



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

### **p MASS (atomic mass units u)**

The mass is known 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>
<b>1.007276466621 ± 0.000000000053</b>	<b>OUR EVALUATION</b>	2018	CODATA
1.007276466574 ± 0.000000000010	<sup>1</sup> FINK	21	SPEC Penning trap
1.007276466621 ± 0.000000000053	<sup>2</sup> TIESINGA	21	RVUE 2018 CODATA value
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
1.007276466598 ± 0.000000000033	<sup>3</sup> HEISSE	19	SPEC Penning Trap
1.007276466583 ± 0.000000000032	<sup>4</sup> HEISSE	17	SPEC See HEISSE 19
1.007276466879 ± 0.000000000091	MOHR	16	RVUE 2014 CODATA value
1.007276466812 ± 0.000000000090	MOHR	12	RVUE 2010 CODATA value
1.00727646677 ± 0.000000000010	MOHR	08	RVUE 2006 CODATA value
1.00727646688 ± 0.000000000013	MOHR	05	RVUE 2002 CODATA value
1.00727646688 ± 0.000000000013	MOHR	99	RVUE 1998 CODATA value
1.007276470 ± 0.0000000012	COHEN	87	RVUE 1986 CODATA value

<sup>1</sup> FINK 21 simultaneously measure the cyclotron frequencies of an  $H_2^+$  ion and a deuteron in a coupled magnetron orbit. The proton mass is extracted using the precise deuteron mass value.

<sup>2</sup> The 2018 CODATA combination in TIESINGA 21 includes data from HEISSE 17, but does not include updates in HEISSE 19, which superseded HEISSE 17. Consequently, we do not average HEISSE 19 and TIESINGA 21. Updating the 2018 CODATA combination to use HEISSE 19 would shift the central value for the proton mass upwards by less than half a standard deviation. Therefore, we take the 2018 CODATA result in TIESINGA 21 as the recommended value for the proton mass.

<sup>3</sup> The value is an update of HEISSE 17; the result is shifted by  $1.5 \times 10^{-11}$  u, corresponding to  $0.45 \sigma$  due to the corrected motional temperatures of the particles. The statistical and total systematic uncertainties are given as 16 and 29 in the last two digits.

<sup>4</sup> The statistical and systematic errors are 15 and 29 in the last two places of the value. Superseded by HEISSE 19.

### **p MASS (MeV)**

The mass is known more precisely in u (atomic mass units) than in MeV.  
The conversion is: 1 u = 931.494 102 42(28) MeV/c<sup>2</sup> (2018 CODATA value, TIESINGA 21).

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>938.27208816 ± 0.00000029</b>	<b>OUR EVALUATION</b>	2018	CODATA
938.27208812 ± 0.00000029	<sup>1</sup> FINK	21	SPEC Penning trap
938.27208816 ± 0.00000029	TIESINGA	21	RVUE 2018 CODATA value

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

938.2720813	±0.0000058	MOHR	16	RVUE	2014 CODATA value
938.272046	±0.000021	MOHR	12	RVUE	2010 CODATA value
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

<sup>1</sup>FINK 21 quote the more precise mass in atomic mass units.

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

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.

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;7 × 10<sup>-10</sup></b>	90	<sup>1</sup> HORI	11	SPEC $\bar{p}e^-$ He atom
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<2 × 10 <sup>-9</sup>	90	<sup>1</sup> HORI	06	SPEC $\bar{p}e^-$ He atom
<1.0 × 10 <sup>-8</sup>	90	<sup>1</sup> HORI	03	SPEC $\bar{p}e^-$ <sup>4</sup> He, $\bar{p}e^-$ <sup>3</sup> He
<6 × 10 <sup>-8</sup>	90	<sup>1</sup> HORI	01	SPEC $\bar{p}e^-$ He atom
<5 × 10 <sup>-7</sup>		<sup>2</sup> TORII	99	SPEC $\bar{p}e^-$ He atom

<sup>1</sup>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.

<sup>2</sup>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.

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

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<sup>-6-10<sup>-7</sup></sup> for violation of the equivalence principle for  $\bar{p}$ 's.

VALUE	DOCUMENT ID	TECN	COMMENT
<b>1.000000000003 ± 0.000000000016</b>	<b>OUR AVERAGE</b>		
1.000000000003 ± 0.000000000016	BORCHERT	22	TRAP Penning trap
1.000000000001 ± 0.000000000069	ULMER	15	TRAP Penning trap
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.99999999991 ± 0.00000000009	GABRIELSE	99	TRAP Penning trap
1.0000000015 ± 0.0000000011	<sup>1</sup> GABRIELSE	95	TRAP Penning trap
1.000000023 ± 0.000000042	<sup>2</sup> GABRIELSE	90	TRAP Penning trap

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

<sup>2</sup>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  $1836.152701 \pm 0.000037$ .

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

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

<i>VALUE</i>	<i>DOCUMENT ID</i>
<b><math>(0.3 \pm 1.6) \times 10^{-11}</math> OUR EVALUATION</b>	

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

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.

<i>VALUE</i>	<i>CL%</i>	<i>DOCUMENT ID</i>	<i>TECN</i>	<i>COMMENT</i>
<b><math>&lt;7 \times 10^{-10}</math></b>	90	<sup>1</sup> 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	<sup>1</sup> HORI	06	SPEC $\bar{p}e^-$ He atom
$<1.0 \times 10^{-8}$	90	<sup>1</sup> HORI	03	SPEC $\bar{p}e^-$ <sup>4</sup> He, $\bar{p}e^-$ <sup>3</sup> He
$<6 \times 10^{-8}$	90	<sup>1</sup> HORI	01	SPEC $\bar{p}e^-$ He atom
$<5 \times 10^{-7}$		<sup>2</sup> TORII	99	SPEC $\bar{p}e^-$ He atom
$<2 \times 10^{-5}$		<sup>3</sup> HUGHES	92	RVUE

<sup>1</sup>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.

<sup>2</sup>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.

<sup>3</sup>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.

<i>VALUE</i>	<i>DOCUMENT ID</i>	<i>COMMENT</i>
<b><math>&lt;1 \times 10^{-21}</math></b>	<sup>1</sup> BRESSI	11 Neutrality of SF <sub>6</sub>
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●		
$<3.2 \times 10^{-20}$	<sup>2</sup> SENGUPTA	00 binary pulsar
$<0.8 \times 10^{-21}$	MARINELLI	84 Magnetic levitation
$<1.0 \times 10^{-21}$	<sup>1</sup> DYLLA	73 Neutrality of SF <sub>6</sub>

<sup>1</sup> 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.

<sup>2</sup> 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.

## $p$ MAGNETIC MOMENT

See the "Quark Model" review.

VALUE ( $\mu_N$ )	DOCUMENT ID	TECN	COMMENT
<b>2.79284734463 ± 0.0000000082</b>	TIESINGA	21	RVUE 2018 CODATA value
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
2.79284734462 ± 0.0000000082	SCHNEIDER	17	TRAP Double Penning trap
2.7928473508 ± 0.0000000085	MOHR	16	RVUE 2014 CODATA value
2.792847356 ± 0.0000000023	MOHR	12	RVUE 2010 CODATA value
2.792847356 ± 0.0000000023	MOHR	08	RVUE 2006 CODATA value
2.792847351 ± 0.0000000028	MOHR	05	RVUE 2002 CODATA value
2.792847337 ± 0.0000000029	MOHR	99	RVUE 1998 CODATA value
2.792847386 ± 0.0000000063	COHEN	87	RVUE 1986 CODATA value

## $\bar{p}$ MAGNETIC MOMENT

A few early results have been omitted.

VALUE ( $\mu_N$ )	DOCUMENT ID	TECN	COMMENT
<b>−2.7928473441 ± 0.0000000042</b>	SMORRA	17	TRAP Hot/cold $\bar{p}$ frequencies, Penning traps
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
−2.7928465 ± 0.00000023	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 <sup>+</sup> hyperfine structure
−2.8005 ± 0.0090	KREISSL	88	CNTR $\bar{p}$ <sup>208</sup> 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 <sup>−6</sup> )	DOCUMENT ID	TECN	COMMENT
<b>0.002 ± 0.004</b>	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
< <b>0.021</b>	<sup>1</sup> SAHOO	17	Theory plus <sup>199</sup> Hg atom EDM
• • • We do not use the following data for averages, fits, limits, etc. • • •			
< 0.54	<sup>1</sup> DMITRIEV	03	Theory plus <sup>199</sup> Hg atom EDM
– 3.7 ± 6.3	CHO	89	NMR TI F molecules
< 400	DZUBA	85	THEO Uses <sup>129</sup> Xe moment
130 ± 200	<sup>2</sup> WILKENING	84	
900 ± 1400	<sup>3</sup> WILKENING	84	
700 ± 900	HARRISON	69	MBR Molecular beam

<sup>1</sup> 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 <sup>199</sup>Hg atom.

<sup>2</sup> This WILKENING 84 value includes a finite-size effect and a magnetic effect.

<sup>3</sup> This WILKENING 84 value is more cautious than the other and excludes the finite-size effect, which relies on uncertain nuclear integrals.

## $\rho$ ELECTRIC POLARIZABILITY $\alpha_p$

For a very complete review of the "polarizability of the nucleon and Compton scattering," see SCHUMACHER 05, updated in SCHUMACHER 19.

See LI 22D and therein for measurements of the mean square proton electric polarizability radius.

VALUE ( $10^{-4}$ fm <sup>3</sup> )	DOCUMENT ID	TECN	COMMENT
<b>11.2 ± 0.4 OUR AVERAGE</b>			
10.65 ± 0.35 ± 0.36	MCGOVERN	13	RVUE $\chi$ EFT + Compton scattering
12.1 ± 1.1 ± 0.5	<sup>1</sup> BEANE	03	EFT + $\gamma p$
11.82 ± 0.98 <sup>+0.52</sup> / <sub>-0.98</sub>	<sup>2</sup> BLANPIED	01	LEGS $\rho(\vec{\gamma}, \gamma)$ , $\rho(\vec{\gamma}, \pi^0)$ , $\rho(\vec{\gamma}, \pi^+)$
11.9 ± 0.5 ± 1.3	<sup>3</sup> OLMOSDEL...	01	CNTR $\gamma p$ Compton scattering
12.1 ± 0.8 ± 0.5	<sup>4</sup> MACGIBBON	95	RVUE global average
• • • We do not use the following data for averages, fits, limits, etc. • • •			
12.03 <sup>+0.48</sup> / <sub>-0.54</sub>	<sup>5</sup> PASQUINI	19	fit of RCS data sets
11.7 ± 0.8 ± 0.7	<sup>6</sup> BARANOV	01	RVUE Global average
12.5 ± 0.6 ± 0.9	MACGIBBON	95	CNTR $\gamma p$ Compton scattering
9.8 ± 0.4 ± 1.1	HALLIN	93	CNTR $\gamma p$ Compton scattering
10.62 <sup>+1.25 +1.07</sup> / <sub>-1.19 -1.03</sub>	ZIEGER	92	CNTR $\gamma p$ Compton scattering
10.9 ± 2.2 ± 1.3	<sup>7</sup> FEDERSPIEL	91	CNTR $\gamma p$ Compton scattering

<sup>1</sup> BEANE 03 uses effective field theory and low-energy  $\gamma p$  and  $\gamma d$  Compton-scattering data. It also gets for the isoscalar polarizabilities (see the erratum)  $\alpha_N = (13.0 \pm 1.9 <sup>+3.9</sup>/<sub>-1.5</sub>) \times 10^{-4}$  fm<sup>3</sup> and  $\beta_N = (-1.8 \pm 1.9 <sup>+2.1</sup>/<sub>-0.9</sub>) \times 10^{-4}$  fm<sup>3</sup>.

<sup>2</sup> BLANPIED 01 gives  $\alpha_p + \beta_p$  and  $\alpha_p - \beta_p$ . The separate  $\alpha_p$  and  $\beta_p$  are provided to us by A. Sandorfi. The first error above is statistics plus systematics; the second is from the model.

- <sup>3</sup> 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.
- <sup>4</sup> 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.
- <sup>5</sup> PASQUINI 19 fit data sets for the unpolarized proton RCS cross section, using fixed-t-subtracted dispersion relations and a bootstrap-based fitting technique.
- <sup>6</sup> 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  $\alpha_p + \beta_p$ .
- <sup>7</sup> FEDERSPIEL 91 obtains for the (static) electric polarizability  $\alpha_p$ , defined in terms of the induced electric dipole moment by  $\mathbf{D} = 4\pi\epsilon_0\alpha_p\mathbf{E}$ , the value  $(7.0 \pm 2.2 \pm 1.3) \times 10^{-4} \text{ fm}^3$ .

## $\rho$ MAGNETIC POLARIZABILITY $\beta_p$

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.

See LI 22D and therein for measurements of the mean square proton magnetic polarizability radius.

VALUE ( $10^{-4} \text{ fm}^3$ )	DOCUMENT ID	TECN	COMMENT
<b>2.5 ± 0.4 OUR AVERAGE</b>	Error includes scale factor of 1.2.		
3.15 ± 0.35 ± 0.36	MCGOVERN	13	RVUE $\chi$ EFT + Compton scattering
3.4 ± 1.1 ± 0.1	<sup>1</sup> BEANE	03	EFT + $\gamma p$
1.43 ± 0.98 <sup>+0.52</sup> / <sub>-0.98</sub>	<sup>2</sup> BLANPIED	01	LEGS $p(\vec{\gamma}, \gamma)$ , $p(\vec{\gamma}, \pi^0)$ , $p(\vec{\gamma}, \pi^+)$
1.2 ± 0.7 ± 0.5	<sup>3</sup> OLMOSDEL...	01	CNTR $\gamma p$ Compton scattering
2.1 ± 0.8 ± 0.5	<sup>4</sup> MACGIBBON	95	RVUE global average
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1.77 <sup>+0.52</sup> / <sub>-0.54</sub>	<sup>5</sup> PASQUINI	19	fit of RCS data sets
2.3 ± 0.9 ± 0.7	<sup>6</sup> BARANOV	01	RVUE Global average
1.7 ± 0.6 ± 0.9	MACGIBBON	95	CNTR $\gamma p$ Compton scattering
4.4 ± 0.4 ± 1.1	HALLIN	93	CNTR $\gamma p$ Compton scattering
3.58 <sup>+1.19 + 1.03</sup> / <sub>-1.25 - 1.07</sub>	ZIEGER	92	CNTR $\gamma p$ Compton scattering
3.3 ± 2.2 ± 1.3	FEDERSPIEL	91	CNTR $\gamma p$ Compton scattering

- <sup>1</sup> BEANE 03 uses effective field theory and low-energy  $\gamma p$  and  $\gamma d$  Compton-scattering data. It also gets for the isoscalar polarizabilities (see the erratum)  $\alpha_N = (13.0 \pm 1.9 <sup>+3.9</sup>/<sub>-1.5</sub>) \times 10^{-4} \text{ fm}^3$  and  $\beta_N = (-1.8 \pm 1.9 <sup>+2.1</sup>/<sub>-0.9</sub>) \times 10^{-4} \text{ fm}^3$ .
- <sup>2</sup> BLANPIED 01 gives  $\alpha_p + \beta_p$  and  $\alpha_p - \beta_p$ . The separate  $\alpha_p$  and  $\beta_p$  are provided to us by A. Sandorfi. The first error above is statistics plus systematics; the second is from the model.
- <sup>3</sup> 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.
- <sup>4</sup> 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.

- <sup>5</sup> PASQUINI 19 fit data sets for the unpolarized proton RCS cross section, using fixed-t subtracted dispersion relations and a bootstrap-based fitting technique.
- <sup>6</sup> 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  $\alpha_p + \beta_p$ .

## $\rho$ 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  $r_p = 0.831(14)$  fm (XIONG 19), and the atomic-hydrogen value,  $r_p = 0.833(10)$  fm (BEZGINOV 19). These agree well with another recent atomic-hydrogen value  $r_p = 0.8335(95)$  fm (BEYER 17), and with the best measurement using muonic hydrogen  $r_p = 0.84087(39)$  fm (ANTOGNINI 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) 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, TIESINGA 21, recommended value is 0.8414(19) 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
<b>0.8409 ± 0.0004 OUR AVERAGE</b>			
0.833 ± 0.010	<sup>1</sup> BEZGINOV	19	LASR 2S-2P transition in H
0.831 ± 0.007 ± 0.012	<sup>2</sup> XIONG	19	SPEC $ep \rightarrow ep$ form factor
0.84087 ± 0.00026 ± 0.00029	ANTOGNINI	13	LASR $\mu p$ -atom Lamb shift
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.847 ± 0.008	<sup>3</sup> CUI	21	FIT use existing $ep$ data
0.878 ± 0.011 ± 0.031	<sup>4</sup> MIHOVILOVIC	21	ISR $ep \rightarrow ep$ reanalysis
0.877 ± 0.013	<sup>5</sup> FLEURBAEY	18	LASR 1S-3S transition in H
0.8335 ± 0.0095	<sup>6</sup> BEYER	17	LASR 2S-4P transition in H
0.8751 ± 0.0061	MOHR	16	RVUE 2014 CODATA value
0.895 ± 0.014 ± 0.014	<sup>7</sup> 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 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		<i>ep</i> → <i>ep</i> reanalysis

<sup>1</sup> 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.

<sup>2</sup> The XIONG 19 value from *ep* → *ep* scattering and supports the muonic hydrogen Lamb shift value.

<sup>3</sup> CUI 21 employ a new mathematical procedure (statistical SPM, Schlessinger point method) based on form-unbiased interpolations of existing *ep* scattering data.

<sup>4</sup> MIHOVILOVIC 21 reports a value of  $0.878 \pm 0.011 \pm 0.031 \pm 0.002$  fm where the last uncertainty comes from the dependence on the model form factor function.

<sup>5</sup> 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.

<sup>6</sup> 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.

<sup>7</sup> Authors also provide values for combinations of all available data.

### **p** MAGNETIC RADIUS

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

<u>VALUE (fm)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.851 ± 0.026</b>	<sup>1</sup> LEE	15	Combination of world and Mainz data
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
0.817 ± 0.027	<sup>2</sup> CUI	21B FIT	use existing <i>ep</i> data
0.87 ± 0.02	EPSTEIN	14	Using <i>ep</i> , <i>en</i> , $\pi\pi$ data
0.867 ± 0.009 ± 0.018	ZHAN	11 SPEC	Recoil polarimetry
0.777 ± 0.013 ± 0.010	BERNAUER	10 SPEC	<i>ep</i> → <i>ep</i> form factor
0.876 ± 0.010 ± 0.016	BORISYUK	10	Reanalyzes old <i>ep</i> → <i>ep</i> data
0.854 ± 0.005	BELUSHKIN	07	Dispersion analysis

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

<sup>2</sup> CUI 21B employ a new mathematical procedure (statistical SPM, Schlessinger point method) based on form-unbiased interpolations of existing *ep* scattering data.

### **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  $3\nu$  modes in the “Partial Mean Lives” section. Table 1 of BACK 03 is a nice summary.

<i>LIMIT</i> (years)	<i>PARTICLE</i>	<i>CL%</i>	<i>DOCUMENT ID</i>	<i>TECN</i>	<i>COMMENT</i>
$>0.96 \times 10^{30}$	<i>p</i>	90	<sup>1</sup> ALLEGA	22 SNO+	<i>p</i> → invisible
$>0.9 \times 10^{30}$	<i>n</i>	90	<sup>2</sup> ALLEGA	22 SNO+	<i>n</i> → invisible
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
$>3.6 \times 10^{29}$	<i>p</i>	90	<sup>3</sup> ANDERSON	19A SNO+	<i>p</i> → invisible
$>2.5 \times 10^{29}$	<i>n</i>	90	<sup>3</sup> ANDERSON	19A SNO+	<i>n</i> → invisible
$>5.8 \times 10^{29}$	<i>n</i>	90	<sup>4</sup> ARAKI	06 KLND	<i>n</i> → invisible
$>2.1 \times 10^{29}$	<i>p</i>	90	<sup>3</sup> AHMED	04 SNO	<i>p</i> → invisible
$>1.9 \times 10^{29}$	<i>n</i>	90	<sup>3</sup> AHMED	04 SNO	<i>n</i> → invisible
$>1.8 \times 10^{25}$	<i>n</i>	90	<sup>5</sup> BACK	03 BORX	
$>1.1 \times 10^{26}$	<i>p</i>	90	<sup>5</sup> BACK	03 BORX	
$>3.5 \times 10^{28}$	<i>p</i>	90	<sup>6</sup> ZDESENKO	03	<i>p</i> → invisible
$>1 \times 10^{28}$	<i>p</i>	90	<sup>7</sup> AHMAD	02 SNO	<i>p</i> → invisible
$>4 \times 10^{23}$	<i>p</i>	95	TRETYAK	01	<i>d</i> → <i>n</i> + ?
$>1.9 \times 10^{24}$	<i>p</i>	90	<sup>8</sup> BERNABEI	00B DAMA	
$>1.6 \times 10^{25}$	<i>p, n</i>		<sup>9,10</sup> EVANS	77	
$>3 \times 10^{23}$	<i>p</i>		<sup>10</sup> DIX	70 CNTR	
$>3 \times 10^{23}$	<i>p, n</i>		<sup>10,11</sup> FLEROV	58	

<sup>1</sup> ALLEGA 22 look for  $\gamma$  rays from the de-excitation of a residual  $^{15}\text{N}^*$  following the disappearance of *p* in  $^{16}\text{O}$ .

<sup>2</sup> ALLEGA 22 look for  $\gamma$  rays from the de-excitation of a residual  $^{15}\text{O}^*$  following the disappearance of *n* in  $^{16}\text{O}$ .

<sup>3</sup> AHMED 04 and ANDERSON 19A look for  $\gamma$  rays from the de-excitation of a residual  $^{15}\text{O}^*$  or  $^{15}\text{N}^*$  following the disappearance of a neutron or proton in  $^{16}\text{O}$ .

<sup>4</sup> ARAKI 06 looks for signs of de-excitation of the residual nucleus after disappearance of a neutron from the *s* shell of  $^{12}\text{C}$ .

<sup>5</sup> BACK 03 looks for decays of unstable nuclides left after *N* decays of parent  $^{12}\text{C}$ ,  $^{13}\text{C}$ ,  $^{16}\text{O}$  nuclei. These are “invisible channel” limits.

<sup>6</sup> ZDESENKO 03 gets this limit on proton disappearance in deuterium by analyzing SNO data in AHMAD 02.

<sup>7</sup> AHMAD 02 (see its footnote 7) looks for neutrons left behind after the disappearance of the proton in deuterons.

<sup>8</sup> 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.

<sup>9</sup> EVANS 77 looks for the daughter nuclide  $^{129}\text{Xe}$  from possible  $^{130}\text{Te}$  decays in ancient Te ore samples.

<sup>10</sup> This mean-life limit has been obtained from a half-life limit by dividing the latter by  $\ln(2) = 0.693$ .

<sup>11</sup> FLEROV 58 looks for the spontaneous fission of a  $^{232}\text{Th}$  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 (life-time/branching fraction) limit there is  $7 \times 10^5$  years, for  $\bar{p} \rightarrow e^- \gamma$ . We advance only the exclusive-mode limits to our Summary Tables.

<i>LIMIT</i> (years)	<i>CL%</i>	<i>EVTS</i>	<i>DOCUMENT ID</i>	<i>TECN</i>	<i>COMMENT</i>
● ● ● 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		<sup>1</sup> 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

<sup>1</sup>GEER 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  $\tau/B_i$ , where  $\tau$  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
<b>Antilepton + meson</b>		
$\tau_1$ $N \rightarrow e^+ \pi$	> 5300 ( $n$ ), > 24000 ( $p$ )	90%
$\tau_2$ $N \rightarrow \mu^+ \pi$	> 3500 ( $n$ ), > 16000 ( $p$ )	90%
$\tau_3$ $N \rightarrow \nu \pi$	> 1100 ( $n$ ), > 390 ( $p$ )	90%
$\tau_4$ $p \rightarrow e^+ \eta$	> 10000	90%
$\tau_5$ $p \rightarrow \mu^+ \eta$	> 4700	90%
$\tau_6$ $n \rightarrow \nu \eta$	> 158	90%
$\tau_7$ $N \rightarrow e^+ \rho$	> 217 ( $n$ ), > 720 ( $p$ )	90%
$\tau_8$ $N \rightarrow \mu^+ \rho$	> 228 ( $n$ ), > 570 ( $p$ )	90%
$\tau_9$ $N \rightarrow \nu \rho$	> 19 ( $n$ ), > 162 ( $p$ )	90%
$\tau_{10}$ $p \rightarrow e^+ \omega$	> 1600	90%
$\tau_{11}$ $p \rightarrow \mu^+ \omega$	> 2800	90%
$\tau_{12}$ $n \rightarrow \nu \omega$	> 108	90%
$\tau_{13}$ $N \rightarrow e^+ K$	> 17 ( $n$ ), > 1000 ( $p$ )	90%
$\tau_{14}$ $p \rightarrow e^+ K_S^0$		
$\tau_{15}$ $p \rightarrow e^+ K_L^0$		
$\tau_{16}$ $N \rightarrow \mu^+ K$	> 26 ( $n$ ), > 4500 ( $p$ )	90%
$\tau_{17}$ $p \rightarrow \mu^+ K_S^0$		

$\tau_{18}$	$p \rightarrow \mu^+ K_L^0$		
$\tau_{19}$	$N \rightarrow \nu K$	> 86 ( <i>n</i> ), > 5900 ( <i>p</i> )	90%
$\tau_{20}$	$n \rightarrow \nu K_S^0$	> 260	90%
$\tau_{21}$	$p \rightarrow e^+ K^*(892)^0$	> 84	90%
$\tau_{22}$	$N \rightarrow \nu K^*(892)$	> 78 ( <i>n</i> ), > 51 ( <i>p</i> )	90%

### Antilepton + mesons

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

### Lepton + meson

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

### Lepton + mesons

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

### Antilepton + photon(s)

$\tau_{42}$	$p \rightarrow e^+ \gamma$	> 670	90%
$\tau_{43}$	$p \rightarrow \mu^+ \gamma$	> 478	90%
$\tau_{44}$	$n \rightarrow \nu \gamma$	> 550	90%
$\tau_{45}$	$p \rightarrow e^+ \gamma \gamma$	> 100	90%
$\tau_{46}$	$n \rightarrow \nu \gamma \gamma$	> 219	90%

### Antilepton + single massless

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

### Three (or more) leptons

$\tau_{49}$	$p \rightarrow e^+ e^+ e^-$	$> 34000$	90%
$\tau_{50}$	$p \rightarrow e^+ \mu^+ \mu^-$	$> 9200$	90%
$\tau_{51}$	$p \rightarrow e^+ \nu \nu$	$> 170$	90%
$\tau_{52}$	$n \rightarrow e^+ e^- \nu$	$> 257$	90%
$\tau_{53}$	$n \rightarrow \mu^+ e^- \nu$	$> 83$	90%
$\tau_{54}$	$n \rightarrow \mu^+ \mu^- \nu$	$> 79$	90%
$\tau_{55}$	$p \rightarrow \mu^+ e^+ e^-$	$> 23000$	90%
$\tau_{56}$	$p \rightarrow \mu^- e^+ e^+$	$> 19000$	90%
$\tau_{57}$	$p \rightarrow \mu^+ \mu^+ \mu^-$	$> 10000$	90%
$\tau_{58}$	$p \rightarrow \mu^+ \nu \nu$	$> 220$	90%
$\tau_{59}$	$p \rightarrow e^- \mu^+ \mu^+$	$> 11000$	90%
$\tau_{60}$	$n \rightarrow 3\nu$	$> 5 \times 10^{-4}$	90%
$\tau_{61}$	$n \rightarrow 5\nu$		

### Inclusive modes

$\tau_{62}$	$N \rightarrow e^+$ anything	$> 0.6 (n, p)$	90%
$\tau_{63}$	$N \rightarrow \mu^+$ anything	$> 12 (n, p)$	90%
$\tau_{64}$	$N \rightarrow \nu$ anything		
$\tau_{65}$	$N \rightarrow e^+ \pi^0$ anything	$> 0.6 (n, p)$	90%
$\tau_{66}$	$N \rightarrow 2$ bodies, $\nu$ -free		

### $\Delta B = 2$ dinucleon modes

The following are lifetime limits per iron nucleus.

$\tau_{67}$	$pp \rightarrow \pi^+ \pi^+$	$> 72.2$	90%
$\tau_{68}$	$pn \rightarrow \pi^+ \pi^0$	$> 170$	90%
$\tau_{69}$	$nn \rightarrow \pi^+ \pi^-$	$> 0.7$	90%
$\tau_{70}$	$nn \rightarrow \pi^0 \pi^0$	$> 404$	90%
$\tau_{71}$	$pp \rightarrow K^+ K^+$	$> 170$	90%
$\tau_{72}$	$pp \rightarrow e^+ e^+$	$> 5.8$	90%
$\tau_{73}$	$pp \rightarrow e^+ \mu^+$	$> 3.6$	90%
$\tau_{74}$	$pp \rightarrow \mu^+ \mu^+$	$> 1.7$	90%
$\tau_{75}$	$pn \rightarrow e^+ \bar{\nu}$	$> 260$	90%
$\tau_{76}$	$pn \rightarrow \mu^+ \bar{\nu}$	$> 200$	90%
$\tau_{77}$	$pn \rightarrow \tau^+ \bar{\nu}_\tau$	$> 29$	90%
$\tau_{78}$	$nn \rightarrow$ invisible	$> 1.4$	90%
$\tau_{79}$	$nn \rightarrow \nu_e \bar{\nu}_e$	$> 1.4$	90%
$\tau_{80}$	$nn \rightarrow \nu_\mu \bar{\nu}_\mu$	$> 1.4$	90%
$\tau_{81}$	$pn \rightarrow$ invisible	$> 0.06$	90%
$\tau_{82}$	$pp \rightarrow$ invisible	$> 0.11$	90%

## $\bar{p}$ DECAY MODES

Mode	Partial mean life (years)	Confidence level
$\tau_{83} \quad \bar{p} \rightarrow e^- \gamma$	$> 7 \times 10^5$	90%
$\tau_{84} \quad \bar{p} \rightarrow \mu^- \gamma$	$> 5 \times 10^4$	90%
$\tau_{85} \quad \bar{p} \rightarrow e^- \pi^0$	$> 4 \times 10^5$	90%
$\tau_{86} \quad \bar{p} \rightarrow \mu^- \pi^0$	$> 5 \times 10^4$	90%
$\tau_{87} \quad \bar{p} \rightarrow e^- \eta$	$> 2 \times 10^4$	90%
$\tau_{88} \quad \bar{p} \rightarrow \mu^- \eta$	$> 8 \times 10^3$	90%
$\tau_{89} \quad \bar{p} \rightarrow e^- K_S^0$	$> 900$	90%
$\tau_{90} \quad \bar{p} \rightarrow \mu^- K_S^0$	$> 4 \times 10^3$	90%
$\tau_{91} \quad \bar{p} \rightarrow e^- K_L^0$	$> 9 \times 10^3$	90%
$\tau_{92} \quad \bar{p} \rightarrow \mu^- K_L^0$	$> 7 \times 10^3$	90%
$\tau_{93} \quad \bar{p} \rightarrow e^- \gamma \gamma$	$> 2 \times 10^4$	90%
$\tau_{94} \quad \bar{p} \rightarrow \mu^- \gamma \gamma$	$> 2 \times 10^4$	90%
$\tau_{95} \quad \bar{p} \rightarrow e^- \omega$	$> 200$	90%

## $p$ PARTIAL MEAN LIVES

The “partial mean life” limits tabulated here are the limits on  $\tau/B_i$ , where  $\tau$  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 ————

$\tau(N \rightarrow e^+ \pi)$						$\tau_1$
LIMIT ( $10^{30}$ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
<b>&gt;24000</b>	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>0.59</b>	<sup>1</sup> TAKENAKA	20 SKAM
<b>&gt; 5300</b>	<b><math>n</math></b>	<b>90</b>	<b>0</b>	<b>0.41</b>	ABE	17D SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
>16000	$p$	90	0	0.61	ABE	17 SKAM
> 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	$\leq 0.1$	BERGER	91 FREJ
> 550	$p$	90	0	0.7	<sup>2</sup> 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	<i>n</i>	90	0		BARTELT	87	SOUD
>	1.3	<i>p</i>	90	0		BARTELT	87	SOUD
>	250	<i>p</i>	90	0	0.3	HAINES	86	IMB
>	31	<i>n</i>	90	8	9	HAINES	86	IMB
>	64	<i>p</i>	90	0	<0.4	ARISAKA	85	KAMI
>	26	<i>n</i>	90	0	<0.7	ARISAKA	85	KAMI
>	82	<i>p</i> (free)	90	0	0.2	BLEWITT	85	IMB
>	250	<i>p</i>	90	0	0.2	BLEWITT	85	IMB
>	25	<i>n</i>	90	4	4	PARK	85	IMB
>	15	<i>p, n</i>	90	0		BATTISTONI	84	NUSX
>	0.5	<i>p</i>	90	1	0.3	<sup>3</sup> BARTELT	83	SOUD
>	0.5	<i>n</i>	90	1	0.3	<sup>3</sup> BARTELT	83	SOUD
>	5.8	<i>p</i>	90	2		<sup>4</sup> KRISHNA...	82	KOLR
>	5.8	<i>n</i>	90	2		<sup>4</sup> KRISHNA...	82	KOLR
>	0.1	<i>n</i>	90			<sup>5</sup> GURR	67	CNTR

<sup>1</sup> TAKENAKA 20 includes data of ABE 17, and thus supersedes ABE 17.

<sup>2</sup> This BECKER-SZENDY 90 result includes data from SEIDEL 88.

<sup>3</sup> Limit based on zero events.

<sup>4</sup> We have calculated 90% CL limit from 1 confined event.

<sup>5</sup> We have converted half-life to 90% CL mean life.

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

$\tau_2$

<i>LIMIT</i> (10 <sup>30</sup> years)	<i>PARTICLE</i>	<i>CL%</i>	<i>EVTS</i>	<i>BKGD EST</i>	<i>DOCUMENT ID</i>	<i>TECN</i>
>16000	<i>p</i>	90	1	0.94	<sup>1</sup> TAKENAKA 20	SKAM
> 3500	<i>n</i>	90	1	0.77	ABE 17D	SKAM

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

>	7700	<i>p</i>	90	2	0.87	ABE	17	SKAM
>	1000	<i>n</i>	90	1	0.43	NISHINO	12	SKAM
>	6600	<i>p</i>	90	0	0.3	NISHINO	09	SKAM
>	473	<i>p</i>	90	0	0.6	MCGREW	99	IMB3
>	90	<i>n</i>	90	1	1.9	MCGREW	99	IMB3
>	81	<i>p</i>	90	0	0.2	BERGER	91	FREJ
>	35	<i>n</i>	90	1	1.0	BERGER	91	FREJ
>	230	<i>p</i>	90	0	<0.07	HIRATA	89C	KAMI
>	100	<i>n</i>	90	0	<0.2	HIRATA	89C	KAMI
>	270	<i>p</i>	90	0	0.5	SEIDEL	88	IMB
>	63	<i>n</i>	90	0	0.5	SEIDEL	88	IMB
>	76	<i>p</i>	90	2	1	HAINES	86	IMB
>	23	<i>n</i>	90	8	7	HAINES	86	IMB
>	46	<i>p</i>	90	0	<0.7	ARISAKA	85	KAMI
>	20	<i>n</i>	90	0	<0.4	ARISAKA	85	KAMI
>	59	<i>p</i> (free)	90	0	0.2	BLEWITT	85	IMB
>	100	<i>p</i>	90	1	0.4	BLEWITT	85	IMB
>	38	<i>n</i>	90	1	4	PARK	85	IMB
>	10	<i>p, n</i>	90	0		BATTISTONI	84	NUSX
>	1.3	<i>p, n</i>	90	0		ALEKSEEV	81	BAKS

<sup>1</sup> TAKENAKA 20 includes the data of ABE 17 and thus supersedes ABE 17.

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

**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>
<b>&gt; 390</b>	<b><math>p</math></b>	<b>90</b>	<b>52.8</b>		ABE	14E SKAM
<b>&gt;1100</b>	<b><math>n</math></b>	<b>90</b>	<b>19.1</b>		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	<sup>1</sup> 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	$\leq 3$		BATTISTONI	84 NUSX
> 5.8	$p$	90	1		<sup>2</sup> KRISHNA...	82 KOLR
> 0.3	$p$	90	2		<sup>3</sup> CHERRY	81 HOME
> 0.1	$p$	90			<sup>4</sup> GURR	67 CNTR

<sup>1</sup>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  $\nu_\mu$  originating in the upper atmosphere is depleted. Doing so would reduce the background and thus also would reduce the limit here.

<sup>2</sup>We have calculated 90% CL limit from 1 confined event.

<sup>3</sup>We have converted 2 possible events to 90% CL limit.

<sup>4</sup>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>
<b>&gt;10000</b>	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>0.78</b>	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		<sup>1</sup> CHERRY	81 HOME

<sup>1</sup>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>
<b>&gt;4700</b>	<b><i>p</i></b>	<b>90</b>	<b>2</b>	<b>0.85</b>	ABE	17D SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
>1300	<i>p</i>	90	2	0.49	NISHINO	12 SKAM
> 89	<i>p</i>	90	0	1.6	WALL	00B SOU2
> 126	<i>p</i>	90	3	2.8	MCGREW	99 IMB3
> 26	<i>p</i>	90	1	0.8	BERGER	91 FREJ
> 69	<i>p</i>	90	1	<0.08	HIRATA	89C KAMI
> 1.3	<i>p</i>	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>
<b>&gt;158</b>	<b><i>n</i></b>	<b>90</b>	<b>0</b>	<b>1.2</b>	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		<sup>1</sup> CHERRY	81 HOME

<sup>1</sup>We 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>
<b>&gt;720</b>	<b><i>p</i></b>	<b>90</b>	<b>2</b>	<b>0.64</b>	ABE	17D SKAM
<b>&gt;217</b>	<b><i>n</i></b>	<b>90</b>	<b>4</b>	<b>4.8</b>	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	<sup>1</sup> BARTELT	83	SOUD
> 0.5	<i>p</i>	90	1 0.3	<sup>1</sup> BARTELT	83	SOUD
> 9.8	<i>p</i>	90	1	<sup>2</sup> KRISHNA...	82	KOLR
> 0.8	<i>p</i>	90	2	<sup>3</sup> CHERRY	81	HOME

<sup>1</sup> Limit based on zero events.

<sup>2</sup> We have calculated 90% CL limit from 0 confined events.

<sup>3</sup> We have converted 2 possible events to 90% CL limit.

### $\tau(N \rightarrow \mu^+ \rho)$

**78**

<i>LIMIT</i> (10 <sup>30</sup> years)	<i>PARTICLE</i>	<i>CL%</i>	<i>EVTS</i>	<i>BKGD EST</i>	<i>DOCUMENT ID</i>	<i>TECN</i>
<b>&gt;570</b>	<b><i>p</i></b>	<b>90</b>	<b>1</b>	<b>1.30</b>	ABE	17D SKAM
<b>&gt;228</b>	<b><i>n</i></b>	<b>90</b>	<b>3</b>	<b>9.5</b>	MCGREW	99 IMB3

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

> 60	<i>n</i>	90	1 0.96	ABE	17D	SKAM
>160	<i>p</i>	90	1 0.42	NISHINO	12	SKAM
> 36	<i>n</i>	90	0 0.29	NISHINO	12	SKAM
> 12	<i>p</i>	90	0 0.5	BERGER	91	FREJ
> 22	<i>n</i>	90	0 1.1	BERGER	91	FREJ
>110	<i>p</i>	90	0 1.7	HIRATA	89C	KAMI
> 23	<i>n</i>	90	1 1.8	HIRATA	89C	KAMI
> 4.3	<i>p</i>	90	0 0.7	PHILLIPS	89	HPW
> 30	<i>p</i>	90	0 0.5	SEIDEL	88	IMB
> 11	<i>n</i>	90	1 1.1	SEIDEL	88	IMB
> 16	<i>p</i>	90	4 4.5	HAINES	86	IMB
> 7	<i>n</i>	90	6 5	HAINES	86	IMB
> 12	<i>p</i>	90	0 <0.7	ARISAKA	85	KAMI
> 5	<i>n</i>	90	1 <1.2	ARISAKA	85	KAMI
> 5.5	<i>p</i> (free)	90	4 5	BLEWITT	85	IMB
> 16	<i>p</i>	90	4 5	BLEWITT	85	IMB
> 9	<i>n</i>	90	1 2	PARK	85	IMB

### $\tau(N \rightarrow \nu \rho)$

**79**

<i>LIMIT</i> (10 <sup>30</sup> years)	<i>PARTICLE</i>	<i>CL%</i>	<i>EVTS</i>	<i>BKGD EST</i>	<i>DOCUMENT ID</i>	<i>TECN</i>
<b>&gt;162</b>	<b><i>p</i></b>	<b>90</b>	<b>18</b>	<b>21.7</b>	MCGREW	99 IMB3
<b>&gt; 19</b>	<b><i>n</i></b>	<b>90</b>	<b>0</b>	<b>0.5</b>	SEIDEL	88 IMB

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

> 9	<i>n</i>	90	4 2.4	BERGER	89	FREJ
> 24	<i>p</i>	90	0 0.9	BERGER	89	FREJ
> 27	<i>p</i>	90	5 1.5	HIRATA	89C	KAMI
> 13	<i>n</i>	90	4 3.6	HIRATA	89C	KAMI
> 13	<i>p</i>	90	1 1.1	SEIDEL	88	IMB
> 8	<i>p</i>	90	6 5	HAINES	86	IMB
> 2	<i>n</i>	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		<sup>1</sup> CHERRY	81	HOME
> 0.6	$n$	90	2		<sup>1</sup> CHERRY	81	HOME

<sup>1</sup>We have converted 2 possible events to 90% CL limit.

### $\tau(p \rightarrow e^+ \omega)$

**$\tau_{10}$**

<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>
<b>&gt;1600</b>	<b><math>p</math></b>	<b>90</b>	<b>1</b>	<b>1.35</b>	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	<sup>1</sup> BARTELT	83	SOUD
> 9.8	$p$	90	1		<sup>2</sup> KRISHNA...	82	KOLR
> 2.8	$p$	90	2		<sup>3</sup> CHERRY	81	HOME

<sup>1</sup>Limit based on zero events.

<sup>2</sup>We have calculated 90% CL limit from 0 confined events.

<sup>3</sup>We have converted 2 possible events to 90% CL limit.

### $\tau(p \rightarrow \mu^+ \omega)$

**$\tau_{11}$**

<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>
<b>&gt;2800</b>	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>1.09</b>	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

### $\tau(n \rightarrow \nu \omega)$

**$\tau_{12}$**

<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>
<b>&gt;108</b>	<b><math>n</math></b>	<b>90</b>	<b>12</b>	<b>22.5</b>	MCGREW	99 IMB3

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

> 17	<i>n</i>	90	1	0.7	BERGER	89	FREJ
> 43	<i>n</i>	90	3	2.7	HIRATA	89C	KAMI
> 6	<i>n</i>	90	2	1.3	SEIDEL	88	IMB
> 12	<i>n</i>	90	6	6	HAINES	86	IMB
> 18	<i>n</i>	90	2	2	KAJITA	86	KAMI
> 16	<i>n</i>	90	1	2	PARK	85	IMB
> 2.0	<i>n</i>	90	2		<sup>1</sup> CHERRY	81	HOME

<sup>1</sup>We have converted 2 possible events to 90% CL limit.

### $\tau(N \rightarrow e^+ K)$

$\tau_{13}$

<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	<b><i>p</i></b>	<b>90</b>	<b>6</b>	<b>4.7</b>	KOBAYASHI	05 SKAM
> 17	<b><i>n</i></b>	<b>90</b>	<b>35</b>	<b>29.4</b>	MCGREW	99 IMB3

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

> 85	<i>p</i>	90	3	4.9	WALL	00	SOU2
> 31	<i>p</i>	90	23	25.2	MCGREW	99	IMB3
> 60	<i>p</i>	90	0		BERGER	91	FREJ
> 150	<i>p</i>	90	0	<0.27	HIRATA	89C	KAMI
> 70	<i>p</i>	90	0	1.8	SEIDEL	88	IMB
> 77	<i>p</i>	90	5	4.5	HAINES	86	IMB
> 38	<i>p</i>	90	0	<0.8	ARISAKA	85	KAMI
> 24	<i>p</i> (free)	90	7	8.5	BLEWITT	85	IMB
> 77	<i>p</i>	90	5	4	BLEWITT	85	IMB
> 1.3	<i>p</i>	90	0		ALEKSEEV	81	BAKS
> 1.3	<i>n</i>	90	0		ALEKSEEV	81	BAKS

### $\tau(p \rightarrow e^+ K_S^0)$

$\tau_{14}$

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

>120	<i>p</i>	90	1	1.3	WALL	00	SOU2
> 76	<i>p</i>	90	0	0.5	BERGER	91	FREJ

### $\tau(p \rightarrow e^+ K_L^0)$

$\tau_{15}$

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

>51	<i>p</i>	90	2	3.5	WALL	00	SOU2
>44	<i>p</i>	90	0	$\leq 0.1$	BERGER	91	FREJ

### $\tau(N \rightarrow \mu^+ K)$

$\tau_{16}$

<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>
>4500	<b><i>p</i></b>	<b>90</b>	<b>1</b>	<b>3.08</b>	<sup>1</sup> MATSUMOTO	22 SKAM
> 26	<b><i>n</i></b>	<b>90</b>	<b>20</b>	<b>28.4</b>	MCGREW	99 IMB3

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

>3600	$p$	90	14	16.3	<sup>2</sup> MATSUMOTO 22	SKAM
>1600	$p$	90	13	13.2	REGIS	12 SKAM
>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		<sup>3</sup> 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		<sup>4</sup> BARTELT	83 SOUD
> 0.4	$n$	90	0		<sup>4</sup> BARTELT	83 SOUD
> 5.8	$p$	90	2		<sup>5</sup> KRISHNA...	82 KOLR
> 2.0	$p$	90	0		CHERRY	81 HOME
> 0.2	$n$	90			<sup>6</sup> GURR	67 CNTR

<sup>1</sup> MATSUMOTO 22 limit  $> 4500 \times 10^{30}$  is derived from the latest dataset SKA IV phase (from 2008 to 2018) with 0.20 Mton-years of exposure.

<sup>2</sup> MATSUMOTO 22 limit  $> 3600 \times 10^{30}$  is derived from a combination of all datasets SKA I,II, III and IV phase (from 1996 to 2018) with a total of 0.37 Mton-years of exposure. Note, the limit from only SKA IV is stronger, because there were some events observed in SKA II.

<sup>3</sup> BARTELT 87 limit applies to  $p \rightarrow \mu^+ K_S^0$ .

<sup>4</sup> Limit based on zero events.

<sup>5</sup> We have calculated 90% CL limit from 1 confined event.

<sup>6</sup> We have converted half-life to 90% CL mean life.

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

**$\tau_{17}$**

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

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

**$\tau_{18}$**

<u>LIMIT</u> <u>(<math>10^{30}</math> years)</u>	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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• • • 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	$\leq 0.1$	BERGER	91 FREJ

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

$\tau_{19}$

LIMIT ( $10^{30}$ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
>5900	<i>p</i>	90	0	1.0	ABE	14G SKAM
> 86	<i>n</i>	90	0	2.4	HIRATA	89C KAMI
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 540	<i>p</i>	90	0	0.9	ASAKURA	15 KLND
>2300	<i>p</i>	90	0	1.3	KOBAYASHI	05 SKAM
> 26	<i>n</i>	90	16	9.1	WALL	00 SOU2
> 670	<i>p</i>	90			HAYATO	99 SKAM
> 151	<i>p</i>	90	15	21.4	MCGREW	99 IMB3
> 30	<i>n</i>	90	34	34.1	MCGREW	99 IMB3
> 43	<i>p</i>	90	1	1.54	<sup>1</sup> ALLISON	98 SOU2
> 15	<i>n</i>	90	1	1.8	BERGER	89 FREJ
> 15	<i>p</i>	90	1	1.8	BERGER	89 FREJ
> 100	<i>p</i>	90	9	7.3	HIRATA	89C KAMI
> 0.28	<i>p</i>	90	0	0.7	PHILLIPS	89 HPW
> 0.3	<i>p</i>	90	0		BARTELT	87 SOUD
> 0.75	<i>n</i>	90	0		<sup>2</sup> BARTELT	87 SOUD
> 10	<i>p</i>	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		<sup>3</sup> BARTELT	83 SOUD
> 0.1	<i>p</i>	90	0		<sup>3</sup> BARTELT	83 SOUD
> 5.8	<i>p</i>	90	1		<sup>4</sup> KRISHNA...	82 KOLR
> 0.3	<i>n</i>	90	2		<sup>5</sup> CHERRY	81 HOME

<sup>1</sup> This ALLISON 98 limit is with no background subtraction; with subtraction the limit becomes  $> 46 \times 10^{30}$  years.

<sup>2</sup> BARTELT 87 limit applies to  $n \rightarrow \nu K_S^0$ .

<sup>3</sup> Limit based on zero events.

<sup>4</sup> We have calculated 90% CL limit from 1 confined event.

<sup>5</sup> We have converted 2 possible events to 90% CL limit.

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

$\tau_{20}$

LIMIT ( $10^{30}$ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
>260	<i>n</i>	90	34	30	<sup>1</sup> KOBAYASHI	05 SKAM
> 51	<i>n</i>	90	16	9.1	WALL	00 SOU2

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

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

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

$\tau_{21}$

<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>
<b>&gt;84</b>	<b><math>p</math></b>	<b>90</b>	<b>38</b>	<b>52.0</b>	MCGREW	99 IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>10	$p$	90	0	0.8	BERGER	91 FREJ
>52	$p$	90	2	1.55	HIRATA	89C KAMI
>10	$p$	90	1	<1	ARISAKA	85 KAMI

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

$\tau_{22}$

<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>
<b>&gt;51</b>	<b><math>p</math></b>	<b>90</b>	<b>7</b>	<b>9.1</b>	MCGREW	99 IMB3
<b>&gt;78</b>	<b><math>n</math></b>	<b>90</b>	<b>40</b>	<b>50</b>	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		<sup>1</sup> BATTISTONI	82 NUSX

<sup>1</sup>We have converted 1 possible event to 90% CL limit.

————— Antilepton + mesons —————

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

$\tau_{23}$

<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>
<b>&gt;82</b>	<b><math>p</math></b>	<b>90</b>	<b>16</b>	<b>23.1</b>	MCGREW	99 IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>21	$p$	90	0	2.2	BERGER	91 FREJ

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

$\tau_{24}$

<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>
<b>&gt;147</b>	<b><math>p</math></b>	<b>90</b>	<b>2</b>	<b>0.8</b>	MCGREW	99 IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •						
> 38	$p$	90	1	0.5	BERGER	91 FREJ

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

$\tau_{25}$

<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>
<b>&gt;52</b>	<b><math>n</math></b>	<b>90</b>	<b>38</b>	<b>34.2</b>	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>
<b>&gt;133</b>	<b><math>p</math></b>	<b>90</b>	<b>25</b>	<b>38.0</b>	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>
<b>&gt;101</b>	<b><math>p</math></b>	<b>90</b>	<b>3</b>	<b>1.6</b>	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>
<b>&gt;74</b>	<b><math>n</math></b>	<b>90</b>	<b>17</b>	<b>20.8</b>	MCGREW 99	IMB3
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
>33	$n$	90	0	1.1	BERGER 91	FREJ

$\tau(n \rightarrow e^+ K^0 \pi^-)$  **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>
<b>&gt;18</b>	<b><math>n</math></b>	<b>90</b>	<b>1</b>	<b>0.2</b>	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>
<b>&gt;65</b>	<b><math>n</math></b>	<b>90</b>	<b>0</b>	<b>1.6</b>	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

$\tau(n \rightarrow \mu^- \pi^+)$  **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>
<b>&gt;49</b>	<b><math>n</math></b>	<b>90</b>	<b>0</b>	<b>0.5</b>	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

$\tau(n \rightarrow e^- \rho^+)$  **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>
<b>&gt;62</b>	<b><i>n</i></b>	<b>90</b>	<b>2</b>	<b>4.1</b>	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>
<b>&gt;7</b>	<b><i>n</i></b>	<b>90</b>	<b>1</b>	<b>1.1</b>	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>
<b>&gt;32</b>	<b><i>n</i></b>	<b>90</b>	<b>3</b>	<b>2.96</b>	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>
<b>&gt;57</b>	<b><i>n</i></b>	<b>90</b>	<b>0</b>	<b>2.18</b>	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>
<b>&gt;30</b>	<b><i>p</i></b>	<b>90</b>	<b>1</b>	<b>2.50</b>	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>
<b>&gt;29</b>	<b><i>n</i></b>	<b>90</b>	<b>1</b>	<b>0.78</b>	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>
<b>&gt;17</b>	<b><i>p</i></b>	<b>90</b>	<b>1</b>	<b>1.72</b>	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>
<b>&gt;34</b>	<b><i>n</i></b>	<b>90</b>	<b>0</b>	<b>0.78</b>	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>
<b>&gt;75</b>	<b><i>p</i></b>	<b>90</b>	<b>81</b>	<b>127.2</b>	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
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$\tau(p \rightarrow \mu^- \pi^+ K^+)$  **T41**

<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>
<b>&gt;245</b>	<b><i>p</i></b>	<b>90</b>	<b>3</b>	<b>4.0</b>	MCGREW	99 IMB3

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

> 5	<i>p</i>	90	2	0.78	BERGER	91B FREJ
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————— **Antilepton + photon(s)** —————

$\tau(p \rightarrow e^+ \gamma)$  **T42**

<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>
<b>&gt;670</b>	<b><i>p</i></b>	<b>90</b>	<b>0</b>	<b>0.1</b>	MCGREW	99 IMB3

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

>133	<i>p</i>	90	0	0.3	BERGER	91 FREJ
>460	<i>p</i>	90	0	0.6	SEIDEL	88 IMB
>360	<i>p</i>	90	0	0.3	HAINES	86 IMB
> 87	<i>p</i> (free)	90	0	0.2	BLEWITT	85 IMB
>360	<i>p</i>	90	0	0.2	BLEWITT	85 IMB
> 0.1	<i>p</i>	90			<sup>1</sup> GURR	67 CNTR

<sup>1</sup>We have converted half-life to 90% CL mean life.

$\tau(p \rightarrow \mu^+ \gamma)$  **T43**

<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>
<b>&gt;478</b>	<b><i>p</i></b>	<b>90</b>	<b>0</b>	<b>0.1</b>	MCGREW	99 IMB3

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

>155	<i>p</i>	90	0	0.1	BERGER	91 FREJ
>380	<i>p</i>	90	0	0.5	SEIDEL	88 IMB
> 97	<i>p</i>	90	3	2	HAINES	86 IMB
> 61	<i>p</i> (free)	90	0	0.2	BLEWITT	85 IMB
>280	<i>p</i>	90	0	0.6	BLEWITT	85 IMB
> 0.3	<i>p</i>	90			<sup>1</sup> GURR	67 CNTR

<sup>1</sup>We 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
<b>&gt;550</b>		<b>90</b>			TAKHISTOV 15	SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 28	<i>n</i>	90	163	144.7	MCGREW 99	IMB3
> 24	<i>n</i>	90	10	6.86	BERGER 91B	FREJ
> 9	<i>n</i>	90	73	60	HAINES 86	IMB
> 11	<i>n</i>	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
<b>&gt;100</b>	<b><i>p</i></b>	<b>90</b>	<b>1</b>	<b>0.8</b>	BERGER 91	FREJ

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

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

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

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

VALUE ( $10^{30}$ years)	CL%	DOCUMENT ID	TECN
<b>&gt;790</b>	90	TAKHISTOV 15	SKAM

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

VALUE ( $10^{30}$ years)	CL%	DOCUMENT ID	TECN
<b>&gt;410</b>	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
<b>&gt;34000</b>	<b><i>p</i></b>	<b>90</b>	<b>0</b>	<b>0.58</b>	TANAKA 20	SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 793	<i>p</i>	90	0	0.5	MCGREW 99	IMB3
> 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
<b>&gt;9200</b>	<b><i>p</i></b>	<b>90</b>	<b>1</b>	<b>0.27</b>	TANAKA 20	SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 359	<i>p</i>	90	1	0.9	MCGREW 99	IMB3
> 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**

<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>
<b>&gt;170</b>	<b><math>p</math></b>	<b>90</b>			<sup>1</sup> 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

<sup>1</sup> Allowed events at 90% CL are 459.

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

**T52**

<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>
<b>&gt;257</b>	<b><math>n</math></b>	<b>90</b>	<b>5</b>	<b>7.5</b>	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

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

**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>
<b>&gt;83</b>	<b><math>n</math></b>	<b>90</b>	<b>25</b>	<b>29.4</b>	MCGREW 99	IMB3
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
>47	$n$	90	0	< 0.1	BERGER 91B	FREJ

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

**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>
<b>&gt;79</b>	<b><math>n</math></b>	<b>90</b>	<b>100</b>	<b>145</b>	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

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

**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>
<b>&gt;23000</b>	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>0.5</b>	TANAKA 20	SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 529	$p$	90	0	1.0	MCGREW 99	IMB3
> 91	$p$	90	0	$\leq 0.1$	BERGER 91	FREJ

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

**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>
<b>&gt;19000</b>	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>0.5</b>	TANAKA 20	SKAM

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

**T57**

LIMIT ( $10^{30}$ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
<b>&gt;10000</b>	<b><math>p</math></b>	<b>90</b>	<b>1</b>	<b>0.4</b>	TANAKA	20 SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 675	$p$	90	0	0.3	MCGREW	99 IMB3
> 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		<sup>1</sup> BATTISTONI	82 NUSX

<sup>1</sup>We have converted 1 possible event to 90% CL limit.

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

**T58**

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

<sup>1</sup>Allowed events at 90% CL are 286.

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

**T59**

LIMIT ( $10^{30}$ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
<b>&gt;11000</b>	<b><math>p</math></b>	<b>90</b>	<b>1</b>	<b>0.27</b>	TANAKA	20 SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 6.0	$p$	90	0	0.7	PHILLIPS	89 HPW

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

**T60**

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
<b>&gt;0.00049</b>	<b><math>n</math></b>	<b>90</b>	<b>2</b>	<b>2</b>	<sup>1</sup> SUZUKI	93B KAMI
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
>0.0023	$n$	90			<sup>2</sup> GLICENSTEIN	97 KAMI
>0.00003	$n$	90	11	6.1	<sup>3</sup> BERGER	91B FREJ
>0.00012	$n$	90	7	11.2	<sup>3</sup> BERGER	91B FREJ
>0.0005	$n$	90	0		LEARNED	79 RVUE

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

<sup>2</sup>GLICENSTEIN 97 uses Kamioka data and the idea that the disappearance of the neutron’s magnetic moment should produce radiation.

<sup>3</sup>The first BERGER 91B limit is for  $n \rightarrow \nu_e \nu_e \bar{\nu}_e$ , the second is for  $n \rightarrow \nu_\mu \nu_\mu \bar{\nu}_\mu$ .

**$\tau(n \rightarrow 5\nu)$**  **T61**

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

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

>0.0017	$n$	90			<sup>1</sup> GLICENSTEIN 97	KAMI
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<sup>1</sup> GLICENSTEIN 97 uses Kamioka data and the idea that the disappearance of the neutron's magnetic moment should produce radiation.

————— **Inclusive modes** —————

**$\tau(N \rightarrow e^+$  anything)** **T62**

<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>
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>0.6	$p, n$	90			<sup>1</sup> LEARNED 79	RVUE
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<sup>1</sup> The electron may be primary or secondary.

**$\tau(N \rightarrow \mu^+$  anything)** **T63**

<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>
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>12	$p, n$	90	2		<sup>1,2</sup> CHERRY 81	HOME
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• • • We do not use the following data for averages, fits, limits, etc. • • •

> 1.8	$p, n$	90			<sup>2</sup> COWSIK 80	CNTR
> 6	$p, n$	90			<sup>2</sup> LEARNED 79	RVUE

<sup>1</sup> We have converted 2 possible events to 90% CL limit.

<sup>2</sup> The muon may be primary or secondary.

**$\tau(N \rightarrow \nu$  anything)** **T64**

Anything =  $\pi, \rho, K$ , etc.

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

>0.0002	$p, n$	90	0		LEARNED 79	RVUE
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**$\tau(N \rightarrow e^+ \pi^0$  anything)** **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>
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>0.6	$p, n$	90	0		LEARNED 79	RVUE
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**$\tau(N \rightarrow 2$  bodies,  $\nu$ -free)** **T66**

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

>1.3	$p, n$	90	0		ALEKSEEV 81	BAKS
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—————  **$\Delta B = 2$  dinucleon modes** —————

**$\tau(pp \rightarrow \pi^+ \pi^+)$**  **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>
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>72.2	90	2	4.45	GUSTAFSON 15	SKAM	per oxygen nucleus
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• • • We do not use the following data for averages, fits, limits, etc. • • •

> 0.7	90	4	2.34	BERGER 91B	FREJ	per iron nucleus
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$\tau(pn \rightarrow \pi^+ \pi^0)$  **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>
<b>&gt;170</b>	<b>90</b>			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

$\tau(nn \rightarrow \pi^+ \pi^-)$  **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>
<b>&gt;0.7</b>	<b>90</b>	<b>4</b>	<b>2.18</b>	BERGER	91B FREJ	$\tau$ per iron nucleus

$\tau(nn \rightarrow \pi^0 \pi^0)$  **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>
<b>&gt;404</b>	<b>90</b>			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

$\tau(pp \rightarrow K^+ K^+)$  **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>
<b>&gt;170</b>	<b>90</b>	<b>0</b>	<b>0.28</b>	LITOS	14 SKAM	$\tau$ per oxygen nucleus

$\tau(pp \rightarrow e^+ e^+)$  **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>
<b>&gt;5.8</b>	<b>90</b>	<b>0</b>	<b>&lt;0.1</b>	BERGER	91B FREJ	$\tau$ per iron nucleus

$\tau(pp \rightarrow e^+ \mu^+)$  **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>
<b>&gt;3.6</b>	<b>90</b>	<b>0</b>	<b>&lt;0.1</b>	BERGER	91B FREJ	$\tau$ per iron nucleus

$\tau(pp \rightarrow \mu^+ \mu^+)$  **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>
<b>&gt;1.7</b>	<b>90</b>	<b>0</b>	<b>0.62</b>	BERGER	91B FREJ	$\tau$ per iron nucleus

$\tau(pn \rightarrow e^+ \bar{\nu})$  **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>
<b>&gt;260</b>	<b>90</b>			TAKHISTOV	15 SKAM	
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 2.8	90	5	9.67	BERGER	91B FREJ	$\tau$ per iron nucleus

$\tau(pn \rightarrow \mu^+ \bar{\nu})$  **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>
<b>&gt;200</b>	<b>90</b>			TAKHISTOV	15 SKAM	
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 1.6	90	4	4.37	BERGER	91B FREJ	$\tau$ per iron nucleus

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

T77

LIMIT (10 <sup>30</sup> years)	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
>29	90			TAKHISTOV	15 SKAM

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

> 1	90			<sup>1</sup> BRYMAN	14 CHER
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<sup>1</sup> BRYMAN 14 uses a MCGREW 99 limit on the  $p \rightarrow e^+ \nu \nu$  lifetime to extract this value.

$\tau(nn \rightarrow \text{invisible})$

T78

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

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

>0.015	90			<sup>2,3</sup> ALLEGA	22 SNO+	$nn \rightarrow \text{invisible}$
>0.013	90			<sup>2</sup> ANDERSON	19A SNO+	$nn \rightarrow \text{invisible}$
>0.000042	90			<sup>4</sup> TRETAK	04 CNTR	$nn \rightarrow \text{invisible}$
>0.000049	90			<sup>5</sup> BACK	03 BORX	$nn \rightarrow \text{invisible}$
>0.000012	90			<sup>6</sup> BERNABEI	00B DAMA	$nn \rightarrow \text{invisible}$

<sup>1</sup> ARAKI 06 looks for signs of de-excitation of the residual nucleus after disappearance of two neutrons from the *s* shell of <sup>12</sup>C.

<sup>2</sup> ALLEGA 22 and ANDERSON 19A look for  $\gamma$  rays from the de-excitation of a residual <sup>14</sup>O\* following the disappearance of  $nn$  in <sup>16</sup>O.

<sup>3</sup> ALLEGA 22 replaces the previous SNO+ value of ANDERSON 19A.

<sup>4</sup> TRETAK 04 uses data from an old Homestake-mine radiochemical experiment on limits for invisible decays of <sup>39</sup>K to <sup>37</sup>Ar.

<sup>5</sup> BACK 03 looks for decays of unstable nuclides left after  $NN$  decays of parent <sup>12</sup>C, <sup>13</sup>C, <sup>16</sup>O nuclei. These are "invisible channel" limits.

<sup>6</sup> BERNABEI 00B looks for the decay of a <sup>127</sup>Xe nucleus following the disappearance of an  $nn$  pair in the otherwise-stable <sup>129</sup>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.

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

T79

LIMIT (10 <sup>30</sup> years)	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN	COMMENT
>0.000012	90	5	9.7	BERGER	91B FREJ	$\tau$ per iron nucleus

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

T80

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

LIMIT (10 <sup>30</sup> years)	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN	COMMENT
<b>&gt; 1.4 (CL=90%) OUR LIMIT</b>						

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

>0.000006	90	4	4.4	BERGER	91B FREJ	$\tau$ per iron nucleus
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**$\tau(pn \rightarrow \text{invisible})$**

**T81**

This violates charge conservation as well as baryon number conservation.

VALUE ( $10^{30}$ years)	CL%	DOCUMENT ID	TECN
<b>&gt;0.06</b>	90	<sup>1,2</sup> ALLEGA 22	SNO+
>0.026	90	<sup>1</sup> ANDERSON 19A	SNO+
>0.000021	90	<sup>3</sup> TRETAK 04	CNTR

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

<sup>1</sup> ALLEGA 22 and ANDERSON 19A look for  $\gamma$  rays from the de-excitation of a residual  $^{14}\text{N}^*$  following the disappearance of  $pn$  in  $^{16}\text{O}$ .

<sup>2</sup> ALLEGA 22 replaces the previous SNO+ value of ANDERSON 19A.

<sup>3</sup> TRETAK 04 uses data from an old Homestake-mine radiochemical experiment on limits for invisible decays of  $^{39}\text{K}$  to  $^{37}\text{Ar}$ .

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

**T82**

This violates charge conservation as well as baryon number conservation.

VALUE ( $10^{30}$ years)	CL%	DOCUMENT ID	TECN
<b>&gt;0.11</b>	90	<sup>1</sup> ALLEGA 22	SNO+
>0.047	90	<sup>1</sup> ANDERSON 19A	SNO+
>0.00005	90	<sup>2</sup> BACK 03	BORX
>0.0000055	90	<sup>3</sup> BERNABEI 00B	DAMA

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

<sup>1</sup> ALLEGA 22 look for  $\gamma$  rays from the de-excitation of a residual  $^{14}\text{C}^*$  following the disappearance of  $pp$  in  $^{16}\text{O}$ . Supersedes ANDERSON 19A result.

<sup>2</sup> BACK 03 looks for decays of unstable nuclides left after  $NN$  decays of parent  $^{12}\text{C}$ ,  $^{13}\text{C}$ ,  $^{16}\text{O}$  nuclei. These are “invisible channel” limits.

<sup>3</sup> 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.

————  **$\Delta B = 1$**  ————

**$\bar{p}$  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.

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

**T83**

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
<b>&gt; <math>7 \times 10^5</math></b>	90	GEER 00	APEX	8.9 GeV/c $\bar{p}$ beam
>1848	95	GEER 94	CALO	8.9 GeV/c $\bar{p}$ beam

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

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

**T84**

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
<b>&gt; <math>5 \times 10^4</math></b>	90	GEER 00	APEX	8.9 GeV/c $\bar{p}$ beam
> $5.0 \times 10^4$	90	HU 98B	APEX	8.9 GeV/c $\bar{p}$ beam

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



$\tau(\bar{p} \rightarrow e^- \pi^0)$  **T85**

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$> 4 \times 10^5$	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

$\tau(\bar{p} \rightarrow \mu^- \pi^0)$  **T86**

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$> 5 \times 10^4$	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

$\tau(\bar{p} \rightarrow e^- \eta)$  **T87**

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$> 2 \times 10^4$	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

$\tau(\bar{p} \rightarrow \mu^- \eta)$  **T88**

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$> 8 \times 10^3$	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

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

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$> 900$	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

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

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$> 4 \times 10^3$	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

$\tau(\bar{p} \rightarrow e^- K_L^0)$  **T91**

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$> 9 \times 10^3$	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

$\tau(\bar{p} \rightarrow \mu^- K_L^0)$  **T92**

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$> 7 \times 10^3$	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

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

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

$\tau(\bar{p} \rightarrow \mu^- \gamma \gamma)$  **T94**

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
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$\tau(\bar{p} \rightarrow e^- \omega)$  **T95**

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

**p REFERENCES**

ALLEGA 22	PR D105 112012	A. Allega <i>et al.</i>	(SNO+ Collab.)
BORCHERT 22	NAT 601 53	M.J. Borchert <i>et al.</i>	(BASE Collab.)
LI 22D	NAT 611 265	R. Li <i>et al.</i>	
MATSUMOTO 22	PR D106 072003	R. Matsumoto <i>et al.</i>	(Super-Kamiokande Collab.)
CUI 21	PRL 127 092001	Z.-F. Cui <i>et al.</i>	(NJU, ECT, HZDR)
CUI 21B	CPL 38 121401	Z.-F. Cui <i>et al.</i>	(NJU, ECT, HZDR)
FINK 21	PRL 127 243001	D.J. Fink, E.G. Myers	(FSU)
MIHOVILOVIC 21	EPJ A57 107	M. Mihovilovic <i>et al.</i>	(LJUB, MAINZ, MIT+)
TIESINGA 21	RMP 93 025010	E. Tiesinga <i>et al.</i>	(NIST)
TAKENAKA 20	PR D102 112011	A. Takenaka <i>et al.</i>	(Super-Kamiokande Collab.)
TANAKA 20	PR D101 052011	M. Tanaka <i>et al.</i>	(Super-Kamiokande Collab.)
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, TINTO)
HEISSE 19	PR A100 022518	F. Heisse <i>et al.</i>	(MPIK, GSI, MAINZ)
PASQUINI 19	JP G46 104001	B. Pasquini, P. Pedroni, S. Sconfiatti	(PAVI)
SCHUMACHER 19	LHEP 4 4	M. Schumacher	(GOET)
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>	(MPIK, GSI, MAINZ, 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>	(MAINZ, 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, MPIK, +)
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. DiSciaccia <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 (errat.)	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. Blanpied <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 (errat.)	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, MAINZ, 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, AARH)
ZIEGER	92	PL B278 34	A. Zieger <i>et al.</i>	(MPCM)
Also		PL B281 417 (errat.)	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, MAINZ, 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 (errat.)	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)