



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

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

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

VALUE ( $u$ )	DOCUMENT ID	TECN	COMMENT
<b><math>1.00727646688 \pm 0.00000000013</math></b>	MOHR	05	RVUE 2002 CODATA value
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
$1.00727646688 \pm 0.00000000013$	MOHR	99	RVUE 1998 CODATA value
$1.007276470 \pm 0.000000012$	COHEN	87	RVUE 1986 CODATA value

### $p$ MASS (MeV)

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

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b><math>938.272029 \pm 0.000080</math></b>	MOHR	05	RVUE 2002 CODATA value
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
$938.271998 \pm 0.000038$	MOHR	99	RVUE 1998 CODATA value
$938.27231 \pm 0.00028$	COHEN	87	RVUE 1986 CODATA value
$938.2796 \pm 0.0027$	COHEN	73	RVUE 1973 CODATA value

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

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

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

<sup>1</sup> HORI 01, HORI 03, and HORI 06 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, and HORI 06 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.

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

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

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

<sup>3</sup>Equation (2) of GABRIELSE 95 should read  $M(\bar{p})/M(p) = 0.999\,999\,9985$  (11) (G. Gabrielse, private communication).

<sup>4</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.

<u>VALUE</u>	<u>DOCUMENT ID</u>
<b><math>(-9 \pm 9) \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.

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b><math>&lt; 2 \times 10^{-9}</math></b>	90	<sup>5</sup> HORI	06	SPEC $\bar{p}e^-$ He atom
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 1.0 \times 10^{-8}$	90	<sup>5</sup> HORI	03	SPEC $\bar{p}e^-$ <sup>4</sup> He, $\bar{p}e^-$ <sup>3</sup> He
$< 6 \times 10^{-8}$	90	<sup>5</sup> HORI	01	SPEC $\bar{p}e^-$ He atom
$< 5 \times 10^{-7}$		<sup>6</sup> TORII	99	SPEC $\bar{p}e^-$ He atom
$< 2 \times 10^{-5}$		<sup>7</sup> HUGHES	92	RVUE

<sup>5</sup>HORI 01, HORI 03, and HORI 06 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, and HORI 06 values for  $|m_p - m_{\bar{p}}|/m_p$ , above.

<sup>6</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>7</sup>HUGHES 92 uses recent measurements of Rydberg-energy and cyclotron-frequency ratios.

$$|q_p + q_e|/e$$

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

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>COMMENT</u>
<b>&lt;1.0 × 10<sup>-21</sup></b>	<sup>8</sup> DYLLA 73	Neutrality of SF <sub>6</sub>
• • • We do not use the following data for averages, fits, limits, etc. • • •		
<3.2 × 10 <sup>-20</sup>	<sup>9</sup> SENGUPTA 00	binary pulsar
<0.8 × 10 <sup>-21</sup>	MARINELLI 84	Magnetic levitation

<sup>8</sup> Assumes that  $q_n = q_p + q_e$ .

<sup>9</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 “Note on Baryon Magnetic Moments” in the  $\Lambda$  Listings.

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

### **$\bar{p}$ MAGNETIC MOMENT**

A few early results have been omitted.

<u>VALUE (<math>\mu_N</math>)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>−2.800 ± 0.008 OUR AVERAGE</b>			
−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. Calculated from the  $p$  and  $\bar{p}$  magnetic moments, above.

<u>VALUE</u>	<u>DOCUMENT ID</u>
<b>(−2.6 ± 2.9) × 10<sup>-3</sup> OUR EVALUATION</b>	

## $\rho$ ELECTRIC DIPOLE MOMENT

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

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

<sup>10</sup> DMITRIEV 03 calculates this limit from the limit on the electric dipole moment of the <sup>199</sup>Hg atom.

<sup>11</sup> This WILKENING 84 value includes a finite-size effect and a magnetic effect.

<sup>12</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. His recommended values for the proton are  $\alpha_p = (12.0 \pm 0.6) \times 10^{-4} \text{ fm}^3$  and  $\beta_p = (1.9 \mp 0.6) \times 10^{-4} \text{ fm}^3$ , almost exactly our averages.

VALUE ( $10^{-4} \text{ fm}^3$ )	DOCUMENT ID	TECN	COMMENT
<b>12.0 ± 0.6 OUR AVERAGE</b>			
12.1 ± 1.1 ± 0.5	<sup>13</sup> BEANE 03		EFT + $\gamma p$
11.82 ± 0.98 <sup>+0.52</sup> <sub>-0.98</sub>	<sup>14</sup> BLANPIED 01	LEGS	$\rho(\vec{\gamma}, \gamma)$ , $\rho(\vec{\gamma}, \pi^0)$ , $\rho(\vec{\gamma}, \pi^+)$
11.9 ± 0.5 ± 1.3	<sup>15</sup> OLMOSDEL... 01	CNTR	$\gamma p$ Compton scattering
12.1 ± 0.8 ± 0.5	<sup>16</sup> MACGIBBON 95	RVUE	global average
• • • We do not use the following data for averages, fits, limits, etc. • • •			
11.7 ± 0.8 ± 0.7	<sup>17</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>18</sup> FEDERSPIEL 91	CNTR	$\gamma p$ Compton scattering

<sup>13</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>14</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>15</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>16</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>17</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>18</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  $(7.0 \pm 2.2 \pm 1.3) \times 10^{-4} \text{ fm}^3$ .

## $p$ 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.

VALUE ( $10^{-4} \text{ fm}^3$ )	DOCUMENT ID	TECN	COMMENT
<b>1.9 ± 0.5 OUR AVERAGE</b>			
3.4 ± 1.1 ± 0.1	<sup>19</sup> BEANE	03	EFT + $\gamma p$
1.43 ± 0.98 <sup>+0.52</sup> <sub>-0.98</sub>	<sup>20</sup> BLANPIED	01	LEGS $p(\vec{\gamma}, \gamma)$ , $p(\vec{\gamma}, \pi^0)$ , $p(\vec{\gamma}, \pi^+)$
1.2 ± 0.7 ± 0.5	<sup>21</sup> OLMOSDEL...	01	CNTR $\gamma p$ Compton scattering
2.1 ± 0.8 ± 0.5	<sup>22</sup> MACGIBBON	95	RVUE global average
• • • We do not use the following data for averages, fits, limits, etc. • • •			
2.3 ± 0.9 ± 0.7	<sup>23</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>19</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>20</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>21</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>22</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>23</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  $\alpha_p + \beta_p$ .

## $p$ CHARGE RADIUS

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

VALUE (fm)	DOCUMENT ID	COMMENT
<b>0.8750 ± 0.0068</b>	MOHR	05 2002 CODATA value

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

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

<sup>24</sup> ESCHRICH 01 actually gives  $\langle r^2 \rangle = (0.69 \pm 0.06 \pm 0.06) \text{ fm}^2$ .

### $p$ MEAN LIFE

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

LIMIT (years)	PARTICLE	CL%	DOCUMENT ID	TECN	COMMENT
<b>&gt;5.8 × 10<sup>29</sup></b>	$n$	90	<sup>25</sup> ARAKI	06	KLND $n \rightarrow$ invisible
<b>&gt;2.1 × 10<sup>29</sup></b>	$p$	90	<sup>26</sup> AHMED	04	SNO $p \rightarrow$ invisible

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

>1.9 × 10 <sup>29</sup>	$n$	90	<sup>26</sup> AHMED	04	SNO	$n \rightarrow$ invisible
>1.8 × 10 <sup>25</sup>	$n$	90	<sup>27</sup> BACK	03	BORX	
>1.1 × 10 <sup>26</sup>	$p$	90	<sup>27</sup> BACK	03	BORX	
>3.5 × 10 <sup>28</sup>	$p$	90	<sup>28</sup> ZDESENKO	03		$p \rightarrow$ invisible
>1 × 10 <sup>28</sup>	$p$	90	<sup>29</sup> AHMAD	02	SNO	$p \rightarrow$ invisible
>4 × 10 <sup>23</sup>	$p$	95	TRETYAK	01		$d \rightarrow n + ?$
>1.9 × 10 <sup>24</sup>	$p$	90	<sup>30</sup> BERNABEI	00B	DAMA	
>1.6 × 10 <sup>25</sup>	$p, n$		<sup>31,32</sup> EVANS	77		
>3 × 10 <sup>23</sup>	$p$		<sup>32</sup> DIX	70	CNTR	
>3 × 10 <sup>23</sup>	$p, n$		<sup>32,33</sup> FLEROV	58		

<sup>25</sup> ARAKI 06 looks for signs of de-excitation of the residual nucleus after disappearance of a neutron from the  $s$  shell of <sup>12</sup>C.

<sup>26</sup> AHMED 04 looks for  $\gamma$  rays from the de-excitation of a residual <sup>15</sup>O\* or <sup>15</sup>N\* following the disappearance of a neutron or proton in <sup>16</sup>O.

<sup>27</sup> BACK 03 looks for decays of unstable nuclides left after  $N$  decays of parent <sup>12</sup>C, <sup>13</sup>C, <sup>16</sup>O nuclei. These are “invisible channel” limits.

<sup>28</sup> ZDESENKO 03 gets this limit on proton disappearance in deuterium by analyzing SNO data in AHMAD 02.

<sup>29</sup> AHMAD 02 (see its footnote 7) looks for neutrons left behind after the disappearance of the proton in deuterons.

<sup>30</sup> BERNABEI 00B looks for the decay of a <sup>128</sup>/<sub>53</sub>I nucleus following the disappearance of a proton in the otherwise-stable <sup>129</sup>/<sub>54</sub>Xe nucleus.

<sup>31</sup> EVANS 77 looks for the daughter nuclide <sup>129</sup>Xe from possible <sup>130</sup>Te decays in ancient Te ore samples.

<sup>32</sup> This mean-life limit has been obtained from a half-life limit by dividing the latter by  $\ln(2) = 0.693$ .

<sup>33</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 (lifetime/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.

<u>LIMIT</u> (years)	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
$>8 \times 10^5$	90		<sup>34</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>34</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>		
$\tau_1 \quad N \rightarrow e^+ \pi$	$> 158 (n), > 1600 (p)$	90%
$\tau_2 \quad N \rightarrow \mu^+ \pi$	$> 100 (n), > 473 (p)$	90%
$\tau_3 \quad N \rightarrow \nu \pi$	$> 112 (n), > 25 (p)$	90%
$\tau_4 \quad p \rightarrow e^+ \eta$	$> 313$	90%
$\tau_5 \quad p \rightarrow \mu^+ \eta$	$> 126$	90%
$\tau_6 \quad n \rightarrow \nu \eta$	$> 158$	90%
$\tau_7 \quad N \rightarrow e^+ \rho$	$> 217 (n), > 75 (p)$	90%
$\tau_8 \quad N \rightarrow \mu^+ \rho$	$> 228 (n), > 110 (p)$	90%
$\tau_9 \quad N \rightarrow \nu \rho$	$> 19 (n), > 162 (p)$	90%
$\tau_{10} \quad p \rightarrow e^+ \omega$	$> 107$	90%

$\tau_{11}$	$p \rightarrow \mu^+ \omega$	> 117	90%
$\tau_{12}$	$n \rightarrow \nu \omega$	> 108	90%
$\tau_{13}$	$N \rightarrow e^+ K$	> 17 ( $n$ ), > 150 ( $p$ )	90%
$\tau_{14}$	$p \rightarrow e^+ K_S^0$	> 120	90%
$\tau_{15}$	$p \rightarrow e^+ K_L^0$	> 51	90%
$\tau_{16}$	$N \rightarrow \mu^+ K$	> 26 ( $n$ ), > 120 ( $p$ )	90%
$\tau_{17}$	$p \rightarrow \mu^+ K_S^0$	> 150	90%
$\tau_{18}$	$p \rightarrow \mu^+ K_L^0$	> 83	90%
$\tau_{19}$	$N \rightarrow \nu K$	> 86 ( $n$ ), > 670 ( $p$ )	90%
$\tau_{20}$	$n \rightarrow \nu K_S^0$	> 51	90%
$\tau_{21}$	$p \rightarrow e^+ K^*(892)^0$	> 84	90%
$\tau_{22}$	$N \rightarrow \nu K^*(892)$	> 78 ( $n$ ), > 51 ( $p$ )	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%
$\tau_{44}$	$n \rightarrow \nu \gamma$	> 28	90%
$\tau_{45}$	$p \rightarrow e^+ \gamma \gamma$	> 100	90%
$\tau_{46}$	$n \rightarrow \nu \gamma \gamma$	> 219	90%



### Three (or more) leptons

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

### Inclusive modes

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

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

The following are lifetime limits per iron nucleus.

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

### $\bar{p}$ DECAY MODES

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

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

### $p$ 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; 158</b>	<b><math>n</math></b>	<b>90</b>	<b>3</b>	<b>5</b>	MCGREW	99	IMB3
<b>&gt;1600</b>	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>0.1</b>	SHIOZAWA	98	SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●							
> 540	$p$	90	0	0.2	MCGREW	99	IMB3
> 70	$p$	90	0	0.5	BERGER	91	FREJ
> 70	$n$	90	0	$\leq 0.1$	BERGER	91	FREJ
> 550	$p$	90	0	0.7	<sup>35</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	$n$	90	0		BARTELT	87	SOUD
> 1.3	$p$	90	0		BARTELT	87	SOUD
> 250	$p$	90	0	0.3	HAINES	86	IMB
> 31	$n$	90	8	9	HAINES	86	IMB
> 64	$p$	90	0	$< 0.4$	ARISAKA	85	KAMI
> 26	$n$	90	0	$< 0.7$	ARISAKA	85	KAMI
> 82	$p$ (free)	90	0	0.2	BLEWITT	85	IMB
> 250	$p$	90	0	0.2	BLEWITT	85	IMB
> 25	$n$	90	4	4	PARK	85	IMB

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

<sup>35</sup> This BECKER-SZENDY 90 result includes data from SEIDEL 88.

<sup>36</sup> Limit based on zero events.

<sup>37</sup> We have calculated 90% CL limit from 1 confined event.

<sup>38</sup> We have converted half-life to 90% CL mean life.

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

**T<sub>2</sub>**

<u>LIMIT</u> (10 <sup>30</sup> years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&gt;473</b>	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>0.6</b>	MCGREW	99 IMB3
<b>&gt;100</b>	<b><math>n</math></b>	<b>90</b>	<b>0</b>	<b>&lt;0.2</b>	HIRATA	89C KAMI

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

> 90	$n$	90	1	1.9	MCGREW	99	IMB3
> 81	$p$	90	0	0.2	BERGER	91	FREJ
> 35	$n$	90	1	1.0	BERGER	91	FREJ
>230	$p$	90	0	<0.07	HIRATA	89C	KAMI
>270	$p$	90	0	0.5	SEIDEL	88	IMB
> 63	$n$	90	0	0.5	SEIDEL	88	IMB
> 76	$p$	90	2	1	HAINES	86	IMB
> 23	$n$	90	8	7	HAINES	86	IMB
> 46	$p$	90	0	<0.7	ARISAKA	85	KAMI
> 20	$n$	90	0	<0.4	ARISAKA	85	KAMI
> 59	$p$ (free)	90	0	0.2	BLEWITT	85	IMB
>100	$p$	90	1	0.4	BLEWITT	85	IMB
> 38	$n$	90	1	4	PARK	85	IMB
> 10	$p, n$	90	0		BATTISTONI	84	NUSX
> 1.3	$p, n$	90	0		ALEKSEEV	81	BAKS

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

**T<sub>3</sub>**

<u>LIMIT</u> (10 <sup>30</sup> years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&gt; 16</b>	<b><math>p</math></b>	<b>90</b>	<b>6</b>	<b>6.7</b>	WALL	00B SOU2
<b>&gt;112</b>	<b><math>n</math></b>	<b>90</b>	<b>6</b>	<b>6.6</b>	MCGREW	99 IMB3

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

> 39	$n$	90	4	3.8	WALL	00B	SOU2
> 10	$p$	90	15	20.3	MCGREW	99	IMB3
> 13	$n$	90	1	1.2	BERGER	89	FREJ
> 10	$p$	90	11	14	BERGER	89	FREJ
> 25	$p$	90	32	32.8	39 HIRATA	89C	KAMI
>100	$n$	90	1	3	HIRATA	89C	KAMI
> 6	$n$	90	73	60	HAINES	86	IMB
> 2	$p$	90	16	13	KAJITA	86	KAMI
> 40	$n$	90	0	1	KAJITA	86	KAMI

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

<sup>39</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>40</sup> We have calculated 90% CL limit from 1 confined event.

<sup>41</sup> We have converted 2 possible events to 90% CL limit.

<sup>42</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;313</b>	<b><i>p</i></b>	<b>90</b>	<b>0</b>	<b>0.2</b>	MCGREW	99 IMB3
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 81	<i>p</i>	90	1	1.7	WALL	00B SOU2
> 44	<i>p</i>	90	0	0.1	BERGER	91 FREJ
>140	<i>p</i>	90	0	<0.04	HIRATA	89C KAMI
>100	<i>p</i>	90	0	0.6	SEIDEL	88 IMB
>200	<i>p</i>	90	5	3.3	HAINES	86 IMB
> 64	<i>p</i>	90	0	<0.8	ARISAKA	85 KAMI
> 64	<i>p</i> (free)	90	5	6.5	BLEWITT	85 IMB
>200	<i>p</i>	90	5	4.7	BLEWITT	85 IMB
> 1.2	<i>p</i>	90	2		43 CHERRY	81 HOME

<sup>43</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;126</b>	<b><i>p</i></b>	<b>90</b>	<b>3</b>	<b>2.8</b>	MCGREW	99 IMB3
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 89	<i>p</i>	90	0	1.6	WALL	00B SOU2
> 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>44</sup> CHERRY	81	HOME

<sup>44</sup>We have converted 2 possible events to 90% CL limit.

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

**77**

<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;217</b>	<b><i>n</i></b>	<b>90</b>	<b>4</b>	<b>4.8</b>	MCGREW	99 IMB3
<b>&gt; 75</b>	<b><i>p</i></b>	<b>90</b>	<b>2</b>	<b>2.7</b>	HIRATA	89C KAMI

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

> 29	<i>p</i>	90	0	2.2	BERGER	91	FREJ
> 41	<i>n</i>	90	0	1.4	BERGER	91	FREJ
> 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>45</sup> BARTELT	83	SOUD
> 0.5	<i>p</i>	90	1	0.3	<sup>45</sup> BARTELT	83	SOUD
> 9.8	<i>p</i>	90	1		<sup>46</sup> KRISHNA...	82	KOLR
> 0.8	<i>p</i>	90	2		<sup>47</sup> CHERRY	81	HOME

<sup>45</sup>Limit based on zero events.

<sup>46</sup>We have calculated 90% CL limit from 0 confined events.

<sup>47</sup>We have converted 2 possible events to 90% CL limit.

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

**78**

<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;228</b>	<b><i>n</i></b>	<b>90</b>	<b>3</b>	<b>9.5</b>	MCGREW	99 IMB3
<b>&gt;110</b>	<b><i>p</i></b>	<b>90</b>	<b>0</b>	<b>1.7</b>	HIRATA	89C KAMI

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

> 12	<i>p</i>	90	0	0.5	BERGER	91	FREJ
> 22	<i>n</i>	90	0	1.1	BERGER	91	FREJ
> 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

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

**T9**

<u>LIMIT</u> (10 <sup>30</sup> years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<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	<i>p</i>	90	2	1	KAJITA	86	KAMI
> 4	<i>n</i>	90	2	2	KAJITA	86	KAMI
> 4.1	<i>p</i> (free)	90	6	7	BLEWITT	85	IMB
> 8.4	<i>p</i>	90	6	5	BLEWITT	85	IMB
> 2	<i>n</i>	90	7	3	PARK	85	IMB
> 0.9	<i>p</i>	90	2		<sup>48</sup> CHERRY	81	HOME
> 0.6	<i>n</i>	90	2		<sup>48</sup> CHERRY	81	HOME

<sup>48</sup>We have converted 2 possible events to 90% CL limit.

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

**T10**

<u>LIMIT</u> (10 <sup>30</sup> years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&gt;107</b>	<b><i>p</i></b>	<b>90</b>	<b>7</b>	<b>10.8</b>	MCGREW	99 IMB3

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

> 17	<i>p</i>	90	0	1.1	BERGER	91	FREJ
> 45	<i>p</i>	90	2	1.45	HIRATA	89C	KAMI
> 26	<i>p</i>	90	1	1.0	SEIDEL	88	IMB
> 1.5	<i>p</i>	90	0		BARTELT	87	SOUD
> 37	<i>p</i>	90	6	5.3	HAINES	86	IMB
> 25	<i>p</i>	90	1	<1.4	ARISAKA	85	KAMI
> 12	<i>p</i> (free)	90	6	7.5	BLEWITT	85	IMB
> 37	<i>p</i>	90	6	5.7	BLEWITT	85	IMB
> 0.6	<i>p</i>	90	1	0.3	<sup>49</sup> BARTELT	83	SOUD
> 9.8	<i>p</i>	90	1		<sup>50</sup> KRISHNA...	82	KOLR
> 2.8	<i>p</i>	90	2		<sup>51</sup> CHERRY	81	HOME

<sup>49</sup>Limit based on zero events.

<sup>50</sup>We have calculated 90% CL limit from 0 confined events.

<sup>51</sup>We have converted 2 possible events to 90% CL limit.

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

$\tau_{11}$

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

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

$\tau_{12}$

LIMIT ( $10^{30}$ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
<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	$n$	90	1	0.7	BERGER	89 FREJ
> 43	$n$	90	3	2.7	HIRATA	89C KAMI
> 6	$n$	90	2	1.3	SEIDEL	88 IMB
> 12	$n$	90	6	6	HAINES	86 IMB
> 18	$n$	90	2	2	KAJITA	86 KAMI
> 16	$n$	90	1	2	PARK	85 IMB
> 2.0	$n$	90	2		<sup>52</sup> CHERRY	81 HOME

<sup>52</sup>We have converted 2 possible events to 90% CL limit.

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

$\tau_{13}$

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

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

$\tau_{14}$

LIMIT ( $10^{30}$ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
<b>&gt;2000</b>	<b><math>p</math></b>	<b>90</b>	<b>6</b>	<b>4.7</b>	<sup>53</sup> KOBAYASHI	05 SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 120	$p$	90	1	1.3	WALL	00 SOU2
> 76	$p$	90	0	0.5	BERGER	91 FREJ

<sup>53</sup>We have doubled the  $p \rightarrow e^+ K^0$  limit given in KOBAYASHI 05 to obtain this  $p \rightarrow e^+ K_S^0$  limit.

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

<i>LIMIT</i> ( $10^{30}$ years)	<i>PARTICLE</i>	<i>CL%</i>	<i>EVTS</i>	<i>BKGD EST</i>	<i>DOCUMENT ID</i>	<i>TECN</i>
<b>&gt;51</b>	<b><math>p</math></b>	<b>90</b>	<b>2</b>	<b>3.5</b>	WALL	00 SOU2
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
>44	$p$	90	0	$\leq 0.1$	BERGER	91 FREJ

**$\tau(N \rightarrow \mu^+ K)$   $\tau_{16}$**

<i>LIMIT</i> ( $10^{30}$ years)	<i>PARTICLE</i>	<i>CL%</i>	<i>EVTS</i>	<i>BKGD EST</i>	<i>DOCUMENT ID</i>	<i>TECN</i>
<b>&gt;120</b>	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>&lt;1.2</b>	WALL	00 SOU2
<b>&gt;120</b>	<b><math>p</math></b>	<b>90</b>	<b>4</b>	<b>7.2</b>	MCGREW	99 IMB3
<b>&gt; 26</b>	<b><math>n</math></b>	<b>90</b>	<b>20</b>	<b>28.4</b>	MCGREW	99 IMB3
<b>&gt;120</b>	<b><math>p</math></b>	<b>90</b>	<b>1</b>	<b>0.4</b>	HIRATA	89C KAMI
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 54	$p$	90	0		BERGER	91 FREJ
> 3.0	$p$	90	0	0.7	PHILLIPS	89 HPW
> 19	$p$	90	3	2.5	SEIDEL	88 IMB
> 1.5	$p$	90	0		<sup>54</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>55</sup> BARTELT	83 SOUD
> 0.4	$n$	90	0		<sup>55</sup> BARTELT	83 SOUD
> 5.8	$p$	90	2		<sup>56</sup> KRISHNA...	82 KOLR
> 2.0	$p$	90	0		CHERRY	81 HOME
> 0.2	$n$	90			<sup>57</sup> GURR	67 CNTR

<sup>54</sup>BARTELT 87 limit applies to  $p \rightarrow \mu^+ K_S^0$ .

<sup>55</sup>Limit based on zero events.

<sup>56</sup>We have calculated 90% CL limit from 1 confined event.

<sup>57</sup>We have converted half-life to 90% CL mean life.

**$\tau(p \rightarrow \mu^+ K_S^0)$   $\tau_{17}$**

<i>LIMIT</i> ( $10^{30}$ years)	<i>PARTICLE</i>	<i>CL%</i>	<i>EVTS</i>	<i>BKGD EST</i>	<i>DOCUMENT ID</i>	<i>TECN</i>
<b>&gt;2600</b>	<b><math>p</math></b>	<b>90</b>	<b>3</b>	<b>3.9</b>	<sup>58</sup> KOBAYASHI	05 SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 150	$p$	90	0	<0.8	WALL	00 SOU2
> 64	$p$	90	0	1.2	BERGER	91 FREJ

<sup>58</sup>We have doubled the  $p \rightarrow \mu^+ K^0$  limit given in KOBAYASHI 05 to obtain this  $p \rightarrow \mu^+ K_S^0$  limit.



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

**$\tau_{18}$**

LIMIT ( $10^{30}$ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
<b>&gt;83</b>	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>0.4</b>	WALL	00 SOU2
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
>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
<b>&gt;2300</b>	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>1.3</b>	KOBAYASHI	05 SKAM
<b>&gt; 86</b>	<b><math>n</math></b>	<b>90</b>	<b>0</b>	<b>2.4</b>	HIRATA	89C KAMI
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 26	$n$	90	16	9.1	WALL	00 SOU2
> 670	$p$	90			HAYATO	99 SKAM
> 151	$p$	90	15	21.4	MCGREW	99 IMB3
> 30	$n$	90	34	34.1	MCGREW	99 IMB3
> 43	$p$	90	1	1.54	<sup>59</sup> ALLISON	98 SOU2
> 15	$n$	90	1	1.8	BERGER	89 FREJ
> 15	$p$	90	1	1.8	BERGER	89 FREJ
> 100	$p$	90	9	7.3	HIRATA	89C KAMI
> 0.28	$p$	90	0	0.7	PHILLIPS	89 HPW
> 0.3	$p$	90	0		BARTELT	87 SOUD
> 0.75	$n$	90	0		<sup>60</sup> BARTELT	87 SOUD
> 10	$p$	90	6	5	HAINES	86 IMB
> 15	$n$	90	3	5	HAINES	86 IMB
> 28	$p$	90	3	3	KAJITA	86 KAMI
> 32	$n$	90	0	1.4	KAJITA	86 KAMI
> 1.8	$p$ (free)	90	6	11	BLEWITT	85 IMB
> 9.6	$p$	90	6	5	BLEWITT	85 IMB
> 10	$n$	90	2	2	PARK	85 IMB
> 5	$n$	90	0		BATTISTONI	84 NUSX
> 2	$p$	90	0		BATTISTONI	84 NUSX
> 0.3	$n$	90	0		<sup>61</sup> BARTELT	83 SOUD
> 0.1	$p$	90	0		<sup>61</sup> BARTELT	83 SOUD
> 5.8	$p$	90	1		<sup>62</sup> KRISHNA...	82 KOLR
> 0.3	$n$	90	2		<sup>63</sup> CHERRY	81 HOME

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

<sup>60</sup> BARTELT 87 limit applies to  $n \rightarrow \nu K_S^0$ .

<sup>61</sup> Limit based on zero events.

<sup>62</sup> We have calculated 90% CL limit from 1 confined event.

<sup>63</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
<b>&gt;260</b>	<b><math>n</math></b>	<b>90</b>	<b>34</b>	<b>30</b>	<sup>64</sup> KOBAYASHI	05 SKAM
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
> 51	$n$	90	16	9.1	WALL	00 SOU2

<sup>64</sup>We have doubled the  $n \rightarrow \nu K^0$  limit given in KOBAYASHI 05 to obtain this  $n \rightarrow \nu K_S^0$  limit.

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

**T21**

<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

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

**T22**

<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>65</sup> BATTISTONI 82	NUSX

<sup>65</sup>We have converted 1 possible event to 90% CL limit.

———— **Antilepton + mesons** ————

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

**T23**

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

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

**T24**

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

$\tau(n \rightarrow e^+ \pi^- \pi^0)$  **T25**

<u>LIMIT</u> ( $10^{30}$ years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&gt;52</b>	<b><i>n</i></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	<i>n</i>	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><i>p</i></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	<i>p</i>	90	1	2.6	BERGER 91	FREJ
> 3.3	<i>p</i>	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><i>p</i></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	<i>p</i>	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><i>n</i></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	<i>n</i>	90	0	1.1	BERGER 91	FREJ

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

<u>LIMIT</u> ( $10^{30}$ years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&gt;18</b>	<b><i>n</i></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><i>n</i></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	<i>n</i>	90	0	1.09	BERGER 91B	FREJ
>16	<i>n</i>	90	9	7	HAINES 86	IMB
>25	<i>n</i>	90	2	4	PARK 85	IMB

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

**T31**

<u>LIMIT</u> ( $10^{30}$ years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&gt;49</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. ● ● ●						
>33	<i>n</i>	90	0	1.40	BERGER	91B FREJ
> 2.7	<i>n</i>	90	0	0.7	PHILLIPS	89 HPW
>25	<i>n</i>	90	7	6	HAINES	86 IMB
>27	<i>n</i>	90	2	3	PARK	85 IMB

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

**T32**

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

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

————— **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>66</sup> GURR	67 CNTR
-------	----------	----	--	--	--------------------	---------

<sup>66</sup>We have converted half-life to 90% CL mean life.

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

LIMIT ( $10^{30}$ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
<b>&gt;478</b>	<b><math>p</math></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	$p$	90	0	0.1	BERGER	91 FREJ
>380	$p$	90	0	0.5	SEIDEL	88 IMB
> 97	$p$	90	3	2	HAINES	86 IMB
> 61	$p$ (free)	90	0	0.2	BLEWITT	85 IMB
>280	$p$	90	0	0.6	BLEWITT	85 IMB
> 0.3	$p$	90			<sup>67</sup> GURR	67 CNTR

<sup>67</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;28</b>	<b><math>n</math></b>	<b>90</b>	<b>163</b>	<b>144.7</b>	MCGREW	99 IMB3
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>24	$n$	90	10	6.86	BERGER	91B FREJ
> 9	$n$	90	73	60	HAINES	86 IMB
>11	$n$	90	28	19	PARK	85 IMB

 $\tau(p \rightarrow e^+ \gamma \gamma)$  **T45**

LIMIT ( $10^{30}$ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
<b>&gt;100</b>	<b><math>p</math></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><math>n</math></b>	<b>90</b>	<b>5</b>	<b>7.5</b>	MCGREW	99 IMB3

————— **Three (or more) leptons** —————

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

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

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

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

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

**T49**

<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><math>p</math></b>	<b>90</b>	<b>152</b>	<b>153.7</b>	MCGREW	99 IMB3
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
>11	$p$	90	11	6.08	BERGER	91B FREJ

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

**T50**

<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

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

**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;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

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

**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;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

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

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

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

**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;675</b>	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>0.3</b>	MCGREW	99 IMB3
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
>119	$p$	90	0	0.2	BERGER	91 FREJ
> 10.5	$p$	90	0	0.7	PHILLIPS	89 HPW
>190	$p$	90	1	0.1	HAINES	86 IMB
> 44	$p$ (free)	90	1	0.7	BLEWITT	85 IMB
>190	$p$	90	1	0.9	BLEWITT	85 IMB
> 2.1	$p$	90	1		<sup>68</sup> BATTISTONI	82 NUSX

<sup>68</sup>We have converted 1 possible event to 90% CL limit.

**$\tau(p \rightarrow \mu^+ \nu \nu)$  T55**

<u>LIMIT</u> (10 <sup>30</sup> years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>21	<b><math>p</math></b>	<b>90</b>	<b>7</b>	<b>11.23</b>	BERGER	91B FREJ

**$\tau(p \rightarrow e^- \mu^+ \mu^+)$  T56**

<u>LIMIT</u> (10 <sup>30</sup> years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>6.0	<b><math>p</math></b>	<b>90</b>	<b>0</b>	<b>0.7</b>	PHILLIPS	89 HPW

**$\tau(n \rightarrow 3\nu)$  T57**

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.

<u>LIMIT</u> (10 <sup>30</sup> years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>0.00049	<b><math>n</math></b>	<b>90</b>	<b>2</b>	<b>2</b>	<sup>69</sup> SUZUKI	93B KAMI

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

>0.0023	$n$	90			<sup>70</sup> GLICENSTEIN	97 KAMI
>0.00003	$n$	90	11	6.1	<sup>71</sup> BERGER	91B FREJ
>0.00012	$n$	90	7	11.2	<sup>71</sup> BERGER	91B FREJ
>0.0005	$n$	90	0		LEARNED	79 RVUE

<sup>69</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>70</sup>GLICENSTEIN 97 uses Kamioka data and the idea that the disappearance of the neutron's magnetic moment should produce radiation.

<sup>71</sup>The first BERGER 91B limit is for  $n \rightarrow \nu_e \nu_e \bar{\nu}_e$ , the second is for  $n \rightarrow \nu_\mu \nu_\mu \bar{\nu}_\mu$ .

**$\tau(n \rightarrow 5\nu)$  T58**

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

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

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

>0.0017	$n$	90			<sup>72</sup> GLICENSTEIN	97 KAMI
---------	-----	----	--	--	---------------------------	---------

<sup>72</sup>GLICENSTEIN 97 uses Kamioka data and the idea that the disappearance of the neutron's magnetic moment should produce radiation.

———— Inclusive modes ————

**$\tau(N \rightarrow e^+ \text{ anything})$  T59**

<u>LIMIT</u> (10 <sup>30</sup> years)	<u>PARTICLE</u>	<u>CL%</u>	<u>EVTS</u>	<u>BKGD EST</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
>0.6	<b><math>p, n</math></b>	<b>90</b>			<sup>73</sup> LEARNED	79 RVUE

<sup>73</sup>The electron may be primary or secondary.



**$\tau(N \rightarrow \mu^+ \text{anything})$**  **T60**

<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;12</b>	<b><math>p, n</math></b>	<b>90</b>	<b>2</b>		<sup>74,75</sup> CHERRY	81 HOME
• • • We do not use the following data for averages, fits, limits, etc. • • •						
> 1.8	$p, n$	90			<sup>75</sup> COWSIK	80 CNTR
> 6	$p, n$	90			<sup>75</sup> LEARNED	79 RVUE

<sup>74</sup>We have converted 2 possible events to 90% CL limit.

<sup>75</sup>The muon may be primary or secondary.

**$\tau(N \rightarrow \nu \text{anything})$**  **T61**

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>
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>0.0002	$p, n$	90	0		LEARNED	79 RVUE

**$\tau(N \rightarrow e^+ \pi^0 \text{anything})$**  **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>
<b>&gt;0.6</b>	<b><math>p, n</math></b>	<b>90</b>	<b>0</b>		LEARNED	79 RVUE

**$\tau(N \rightarrow 2 \text{ bodies}, \nu\text{-free})$**  **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>
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>1.3	$p, n$	90	0		ALEKSEEV	81 BAKS

————  **$\Delta B = 2$  dinucleon modes** ————

**$\tau(pp \rightarrow \pi^+ \pi^+)$**  **T64**

<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>2.34</b>	BERGER	91B FREJ	$\tau$ per iron nucleus

**$\tau(pn \rightarrow \pi^+ \pi^0)$**  **T65**

<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;2.0</b>	<b>90</b>	<b>0</b>	<b>0.31</b>	BERGER	91B FREJ	$\tau$ per iron nucleus

**$\tau(nn \rightarrow \pi^+ \pi^-)$**  **T66**

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

**$\tau(nn \rightarrow \pi^0 \pi^0)$**  **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>
<b>&gt;3.4</b>	<b>90</b>	<b>0</b>	<b>0.78</b>	BERGER	91B FREJ	$\tau$ per iron nucleus

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

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

$\tau(pp \rightarrow \mu^+ \mu^+)$  **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>
>1.7	90	0	0.62	BERGER	91B FREJ	$\tau$ per iron nucleus

$\tau(pn \rightarrow e^+ \bar{\nu})$  **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>
>2.8	90	5	9.67	BERGER	91B FREJ	$\tau$ per iron nucleus

$\tau(pn \rightarrow \mu^+ \bar{\nu})$  **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>
>1.6	90	4	4.37	BERGER	91B FREJ	$\tau$ per iron nucleus

$\tau(nn \rightarrow \nu_e \bar{\nu}_e)$  **T73**

We include "invisible" modes here.

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

<sup>76</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>77</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>78</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>79</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.

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

T74

LIMIT

(10 <sup>30</sup> years)	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN	COMMENT
--------------------------	-----	------	----------	-------------	------	---------

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

>0.000006	90	4	4.4	BERGER	91B FREJ	$\tau$ per iron nucleus
-----------	----	---	-----	--------	----------	-------------------------

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

T75

This violates charge conservation as well as baryon number conservation.

VALUE (10 <sup>30</sup> years)	CL%	DOCUMENT ID	TECN
--------------------------------	-----	-------------	------

>0.000021	90	80 TRETAK 04	CNTR
-----------	----	--------------	------

<sup>80</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.

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

T76

This violates charge conservation as well as baryon number conservation.

LIMIT

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

>0.00005				90	81 BACK 03	BORX
----------	--	--	--	----	------------	------

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

>0.0000055	90			82 BERNABEI 00B	DAMA
------------	----	--	--	-----------------	------

<sup>81</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>82</sup>BERNABEI 00B looks for the decay of a <sup>127</sup>/<sub>52</sub>Te nucleus following the disappearance of a  $pp$  pair in the otherwise-stable <sup>129</sup>/<sub>54</sub>Xe nucleus.

 $\bar{p}$  PARTIAL MEAN LIVES

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

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

T77

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
---------------	-----	-------------	------	---------

> $7 \times 10^5$	90	GEER 00	APEX	8.9 GeV/c $\bar{p}$ beam
-------------------	----	---------	------	--------------------------

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

>1848	95	GEER 94	CALO	8.9 GeV/c $\bar{p}$ beam
-------	----	---------	------	--------------------------

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

T78

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
---------------	-----	-------------	------	---------

> $5 \times 10^4$	90	GEER 00	APEX	8.9 GeV/c $\bar{p}$ beam
-------------------	----	---------	------	--------------------------

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

> $5.0 \times 10^4$	90	HU 98B	APEX	8.9 GeV/c $\bar{p}$ beam
---------------------	----	--------	------	--------------------------

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

T79

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
---------------	-----	-------------	------	---------

> $4 \times 10^5$	90	GEER 00	APEX	8.9 GeV/c $\bar{p}$ beam
-------------------	----	---------	------	--------------------------

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

>554	95	GEER 94	CALO	8.9 GeV/c $\bar{p}$ beam
------	----	---------	------	--------------------------

**$\tau(\bar{p} \rightarrow \mu^- \pi^0)$**  **T80**

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&gt;5 × 10<sup>4</sup></b>	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 × 10 <sup>4</sup>	90	HU	98B	APEX 8.9 GeV/c $\bar{p}$ beam

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

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&gt; 2 × 10<sup>4</sup></b>	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

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

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&gt;8 × 10<sup>3</sup></b>	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 × 10 <sup>3</sup>	90	HU	98B	APEX 8.9 GeV/c $\bar{p}$ beam

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

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&gt;900</b>	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

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

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&gt;4 × 10<sup>3</sup></b>	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 × 10 <sup>3</sup>	90	HU	98B	APEX 8.9 GeV/c $\bar{p}$ beam

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

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&gt;9 × 10<sup>3</sup></b>	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

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

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&gt;7 × 10<sup>3</sup></b>	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 × 10 <sup>3</sup>	90	HU	98B	APEX 8.9 GeV/c $\bar{p}$ beam

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

<u>VALUE (years)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&gt;2 × 10<sup>4</sup></b>	90	GEER	00	APEX 8.9 GeV/c $\bar{p}$ beam

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

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

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

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
$>200$	90	<sup>83</sup> GEER	00	APEX 8.9 GeV/c $\bar{p}$ beam
<sup>83</sup> This GEER 00 measurement has been withdrawn; see GEER 00C.				

 $\tau(\bar{p} \rightarrow e^- \omega)$  T90

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

 $\tau(\bar{p} \rightarrow e^- K^*(892)^0)$  T91

VALUE (years)	CL%	DOCUMENT ID	TECN	COMMENT
$>1 \times 10^3$	90	<sup>84</sup> GEER	00	APEX 8.9 GeV/c $\bar{p}$ beam
<sup>84</sup> This GEER 00 measurement has been withdrawn; see GEER 00C.				

**p REFERENCES**

ARAKI	06	PRL 96 101802	T. Araki <i>et al.</i>	(KamLAND Collab.)
HORI	06	PRL 96 243401	M. Hori <i>et al.</i>	
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 (erratum)	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.)
ESCHRICH	01	PL B522 233	I. Eschrich <i>et al.</i>	(FNAL SELEX 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 (erratum)	S. Geer <i>et al.</i>	(FNAL APEX Collab.)
GEER	00C	PRL 85 3546 (erratum)	S. Geer <i>et al.</i>	(FNAL APEX Collab.)
GEER	00D	APJ 532 648	S.H. Geer, D.C. Kennedy	
MELNIKOV	00	PRL 84 1673	K. Melnikov <i>et al.</i>	(SLAC, KARL)
ROSENFELDR..	00	PL B479 381	R. Rosenfelder	
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)
MERGELL	96	NP A596 367	P. Mergell <i>et al.</i>	(MANZ, BONN)
GABRIELSE	95	PRL 74 3544	G. Gabrielse <i>et al.</i>	(HARV, MANZ, SEOUL)
MACGIBBON	95	PR C52 2097	B.E. MacGibbon <i>et al.</i>	(ILL, SASK, INRM)
GEER	94	PRL 72 1596	S. Geer <i>et al.</i>	(FNAL, UCLA, PSU)
WONG	94	IJMP E3 821	C.W. Wong	(UCLA)
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 (erratum)	A. Zieger <i>et al.</i>	(MPCM)
BERGER	91	ZPHY C50 385	C. Berger <i>et al.</i>	(FREJUS Collab.)
BERGER	91B	PL B269 227	C. Berger <i>et al.</i>	(FREJUS Collab.)
FEDERSPIEL	91	PRL 67 1511	F.J. Federspiel <i>et al.</i>	(ILL)
MCCORD	91	NIM B56/57 496	M. McCord <i>et al.</i>	
BECKER-SZ...	90	PR D42 2974	R.A. Becker-Szendy <i>et al.</i>	(IMB-3 Collab.)
ERICSON	90	EPL 11 295	T.E.O. Ericson, A. Richter	(CERN, DARM)
GABRIELSE	90	PRL 65 1317	G. Gabrielse <i>et al.</i>	(HARV, MANZ, WASH+)
BERGER	89	NP B313 509	C. Berger <i>et al.</i>	(FREJUS Collab.)
CHO	89	PRL 63 2559	D. Cho, K. Sangster, E.A. Hinds	(YALE)
HIRATA	89C	PL B220 308	K.S. Hirata <i>et al.</i>	(Kamiokande Collab.)
PHILLIPS	89	PL B224 348	T.J. Phillips <i>et al.</i>	(HPW Collab.)
KREISSL	88	ZPHY C37 557	A. Kreissl <i>et al.</i>	(CERN PS176 Collab.)
SEIDEL	88	PRL 61 2522	S. Seidel <i>et al.</i>	(IMB Collab.)
BARTELT	87	PR D36 1990	J.E. Bartelt <i>et al.</i>	(Soudan Collab.)
Also		PR D40 1701 (erratum)	J.E. Bartelt <i>et al.</i>	(Soudan Collab.)
COHEN	87	RMP 59 1121	E.R. Cohen, B.N. Taylor	(RISC, NBS)
HAINES	86	PRL 57 1986	T.J. Haines <i>et al.</i>	(IMB Collab.)
KAJITA	86	JPSJ 55 711	T. Kajita <i>et al.</i>	(Kamiokande Collab.)
ARISAKA	85	JPSJ 54 3213	K. Arisaka <i>et al.</i>	(Kamiokande Collab.)
BLEWITT	85	PRL 55 2114	G.B. Blewitt <i>et al.</i>	(IMB Collab.)
DZUBA	85	PL 154B 93	V.A. Dzuba, V.V. Flambaum, P.G. Silvestrov	(NOVO)
PARK	85	PRL 54 22	H.S. Park <i>et al.</i>	(IMB Collab.)
BATTISTONI	84	PL 133B 454	G. Battistoni <i>et al.</i>	(NUSEX Collab.)
MARINELLI	84	PL 137B 439	M. Marinelli, G. Morpurgo	(GENO)
WILKENING	84	PR A29 425	D.A. Wilkening, N.F. Ramsey, D.J. Larson	(HARV+)
BARTELT	83	PRL 50 651	J.E. Bartelt <i>et al.</i>	(MINN, ANL)
BATTISTONI	82	PL 118B 461	G. Battistoni <i>et al.</i>	(NUSEX Collab.)
KRISHNA...	82	PL 115B 349	M.R. Krishnaswamy <i>et al.</i>	(TATA, OSKC+)
ALEKSEEV	81	JETPL 33 651	E.N. Alekseev <i>et al.</i>	(PNPI)
		Translated from ZETFP 33 664.		
CHERRY	81	PRL 47 1507	M.L. Cherry <i>et al.</i>	(PENN, BNL)
COWSIK	80	PR D22 2204	R. Cowsik, V.S. Narasimham	(TATA)
SIMON	80	NP A333 381	G.G. Simon <i>et al.</i>	
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)
BORKOWSKI	74	NP A222 269	F. Borkowski <i>et al.</i>	
COHEN	73	JPCRD 2 664	E.R. Cohen, B.N. Taylor	(RISC, NBS)
DYLLA	73	PR A7 1224	H.F. Dylla, J.G. King	(MIT)
AKIMOV	72	JETP 35 651	Yu.K. Akimov <i>et al.</i>	(YERE)
		Translated from ZETF 62 1231.		

DIX	70	Thesis Case	F.W. Dix	(CASE)
HARRISON	69	PRL 22 1263	G.E. Harrison, P.G.H. Sandars, S.J. Wright	(OXF)
GURR	67	PR 158 1321	H.S. Gurr <i>et al.</i>	(CASE, WITW)
FREREJACQ...	66	PR 141 1308	D. Frerejacque <i>et al.</i>	
HAND	63	RMP 35 335	L.N. Hand <i>et al.</i>	
FLEROV	58	DOKL 3 79	G.N. Flerov <i>et al.</i>	(ASCI)

---