7	*n*	90	0	0.7	PHILLIPS	89	HPW

Lepton + mesons

$\tau(p \to e^- \pi^+ \pi^+)$ τ_{36}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>30	***p***	**90**	**1**	**2.50**	BERGER	91B	FREJ
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 2.0	*p*	90	0	0.7	PHILLIPS	89	HPW

$\tau(n \to e^- \pi^+ \pi^0)$ τ_{37}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>29	***n***	**90**	**1**	**0.78**	BERGER	91B	FREJ

$\tau(p \to \mu^- \pi^+ \pi^+)$ τ_{38}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>17	***p***	**90**	**1**	**1.72**	BERGER	91B	FREJ
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 7.8	*p*	90	0	0.7	PHILLIPS	89	HPW

$\tau(n \to \mu^- \pi^+ \pi^0)$ τ_{39}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>34	***n***	**90**	**0**	**0.78**	BERGER	91B	FREJ

$\tau(p \to e^- \pi^+ K^+)$ τ_{40}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>75	***p***	**90**	**81**	**127.2**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>20	*p*	90	3	2.50	BERGER	91B	FREJ

$\tau(p \to \mu^- \pi^+ K^+)$ τ_{41}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>245	***p***	**90**	**3**	**4.0**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 5	*p*	90	2	0.78	BERGER	91B	FREJ

Antilepton + photon(s)

$\tau(p \to e^+ \gamma)$ τ_{42}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>670	***p***	**90**	**0**	**0.1**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>133	*p*	90	0	0.3	BERGER	91	FREJ
>460	*p*	90	0	0.6	SEIDEL	88	IMB
>360	*p*	90	0	0.3	HAINES	86	IMB
> 87	*p* (free)	90	0	0.2	BLEWITT	85	IMB
>360	*p*	90	0	0.2	BLEWITT	85	IMB
> 0.1	*p*	90		[66]	GURR	67	CNTR

[66] We have converted half-life to 90% CL mean life.

$\tau(p \to \mu^+ \gamma)$ τ_{43}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>478	***p***	**90**	**0**	**0.1**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>155	*p*	90	0	0.1	BERGER	91	FREJ
>380	*p*	90	0	0.5	SEIDEL	88	IMB
> 97	*p*	90	3	2	HAINES	86	IMB
> 61	*p* (free)	90	0	0.2	BLEWITT	85	IMB
>280	*p*	90	0	0.6	BLEWITT	85	IMB
> 0.3	*p*	90			[67] GURR	67	CNTR

[67] We have converted half-life to 90% CL mean life.

$\tau(n \to \nu \gamma)$ τ_{44}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>28	***n***	**90**	**163**	**144.7**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>24	*n*	90	10	6.86	BERGER	91B	FREJ
> 9	*n*	90	73	60	HAINES	86	IMB
>11	*n*	90	28	19	PARK	85	IMB

$\tau(p \to e^+ \gamma\gamma)$ τ_{45}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>100	***p***	**90**	**1**	**0.8**	BERGER	91	FREJ

$\tau(n \to \nu \gamma\gamma)$ τ_{46}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>219	***n***	**90**	**5**	**7.5**	MCGREW	99	IMB3

Three (or more) leptons

$\tau(p \to e^+ e^+ e^-)$ τ_{47}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>793	***p***	**90**	**0**	**0.5**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>147	*p*	90	0	0.1	BERGER	91	FREJ
>510	*p*	90	0	0.3	HAINES	86	IMB
> 89	*p* (free)	90	0	0.5	BLEWITT	85	IMB
>510	*p*	90	0	0.7	BLEWITT	85	IMB

$\tau(p \to e^+ \mu^+ \mu^-)$ τ_{48}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>359	***p***	**90**	**1**	**0.9**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 81	*p*	90	0	0.16	BERGER	91	FREJ
> 5.0	*p*	90	0	0.7	PHILLIPS	89	HPW

$\tau(p \to e^+ \nu \nu)$ τ_{49}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>17	***p***	**90**	**152**	**153.7**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>11	*p*	90	11	6.08	BERGER	91B	FREJ

$\tau(n \to e^+ e^- \nu)$ τ_{50}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>257	***n***	**90**	**5**	**7.5**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 74	*n*	90	0	< 0.1	BERGER	91B	FREJ
> 45	*n*	90	5	5	HAINES	86	IMB
> 26	*n*	90	4	3	PARK	85	IMB

$\tau(n \to \mu^+ e^- \nu)$ τ_{51}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>83	***n***	**90**	**25**	**29.4**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>47	*n*	90	0	< 0.1	BERGER	91B	FREJ

$\tau(n \to \mu^+ \mu^- \nu)$ τ_{52}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>79	***n***	**90**	**100**	**145**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>42	*n*	90	0	1.4	BERGER	91B	FREJ
> 5.1	*n*	90	0	0.7	PHILLIPS	89	HPW
>16	*n*	90	14	7	HAINES	86	IMB
>19	*n*	90	4	7	PARK	85	IMB

$\tau(p \to \mu^+ e^+ e^-)$ τ_{53}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>529	***p***	**90**	**0**	**1.0**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 91	*p*	90	0	≤ 0.1	BERGER	91	FREJ

$\tau(p \to \mu^+ \mu^+ \mu^-)$ τ_{54}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>675	***p***	**90**	**0**	**0.3**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>119	*p*	90	0	0.2	BERGER	91	FREJ
> 10.5	*p*	90	0	0.7	PHILLIPS	89	HPW
>190	*p*	90	1	0.1	HAINES	86	IMB
> 44	*p* (free)	90	1	0.7	BLEWITT	85	IMB
>190	*p*	90	1	0.9	BLEWITT	85	IMB
> 2.1	*p*	90	1	[68]	BATTISTONI	82	NUSX

[68] We have converted 1 possible event to 90% CL limit.

$\tau(p \to \mu^+ \nu\nu)$ τ_{55}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>21	***p***	**90**	**7**	**11.23**	BERGER	91B	FREJ

$\tau(p \to e^- \mu^+ \mu^+)$ τ_{56}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>6.0	***p***	**90**	**0**	**0.7**	PHILLIPS	89	HPW

$\tau(n \to 3\nu)$ τ_{57}

See also the "to anything" and "disappearance" limits for bound nucleons in the "*p* Mean Life" data block just in front of the list of possible *p* decay modes. Such modes could of course be to three (or five) neutrinos, and the limits are stronger, but we do not repeat them here.

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>0.00049	***n***	**90**	**2**	**2**	[69] SUZUKI	93B	KAMI
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.0023	*n*	90			[70] GLICENSTEIN	97	KAMI
>0.00003	*n*	90	11	6.1	[71] BERGER	91B	FREJ
>0.00012	*n*	90	7	11.2	[71] BERGER	91B	FREJ
>0.0005	*n*	90	0		LEARNED	79	RVUE

[69] The SUZUKI 93B limit applies to any of $\nu_e \nu_e \overline{\nu}_e$, $\nu_\mu \nu_\mu \overline{\nu}_\mu$, or $\nu_\tau \nu_\tau \overline{\nu}_\tau$.

[70] GLICENSTEIN 97 uses Kamioka data and the idea that the disappearance of the neutron's magnetic moment should produce radiation.

[71] The first BERGER 91B limit is for $n \to \nu_e \nu_e \overline{\nu}_e$, the second is for $n \to \nu_\mu \nu_\mu \overline{\nu}_\mu$.

$\tau(n \to 5\nu)$ τ_{58}

See the note on $\tau(n \to 3\nu)$ on the previous data block.

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.0017	*n*	90			[72] GLICENSTEIN	97	KAMI

[72] GLICENSTEIN 97 uses Kamioka data and the idea that the disappearance of the neutron's magnetic moment should produce radiation.

Inclusive modes

$\tau(N \to e^+ \text{anything})$ τ_{59}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>0.6	***p, n***	**90**			[73] LEARNED	79	RVUE

[73] The electron may be primary or secondary.

$\tau(N \to \mu^+ \text{anything})$ τ_{60}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>12	***p, n***	**90**	**2**		[74,75] CHERRY	81	HOME
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 1.8	*p, n*	90			[75] COWSIK	80	CNTR
> 6	*p, n*	90			[75] LEARNED	79	RVUE

[74] We have converted 2 possible events to 90% CL limit.
[75] The muon may be primary or secondary.

$\tau(N \to \nu \text{anything})$ τ_{61}

Anything = π, ρ, K, etc.

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.0002	*p, n*	90	0		LEARNED	79	RVUE

$\tau(N \to e^+ \pi^0 \text{anything})$ τ_{62}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>0.6	***p, n***	**90**	**0**		LEARNED	79	RVUE

$\tau(N \to 2 \text{ bodies}, \nu\text{-free})$ τ_{63}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>1.3	*p, n*	90	0		ALEKSEEV	81	BAKS

$\Delta B = 2$ dinucleon modes

$\tau(pp \to \pi^+\pi^+)$ τ_{64}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>0.7	**90**	**4**	**2.34**	BERGER	91B	FREJ	τ per iron nucleus

$\tau(pn \to \pi^+\pi^0)$ τ_{65}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>2.0	**90**	**0**	**0.31**	BERGER	91B	FREJ	τ per iron nucleus

$\tau(nn \to \pi^+\pi^-)$ τ_{66}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>0.7	**90**	**4**	**2.18**	BERGER	91B	FREJ	τ per iron nucleus

$\tau(nn \to \pi^0\pi^0)$ τ_{67}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>3.4	**90**	**0**	**0.78**	BERGER	91B	FREJ	τ per iron nucleus

$\tau(pp \to e^+ e^+)$ τ_{68}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>5.8	**90**	**0**	**<0.1**	BERGER	91B	FREJ	τ per iron nucleus

$\tau(pp \to e^+ \mu^+)$ τ_{69}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>3.6	**90**	**0**	**<0.1**	BERGER	91B	FREJ	τ per iron nucleus

$\tau(pp \to \mu^+ \mu^+)$ τ_{70}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>1.7	**90**	**0**	**0.62**	BERGER	91B	FREJ	τ per iron nucleus

$\tau(pn \to e^+ \overline{\nu})$ τ_{71}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>2.8	**90**	**5**	**9.67**	BERGER	91B	FREJ	τ per iron nucleus

$\tau(pn \to \mu^+ \overline{\nu})$ τ_{72}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>1.6	**90**	**4**	**4.37**	BERGER	91B	FREJ	τ per iron nucleus

$\tau(nn \to \nu_e \overline{\nu}_e)$ τ_{73}

We include "invisible" modes here.

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>1.4	**90**			[76] ARAKI	06	KLND	$nn \to$ invisible
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.000042	90			[77] TRETYAK	04	CNTR	
>0.000049	90			[78] BACK	03	BORX	
>0.000012	90			[79] BERNABEI	00B	DAMA	
>0.000012	90	5	9.7	BERGER	91B	FREJ	τ per iron nucleus

[76] ARAKI 06 looks for signs of de-excitation of the residual nucleus after disappearance of two neutrons from the s shell of ^{12}C.

[77] TRETYAK 04 uses data from an old Homestake-mine radiochemical experiment on limits for invisible decays of ^{39}K to ^{37}Ar.

[78] BACK 03 looks for decays of unstable nuclides left after NN decays of parent ^{12}C, ^{13}C, ^{16}O nuclei. These are "invisible channel" limits.

[79] BERNABEI 00B looks for the decay of a $^{127}_{54}$Xe nucleus following the disappearance of an nn pair in the otherwise-stable $^{129}_{54}$Xe nucleus. The limit here applies as well to $nn \to \nu_\mu \overline{\nu}_\mu$, $nn \to \nu_\tau \overline{\nu}_\tau$, or any "disappearance" mode.

$\tau(nn \to \nu_\mu \overline{\nu}_\mu)$ τ_{74}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.000006	90	4	4.4	BERGER	91B	FREJ	τ per iron nucleus

$\tau(pn \to$ invisible$)$ τ_{75}

This violates charge conservation as well as baryon number conservation.

VALUE (10^{30} years)	CL%	DOCUMENT ID		TECN
>0.000021	90	[80] TRETYAK	04	CNTR

[80] TRETYAK 04 uses data from an old Homestake-mine radiochemical experiment on limits for invisible decays of ^{39}K to ^{37}Ar.

$\tau(pp \to$ invisible$)$ τ_{76}

This violates charge conservation as well as baryon number conservation.

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	CL%	DOCUMENT ID		TECN
>0.00005				90	[81] BACK	03	BORX
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.00000055	90				[82] BERNABEI	00B	DAMA

[81] BACK 03 looks for decays of unstable nuclides left after NN decays of parent ^{12}C, ^{13}C, ^{16}O nuclei. These are "invisible channel" limits.

[82] BERNABEI 00B looks for the decay of a $^{127}_{52}$Te nucleus following the disappearance of a pp pair in the otherwise-stable $^{129}_{54}$Xe nucleus.

$\overline{p}$ PARTIAL MEAN LIVES

The "partial mean life" limits tabulated here are the limits on $\overline{\tau}/B_i$, where $\overline{\tau}$ is the total mean life for the antiproton and B_i is the branching fraction for the mode in question.

$\tau(\overline{p} \to e^- \gamma)$ τ_{77}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
> 7×10^5	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>1848	95	GEER	94	CALO	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to \mu^- \gamma)$ τ_{78}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
>5 $\times 10^4$	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>5.0 $\times 10^4$	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- \pi^0)$ τ_{79}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
> 4×10^5	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>554	95	GEER	94	CALO	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to \mu^- \pi^0)$ — τ_{80}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
$>5 \times 10^4$	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$>4.8 \times 10^4$	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- \eta)$ — τ_{81}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
$> 2 \times 10^4$	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>171	95	GEER	94	CALO	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to \mu^- \eta)$ — τ_{82}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
$>8 \times 10^3$	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$>7.9 \times 10^3$	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- K^0_S)$ — τ_{83}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
>900	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam
• • • We do not use the following data for averages, fits, limits, etc. • • •					
> 29	95	GEER	94	CALO	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to \mu^- K^0_S)$ — τ_{84}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
$>4 \times 10^3$	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$>4.3 \times 10^3$	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- K^0_L)$ — τ_{85}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
$>9 \times 10^3$	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>9	95	GEER	94	CALO	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to \mu^- K^0_L)$ — τ_{86}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
$>7 \times 10^3$	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$>6.5 \times 10^3$	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- \gamma\gamma)$ — τ_{87}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
$>2 \times 10^4$	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to \mu^- \gamma\gamma)$ τ_{88}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
>2 × 10^4	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>2.3 × 10^4	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- \rho)$ τ_{89}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>200	90	[83] GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam

[83] This GEER 00 measurement has been withdrawn; see GEER 00C.

$\tau(\overline{p} \to e^- \omega)$ τ_{90}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
>200	90	GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- K^*(892)^0)$ τ_{91}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>1 × 10^3	90	[84] GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam

[84] This GEER 00 measurement has been withdrawn; see GEER 00C.

p REFERENCES

ARAKI	06	PRL 96 101802	T. Araki et al.	(KamLAND Collab.)
BLUNDEN	05	PR C72 057601	P.G. Blunden, I. Sick	(MANI, BASL)
KOBAYASHI	05	PR D72 052007	K. Kobayashi et al.	(Super-Kamiokande Collab.)
MOHR	05	RMP 77 1	P.J. Mohr, B.N. Taylor	(NIST)
SCHUMACHER	05	PPNP 55 567	M. Schumacher	(GOET)
AHMED	04	PRL 92 102004	S.N. Ahmed et al.	(SNO Collab.)
TRETYAK	04	JETPL 79 106	V.I. Tretyak, V.Yu. Denisov, Yu.G. Zdesenko	(KIEV)
		Translated from ZETFP 79 136.		
BACK	03	PL B563 23	H.O. Back et al.	(BOREXINO Collab.)
BEANE	03	PL B567 200	S.R. Beane et al.	
Also		PL B607 320 (erratum)	S.R. Beane et al.	
DMITRIEV	03	PRL 91 212303	V.F. Dmitriev, R.A. Senkov	(NOVO)
HORI	03	PRL 91 123401	M. Hori et al.	(CERN ASACUSA Collab.)
SICK	03	PL B576 62	I. Sick	(BASL)
ZDESENKO	03	PL B553 135	Yu.G. Zdesenko, V.I. Tretyak	(KIEV)
AHMAD	02	PRL 89 011301	Q.R. Ahmad et al.	(SNO Collab.)
BARANOV	01	PPN 32 376	P.S. Baranov et al.	
		Translated from FECAY 32 699.		
BLANPIED	01	PR C64 025203	G. Blanpied et al.	(BNL LEGS Collab.)
ESCHRICH	01	PL B522 233	I. Eschrich et al.	(FNAL SELEX Collab.)
HORI	01	PRL 87 093401	M. Hori et al.	(CERN ASACUSA Collab.)
OLMOSDEL...	01	EPJ A10 207	V. Olmos de Leon et al.	(MAMI TAPS Collab.)
TRETYAK	01	PL B505 59	V.I. Tretyak, Yu.G. Zdesenko	(KIEV)
BERNABEI	00B	PL B493 12	R. Bernabei et al.	(Gran Sasso DAMA Collab.)
GEER	00	PRL 84 590	S. Geer et al.	(FNAL APEX Collab.)
Also		PR D62 052004	S. Geer et al.	(FNAL APEX Collab.)
Also		PRL 85 3546 (erratum)	S. Geer et al.	(FNAL APEX Collab.)
GEER	00C	PRL 85 3546 (erratum)	S. Geer et al.	(FNAL APEX Collab.)
GEER	00D	APJ 532 648	S.H. Geer, D.C. Kennedy	
MELNIKOV	00	PRL 84 1673	K. Melnikov et al.	(SLAC, KARL)
ROSENFELDR...	00	PL B479 381	R. Rosenfelder	
SENGUPTA	00	PL B484 275	S. Sengupta	
WALL	00	PR D61 072004	D. Wall et al.	(Soudan-2 Collab.)
WALL	00B	PR D62 092003	D. Wall et al.	(Soudan-2 Collab.)
GABRIELSE	99	PRL 82 3198	G. Gabrielse et al.	

HAYATO	99	PRL 83 1529	Y. Hayato *et al.*	(Super-Kamiokande Collab.)
MCGREW	99	PR D59 052004	C. McGrew *et al.*	(IMB-3 Collab.)
MOHR	99	JPCRD 28 1713	P.J. Mohr, B.N. Taylor	(NIST)
Also		RMP 72 351	P.J. Mohr, B.N. Taylor	(NIST)
TORII	99	PR A59 223	H.A. Torii *et al.*	(CERN PS-205 Collab.)
ALLISON	98	PL B427 217	W.W.M. Allison *et al.*	(Soudan-2 Collab.)
HU	98B	PR D58 111101	M. Hu *et al.*	(FNAL APEX Collab.)
SHIOZAWA	98	PRL 81 3319	M. Shiozawa *et al.*	(Super-Kamiokande Collab.)
GLICENSTEIN	97	PL B411 326	J.F. Glicenstein	(SACL)
MERGELL	96	NP A596 367	P. Mergell *et al.*	(MANZ, BONN)
GABRIELSE	95	PRL 74 3544	G. Gabrielse *et al.*	(HARV, MANZ, SEOUL)
MACGIBBON	95	PR C52 2097	B.E. MacGibbon *et al.*	(ILL, SASK, INRM)
GEER	94	PRL 72 1596	S. Geer *et al.*	(FNAL, UCLA, PSU)
WONG	94	IJMP E3 821	C.W. Wong	(UCLA)
HALLIN	93	PR C48 1497	E.L. Hallin *et al.*	(SASK, BOST, ILL)
SUZUKI	93B	PL B311 357	Y. Suzuki *et al.*	(KAMIOKANDE Collab.)
HUGHES	92	PRL 69 578	R.J. Hughes, B.I. Deutch	(LANL, AARH)
ZIEGER	92	PL B278 34	A. Zieger *et al.*	(MPCM)
Also		PL B281 417 (erratum)	A. Zieger *et al.*	(MPCM)
BERGER	91	ZPHY C50 385	C. Berger *et al.*	(FREJUS Collab.)
BERGER	91B	PL B269 227	C. Berger *et al.*	(FREJUS Collab.)
FEDERSPIEL	91	PRL 67 1511	F.J. Federspiel *et al.*	(ILL)
MCCORD	91	NIM B56/57 496	M. McCord *et al.*	
BECKER-SZ...	90	PR D42 2974	R.A. Becker-Szendy *et al.*	(IMB-3 Collab.)
ERICSON	90	EPL 11 295	T.E.O. Ericson, A. Richter	(CERN, DARM)
GABRIELSE	90	PRL 65 1317	G. Gabrielse *et al.*	(HARV, MANZ, WASH+)
BERGER	89	NP B313 509	C. Berger *et al.*	(FREJUS Collab.)
CHO	89	PRL 63 2559	D. Cho, K. Sangster, E.A. Hinds	(YALE)
HIRATA	89C	PL B220 308	K.S. Hirata *et al.*	(Kamiokande Collab.)
PHILLIPS	89	PL B224 348	T.J. Phillips *et al.*	(HPW Collab.)
KREISSL	88	ZPHY C37 557	A. Kreissl *et al.*	(CERN PS176 Collab.)
SEIDEL	88	PRL 61 2522	S. Seidel *et al.*	(IMB Collab.)
BARTELT	87	PR D36 1990	J.E. Bartelt *et al.*	(Soudan Collab.)
Also		PR D40 1701 (erratum)	J.E. Bartelt *et al.*	(Soudan Collab.)
COHEN	87	RMP 59 1121	E.R. Cohen, B.N. Taylor	(RISC, NBS)
HAINES	86	PRL 57 1986	T.J. Haines *et al.*	(IMB Collab.)
KAJITA	86	JPSJ 55 711	T. Kajita *et al.*	(Kamiokande Collab.)
ARISAKA	85	JPSJ 54 3213	K. Arisaka *et al.*	(Kamiokande Collab.)
BLEWITT	85	PRL 55 2114	G.B. Blewitt *et al.*	(IMB Collab.)
DZUBA	85	PL 154B 93	V.A. Dzuba, V.V. Flambaum, P.G. Silvestrov	(NOVO)
PARK	85	PRL 54 22	H.S. Park *et al.*	(IMB Collab.)
BATTISTONI	84	PL 133B 454	G. Battistoni *et al.*	(NUSEX Collab.)
MARINELLI	84	PL 137B 439	M. Marinelli, G. Morpurgo	(GENO)
WILKENING	84	PR A29 425	D.A. Wilkening, N.F. Ramsey, D.J. Larson	(HARV+)
BARTELT	83	PRL 50 651	J.E. Bartelt *et al.*	(MINN, ANL)
BATTISTONI	82	PL 118B 461	G. Battistoni *et al.*	(NUSEX Collab.)
KRISHNA...	82	PL 115B 349	M.R. Krishnaswamy *et al.*	(TATA, OSKC+)
ALEKSEEV	81	JETPL 33 651	E.N. Alekseev *et al.*	(PNPI)
		Translated from ZETFP 33 664.		
CHERRY	81	PRL 47 1507	M.L. Cherry *et al.*	(PENN, BNL)
COWSIK	80	PR D22 2204	R. Cowsik, V.S. Narasimham	(TATA)
SIMON	80	NP A333 381	G.G. Simon *et al.*	
BELL	79	PL 86B 215	M. Bell *et al.*	(CERN)
GOLDEN	79	PRL 43 1196	R.L. Golden *et al.*	(NASA, PSLL)
LEARNED	79	PRL 43 907	J.G. Learned, F. Reines, A. Soni	(UCI)
BREGMAN	78	PL 78B 174	M. Bregman *et al.*	(CERN)
ROBERTS	78	PR D17 358	B.L. Roberts	(WILL, RHEL)
EVANS	77	SCI 197 989	J.C. Evans Jr., R.I. Steinberg	(BNL, PENN)
HU	75	NP A254 403	E. Hu *et al.*	(COLU, YALE)
BORKOWSKI	74	NP A222 269	F. Borkowski *et al.*	
COHEN	73	JPCRD 2 664	E.R. Cohen, B.N. Taylor	(RISC, NBS)
DYLLA	73	PR A7 1224	H.F. Dylla, J.G. King	(MIT)
AKIMOV	72	JETP 35 651	Yu.K. Akimov *et al.*	(YERE)
		Translated from ZETF 62 1231.		
DIX	70	Thesis Case	F.W. Dix	(CASE)
HARRISON	69	PRL 22 1263	G.E. Harrison, P.G.H. Sandars, S.J. Wright	(OXF)
GURR	67	PR 158 1321	H.S. Gurr *et al.*	(CASE, WITW)
FREREJACQ...	66	PR 141 1308	D. Frerejacque *et al.*	
HAND	63	RMP 35 335	L.N. Hand *et al.*	
FLEROV	58	DOKL 3 79	G.N. Flerov *et al.*	(ASCI)