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
1.007276466812±0.000000000090	MOHR	12	RVUE	2010 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.00727646677 ±0.00000000010	MOHR	08	RVUE	2006 CODATA value
1.00727646688 ±0.00000000013	MOHR	05	RVUE	2002 CODATA value
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 = 931.494 061(21) MeV/c^2 (MOHR 12, the 2010 CODATA value), involves the relatively poorly known electronic charge.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
938.272046±0.000021	MOHR	12	RVUE	2010 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
938.272013±0.000023	MOHR	08	RVUE	2006 CODATA value
938.272029±0.000080	MOHR	05	RVUE	2002 CODATA value
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
$\mathbf{<7 \times 10^{-10}}$	90	[1] HORI	11	SPEC	$\overline{p}e^-$He atom
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<2 \times 10^{-9}$	90	[1] HORI	06	SPEC	$\overline{p}e^-$He atom
$<1.0 \times 10^{-8}$	90	[1] HORI	03	SPEC	$\overline{p}e^-$ ^{4}He, $\overline{p}e^-$ ^{3}He
$<6 \times 10^{-8}$	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, HORI 03, HORI 06, and HORI 11 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, HORI 03, HORI 06, and HORI 11 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	[1] GABRIELSE	95	TRAP	Penning trap
1.000000023 ±0.000000042	[2] GABRIELSE	90	TRAP	Penning trap

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

[2] 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	

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

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
$<7 \times 10^{-10}$	90	[1] HORI	11	SPEC	$\overline{p}e^-$He atom
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<2 \times 10^{-9}$	90	[1] HORI	06	SPEC	$\overline{p}e^-$He atom
$<1.0 \times 10^{-8}$	90	[1] HORI	03	SPEC	$\overline{p}e^-\,{}^4$He, $\overline{p}e^-\,{}^3$He
$<6 \times 10^{-8}$	90	[1] HORI	01	SPEC	$\overline{p}e^-$He atom
$<5 \times 10^{-7}$		[2] TORII	99	SPEC	$\overline{p}e^-$He atom
$<2 \times 10^{-5}$		[3] HUGHES	92	RVUE	

[1] HORI 01, HORI 03, HORI 06, and HORI 11 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, HORI 03, HORI 06, and HORI 11 values for $|m_p - m_{\overline{p}}|/m_p$, above.

[2] 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.

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

$|q_p + q_e|/e$

See BRESSI 11 for a summary of experiments on the neutrality of matter.
See also "*n* CHARGE" in the neutron Listings.

VALUE	*DOCUMENT ID*		*COMMENT*
<1 × 10^{-21}	[1] BRESSI	11	Neutrality of SF_6
• • • We do not use the following data for averages, fits, limits, etc. • • •			
$<3.2 \times 10^{-20}$	[2] SENGUPTA	00	binary pulsar
$<0.8 \times 10^{-21}$	MARINELLI	84	Magnetic levitation
$<1.0 \times 10^{-21}$	[1] DYLLA	73	Neutrality of SF_6

[1] BRESSI 11 uses the method of DYLLA 73 but finds serious errors in that experiment that greatly reduce its accuracy. The BRESSI 11 limit assumes that $n \to p e^- \nu_e$ conserves charge. Thus the limit applies equally to the charge of the neutron.

[2] 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*
2.792847356±0.000000023	MOHR	12	RVUE	2010 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.792847356±0.000000023	MOHR	08	RVUE	2006 CODATA value
2.792847351±0.000000028	MOHR	05	RVUE	2002 CODATA value
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*
−2.792845±0.000012	DISCIACCA	13	TRAP	Single $\overline{p}$, Penning trap

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

−2.7862	±0.0083	PASK	09	CNTR	$\overline{p}$ He^+ hyperfine structure
−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.

VALUE (units 10^{-6})	*DOCUMENT ID*		*TECN*	*COMMENT*
0±5	DISCIACCA	13	TRAP	Single $\overline{p}$, Penning trap

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		[1] 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		[2] WILKENING	84		
900 ±1400		[3] WILKENING	84		
700 ± 900	1G	HARRISON	69	MBR	Molecular beam

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

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

[3] 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*
11.2 ±0.4 OUR AVERAGE				
10.65±0.35±0.36	MCGOVERN	13	RVUE	χEFT + Compton scattering
12.1 ±1.1 ±0.5	[1] BEANE	03		EFT + γp
$11.82 \pm 0.98 ^{+0.52}_{-0.98}$	[2] BLANPIED	01	LEGS	$p(\vec{\gamma},\gamma)$, $p(\vec{\gamma},\pi^0)$, $p(\vec{\gamma},\pi^+)$
11.9 ±0.5 ±1.3	[3] OLMOSDEL...	01	CNTR	γp Compton scattering
12.1 ±0.8 ±0.5	[4] MACGIBBON	95	RVUE	global average

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

11.7 ± 0.8 ± 0.7	[5] 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	[6] FEDERSPIEL	91	CNTR	γp Compton scattering

[1] 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.

[2] 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.

[3] 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.

[4] 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.

[5] 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 $\alpha_p + \beta_p$.

[6] 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 $(7.0 \pm 2.2 \pm 1.3) \times 10^{-4}$ 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*
2.5 $\pm$0.4 OUR AVERAGE	Error includes scale factor of 1.2.			
3.15$\pm$0.35$\pm$0.36	MCGOVERN	13	RVUE	χEFT + Compton scattering
3.4 ± 1.1 ± 0.1	[1] BEANE	03		EFT + γp
$1.43 \pm 0.98^{+0.52}_{-0.98}$	[2] BLANPIED	01	LEGS	$p(\vec{\gamma},\gamma)$, $p(\vec{\gamma},\pi^0)$, $p(\vec{\gamma},\pi^+)$
1.2 ± 0.7 ± 0.5	[3] OLMOSDEL...	01	CNTR	γp Compton scattering
2.1 ± 0.8 ± 0.5	[4] MACGIBBON	95	RVUE	global average
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.3 ± 0.9 ± 0.7	[5] 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

[1] 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.

[2] 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.

[3] 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.

[4] 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.

[5] 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 electric charge radius, $\sqrt{\langle r_E^2 \rangle}$.

Most measurements of the radius of the proton involve electron-proton interactions, and most of the more recent values agree with one another. The most precise of these is $r_p = 0.879(8)$ fm (BERNAUER 14), which uses all the world's data on $e p$ scattering. The CODATA 10 value (MOHR 12), obtained from the electronic results, is 0.8775(51). However, a measurement using muonic hydrogen finds $r_p = 0.84087(39)$ fm (ANTOGNINI 13), which is 13 times more precise and seven standard deviations (using the CODATA 10 error) from the electronic results.

Since POHL 10 (the first μp result), there has been a lot of discussion about the disagreement, especially concerning the modeling of muonic hydrogen. Here is an incomplete list of papers: DERUJULA 10, CLOET 11, DISTLER 11, DERUJULA 11, ARRINGTON 11, BERNAUER 11, HILL 11, LORENZ 14, and KARSHENBOIM 14A.

Until the difference between the $e p$ and μp values is understood, it does not make sense to average the values together. For the present, we give both values. It is up to workers in this field to solve this puzzle.

See our 2014 edition (Chinese Physics C **38** 070001 (2014)) for values published before 2003.

VALUE (fm)	*DOCUMENT ID*		*TECN*	*COMMENT*
0.84087±0.00026±0.00029	ANTOGNINI	13	LASR	μp-atom Lamb shift
0.8775 ±0.0051	MOHR	12	RVUE	2010 CODATA, $e p$ data
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.879 ±0.005 ±0.006	BERNAUER	14	SPEC	$e p \rightarrow e p$ form factor
0.879 ±0.005 ±0.006	BERNAUER	10	SPEC	See BERNAUER 14
0.912 ±0.009 ±0.007	BORISYUK	10		reanalyzes old $e p$ data
0.871 ±0.009 ±0.003	HILL	10		z-expansion reanalysis
0.84184±0.00036±0.00056	POHL	10	LASR	See ANTOGNINI 13

0.8768	±0.0069		MOHR	08	RVUE	2006 CODATA value
0.844	$^{+0.008}_{-0.004}$		BELUSHKIN	07		Dispersion analysis
0.897	±0.018		BLUNDEN	05		SICK 03 + 2γ correction
0.8750	±0.0068		MOHR	05	RVUE	2002 CODATA value
0.895	±0.010	±0.013	SICK	03		$e p \to e p$ reanalysis

p MAGNETIC RADIUS

This is the rms magnetic radius, $\sqrt{\langle r^2_M \rangle}$. See, for example, EPSTEIN 14 and KARSHENBOIM 14 for "model independent" extractions of the magnetic radius.

VALUE (fm)	*DOCUMENT ID*		*TECN*	*COMMENT*
0.777±0.013±0.010	BERNAUER	14	SPEC	$e p \to e p$ form factor
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.777±0.013±0.010	BERNAUER	10	SPEC	See BERNAUER 14
0.876±0.010±0.016	BORISYUK	10		reanalyzes old $e p \to e p$ data
0.854±0.005	BELUSHKIN	07		Dispersion analysis

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	[1] ARAKI	06	KLND	$n \to$ invisible
$>2.1 \times 10^{29}$	***p***	90	[2] AHMED	04	SNO	$p \to$ invisible
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$>1.9 \times 10^{29}$	*n*	90	[2] AHMED	04	SNO	$n \to$ invisible
$>1.8 \times 10^{25}$	*n*	90	[3] BACK	03	BORX	
$>1.1 \times 10^{26}$	*p*	90	[3] BACK	03	BORX	
$>3.5 \times 10^{28}$	*p*	90	[4] ZDESENKO	03		$p \to$ invisible
$>1 \times 10^{28}$	*p*	90	[5] AHMAD	02	SNO	$p \to$ invisible
$>4 \times 10^{23}$	*p*	95	TRETYAK	01		$d \to n + ?$
$>1.9 \times 10^{24}$	*p*	90	[6] BERNABEI	00B	DAMA	
$>1.6 \times 10^{25}$	*p*, *n*		[7,8] EVANS	77		
$>3 \times 10^{23}$	*p*		[8] DIX	70	CNTR	
$>3 \times 10^{23}$	*p*, *n*		[8,9] FLEROV	58		

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

[2] 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.

[3] 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.

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

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

[6] 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.
[7] EVANS 77 looks for the daughter nuclide ^{129}Xe from possible ^{130}Te decays in ancient Te ore samples.
[8] This mean-life limit has been obtained from a half-life limit by dividing the latter by ln(2) = 0.693.
[9] 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 $\overline{p} \to e^- \gamma$. 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		[1] 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

[1] 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**, 1173) 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	$N \to e^+ \pi$	> 2000 (n), > 8200 (p)	90%
τ_2	$N \to \mu^+ \pi$	> 1000 (n), > 6600 (p)	90%
τ_3	$N \to \nu \pi$	> 1100 (n), > 390 (p)	90%
τ_4	$p \to e^+ \eta$	> 4200	90%
τ_5	$p \to \mu^+ \eta$	> 1300	90%
τ_6	$n \to \nu \eta$	> 158	90%
τ_7	$N \to e^+ \rho$	> 217 (n), > 710 (p)	90%
τ_8	$N \to \mu^+ \rho$	> 228 (n), > 160 (p)	90%

τ_{9}	$N \rightarrow \nu \rho$	> 19 (n), > 162 (p)	90%
τ_{10}	$p \rightarrow e^+ \omega$	> 320	90%
τ_{11}	$p \rightarrow \mu^+ \omega$	> 780	90%
τ_{12}	$n \rightarrow \nu \omega$	> 108	90%
τ_{13}	$N \rightarrow e^+ K$	> 17 (n), > 1000 (p)	90%
τ_{14}	$p \rightarrow e^+ K^0_S$		
τ_{15}	$p \rightarrow e^+ K^0_L$		
τ_{16}	$N \rightarrow \mu^+ K$	> 26 (n), > 1600 (p)	90%
τ_{17}	$p \rightarrow \mu^+ K^0_S$		
τ_{18}	$p \rightarrow \mu^+ K^0_L$		
τ_{19}	$N \rightarrow \nu K$	> 86 (n), > 5900 (p)	90%
τ_{20}	$n \rightarrow \nu K^0_S$	> 260	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}	$p \rightarrow e^+ \nu \nu$	> 170	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}	$p \rightarrow \mu^+ \nu \nu$	> 220	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}	$pp \rightarrow \pi^+ \pi^+$	> 0.7	90%
τ_{65}	$pn \rightarrow \pi^+ \pi^0$	> 2	90%
τ_{66}	$nn \rightarrow \pi^+ \pi^-$	> 0.7	90%
τ_{67}	$nn \rightarrow \pi^0 \pi^0$	> 3.4	90%
τ_{68}	$pp \rightarrow K^+ K^+$	> 170	90%
τ_{69}	$pp \rightarrow e^+ e^+$	> 5.8	90%
τ_{70}	$pp \rightarrow e^+ \mu^+$	> 3.6	90%
τ_{71}	$pp \rightarrow \mu^+ \mu^+$	> 1.7	90%
τ_{72}	$pn \rightarrow e^+ \overline{\nu}$	> 2.8	90%
τ_{73}	$pn \rightarrow \mu^+ \overline{\nu}$	> 1.6	90%
τ_{74}	$pn \rightarrow \tau^+ \overline{\nu}_\tau$	> 1.0	90%
τ_{75}	$nn \rightarrow \nu_e \overline{\nu}_e$	> 1.4	90%
τ_{76}	$nn \rightarrow \nu_\mu \overline{\nu}_\mu$	> 1.4	90%
τ_{77}	$pn \rightarrow$ invisible	> 0.000021	90%
τ_{78}	$pp \rightarrow$ invisible	> 0.00005	90%

$\overline{p}$ DECAY MODES

	Mode	Partial mean life (years)	Confidence level
τ_{79}	$\overline{p} \to e^- \gamma$	$> 7 \times 10^5$	90%
τ_{80}	$\overline{p} \to \mu^- \gamma$	$> 5 \times 10^4$	90%
τ_{81}	$\overline{p} \to e^- \pi^0$	$> 4 \times 10^5$	90%
τ_{82}	$\overline{p} \to \mu^- \pi^0$	$> 5 \times 10^4$	90%
τ_{83}	$\overline{p} \to e^- \eta$	$> 2 \times 10^4$	90%
τ_{84}	$\overline{p} \to \mu^- \eta$	$> 8 \times 10^3$	90%
τ_{85}	$\overline{p} \to e^- K^0_S$	> 900	90%
τ_{86}	$\overline{p} \to \mu^- K^0_S$	$> 4 \times 10^3$	90%
τ_{87}	$\overline{p} \to e^- K^0_L$	$> 9 \times 10^3$	90%
τ_{88}	$\overline{p} \to \mu^- K^0_L$	$> 7 \times 10^3$	90%
τ_{89}	$\overline{p} \to e^- \gamma\gamma$	$> 2 \times 10^4$	90%
τ_{90}	$\overline{p} \to \mu^- \gamma\gamma$	$> 2 \times 10^4$	90%
τ_{91}	$\overline{p} \to e^- \rho$		
τ_{92}	$\overline{p} \to e^- \omega$	> 200	90%
τ_{93}	$\overline{p} \to e^- K^*(892)^0$		

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

$\tau(N \to e^+ \pi)$ τ_1

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>2000	***n***	**90**	**0**	**0.27**	NISHINO	12	SKAM
>8200	***p***	**90**	**0**	**0.3**	NISHINO	09	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 540	*p*	90	0	0.2	MCGREW	99	IMB3
> 158	*n*	90	3	5	MCGREW	99	IMB3
>1600	*p*	90	0	0.1	SHIOZAWA	98	SKAM
> 70	*p*	90	0	0.5	BERGER	91	FREJ
> 70	*n*	90	0	≤ 0.1	BERGER	91	FREJ
> 550	*p*	90	0	0.7	[1] 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	[2] BARTELT	83	SOUD
> 0.5	*n*	90	1	0.3	[2] BARTELT	83	SOUD
> 5.8	*p*	90	2		[3] KRISHNA...	82	KOLR
> 5.8	*n*	90	2		[3] KRISHNA...	82	KOLR
> 0.1	*n*	90			[4] GURR	67	CNTR

[1] This BECKER-SZENDY 90 result includes data from SEIDEL 88.
[2] Limit based on zero events.
[3] We have calculated 90% CL limit from 1 confined event.
[4] 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
>1000	***n***	**90**	**1**	**0.43**	NISHINO	12	SKAM
>6600	***p***	**90**	**0**	**0.3**	NISHINO	09	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 473	*p*	90	0	0.6	MCGREW	99	IMB3
> 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
> 100	*n*	90	0	<0.2	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
> 390	***p***	**90**	**52.8**		ABE	14E	SKAM
>1100	***n***	**90**	**19.1**		ABE	14E	SKAM

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

> 16	p	90	6	6.7	WALL	00B	SOU2
> 39	n	90	4	3.8	WALL	00B	SOU2
> 10	p	90	15	20.3	MCGREW	99	IMB3
> 112	n	90	6	6.6	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	[1] 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		[2] KRISHNA...	82	KOLR
> 0.3	p	90	2		[3] CHERRY	81	HOME
> 0.1	p	90			[4] GURR	67	CNTR

[1] 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.

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

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

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

$\tau(p \rightarrow e^+ \eta)$ τ_4

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>4200	**p**	**90**	**0**	**0.44**	NISHINO	12	SKAM

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

> 81	p	90	1	1.7	WALL	00B	SOU2
> 313	p	90	0	0.2	MCGREW	99	IMB3
> 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		[1] CHERRY	81	HOME

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

$\tau(p \rightarrow \mu^+ \eta)$ τ_5

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>1300	**p**	**90**	**2**	**0.49**	NISHINO	12	SKAM

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

> 89	p	90	0	1.6	WALL	00B	SOU2
> 126	p	90	3	2.8	MCGREW	99	IMB3
> 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

$\tau(n \rightarrow \nu\eta)$ — 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		[1] CHERRY	81	HOME

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

$\tau(N \rightarrow e^+\rho)$ — τ_7

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>710	**p**	**90**	**0**	**0.35**	NISHINO	12	SKAM
>217	**n**	**90**	**4**	**4.8**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 70	n	90	1	0.38	NISHINO	12	SKAM
> 29	p	90	0	2.2	BERGER	91	FREJ
> 41	n	90	0	1.4	BERGER	91	FREJ
> 75	p	90	2	2.7	HIRATA	89C	KAMI
> 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	[1] BARTELT	83	SOUD
> 0.5	*p*	90	1	0.3	[1] BARTELT	83	SOUD
> 9.8	*p*	90	1		[2] KRISHNA...	82	KOLR
> 0.8	*p*	90	2		[3] CHERRY	81	HOME

[1] Limit based on zero events.
[2] We have calculated 90% CL limit from 0 confined events.
[3] 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
>160	***p***	**90**	**1**	**0.42**	NISHINO	12	SKAM
>228	***n***	**90**	**3**	**9.5**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 36	*n*	90	0	0.29	NISHINO	12	SKAM
> 12	*p*	90	0	0.5	BERGER	91	FREJ
> 22	*n*	90	0	1.1	BERGER	91	FREJ
>110	*p*	90	0	1.7	HIRATA	89C	KAMI
> 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

$\tau(N \to \nu \rho)$ 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		[1] CHERRY	81	HOME
> 0.6	*n*	90	2		[1] CHERRY	81	HOME

[1] 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
>320	***p***	**90**	**1**	**0.53**	NISHINO	12	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>107	*p*	90	7	10.8	MCGREW	99	IMB3
> 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	[1] BARTELT	83	SOUD
> 9.8	*p*	90	1		[2] KRISHNA...	82	KOLR
> 2.8	*p*	90	2		[3] CHERRY	81	HOME

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

$\tau(p \rightarrow \mu^+ \omega)$ τ_{11}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>780	***p***	**90**	**0**	**0.48**	NISHINO	12	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>117	*p*	90	11	12.1	MCGREW	99	IMB3
> 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

$\tau(n \rightarrow \nu \omega)$ 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		[1] CHERRY	81	HOME

[1] 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
>1000	***p***	**90**	**6**	**4.7**	KOBAYASHI	05	SKAM
> 17	***n***	**90**	**35**	**29.4**	MCGREW	99	IMB3
• • • 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
> 150	*p*	90	0	<0.27	HIRATA	89C	KAMI
> 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
• • • 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

$\tau(p \to e^+ K^0_L)$ — τ_{15}

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

$\tau(N \to \mu^+ K)$ — τ_{16}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>1600	***p***	**90**	**13**	**13.2**	REGIS	12	SKAM
> 26	***n***	**90**	**20**	**28.4**	MCGREW	99	IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>1300	p	90	3	3.9	KOBAYASHI	05	SKAM
> 120	*p*	90	0	<1.2	WALL	00	SOU2
> 120	*p*	90	4	7.2	MCGREW	99	IMB3
> 54	*p*	90	0		BERGER	91	FREJ
> 120	*p*	90	1	0.4	HIRATA	89C	KAMI
> 3.0	*p*	90	0	0.7	PHILLIPS	89	HPW
> 19	*p*	90	3	2.5	SEIDEL	88	IMB
> 1.5	*p*	90	0		[1] 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		[2] BARTELT	83	SOUD
> 0.4	n	90	0		[2] BARTELT	83	SOUD
> 5.8	p	90	2		[3] KRISHNA...	82	KOLR
> 2.0	p	90	0		CHERRY	81	HOME
> 0.2	n	90			[4] GURR	67	CNTR

[1] BARTELT 87 limit applies to $p \to \mu^+ K^0_S$.

[2] Limit based on zero events.

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

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

$\tau(p \to \mu^+ K^0_S)$ τ_{17}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
• • • 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

$\tau(p \to \mu^+ K^0_L)$ τ_{18}

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>83	p	90	0	0.4	WALL	00	SOU2
>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
>5900	**p**	**90**	**0**	**1.0**	ABE	14G	SKAM
> 86	**n**	**90**	**0**	**2.4**	HIRATA	89C	KAMI
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>2300	p	90	0	1.3	KOBAYASHI	05	SKAM
> 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	[1] 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		[2] 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		[3] BARTELT	83	SOUD
$>$ 0.1	p	90	0		[3] BARTELT	83	SOUD
$>$ 5.8	p	90	1		[4] KRISHNA...	82	KOLR
$>$ 0.3	n	90	2		[5] CHERRY	81	HOME

[1] This ALLISON 98 limit is with no background subtraction; with subtraction the limit becomes $> 46 \times 10^{30}$ years.
[2] BARTELT 87 limit applies to $n \to \nu K^0_S$.
[3] Limit based on zero events.
[4] We have calculated 90% CL limit from 1 confined event.
[5] 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**	[1] KOBAYASHI	05	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$>$ 51	n	90	16	9.1	WALL	00	SOU2

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

$\tau(p \to e^+ K^*(892)^0)$ 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

$\tau(N \to \nu K^*(892))$ 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		[1] BATTISTONI	82	NUSX

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

Antilepton + mesons

$\tau(p \to e^+ \pi^+ \pi^-)$ — 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

$\tau(p \to e^+ \pi^0 \pi^0)$ — 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

$\tau(p \rightarrow \mu^- \pi^+ K^+)$ 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)

$\tau(p \rightarrow e^+ \gamma)$ 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			[1] GURR	67	CNTR

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

$\tau(p \rightarrow \mu^+ \gamma)$ 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			[1] GURR	67	CNTR

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

$\tau(n \rightarrow \nu \gamma)$ 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

$\tau(p \rightarrow e^+ \gamma \gamma)$ 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
>170	***p***	**90**			[1] TAKHISTOV	14	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 17	*p*	90	152	153.7	MCGREW	99	IMB3
> 11	*p*	90	11	6.08	BERGER	91B	FREJ

[1] Allowed events at 90% CL are 459.

$\tau(n \to e^+ e^- \nu)$ 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		[1] BATTISTONI	82	NUSX

[1] 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
>220	***p***	**90**			[1] TAKHISTOV	14	SKAM

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

> 21	*p*	90	7	11.23	BERGER	91B	FREJ

[1] Allowed events at 90% CL are 286.

$\tau(p \to e^- \mu^+ \mu^+)$ 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**	[1] SUZUKI	93B	KAMI

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

>0.0023	n	90			[2] GLICENSTEIN	97	KAMI
>0.00003	n	90	11	6.1	[3] BERGER	91B	FREJ
>0.00012	n	90	7	11.2	[3] BERGER	91B	FREJ
>0.0005	n	90	0		LEARNED	79	RVUE

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

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

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

$\tau(n \rightarrow 5\nu)$ τ_{58}

See the note on $\tau(n \rightarrow 3\nu)$ 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			[1] GLICENSTEIN	97	KAMI

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

Inclusive modes

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

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>0.6	***p, n***	**90**			[1] LEARNED	79	RVUE

[1] The electron may be primary or secondary.

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

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>12	***p, n***	**90**	**2**		[1,2] CHERRY	81	HOME
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 1.8	p, n	90			[2] COWSIK	80	CNTR
> 6	p, n	90			[2] LEARNED	79	RVUE

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

[2] The muon may be primary or secondary.

$\tau(N \rightarrow \nu \text{anything})$ 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

$\tau(N \rightarrow e^+ \pi^0 \text{anything})$ 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

$\tau(pp \to K^+K^+)$ τ_{68}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>170	**90**	**0**	**0.28**	LITOS	14	SKAM	τ per oxygen nucleus

$\tau(pp \to e^+e^+)$ τ_{69}

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_{70}

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_{71}

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_{72}

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_{73}

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

$\tau(pn \to \tau^+ \overline{\nu}_\tau)$ τ_{74}

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>1	**90**			[1] BRYMAN	14	CHER

[1] BRYMAN 14 uses a MCGREW 99 limit on the $p \to e^+ \nu \nu$ lifetime to extract this value.

$\tau(nn \to \nu_e \overline{\nu}_e)$ τ_{75}

We include "invisible" modes here.

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>1.4	**90**			[1] ARAKI	06	KLND	$nn \to$ invisible
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.000042	90			[2] TRETYAK	04	CNTR	$nn \to$ invisible
>0.000049	90			[3] BACK	03	BORX	$nn \to$ invisible
>0.000012	90			[4] BERNABEI	00B	DAMA	$nn \to$ invisible
>0.000012	90	5	9.7	BERGER	91B	FREJ	τ per iron nucleus

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

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

[3] 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.

[4] 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_{76}

See the proceeding data block. "Invisible modes" would include any multi-neutrino mode.

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	CL%	DOCUMENT ID		TECN	COMMENT
>1.4	**(CL = 90%) OUR LIMIT**							
• • • 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

$\tau(pn \to \text{invisible})$ τ_{77}

This violates charge conservation as well as baryon number conservation.

VALUE (10^{30} years)	CL%	DOCUMENT ID		TECN
>0.000021	90	[1] TRETYAK	04	CNTR

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

$\tau(pp \to \text{invisible})$ τ_{78}

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	[1] BACK	03	BORX
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.00000055	90				[2] BERNABEI	00B	DAMA

[1] 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.

[2] 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_{79}

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_{80}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
>5 × 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 × 10^4	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- \pi^0)$ τ_{81}

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_{82}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
>5 × 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 × 10^4	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- \eta)$ τ_{83}

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. • • •					
>171	95	GEER	94	CALO	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to \mu^- \eta)$ τ_{84}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
>8 × 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_{85}

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_{86}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
>4 × 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_{87}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
>9 × 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_{88}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
>7 × 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_{89}

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

$\tau(\overline{p} \to \mu^- \gamma\gamma)$ τ_{90}

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. • • •					
$>2.3 \times 10^4$	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- \rho)$ τ_{91}

VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>200	90	[1] GEER	00	APEX	8.9 GeV/c $\overline{p}$ beam

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

$\tau(\overline{p} \rightarrow e^- \omega)$ — τ_{92}

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

$\tau(\overline{p} \rightarrow e^- K^*(892)^0)$ — τ_{93}

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

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

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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)
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)
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)

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)
FLEROV	58	DOKL 3 79	G.N. Flerov *et al.*	(ASCI)