



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

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.

<u>VALUE (u)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
1.00727646662 \pm 0.00000000009	OUR AVERAGE	Error	includes scale factor of 3.1.
1.007276466583 \pm 0.000000000032	¹ HEISSE	17	SPEC Penning trap
1.007276466879 \pm 0.000000000091	MOHR	16	RVUE 2014 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1.007276466812 \pm 0.000000000090	MOHR	12	RVUE 2010 CODATA value
1.00727646677 \pm 0.00000000010	MOHR	08	RVUE 2006 CODATA value
1.00727646688 \pm 0.00000000013	MOHR	05	RVUE 2002 CODATA value
1.00727646688 \pm 0.00000000013	MOHR	99	RVUE 1998 CODATA value
1.007276470 \pm 0.000000012	COHEN	87	RVUE 1986 CODATA value

¹ The statistical and systematic errors are 15 and 29 in the last two places of the value. The value disagrees with the MOHR 16 value by over 3 standard deviations.

p MASS (MeV)

The mass is known much more precisely in u (atomic mass units) than in MeV. The conversion from u to MeV, $1 u = 931.494\,0054(57) \text{ MeV}/c^2$ (MOHR 16, the 2014 CODATA value), involves the relatively poorly known electronic charge.

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
938.2720813 \pm 0.0000058	MOHR	16	RVUE 2014 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •			
938.272046 \pm 0.000021	MOHR	12	RVUE 2010 CODATA value
938.272013 \pm 0.000023	MOHR	08	RVUE 2006 CODATA value
938.272029 \pm 0.000080	MOHR	05	RVUE 2002 CODATA value
938.271998 \pm 0.000038	MOHR	99	RVUE 1998 CODATA value
938.27231 \pm 0.00028	COHEN	87	RVUE 1986 CODATA value
938.2796 \pm 0.0027	COHEN	73	RVUE 1973 CODATA value

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

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

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$<7 \times 10^{-10}$	90	¹ HORI	11	SPEC $\bar{p}e^-$ He atom

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

$<2 \times 10^{-9}$	90	¹ HORI	06	SPEC	$\bar{p}e^-$ He atom
$<1.0 \times 10^{-8}$	90	¹ HORI	03	SPEC	$\bar{p}e^-$ ⁴ He, $\bar{p}e^-$ ³ He
$<6 \times 10^{-8}$	90	¹ HORI	01	SPEC	$\bar{p}e^-$ He atom
$<5 \times 10^{-7}$		² TORII	99	SPEC	$\bar{p}e^-$ He atom

¹ HORI 01, HORI 03, HORI 06, and HORI 11 use the more-precisely-known constraint on the \bar{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 $|q_p + q_{\bar{p}}|/e$, below.

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

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

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 \bar{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 \bar{p} 's.

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
1.00000000001 ± 0.00000000069	ULMER	15	TRAP Penning trap
0.99999999991 ± 0.00000000009	GABRIELSE	99	TRAP Penning trap
1.0000000015 ± 0.0000000011	¹ GABRIELSE	95	TRAP Penning trap
1.000000023 ± 0.000000042	² GABRIELSE	90	TRAP Penning trap

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

¹ Equation (2) of GABRIELSE 95 should read $M(\bar{p})/M(p) = 0.999\,999\,9985$ (11) (G. Gabrielse, private communication).

² GABRIELSE 90 also measures $m_{\bar{p}}/m_{e^-} = 1836.152660 \pm 0.000083$ 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 .

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

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

<u>VALUE</u>	<u>DOCUMENT ID</u>
$(0.1 \pm 6.9) \times 10^{-11}$ OUR EVALUATION	

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

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

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$<7 \times 10^{-10}$	90	¹ HORI	11	SPEC $\bar{p}e^-$ He atom

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

$<2 \times 10^{-9}$	90	¹ HORI	06	SPEC	$\bar{p}e^-$ He atom
$<1.0 \times 10^{-8}$	90	¹ HORI	03	SPEC	$\bar{p}e^-$ ⁴ He, $\bar{p}e^-$ ³ He
$<6 \times 10^{-8}$	90	¹ HORI	01	SPEC	$\bar{p}e^-$ He atom
$<5 \times 10^{-7}$		² TORII	99	SPEC	$\bar{p}e^-$ 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 \bar{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 $|m_p - m_{\bar{p}}|/m_p$, above.

² TORII 99 uses the more-precisely-known constraint on the \bar{p} charge-to-mass ratio of GABRIELSE 95 (see above) to get this result. This is not independent of the TORII 99 value for $|m_p - m_{\bar{p}}|/m_p$, 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.

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>COMMENT</u>
$<1 \times 10^{-21}$	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 $n \rightarrow p e^- \nu_e$ conserves charge. Thus the limit applies equally to the charge of the neutron.

² SENGUPTA 00 uses the difference between the observed rate of 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.

ρ MAGNETIC MOMENT

See the “Note on Baryon Magnetic Moments” in the Λ Listings.

<u>VALUE (μ_N)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$2.79284734462 \pm 0.0000000082$	SCHNEIDER 17	TRAP	Double Penning trap

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

2.7928473508 ± 0.0000000085	MOHR 16	RVUE	2014 CODATA value
2.792847356 ± 0.000000023	MOHR 12	RVUE	2010 CODATA value
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

\bar{p} MAGNETIC MOMENT

A few early results have been omitted.

VALUE (μ_N)	DOCUMENT ID	TECN	COMMENT
$-2.7928473441 \pm 0.0000000042$	SMORRA	17	TRAP Hot/cold \bar{p} frequencies, Penning traps
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
-2.7928465 ± 0.0000023	NAGAHAMA	17	TRAP Single \bar{p} , Penning trap
-2.792845 ± 0.000012	DISCIACCA	13	TRAP Single \bar{p} , Penning trap
-2.7862 ± 0.0083	PASK	09	CNTR \bar{p} He ⁺ hyperfine structure
-2.8005 ± 0.0090	KREISSL	88	CNTR \bar{p} ²⁰⁸ Pb 11→10 X-ray
-2.817 ± 0.048	ROBERTS	78	CNTR
-2.791 ± 0.021	HU	75	CNTR Exotic atoms

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

A test of *CPT* invariance.

VALUE (units 10^{-6})	DOCUMENT ID	TECN	COMMENT
0.002 ± 0.004	SMORRA	17	TRAP Hot/cold \bar{p} frequencies, Penning traps
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
0.3 ± 0.8	NAGAHAMA	17	TRAP Single \bar{p} , Penning trap
0 ± 5	DISCIACCA	13	TRAP Single \bar{p} , Penning trap

p ELECTRIC DIPOLE MOMENT

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

VALUE (10^{-23} ecm)	DOCUMENT ID	TECN	COMMENT
< 0.021	¹ SAHOO	17	Theory plus ¹⁹⁹ Hg atom EDM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
< 0.54	¹ DMITRIEV	03	Theory plus ¹⁹⁹ Hg atom EDM
$- 3.7 \pm 6.3$	CHO	89	NMR TI F molecules
< 400	DZUBA	85	THEO Uses ¹²⁹ Xe moment
130 ± 200	² WILKENING	84	
900 ± 1400	³ WILKENING	84	
700 ± 900	HARRISON	69	MBR Molecular beam

¹ SAHOO 17 and DMITRIEV 03 are not direct measurements of the proton electric dipole moment. They use theory to calculate this limit from the limit on the electric dipole moment of the ¹⁹⁹Hg 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 $\alpha_p = (12.0 \pm 0.6) \times 10^{-4} \text{ fm}^3$ and $\beta_p = (1.9 \mp 0.6) \times 10^{-4} \text{ fm}^3$, almost exactly our averages.

VALUE (10^{-4} fm^3)	DOCUMENT ID	TECN	COMMENT
11.2 \pm 0.4 OUR AVERAGE			
10.65 \pm 0.35 \pm 0.36	MCGOVERN	13	RVUE χ EFT + Compton scattering
12.1 \pm 1.1 \pm 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 \pm 0.5 \pm 1.3	³ OLMOSDEL...	01	CNTR γp Compton scattering
12.1 \pm 0.8 \pm 0.5	⁴ MACGIBBON	95	RVUE global average
• • • We do not use the following data for averages, fits, limits, etc. • • •			
11.7 \pm 0.8 \pm 0.7	⁵ BARANOV	01	RVUE Global average
12.5 \pm 0.6 \pm 0.9	MACGIBBON	95	CNTR γp Compton scattering
9.8 \pm 0.4 \pm 1.1	HALLIN	93	CNTR γp Compton scattering
10.62 $^{+1.25+1.07}_{-1.19-1.03}$	ZIEGER	92	CNTR γp Compton scattering
10.9 \pm 2.2 \pm 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) $\alpha_N = (13.0 \pm 1.9^{+3.9}_{-1.5}) \times 10^{-4} \text{ fm}^3$ and $\beta_N = (-1.8 \pm 1.9^{+2.1}_{-0.9}) \times 10^{-4} \text{ fm}^3$.

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 $\alpha + \beta = (13.8 \pm 0.4) \times 10^{-4} \text{ fm}^3$. 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 $(7.0 \pm 2.2 \pm 1.3) \times 10^{-4} \text{ fm}^3$.

p MAGNETIC POLARIZABILITY β_p

The electric and magnetic polarizabilities are subject to a dispersion sum-rule constraint $\bar{\alpha} + \bar{\beta} = (14.2 \pm 0.5) \times 10^{-4} \text{ fm}^3$. Errors here are anticorrelated with those on $\bar{\alpha}_p$ 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 χ EFT + Compton scattering
3.4 \pm 1.1 \pm 0.1	¹ BEANE	03	EFT + γp

$1.43 \pm 0.98 \begin{smallmatrix} +0.52 \\ -0.98 \end{smallmatrix}$	² BLANPIED	01	LEGS	$\rho(\vec{\gamma}, \gamma), \rho(\vec{\gamma}, \pi^0), \rho(\vec{\gamma}, \pi^+)$
$1.2 \pm 0.7 \pm 0.5$	³ OLMOSDEL...	01	CNTR	γp Compton scattering
$2.1 \pm 0.8 \pm 0.5$	⁴ MACGIBBON	95	RVUE	global average
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$2.3 \pm 0.9 \pm 0.7$	⁵ BARANOV	01	RVUE	Global average
$1.7 \pm 0.6 \pm 0.9$	MACGIBBON	95	CNTR	γp Compton scattering
$4.4 \pm 0.4 \pm 1.1$	HALLIN	93	CNTR	γp Compton scattering
$3.58 \begin{smallmatrix} +1.19 +1.03 \\ -1.25 -1.07 \end{smallmatrix}$	ZIEGER	92	CNTR	γp Compton scattering
$3.3 \pm 2.2 \pm 1.3$	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) $\alpha_N = (13.0 \pm 1.9 \begin{smallmatrix} +3.9 \\ -1.5 \end{smallmatrix}) \times 10^{-4} \text{ fm}^3$ and $\beta_N = (-1.8 \pm 1.9 \begin{smallmatrix} +2.1 \\ -0.9 \end{smallmatrix}) \times 10^{-4} \text{ fm}^3$.

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 $\alpha + \beta = (13.8 \pm 0.4) \times 10^{-4} \text{ fm}^3$. 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, $\sqrt{\langle r_E^2 \rangle}$.

There are three kinds of measurements of the proton radius: via transitions in atomic hydrogen; via electron scattering off hydrogen; and via muonic hydrogen Lamb shift. Most measurements of the radius of the proton involve electron-proton interactions, the most recent of which is the electron scattering measurement $r_p = 0.831(14) \text{ fm}$ (XIONG 19), and the atomic-hydrogen value, $r_p = 0.833(10) \text{ fm}$ (BEZGINOV 19). These agree well with another recent atomic-hydrogen value $r_p = 0.8335(95) \text{ fm}$ (BEYER 17), and with the best measurement using muonic hydrogen $r_p = 0.84087(39) \text{ fm}$ (ANTOIGNINI 13), that is far more precise.

The MOHR 16 value (2014 CODATA), obtained from the electronic results available at the time, was $0.8751(61) \text{ fm}$. This differs by 5.6 standard deviations from the muonic hydrogen value, leading to the so-called proton charge radius puzzle. See our 2018 edition (Physical Review **D98** 030001 (2018)) for a further discussion of interpretations of this puzzle. However, reflecting the new electronic measurements, the 2018 CODATA recommended value is $0.8414(19) \text{ fm}$, and the puzzle appears to be resolved.

See our 2014 edition (Chinese Physics **C38** 070001 (2014)) for values published before 2003.

VALUE (fm)	DOCUMENT ID	TECN	COMMENT
0.8409 ± 0.0004	OUR AVERAGE		
0.833 ± 0.010	¹ BEZGINOV	19	LASR 2S-2P transition in H
0.831 ± 0.007 ± 0.012	² XIONG	19	SPEC $ep \rightarrow ep$ form factor
0.84087 ± 0.00026 ± 0.00029	ANTOIGNINI	13	LASR μp -atom Lamb shift
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.877 ± 0.013	³ FLEURBAEY	18	LASR 1S-3S transition in H
0.8335 ± 0.0095	⁴ BEYER	17	LASR 2S-4P transition in H
0.8751 ± 0.0061	MOHR	16	RVUE 2014 CODATA value
0.895 ± 0.014 ± 0.014	⁵ LEE	15	SPEC Just 2010 Mainz data
0.916 ± 0.024	LEE	15	SPEC World data, no Mainz
0.8775 ± 0.0051	MOHR	12	RVUE 2010 CODATA, ep data
0.875 ± 0.008 ± 0.006	ZHAN	11	SPEC Recoil polarimetry
0.879 ± 0.005 ± 0.006	BERNAUER	10	SPEC $ep \rightarrow ep$ form factor
0.912 ± 0.009 ± 0.007	BORISYUK	10	reanalyzes old ep data
0.871 ± 0.009 ± 0.003	HILL	10	z-expansion reanalysis
0.84184 ± 0.00036 ± 0.00056	POHL	10	LASR See ANTOIGNINI 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	$ep \rightarrow ep$ reanalysis

¹ BEZGINOV 19 measures the $2S_{1/2}$ to $2P_{1/2}$ transition frequency in atomic hydrogen using the frequency-offset separated oscillatory field (FOSOF) technique. The result agrees well with the muonic hydrogen Lamb shift value.

² The XIONG 19 value from $ep \rightarrow ep$ scattering and supports the muonic hydrogen Lamb shift value.

³ FLEURBAEY 18 measures the 1S-3S transition frequency in hydrogen and in combination with the 1S-2S transition frequency deduces the proton radius and the Rydberg constant.

⁴ The BEYER 17 result is 3.3 combined standard deviations below the MOHR 16 (2014 CODATA) value. The experiment measures the 2S-4P transition in hydrogen and gets the proton radius and the Rydberg constant.

⁵ Authors also provide values for combinations of all available data.

p MAGNETIC RADIUS

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

VALUE (fm)	DOCUMENT ID	TECN	COMMENT
0.851 ± 0.026	¹ LEE	15	Combination of world and Mainz data
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.87 ± 0.02	EPSTEIN	14	Using ep , en , $\pi\pi$ data
0.867 ± 0.009 ± 0.018	ZHAN	11	SPEC Recoil polarimetry
0.777 ± 0.013 ± 0.010	BERNAUER	10	SPEC $ep \rightarrow ep$ form factor
0.876 ± 0.010 ± 0.016	BORISYUK	10	Reanalyzes old $ep \rightarrow ep$ data
0.854 ± 0.005	BELUSHKIN	07	Dispersion analysis

¹ In a consistent reanalysis LEE 2015 extract values separately for the Mainz 2010 data only (0.776+0.034+0.017) fm and for the world data without Mainz data (0.914+0.035) fm. The quoted value is a simple combination of the two, which ignores possible discrepancies and unknown correlations and should be considered with caution.

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
$>3.6 \times 10^{29}$	p	90	¹ ANDERSON 19A	SNO+	$p \rightarrow$ invisible
$>5.8 \times 10^{29}$	n	90	² ARAKI 06	KLND	$n \rightarrow$ invisible
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$>2.5 \times 10^{29}$	n	90	¹ ANDERSON 19A	SNO+	$n \rightarrow$ invisible
$>2.1 \times 10^{29}$	p	90	¹ AHMED 04	SNO	$p \rightarrow$ invisible
$>1.9 \times 10^{29}$	n	90	¹ AHMED 04	SNO	$n \rightarrow$ 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		$p \rightarrow$ invisible
$>1 \times 10^{28}$	p	90	⁵ AHMAD 02	SNO	$p \rightarrow$ invisible
$>4 \times 10^{23}$	p	95	TRETYAK 01		$d \rightarrow n + ?$
$>1.9 \times 10^{24}$	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 AHMED 04 and ANDERSON 19A look for γ rays from the de-excitation of a residual $^{15}\text{O}^*$ or $^{15}\text{N}^*$ following the disappearance of a neutron or proton in ^{16}O .

² ARAKI 06 looks for signs of de-excitation of the residual nucleus after disappearance of a neutron from the s shell of ^{12}C .

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 $^{128}_{53}\text{I}$ nucleus following the disappearance of a proton in the otherwise-stable $^{129}_{54}\text{Xe}$ 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.

\bar{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 “ \bar{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 $\bar{p} \rightarrow e^- \gamma$. We advance only the exclusive-mode limits to our Summary Tables.

<u>LIMIT</u> (years)	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
>5.0	90		SELLNER	17	TRAP Penning trap
>8 $\times 10^5$	90		¹ GEER	00D	\bar{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 \bar{p}/p ratio, cosmic rays
>3.7 $\times 10^{-3}$			BREGMAN	78	CNTR Storage ring

¹GEER 00D uses agreement between a model of galactic \bar{p} production and propagation and the observed \bar{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 $N \rightarrow e^+ \pi$	> 5300 (n), > 16000 (p)	90%
τ_2 $N \rightarrow \mu^+ \pi$	> 3500 (n), > 7700 (p)	90%
τ_3 $N \rightarrow \nu \pi$	> 1100 (n), > 390 (p)	90%
τ_4 $p \rightarrow e^+ \eta$	> 10000	90%
τ_5 $p \rightarrow \mu^+ \eta$	> 4700	90%
τ_6 $n \rightarrow \nu \eta$	> 158	90%
τ_7 $N \rightarrow e^+ \rho$	> 217 (n), > 720 (p)	90%
τ_8 $N \rightarrow \mu^+ \rho$	> 228 (n), > 570 (p)	90%
τ_9 $N \rightarrow \nu \rho$	> 19 (n), > 162 (p)	90%
τ_{10} $p \rightarrow e^+ \omega$	> 1600	90%
τ_{11} $p \rightarrow \mu^+ \omega$	> 2800	90%
τ_{12} $n \rightarrow \nu \omega$	> 108	90%
τ_{13} $N \rightarrow e^+ K$	> 17 (n), > 1000 (p)	90%

τ_{14}	$p \rightarrow e^+ K_S^0$		
τ_{15}	$p \rightarrow e^+ K_L^0$		
τ_{16}	$N \rightarrow \mu^+ K$	> 26 (<i>n</i>), > 1600 (<i>p</i>)	90%
τ_{17}	$p \rightarrow \mu^+ K_S^0$		
τ_{18}	$p \rightarrow \mu^+ K_L^0$		
τ_{19}	$N \rightarrow \nu K$	> 86 (<i>n</i>), > 5900 (<i>p</i>)	90%
τ_{20}	$n \rightarrow \nu K_S^0$	> 260	90%
τ_{21}	$p \rightarrow e^+ K^*(892)^0$	> 84	90%
τ_{22}	$N \rightarrow \nu K^*(892)$	> 78 (<i>n</i>), > 51 (<i>p</i>)	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}	$n \rightarrow \nu \gamma$	> 550	90%
τ_{45}	$p \rightarrow e^+ \gamma \gamma$	> 100	90%
τ_{46}	$n \rightarrow \nu \gamma \gamma$	> 219	90%

Antilepton + single massless

τ_{47}	$p \rightarrow e^+ X$	> 790	90%
τ_{48}	$p \rightarrow \mu^+ X$	> 410	90%

Three (or more) leptons

τ_{49}	$p \rightarrow e^+ e^+ e^-$	> 793	90%
τ_{50}	$p \rightarrow e^+ \mu^+ \mu^-$	> 359	90%
τ_{51}	$p \rightarrow e^+ \nu \nu$	> 170	90%
τ_{52}	$n \rightarrow e^+ e^- \nu$	> 257	90%
τ_{53}	$n \rightarrow \mu^+ e^- \nu$	> 83	90%
τ_{54}	$n \rightarrow \mu^+ \mu^- \nu$	> 79	90%
τ_{55}	$p \rightarrow \mu^+ e^+ e^-$	> 529	90%
τ_{56}	$p \rightarrow \mu^+ \mu^+ \mu^-$	> 675	90%
τ_{57}	$p \rightarrow \mu^+ \nu \nu$	> 220	90%
τ_{58}	$p \rightarrow e^- \mu^+ \mu^+$	> 6	90%
τ_{59}	$n \rightarrow 3\nu$	$> 5 \times 10^{-4}$	90%
τ_{60}	$n \rightarrow 5\nu$		

Inclusive modes

τ_{61}	$N \rightarrow e^+$ anything	> 0.6 (n, p)	90%
τ_{62}	$N \rightarrow \mu^+$ anything	> 12 (n, p)	90%
τ_{63}	$N \rightarrow \nu$ anything		
τ_{64}	$N \rightarrow e^+ \pi^0$ anything	> 0.6 (n, p)	90%
τ_{65}	$N \rightarrow 2$ bodies, ν -free		

$\Delta B = 2$ dinucleon modes

The following are lifetime limits per iron nucleus.

τ_{66}	$pp \rightarrow \pi^+ \pi^+$	> 72.2	90%
τ_{67}	$pn \rightarrow \pi^+ \pi^0$	> 170	90%
τ_{68}	$nn \rightarrow \pi^+ \pi^-$	> 0.7	90%
τ_{69}	$nn \rightarrow \pi^0 \pi^0$	> 404	90%
τ_{70}	$pp \rightarrow K^+ K^+$	> 170	90%
τ_{71}	$pp \rightarrow e^+ e^+$	> 5.8	90%
τ_{72}	$pp \rightarrow e^+ \mu^+$	> 3.6	90%
τ_{73}	$pp \rightarrow \mu^+ \mu^+$	> 1.7	90%
τ_{74}	$pn \rightarrow e^+ \bar{\nu}$	> 260	90%
τ_{75}	$pn \rightarrow \mu^+ \bar{\nu}$	> 200	90%
τ_{76}	$pn \rightarrow \tau^+ \bar{\nu}_\tau$	> 29	90%
τ_{77}	$nn \rightarrow \nu_e \bar{\nu}_e$	> 1.4	90%
τ_{78}	$nn \rightarrow \nu_\mu \bar{\nu}_\mu$	> 1.4	90%
τ_{79}	$pn \rightarrow$ invisible	$> 2.1 \times 10^{-5}$	90%
τ_{80}	$pp \rightarrow$ invisible	$> 5 \times 10^{-5}$	90%

\bar{p} DECAY MODES

	Mode	Partial mean life (years)	Confidence level
τ_{81}	$\bar{p} \rightarrow e^- \gamma$	$> 7 \times 10^5$	90%
τ_{82}	$\bar{p} \rightarrow \mu^- \gamma$	$> 5 \times 10^4$	90%

τ_{83}	$\bar{p} \rightarrow e^- \pi^0$	$> 4 \times 10^5$	90%
τ_{84}	$\bar{p} \rightarrow \mu^- \pi^0$	$> 5 \times 10^4$	90%
τ_{85}	$\bar{p} \rightarrow e^- \eta$	$> 2 \times 10^4$	90%
τ_{86}	$\bar{p} \rightarrow \mu^- \eta$	$> 8 \times 10^3$	90%
τ_{87}	$\bar{p} \rightarrow e^- K_S^0$	> 900	90%
τ_{88}	$\bar{p} \rightarrow \mu^- K_S^0$	$> 4 \times 10^3$	90%
τ_{89}	$\bar{p} \rightarrow e^- K_L^0$	$> 9 \times 10^3$	90%
τ_{90}	$\bar{p} \rightarrow \mu^- K_L^0$	$> 7 \times 10^3$	90%
τ_{91}	$\bar{p} \rightarrow e^- \gamma \gamma$	$> 2 \times 10^4$	90%
τ_{92}	$\bar{p} \rightarrow \mu^- \gamma \gamma$	$> 2 \times 10^4$	90%
τ_{93}	$\bar{p} \rightarrow e^- \omega$	> 200	90%

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
>16000	p	90	0	0.61	ABE 17	SKAM
> 5300	n	90	0	0.41	ABE 17D	SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 2000	n	90	0	0.27	NISHINO 12	SKAM
> 8200	p	90	0	0.3	NISHINO 09	SKAM
> 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

¹This BECKER-SZENDY 90 result includes data from SEIDEL 88.

²Limit based on zero events.

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

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

$\tau(N \rightarrow \mu^+ \pi)$

T2

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>7700	p	90	2	0.87	ABE	17 SKAM
>3500	n	90	1	0.77	ABE	17D SKAM

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

>1000	n	90	1	0.43	NISHINO	12	SKAM
>6600	p	90	0	0.3	NISHINO	09	SKAM
> 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

$\tau(N \rightarrow \nu \pi)$

T3

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
> 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.

$\tau(p \rightarrow e^+ \eta)$

T4

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>10000	p	90	0	0.78	ABE	17D SKAM

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

> 4200	p	90	0	0.44	NISHINO	12	SKAM
> 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.

$\tau(p \rightarrow \mu^+ \eta)$

T5

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>4700	p	90	2	0.85	ABE	17D SKAM

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

>1300	p	90	2	0.49	NISHINO	12	SKAM
> 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	<i>p</i>	90	1	1.5	SEIDEL	88	IMB
> 46	<i>p</i>	90	7	6	HAINES	86	IMB
> 26	<i>p</i>	90	1	<0.8	ARISAKA	85	KAMI
> 17	<i>p</i> (free)	90	6	6	BLEWITT	85	IMB
> 46	<i>p</i>	90	7	8	BLEWITT	85	IMB

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

T6

<u>LIMIT</u> (10 ³⁰ years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>158	<i>n</i>	90	0	1.2	MCGREW	99 IMB3
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 71	<i>n</i>	90	2	3.7	WALL	00B SOU2
> 29	<i>n</i>	90	0	0.9	BERGER	89 FREJ
> 54	<i>n</i>	90	2	0.9	HIRATA	89C KAMI
> 16	<i>n</i>	90	3	2.1	SEIDEL	88 IMB
> 25	<i>n</i>	90	7	6	HAINES	86 IMB
> 30	<i>n</i>	90	0	0.4	KAJITA	86 KAMI
> 18	<i>n</i>	90	4	3	PARK	85 IMB
> 0.6	<i>n</i>	90	2		¹ CHERRY	81 HOME

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

$\tau(N \rightarrow e^+ \rho)$

T7

<u>LIMIT</u> (10 ³⁰ years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>720	<i>p</i>	90	2	0.64	ABE	17D SKAM
>217	<i>n</i>	90	4	4.8	MCGREW	99 IMB3
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 30	<i>n</i>	90	4	0.87	ABE	17D SKAM
>710	<i>p</i>	90	0	0.35	NISHINO	12 SKAM
> 70	<i>n</i>	90	1	0.38	NISHINO	12 SKAM
> 29	<i>p</i>	90	0	2.2	BERGER	91 FREJ
> 41	<i>n</i>	90	0	1.4	BERGER	91 FREJ
> 75	<i>p</i>	90	2	2.7	HIRATA	89C KAMI
> 58	<i>n</i>	90	0	1.9	HIRATA	89C KAMI
> 38	<i>n</i>	90	2	4.1	SEIDEL	88 IMB
> 1.2	<i>p</i>	90	0		BARTELT	87 SOUD
> 1.5	<i>n</i>	90	0		BARTELT	87 SOUD
> 17	<i>p</i>	90	7	7	HAINES	86 IMB
> 14	<i>n</i>	90	9	4	HAINES	86 IMB
> 12	<i>p</i>	90	0	<1.2	ARISAKA	85 KAMI
> 6	<i>n</i>	90	2	<1	ARISAKA	85 KAMI
> 6.7	<i>p</i> (free)	90	6	6	BLEWITT	85 IMB
> 17	<i>p</i>	90	7	7	BLEWITT	85 IMB
> 12	<i>n</i>	90	4	2	PARK	85 IMB
> 0.6	<i>n</i>	90	1	0.3	¹ BARTELT	83 SOUD
> 0.5	<i>p</i>	90	1	0.3	¹ BARTELT	83 SOUD
> 9.8	<i>p</i>	90	1		² KRISHNA...	82 KOLR
> 0.8	<i>p</i>	90	2		³ CHERRY	81 HOME

¹Limit based on zero events.

²We have calculated 90% CL limit from 0 confined events.

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

$\tau(N \rightarrow \mu^+ \rho)$ **T8**

$LIMIT$ (10^{30} years)	$PARTICLE$	$CL\%$	$EVTS$	$BKGD$ EST	$DOCUMENT$ ID	$TECN$
>570	p	90	1	1.30	ABE	17D SKAM
>228	n	90	3	9.5	MCGREW	99 IMB3
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 60	n	90	1	0.96	ABE	17D SKAM
>160	p	90	1	0.42	NISHINO	12 SKAM
> 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

 $\tau(N \rightarrow \nu \rho)$ **T9**

$LIMIT$ (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

¹We have converted 2 possible events to 90% CL limit. $\tau(p \rightarrow e^+ \omega)$ **T10**

$LIMIT$ (10^{30} years)	$PARTICLE$	$CL\%$	$EVTS$	$BKGD$ EST	$DOCUMENT$ ID	$TECN$
>1600	p	90	1	1.35	ABE	17D SKAM

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

> 320	p	90	1	0.53	NISHINO	12	SKAM
> 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}

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>2800	p	90	0	1.09	ABE	17D SKAM

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

> 780	p	90	0	0.48	NISHINO	12	SKAM
> 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}

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>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.

$\tau(N \rightarrow e^+ K)$ τ_{13}

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>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

 $\tau(p \rightarrow e^+ K_S^0)$ τ_{14}

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
● ● ● 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

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

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
● ● ● 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

 $\tau(N \rightarrow \mu^+ K)$ τ_{16}

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>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	SOD
> 1.1	n	90	0		BARTELT 87	SOD
> 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	SOD
> 0.4	n	90	0		² BARTELT	83	SOD
> 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 $p \rightarrow \mu^+ K_S^0$.

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.

$\tau(p \rightarrow \mu^+ K_S^0)$

τ_{17}

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
------------------------------------	-----------------	------------	-------------	-----------------	--------------------	-------------

• • • 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

$\tau(p \rightarrow \mu^+ K_L^0)$

τ_{18}

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
------------------------------------	-----------------	------------	-------------	-----------------	--------------------	-------------

• • • 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

$\tau(N \rightarrow \nu K)$

τ_{19}

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
------------------------------------	-----------------	------------	-------------	-----------------	--------------------	-------------

>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. • • •

> 540	p	90	0	0.9	ASAKURA	15	KLND
>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	SOD
> 0.75	n	90	0		² BARTELT	87	SOD
> 10	p	90	6	5	HAINES	86	IMB

> 15	<i>n</i>	90	3 5	HAINES	86	IMB
> 28	<i>p</i>	90	3 3	KAJITA	86	KAMI
> 32	<i>n</i>	90	0 1.4	KAJITA	86	KAMI
> 1.8	<i>p</i> (free)	90	6 11	BLEWITT	85	IMB
> 9.6	<i>p</i>	90	6 5	BLEWITT	85	IMB
> 10	<i>n</i>	90	2 2	PARK	85	IMB
> 5	<i>n</i>	90	0	BATTISTONI	84	NUSX
> 2	<i>p</i>	90	0	BATTISTONI	84	NUSX
> 0.3	<i>n</i>	90	0	³ BARTELT	83	SOUD
> 0.1	<i>p</i>	90	0	³ BARTELT	83	SOUD
> 5.8	<i>p</i>	90	1	⁴ KRISHNA...	82	KOLR
> 0.3	<i>n</i>	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 $n \rightarrow \nu K_S^0$.

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.

$\tau(n \rightarrow \nu K_S^0)$

τ_{20}

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>260	<i>n</i>	90	34	30	¹ KOBAYASHI 05	SKAM

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

> 51	<i>n</i>	90	16	9.1	WALL	00	SOU2
------	----------	----	----	-----	------	----	------

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

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

τ_{21}

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	
>84	<i>p</i>	90	38	52.0	MCGREW	99	IMB3

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

>10	<i>p</i>	90	0	0.8	BERGER	91	FREJ
>52	<i>p</i>	90	2	1.55	HIRATA	89c	KAMI
>10	<i>p</i>	90	1	<1	ARISAKA	85	KAMI

$\tau(N \rightarrow \nu K^*(892))$

τ_{22}

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	
>51	<i>p</i>	90	7	9.1	MCGREW	99	IMB3
>78	<i>n</i>	90	40	50	MCGREW	99	IMB3

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

>22	<i>n</i>	90	0	2.1	BERGER	89	FREJ
>17	<i>p</i>	90	0	2.4	BERGER	89	FREJ
>20	<i>p</i>	90	5	2.1	HIRATA	89c	KAMI
>21	<i>n</i>	90	4	2.4	HIRATA	89c	KAMI
>10	<i>p</i>	90	7	6	HAINES	86	IMB
> 5	<i>n</i>	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

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

————— **Antilepton + mesons** —————

$\tau(p \rightarrow e^+ \pi^+ \pi^-)$

T23

<u>LIMIT</u> (10 ³⁰ years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>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
-----	-----	----	---	-----	--------	----	------

$\tau(p \rightarrow e^+ \pi^0 \pi^0)$

T24

<u>LIMIT</u> (10 ³⁰ years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>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
------	-----	----	---	-----	--------	----	------

$\tau(n \rightarrow e^+ \pi^- \pi^0)$

T25

<u>LIMIT</u> (10 ³⁰ years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>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
-----	-----	----	---	-----	--------	----	------

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

T26

<u>LIMIT</u> (10 ³⁰ years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>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

$\tau(p \rightarrow \mu^+ \pi^0 \pi^0)$

T27

<u>LIMIT</u> (10 ³⁰ years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>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
------	-----	----	---	-----	--------	----	------

$\tau(n \rightarrow \mu^+ \pi^- \pi^0)$ **T28**

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

$\tau(n \rightarrow e^+ K^0 \pi^-)$ **T29**

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

———— Lepton + meson ————

$\tau(n \rightarrow e^- \pi^+)$ **T30**

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

$\tau(n \rightarrow \mu^- \pi^+)$ **T31**

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

$\tau(n \rightarrow e^- \rho^+)$ **T32**

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

$\tau(n \rightarrow \mu^- \rho^+)$ **T33**

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

$\tau(n \rightarrow e^- K^+)$

T34

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

 $\tau(n \rightarrow \mu^- K^+)$

T35

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

———— Lepton + mesons ————

 $\tau(p \rightarrow e^- \pi^+ \pi^+)$

T36

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

 $\tau(n \rightarrow e^- \pi^+ \pi^0)$

T37

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

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

T38

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

 $\tau(n \rightarrow \mu^- \pi^+ \pi^0)$

T39

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

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

T40

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

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

T41

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) —————

 $\tau(p \rightarrow e^+ \gamma)$

T42

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

¹We have converted half-life to 90% CL mean life. $\tau(p \rightarrow \mu^+ \gamma)$

T43

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

¹We have converted half-life to 90% CL mean life. $\tau(n \rightarrow \nu \gamma)$

T44

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
>550		90			TAKHISTOV	15 SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 28	n	90	163	144.7	MCGREW	99 IMB3
> 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

 $\tau(p \rightarrow e^+ \gamma \gamma)$

T45

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

$\tau(n \rightarrow \nu \gamma \gamma)$ T46

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

————— Antilepton + single massless —————

 $\tau(p \rightarrow e^+ X)$ T47

VALUE (10^{30} years)	CL%	DOCUMENT ID	TECN
>790	90	TAKHISTOV 15	SKAM

 $\tau(p \rightarrow \mu^+ X)$ T48

VALUE (10^{30} years)	CL%	DOCUMENT ID	TECN
>410	90	TAKHISTOV 15	SKAM

————— Three (or more) leptons —————

 $\tau(p \rightarrow e^+ e^+ e^-)$ T49

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

 $\tau(p \rightarrow e^+ \mu^+ \mu^-)$ T50

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

 $\tau(p \rightarrow e^+ \nu \nu)$ T51

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
>170	<i>p</i>	90			¹ TAKHISTOV	14 SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •						
> 17	<i>p</i>	90	152	153.7	MCGREW	99 IMB3
> 11	<i>p</i>	90	11	6.08	BERGER	91B FREJ

¹ Allowed events at 90% CL are 459. $\tau(n \rightarrow e^+ e^- \nu)$ T52

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

$\tau(n \rightarrow \mu^+ e^- \nu)$

T53

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

 $\tau(n \rightarrow \mu^+ \mu^- \nu)$

T54

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

 $\tau(p \rightarrow \mu^+ e^+ e^-)$

T55

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

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

T56

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

¹We have converted 1 possible event to 90% CL limit. $\tau(p \rightarrow \mu^+ \nu \nu)$

T57

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>220	<i>p</i>	90			¹ TAKHISTOV 14	SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 21	<i>p</i>	90	7	11.23	BERGER 91B	FREJ

¹Allowed events at 90% CL are 286. $\tau(p \rightarrow e^- \mu^+ \mu^+)$

T58

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

$\tau(n \rightarrow 3\nu)$ **T59**

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	<i>n</i>	90	2	2	¹ SUZUKI	93B KAMI
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
>0.0023	<i>n</i>	90			² GLICENSTEIN	97 KAMI
>0.00003	<i>n</i>	90	11	6.1	³ BERGER	91B FREJ
>0.00012	<i>n</i>	90	7	11.2	³ BERGER	91B FREJ
>0.0005	<i>n</i>	90	0		LEARNED	79 RVUE

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

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 $n \rightarrow \nu_e \nu_e \bar{\nu}_e$, the second is for $n \rightarrow \nu_\mu \nu_\mu \bar{\nu}_\mu$.

 $\tau(n \rightarrow 5\nu)$ **T60**

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	<i>n</i>	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 —————

 $\tau(N \rightarrow e^+ \text{ anything})$ **T61**

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

¹ The electron may be primary or secondary.

 $\tau(N \rightarrow \mu^+ \text{ anything})$ **T62**

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

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

² The muon may be primary or secondary.

 $\tau(N \rightarrow \nu \text{ anything})$ **T63**

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	<i>p, n</i>	90	0		LEARNED	79 RVUE

$\tau(N \rightarrow e^+ \pi^0 \text{ anything})$ **T64**

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

 $\tau(N \rightarrow 2 \text{ bodies, } \nu\text{-free})$ **T65**

<u>LIMIT</u> (10^{30} years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>1.3	<i>p, n</i>	90	0		ALEKSEEV 81	BAKS

 $\Delta B = 2$ dinucleon modes $\tau(pp \rightarrow \pi^+ \pi^+)$ **T66**

<u>LIMIT</u> (10^{30} years)	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
>72.2	90	2	4.45	GUSTAFSON 15	SKAM	per oxygen nucleus

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

> 0.7	90	4	2.34	BERGER 91B	FREJ	per iron nucleus
-------	----	---	------	------------	------	------------------

 $\tau(pn \rightarrow \pi^+ \pi^0)$ **T67**

<u>LIMIT</u> (10^{30} years)	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
>170	90			GUSTAFSON 15	SKAM	per oxygen nucleus

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

> 2.0	90	0	0.31	BERGER 91B	FREJ	per iron nucleus
-------	----	---	------	------------	------	------------------

 $\tau(nn \rightarrow \pi^+ \pi^-)$ **T68**

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

 $\tau(nn \rightarrow \pi^0 \pi^0)$ **T69**

<u>LIMIT</u> (10^{30} years)	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
>404	90			GUSTAFSON 15	SKAM	per oxygen nucleus

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

> 3.4	90	0	0.78	BERGER 91B	FREJ	per iron nucleus
-------	----	---	------	------------	------	------------------

 $\tau(pp \rightarrow K^+ K^+)$ **T70**

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

 $\tau(pp \rightarrow e^+ e^+)$ **T71**

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

$\tau(pp \rightarrow e^+ \mu^+)$ **T72**

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

$\tau(pp \rightarrow \mu^+ \mu^+)$ **T73**

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

$\tau(pn \rightarrow e^+ \bar{\nu})$ **T74**

<u>LIMIT</u> (10^{30} years)	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
>260	90			TAKHISTOV	15 SKAM	

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

>	2.8	90	5	9.67	BERGER	91B FREJ	τ per iron nucleus
---	-----	----	---	------	--------	----------	-------------------------

$\tau(pn \rightarrow \mu^+ \bar{\nu})$ **T75**

<u>LIMIT</u> (10^{30} years)	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
>200	90			TAKHISTOV	15 SKAM	

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

>	1.6	90	4	4.37	BERGER	91B FREJ	τ per iron nucleus
---	-----	----	---	------	--------	----------	-------------------------

$\tau(pn \rightarrow \tau^+ \bar{\nu}_\tau)$ **T76**

<u>LIMIT</u> (10^{30} years)	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
>29	90			TAKHISTOV	15 SKAM	

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

>	1	90		¹ BRYMAN	14	CHER	
---	---	----	--	---------------------	----	------	--

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

$\tau(nn \rightarrow \nu_e \bar{\nu}_e)$ **T77**

We include "invisible" modes here.

<u>LIMIT</u> (10^{30} years)	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
>1.4	90			¹ ARAKI	06 KLND	$nn \rightarrow$ invisible

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

>	0.013	90		² ANDERSON	19A SNO+	$nn \rightarrow$ invisible	
>	0.000042	90		³ TRETYAK	04 CNTR	$nn \rightarrow$ invisible	
>	0.000049	90		⁴ BACK	03 BORX	$nn \rightarrow$ invisible	
>	0.000012	90		⁵ BERNABEI	00B DAMA	$nn \rightarrow$ invisible	
>	0.000012	90	5	9.7	BERGER	91B FREJ	τ per iron nucleus

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

²ANDERSON 19A looks for γ rays from the de-excitation of a residual $^{14}\text{O}^*$ following the disappearance of nn in ^{16}O .

³TRETYAK 04 uses data from an old Homestake-mine radiochemical experiment on limits for invisible decays of ^{39}K to ^{37}Ar .

- ⁴ 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.
⁵ BERNABEI 00B looks for the decay of a $^{127}_{54}\text{Xe}$ nucleus following the disappearance of an nn pair in the otherwise-stable $^{129}_{54}\text{Xe}$ nucleus. The limit here applies as well to $nn \rightarrow \nu_{\mu}\bar{\nu}_{\mu}$, $nn \rightarrow \nu_{\tau}\bar{\nu}_{\tau}$, or any “disappearance” mode.

$\tau(nn \rightarrow \nu_{\mu}\bar{\nu}_{\mu})$ T78

See the preceding data block. “Invisible modes” would include any multi-neutrino mode.

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	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 |
|-----------|----|---|-----|--------|-----|------------------------------|

$\tau(pn \rightarrow \text{invisible})$ T79

This violates charge conservation as well as baryon number conservation.

VALUE (10^{30} years)	CL%	DOCUMENT ID	TECN
>0.026	90	¹ ANDERSON 19A	SNO+
>0.000021	90	² TRETYAK 04	CNTR

- ¹ ANDERSON 19A looks for γ rays from the de-excitation of a residual $^{14}\text{N}^*$ following the disappearance of pn in ^{16}O .
² TRETYAK 04 uses data from an old Homestake-mine radiochemical experiment on limits for invisible decays of ^{39}K to ^{37}Ar .

$\tau(pp \rightarrow \text{invisible})$ T80

This violates charge conservation as well as baryon number conservation.

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
>0.047	90			¹ ANDERSON 19A	SNO+
>0.00005	90			² BACK 03	BORX
>0.0000055	90			³ BERNABEI 00B	DAMA

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

- ¹ ANDERSON 19A looks for γ rays from the de-excitation of a residual $^{14}\text{C}^*$ following the disappearance of pp in ^{16}O .
² 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.
³ BERNABEI 00B looks for the decay of a $^{127}_{52}\text{Te}$ nucleus following the disappearance of a pp pair in the otherwise-stable $^{129}_{54}\text{Xe}$ nucleus.

\bar{p} PARTIAL MEAN LIVES

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

$\tau(\bar{p} \rightarrow e^- \gamma)$ T81

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
> 7×10^5	90	GEER 00	APEX	8.9 GeV/c \bar{p} beam
>1848	95	GEER 94	CALO	8.9 GeV/c \bar{p} beam

$\tau(\bar{p} \rightarrow \mu^- \gamma)$ T82

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
$> 5 \times 10^4$	90	GEER 00	APEX	8.9 GeV/c \bar{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 \bar{p} beam

 $\tau(\bar{p} \rightarrow e^- \pi^0)$ T83

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

 $\tau(\bar{p} \rightarrow \mu^- \pi^0)$ T84

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
$> 5 \times 10^4$	90	GEER 00	APEX	8.9 GeV/c \bar{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 \bar{p} beam

 $\tau(\bar{p} \rightarrow e^- \eta)$ T85

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

 $\tau(\bar{p} \rightarrow \mu^- \eta)$ T86

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
$> 8 \times 10^3$	90	GEER 00	APEX	8.9 GeV/c \bar{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 \bar{p} beam

 $\tau(\bar{p} \rightarrow e^- K_S^0)$ T87

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

 $\tau(\bar{p} \rightarrow \mu^- K_S^0)$ T88

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
$> 4 \times 10^3$	90	GEER 00	APEX	8.9 GeV/c \bar{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 \bar{p} beam

 $\tau(\bar{p} \rightarrow e^- K_L^0)$ T89

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

$\tau(\bar{p} \rightarrow \mu^- K_L^0)$ **T90**

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
$>7 \times 10^3$	90	GEER 00	APEX	8.9 GeV/c \bar{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 \bar{p} beam

 $\tau(\bar{p} \rightarrow e^- \gamma \gamma)$ **T91**

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

 $\tau(\bar{p} \rightarrow \mu^- \gamma \gamma)$ **T92**

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

 $\tau(\bar{p} \rightarrow e^- \omega)$ **T93**

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

p REFERENCES

ANDERSON 19A	PR D99 032008	M. Anderson <i>et al.</i>	(SNO+ Collab.)
BEZGINOV 19	SCI 365 1007	N. Bezginov <i>et al.</i>	(YORKC, TNT0)
XIONG 19	NAT 575 147	W. Xiong <i>et al.</i>	(PRad Collab.)
FLEURBAEY 18	PRL 120 183001	H. Fleurbaey <i>et al.</i>	(SORB)
PDG 18	PR D98 030001	M. Tanabashi <i>et al.</i>	(PDG Collab.)
ABE 17	PR D95 012004	K. Abe <i>et al.</i>	(Super-Kamiokande Collab.)
ABE 17D	PR D96 012003	K. Abe <i>et al.</i>	(Super-Kamiokande Collab.)
BEYER 17	SCI 358 79	A. Beyer <i>et al.</i>	(MPQG Collab.)
HEISSE 17	PRL 119 033001	F. Heisse <i>et al.</i>	(MPIH, GSI, MANZ, RIKEN)
NAGAHAMA 17	NATC 8 14084	H. Nagahama <i>et al.</i>	(RIKEN, TOKY, CERN+)
SAHOO 17	PR D95 013002	B.K. Sahoo	(AHMEB)
SCHNEIDER 17	SCI 358 1081	G. Schneider <i>et al.</i>	(MANZ, RIKEN, +)
SELLNER 17	NJP 19 083023	S. Sellner <i>et al.</i>	(RIKEN, MPIK, +)
SMORRA 17	NAT 550 371	C. Smorra <i>et al.</i>	(RIKEN, CERN, +)
MOHR 16	RMP 88 035009	P.J. Mohr, D.B. Newell, B.N. Taylor	(NIST)
ASAKURA 15	PR D92 052006	K. Asakura <i>et al.</i>	(KamLAND Collab.)
GUSTAFSON 15	PR D91 072009	J. Gustafson <i>et al.</i>	(Super-Kamiokande Collab.)
LEE 15	PR D92 013013	G. Lee, J.R. Arrington, R.J. Hill	(ANL, EFI+)
TAKHISTOV 15	PRL 115 121803	V. Takhistov <i>et al.</i>	(Super-Kamiokande Collab.)
ULMER 15	NAT 524 196	S. Ulmer <i>et al.</i>	(RIKEN, CERN, MPIH, +)
ABE 14E	PRL 113 121802	K. Abe <i>et al.</i>	(Super-Kamiokande Collab.)
ABE 14G	PR D90 072005	K. Abe <i>et al.</i>	(Super-Kamiokande Collab.)
BRYMAN 14	PL B733 190	D. Bryman	(BRCO)
EPSTEIN 14	PR D90 074027	Z. Epstein, G. Paz, J. Roy	(UMD, WAYN)
LITOS 14	PRL 112 131803	M. Litos <i>et al.</i>	(Super-Kamiokande Collab.)
PDG 14	CP C38 070001	K. Olive <i>et al.</i>	(PDG Collab.)
TAKHISTOV 14	PRL 113 101801	V. Takhistov <i>et al.</i>	(Super-Kamiokande Collab.)
ANTOGNINI 13	SCI 339 417	A. Antognini <i>et al.</i>	(MPIM, ETH, UPMC+)
DISCIACCA 13	PRL 110 130801	J. DiSciacca <i>et al.</i>	(ATRAP Collab.)
MCGOVERN 13	EPJ A49 12	J.A. McGovern, D.R. Phillips, H.W. Griesshammer	
MOHR 12	RMP 84 1527	P.J. Mohr, B.N. Taylor, D.B. Newell	(NIST)
NISHINO 12	PR D85 112001	H. Nishino <i>et al.</i>	(Super-Kamiokande Collab.)
REGIS 12	PR D86 012006	C. Regis <i>et al.</i>	(Super-Kamiokande Collab.)
BRESSI 11	PR A83 052101	G. Bressi <i>et al.</i>	(LEGN, PAVII, PADO, TRST+)
HORI 11	NAT 475 484	M. Hori <i>et al.</i>	(MPIG, TOKY, BUDA, +)
ZHAN 11	PL B705 59	X. Zhan <i>et al.</i>	(JLAB-Hall A Collab.)
BERNAUER 10	PRL 105 242001	J.C. Bernauer <i>et al.</i>	(MAMI A1 Collab.)
Also	PR C90 015206	J.C. Bernauer <i>et al.</i>	(MAMI A1 Collab.)

BORISYUK	10	NP A843 59	D. Borisyuk	(KIEV)
HILL	10	PR D82 113005	R.J. Hill, G. Paz	(CHIC)
POHL	10	NAT 466 213	R. Pohl <i>et al.</i>	(MPIQ, ENSP, COIM, +)
NISHINO	09	PRL 102 141801	H. Nishino <i>et al.</i>	(Super-Kamiokande Collab.)
PASK	09	PL B678 55	T. Pask <i>et al.</i>	(Stefan Meyer Inst., Vienna, TOKY+)
MOHR	08	RMP 80 633	P.J. Mohr, B.N. Taylor, D.B. Newell	(NIST)
BELUSHKIN	07	PR C75 035202	M.A. Belushkin, H.W. Hammer, U.-G. Meissner	(BONN+)
ARAKI	06	PRL 96 101802	T. Araki <i>et al.</i>	(KamLAND Collab.)
HORI	06	PRL 96 243401	M. Hori <i>et al.</i>	(CERN, TOKYO+)
BLUNDEN	05	PR C72 057601	P.G. Blunden, I. Sick	(MANI, BASL)
KOBAYASHI	05	PR D72 052007	K. Kobayashi <i>et al.</i>	(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 <i>et al.</i>	(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 <i>et al.</i>	(Borexino Collab.)
BEANE	03	PL B567 200	S.R. Beane <i>et al.</i>	
	Also	PL B607 320 (errata.)	S.R. Beane <i>et al.</i>	
DMITRIEV	03	PRL 91 212303	V.F. Dmitriev, R.A. Senkov	(NOVO)
HORI	03	PRL 91 123401	M. Hori <i>et al.</i>	(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 <i>et al.</i>	(SNO Collab.)
BARANOV	01	PPN 32 376	P.S. Baranov <i>et al.</i>	
		Translated from FECAY 32 699.		
BLANPIED	01	PR C64 025203	G. Blaupied <i>et al.</i>	(BNL LEGS Collab.)
HORI	01	PRL 87 093401	M. Hori <i>et al.</i>	(CERN ASACUSA Collab.)
OLMOSDEL...	01	EPJ A10 207	V. Olmos de Leon <i>et al.</i>	(MAMI TAPS Collab.)
TRETYAK	01	PL B505 59	V.I. Tretyak, Yu.G. Zdesenko	(KIEV)
BERNABEI	00B	PL B493 12	R. Bernabei <i>et al.</i>	(Gran Sasso DAMA Collab.)
GEER	00	PRL 84 590	S. Geer <i>et al.</i>	(FNAL APEX Collab.)
	Also	PR D62 052004	S. Geer <i>et al.</i>	(FNAL APEX Collab.)
	Also	PRL 85 3546 (errata.)	S. Geer <i>et al.</i>	(FNAL APEX Collab.)
GEER	00D	APJ 532 648	S.H. Geer, D.C. Kennedy	
SENGUPTA	00	PL B484 275	S. Sengupta	
WALL	00	PR D61 072004	D. Wall <i>et al.</i>	(Soudan-2 Collab.)
WALL	00B	PR D62 092003	D. Wall <i>et al.</i>	(Soudan-2 Collab.)
GABRIELSE	99	PRL 82 3198	G. Gabrielse <i>et al.</i>	
HAYATO	99	PRL 83 1529	Y. Hayato <i>et al.</i>	(Super-Kamiokande Collab.)
MCGREW	99	PR D59 052004	C. McGrew <i>et al.</i>	(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 <i>et al.</i>	(CERN PS-205 Collab.)
ALLISON	98	PL B427 217	W.W.M. Allison <i>et al.</i>	(Soudan-2 Collab.)
HU	98B	PR D58 111101	M. Hu <i>et al.</i>	(FNAL APEX Collab.)
SHIOZAWA	98	PRL 81 3319	M. Shiozawa <i>et al.</i>	(Super-Kamiokande Collab.)
GLICENSTEIN	97	PL B411 326	J.F. Glicenstein	(SACL)
GABRIELSE	95	PRL 74 3544	G. Gabrielse <i>et al.</i>	(HARV, MANZ, SEOUL)
MACGIBBON	95	PR C52 2097	B.E. MacGibbon <i>et al.</i>	(ILL, SASK, INRM)
GEER	94	PRL 72 1596	S. Geer <i>et al.</i>	(FNAL, UCLA, PSU)
HALLIN	93	PR C48 1497	E.L. Hallin <i>et al.</i>	(SASK, BOST, ILL)
SUZUKI	93B	PL B311 357	Y. Suzuki <i>et al.</i>	(Kamiokande Collab.)
HUGHES	92	PRL 69 578	R.J. Hughes, B.I. Deutch	(LANL, AARM)
ZIEGER	92	PL B278 34	A. Zieger <i>et al.</i>	(MPCM)
	Also	PL B281 417 (erratum)	A. Zieger <i>et al.</i>	(MPCM)
BERGER	91	ZPHY C50 385	C. Berger <i>et al.</i>	(FREJUS Collab.)
BERGER	91B	PL B269 227	C. Berger <i>et al.</i>	(FREJUS Collab.)
FEDERSPIEL	91	PRL 67 1511	F.J. Federspiel <i>et al.</i>	(ILL)
BECKER-SZ...	90	PR D42 2974	R.A. Becker-Szendy <i>et al.</i>	(IMB-3 Collab.)
ERICSON	90	EPL 11 295	T.E.O. Ericson, A. Richter	(CERN, DARM)
GABRIELSE	90	PRL 65 1317	G. Gabrielse <i>et al.</i>	(HARV, MANZ, WASH+)
BERGER	89	NP B313 509	C. Berger <i>et al.</i>	(FREJUS Collab.)
CHO	89	PRL 63 2559	D. Cho, K. Sangster, E.A. Hinds	(YALE)
HIRATA	89C	PL B220 308	K.S. Hirata <i>et al.</i>	(Kamiokande Collab.)
PHILLIPS	89	PL B224 348	T.J. Phillips <i>et al.</i>	(HPW Collab.)
KREISSL	88	ZPHY C37 557	A. Kreissl <i>et al.</i>	(CERN PS176 Collab.)
SEIDEL	88	PRL 61 2522	S. Seidel <i>et al.</i>	(IMB Collab.)
BARTELT	87	PR D36 1990	J.E. Bartelt <i>et al.</i>	(Soudan Collab.)
	Also	PR D40 1701 (erratum)	J.E. Bartelt <i>et al.</i>	(Soudan Collab.)
COHEN	87	RMP 59 1121	E.R. Cohen, B.N. Taylor	(RISC, NBS)

HAINES	86	PRL 57 1986	T.J. Haines <i>et al.</i>	(IMB Collab.)
KAJITA	86	JPSJ 55 711	T. Kajita <i>et al.</i>	(Kamiokande Collab.)
ARISAKA	85	JPSJ 54 3213	K. Arisaka <i>et al.</i>	(Kamiokande Collab.)
BLEWITT	85	PRL 55 2114	G.B. Blewitt <i>et al.</i>	(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 <i>et al.</i>	(IMB Collab.)
BATTISTONI	84	PL 133B 454	G. Battistoni <i>et al.</i>	(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 <i>et al.</i>	(MINN, ANL)
BATTISTONI	82	PL 118B 461	G. Battistoni <i>et al.</i>	(NUSEX Collab.)
KRISHNA...	82	PL 115B 349	M.R. Krishnaswamy <i>et al.</i>	(TATA, OSKC+)
ALEKSEEV	81	JETPL 33 651	E.N. Alekseev <i>et al.</i>	(PNPI)
		Translated from ZETFP 33 664.		
CHERRY	81	PRL 47 1507	M.L. Cherry <i>et al.</i>	(PENN, BNL)
COWSIK	80	PR D22 2204	R. Cowsik, V.S. Narasimham	(TATA)
BELL	79	PL 86B 215	M. Bell <i>et al.</i>	(CERN)
GOLDEN	79	PRL 43 1196	R.L. Golden <i>et al.</i>	(NASA, PSLL)
LEARNED	79	PRL 43 907	J.G. Learned, F. Reines, A. Soni	(UCI)
BREGMAN	78	PL 78B 174	M. Bregman <i>et al.</i>	(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 <i>et al.</i>	(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 <i>et al.</i>	(CASE, WITW)
FLEROV	58	DOKL 3 79	G.N. Flerov <i>et al.</i>	(ASCI)