NODE=S016

# $p$

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

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

NODE=S016203

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

NODE=S016203

NODE=S016AMU

| VALUE (u) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **1.00727646677±0.00000000010** | MOHR | 08 | RVUE | 2006 CODATA value |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 1.00727646688±0.00000000013 | MOHR | 05 | RVUE | 2002 CODATA value |
| 1.00727646688±0.00000000013 | MOHR | 99 | RVUE | 1998 CODATA value |
| 1.007276470 ±0.000000012 | COHEN | 87 | RVUE | 1986 CODATA value |

## $p$ MASS (MeV)

NODE=S016205

The mass is known much more precisely in u (atomic mass units) than in MeV. The conversion from u to MeV, 1 u = 931.494028±0.000023 MeV/$c^2$ (MOHR 08, the 2006 CODATA value), involves the relatively poorly known electronic charge.

NODE=S016205

NODE=S016M

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **938.272013±0.000023** | MOHR | 08 | RVUE | 2006 CODATA value |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 938.272029±0.000080 | MOHR | 05 | RVUE | 2002 CODATA value |
| 938.271998±0.000038 | MOHR | 99 | RVUE | 1998 CODATA value |
| 938.27231 ±0.00028 | COHEN | 87 | RVUE | 1986 CODATA value |
| 938.2796 ±0.0027 | COHEN | 73 | RVUE | 1973 CODATA value |

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

NODE=S016211

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

NODE=S016211

NODE=S016DM

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| $\mathbf{<2 \times 10^{-9}}$ | 90 | [1] HORI | 06 | SPEC | $\overline{p}e^-$He atom |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<1.0 \times 10^{-8}$ | 90 | [1] HORI | 03 | SPEC | $\overline{p}e^-$ $^4$He, $\overline{p}e^-$ $^3$He |
| $<6 \times 10^{-8}$ | 90 | [1] HORI | 01 | SPEC | $\overline{p}e^-$He atom |
| $<5 \times 10^{-7}$ | | [2] TORII | 99 | SPEC | $\overline{p}e^-$He atom |

[1] HORI 01, HORI 03, and HORI 06 use the more-precisely-known constraint on the $\overline{p}$ charge-to-mass ratio of GABRIELSE 99 (see below) to get their results. Their results are not independent of the HORI 01, HORI 03, and HORI 06 values for $|q_p + q_{\overline{p}}|/e$, below.

NODE=S016DM;LINKAGE=C

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

NODE=S016DM;LINKAGE=B

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

NODE=S016212

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

NODE=S016212

NODE=S016CMR

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

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

NODE=S016CMR;LINKAGE=B

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

NODE=S016CMR;LINKAGE=A

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

NODE=S016213

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

NODE=S016213

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

NODE=S016DMM

→ NOT CHECKED ←

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

NODE=S016237

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

NODE=S016237

| *VALUE* | *CL%* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **$<2 \times 10^{-9}$** | 90 | [5] HORI | 06 | SPEC | $\overline{p}e^-$He atom |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<1.0\times10^{-8}$ | 90 | [5] HORI | 03 | SPEC | $\overline{p}e^-\,{}^4$He, $\overline{p}e^-\,{}^3$He |
| $<6\times10^{-8}$ | 90 | [5] HORI | 01 | SPEC | $\overline{p}e^-$He atom |
| $<5\times10^{-7}$ | | [6] TORII | 99 | SPEC | $\overline{p}e^-$He atom |
| $<2\times10^{-5}$ | | [7] HUGHES | 92 | RVUE | |

NODE=S016DQ2

[5] HORI 01, HORI 03, and HORI 06 use the more-precisely-known constraint on the $\overline{p}$ charge-to-mass ratio of GABRIELSE 99 (see above) to get their results. Their results are not independent of the HORI 01, HORI 03, and HORI 06 values for $|m_p - m_{\overline{p}}|/m_p$, above.

NODE=S016DQ2;LINKAGE=C

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

NODE=S016DQ2;LINKAGE=B

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

NODE=S016DQ2;LINKAGE=A

## $|q_p + q_e|/e$

NODE=S016250

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

NODE=S016250

| *VALUE* | *DOCUMENT ID* | | *COMMENT* |
|---|---|---|---|
| **$<1.0\times10^{-21}$** | [8] DYLLA | 73 | Neutrality of $SF_6$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | |
| $<3.2\times10^{-20}$ | [9] SENGUPTA | 00 | binary pulsar |
| $<0.8\times10^{-21}$ | MARINELLI | 84 | Magnetic levitation |

NODE=S016DQ

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

NODE=S016DQ;LINKAGE=D

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

NODE=S016DQ;LINKAGE=SE

## *p* MAGNETIC MOMENT

NODE=S016235

See the "Note on Baryon Magnetic Moments" in the $\Lambda$ Listings.

NODE=S016235

| *VALUE* ($\mu_N$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **2.792847356±0.000000023** | MOHR | 08 | RVUE | 2006 CODATA value |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 2.792847351±0.000000028 | MOHR | 05 | RVUE | 2002 CODATA value |
| 2.792847337±0.000000029 | MOHR | 99 | RVUE | 1998 CODATA value |
| 2.792847386±0.000000063 | COHEN | 87 | RVUE | 1986 CODATA value |
| 2.7928456 ±0.0000011 | COHEN | 73 | RVUE | 1973 CODATA value |

NODE=S016MM

## $\overline{p}$ MAGNETIC MOMENT

NODE=S016240

A few early results have been omitted.

NODE=S016240

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

NODE=S016MM1

## $(\mu_p + \mu_{\overline{p}}) / \mu_p$ NODE=S016242

A test of $CPT$ invariance. Calculated from the $p$ and $\overline{p}$ magnetic moments, above. NODE=S016242

NODE=S016MMD

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

→ NOT CHECKED ←

## $p$ ELECTRIC DIPOLE MOMENT NODE=S016245

A nonzero value is forbidden by both $T$ invariance and $P$ invariance. NODE=S016245

NODE=S016EDM

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

OCCUR=2

[10] DMITRIEV 03 calculates this limit from the limit on the electric dipole moment of the $^{199}$Hg atom. NODE=S016EDM;LINKAGE=DM

[11] This WILKENING 84 value includes a finite-size effect and a magnetic effect. NODE=S016EDM;LINKAGE=A

[12] This WILKENING 84 value is more cautious than the other and excludes the finite-size effect, which relies on uncertain nuclear integrals. NODE=S016EDM;LINKAGE=B

## $p$ ELECTRIC POLARIZABILITY $\alpha_p$ NODE=S016247

For a very complete review of the "polarizability of the nucleon and Compton scattering," see SCHUMACHER 05. His recommended values for the proton are $\alpha_p = (12.0 \pm 0.6) \times 10^{-4}$ fm$^3$ and $\beta_p = (1.9 \mp 0.6) \times 10^{-4}$ fm$^3$, almost exactly our averages. NODE=S016EPL

NODE=S016EPL

| VALUE ($10^{-4}$ fm$^3$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **12.0 $\pm$0.6 OUR AVERAGE** | | | | |
| 12.1 $\pm$1.1 $\pm$0.5 | [13] BEANE | 03 | | EFT + $\gamma p$ |
| $11.82\pm0.98^{+0.52}_{-0.98}$ | [14] BLANPIED | 01 | LEGS | $p(\vec{\gamma},\gamma)$, $p(\vec{\gamma},\pi^0)$, $p(\vec{\gamma},\pi^+)$ |
| 11.9 $\pm$0.5 $\pm$1.3 | [15] OLMOSDEL... | 01 | CNTR | $\gamma p$ Compton scattering |
| 12.1 $\pm$0.8 $\pm$0.5 | [16] MACGIBBON | 95 | RVUE | global average |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 11.7 $\pm$0.8 $\pm$0.7 | [17] BARANOV | 01 | RVUE | Global average |
| 12.5 $\pm$0.6 $\pm$0.9 | MACGIBBON | 95 | CNTR | $\gamma p$ Compton scattering |
| 9.8 $\pm$0.4 $\pm$1.1 | HALLIN | 93 | CNTR | $\gamma p$ Compton scattering |
| $10.62^{+1.25}_{-1.19}{}^{+1.07}_{-1.03}$ | ZIEGER | 92 | CNTR | $\gamma p$ Compton scattering |
| 10.9 $\pm$2.2 $\pm$1.3 | [18] FEDERSPIEL | 91 | CNTR | $\gamma p$ Compton scattering |

OCCUR=2

[13] 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) $\alpha_N = (13.0 \pm 1.9^{+3.9}_{-1.5}) \times 10^{-4}$ fm$^3$ and $\beta_N = (-1.8 \pm 1.9^{+2.1}_{-0.9}) \times 10^{-4}$ fm$^3$. NODE=S016EPL;LINKAGE=B3

[14] 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. NODE=S016EPL;LINKAGE=SF

[15] This OLMOSDELEON 01 result uses the TAPS data alone, and does not use the (re-evaluated) sum-rule constraint that $\alpha+\beta = (13.8 \pm 0.4) \times 10^{-4}$ fm$^3$. See the paper for a discussion. NODE=S016EPL;LINKAGE=OD

[16] MACGIBBON 95 combine the results of ZIEGER 92, FEDERSPIEL 91, and their own experiment to get a "global average" in which model errors and systematic errors are treated in a consistent way. See MACGIBBON 95 for a discussion. NODE=S016EPL;LINKAGE=MG

[17] BARANOV 01 combines the results of 10 experiments from 1958 through 1995 to get a global average that takes into account both systematic and model errors and does not use the theoretical constraint on the sum $\alpha_p + \beta_p$. NODE=S016EPL;LINKAGE=BV

[18] 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 $(7.0\pm2.2\pm1.3)\times10^{-4}$ fm$^3$. NODE=S016EPL;LINKAGE=A

## $p$ MAGNETIC POLARIZABILITY $\beta_p$

NODE=S016248

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

NODE=S016248

NODE=S016MPL

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

OCCUR=2

[19] 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) $\alpha_N = (13.0 \pm 1.9 ^{+3.9}_{-1.5}) \times 10^{-4}$ fm$^3$ and $\beta_N = (-1.8 \pm 1.9 ^{+2.1}_{-0.9}) \times 10^{-4}$ fm$^3$.

NODE=S016MPL;LINKAGE=B3

[20] 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.

NODE=S016MPL;LINKAGE=SF

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

NODE=S016MPL;LINKAGE=OD

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

NODE=S016MPL;LINKAGE=MG

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

NODE=S016MPL;LINKAGE=BV

## $p$ CHARGE RADIUS

NODE=S016249

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

NODE=S016CR

NODE=S016CR

| VALUE (fm) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.8768±0.0069** | MOHR | 08 | RVUE | 2006 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 |
| 0.8750±0.0068 | MOHR | 05 | RVUE | 2002 CODATA value |
| 0.895 ±0.010 ±0.013 | SICK | 03 | | $e p \to e p$ reanalysis |
| 0.830 ±0.040 ±0.040 | [24] ESCHRICH | 01 | | $e p \to e p$ |
| 0.883 ±0.014 | MELNIKOV | 00 | | 1S Lamb Shift in H |
| 0.880 ±0.015 | ROSENFELDR... | 00 | | $e p$ + Coul. corrections |
| 0.847 ±0.008 | MERGELL | 96 | | $e p$ + disp. relations |
| 0.877 ±0.024 | WONG | 94 | | reanalysis of Mainz $e p$ data |
| 0.865 ±0.020 | MCCORD | 91 | | $e p \to e p$ |
| 0.862 ±0.012 | SIMON | 80 | | $e p \to e p$ |
| 0.880 ±0.030 | BORKOWSKI | 74 | | $e p \to e p$ |
| 0.810 ±0.020 | AKIMOV | 72 | | $e p \to e p$ |
| 0.800 ±0.025 | FREREJACQ... | 66 | | $e p \to e p$ ($CH_2$ tgt.) |
| 0.805 ±0.011 | HAND | 63 | | $e p \to e p$ |

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

NODE=S016CR;LINKAGE=ES

## $p$ MEAN LIFE

NODE=S016215

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.

NODE=S016T

NODE=S016T

| LIMIT (years) | PARTICLE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **>5.8 × 10$^{29}$** | ***n*** | 90 | [25] ARAKI | 06 | KLND | $n \to$ invisible |
| **>2.1 × 10$^{29}$** | ***p*** | 90 | [26] AHMED | 04 | SNO | $p \to$ invisible |

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $>1.9 \times 10^{29}$ | $n$ | 90 | [26] AHMED | 04 | SNO | $n \rightarrow$ invisible | OCCUR=2 |
| $>1.8 \times 10^{25}$ | $n$ | 90 | [27] BACK | 03 | BORX | | |
| $>1.1 \times 10^{26}$ | $p$ | 90 | [27] BACK | 03 | BORX | | OCCUR=2 |
| $>3.5 \times 10^{28}$ | $p$ | 90 | [28] ZDESENKO | 03 | | $p \rightarrow$ invisible | |
| $>1 \times 10^{28}$ | $p$ | 90 | [29] AHMAD | 02 | SNO | $p \rightarrow$ invisible | |
| $>4 \times 10^{23}$ | $p$ | 95 | TRETYAK | 01 | | $d \rightarrow n + ?$ | |
| $>1.9 \times 10^{24}$ | $p$ | 90 | [30] BERNABEI | 00B | DAMA | | |
| $>1.6 \times 10^{25}$ | $p$, $n$ | | [31,32] EVANS | 77 | | | |
| $>3 \times 10^{23}$ | $p$ | | [32] DIX | 70 | CNTR | | |
| $>3 \times 10^{23}$ | $p$, $n$ | | [32,33] FLEROV | 58 | | | |

[25] ARAKI 06 looks for signs of de-excitation of the residual nucleus after disappearance of a neutron from the $s$ shell of $^{12}$C. NODE=S016T;LINKAGE=AR

[26] AHMED 04 looks for $\gamma$ rays from the de-excitation of a residual $^{15}$O* or $^{15}$N* following the disappearance of a neutron or proton in $^{16}$O. NODE=S016T;LINKAGE=A4

[27] BACK 03 looks for decays of unstable nuclides left after $N$ decays of parent $^{12}$C, $^{13}$C, $^{16}$O nuclei. These are "invisible channel" limits. NODE=S016T;LINKAGE=BK

[28] ZDESENKO 03 gets this limit on proton disappearance in deuterium by analyzing SNO data in AHMAD 02. NODE=S016T;LINKAGE=ZO

[29] AHMAD 02 (see its footnote 7) looks for neutrons left behind after the disappearance of the proton in deuterons. NODE=S016T;LINKAGE=KH

[30] BERNABEI 00B looks for the decay of a $^{128}_{53}$I nucleus following the disappearance of a proton in the otherwise-stable $^{129}_{54}$Xe nucleus. NODE=S016T;LINKAGE=BN

[31] EVANS 77 looks for the daughter nuclide $^{129}$Xe from possible $^{130}$Te decays in ancient Te ore samples. NODE=S016T;LINKAGE=E

[32] This mean-life limit has been obtained from a half-life limit by dividing the latter by ln(2) = 0.693. NODE=S016T;LINKAGE=H

[33] FLEROV 58 looks for the spontaneous fission of a $^{232}$Th nucleus after the disappearance of one of its nucleons. NODE=S016T;LINKAGE=F

## $\overline{p}$ MEAN LIFE

NODE=S016220

Of the two astrophysical limits here, that of GEER 00D involves considerably more refinements in its modeling. The other limits come from direct observations of stored antiprotons. See also "$\overline{p}$ Partial Mean Lives" after "$p$ Partial Mean Lives," below, for exclusive-mode limits. The best (lifetime/branching fraction) limit there is $7 \times 10^5$ years, for $\overline{p} \rightarrow e^- \gamma$. We advance only the exclusive-mode limits to our Summary Tables. NODE=S016220

NODE=S016TA

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

[34] GEER 00D uses agreement between a model of galactic $\overline{p}$ production and propagation and the observed $\overline{p}/p$ cosmic-ray spectrum to set this limit. NODE=S016TA;LINKAGE=GE

## $p$ DECAY MODES

NODE=S016225;NODE=S016

See the "Note on Nucleon Decay" in our 1994 edition (Phys. Rev. **D50**, 1173) for a short review. NODE=S016

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 |
|---|---|---|

## Antilepton + meson

NODE=S016;CLUMP=B

| | | | | |
|---|---|---|---|---|
| $\tau_1$ | $N \to e^+ \pi$ | $> 158$ ($n$), $> 1600$ ($p$) | 90% | DESIG=6;OUR LIM;→ NOT CHECKED ← |
| $\tau_2$ | $N \to \mu^+ \pi$ | $> 100$ ($n$), $> 473$ ($p$) | 90% | DESIG=7;OUR LIM;→ NOT CHECKED ← |
| $\tau_3$ | $N \to \nu \pi$ | $> 112$ ($n$), $> 25$ ($p$) | 90% | DESIG=10;OUR LIM;→ NOT CHECKED ← |
| $\tau_4$ | $p \to e^+ \eta$ | $> 313$ | 90% | DESIG=22;OUR LIM;→ NOT CHECKED ← |
| $\tau_5$ | $p \to \mu^+ \eta$ | $> 126$ | 90% | DESIG=23;OUR LIM;→ NOT CHECKED ← |
| $\tau_6$ | $n \to \nu \eta$ | $> 158$ | 90% | DESIG=24;OUR LIM;→ NOT CHECKED ← |
| $\tau_7$ | $N \to e^+ \rho$ | $> 217$ ($n$), $> 75$ ($p$) | 90% | DESIG=14;OUR LIM;→ NOT CHECKED ← |
| $\tau_8$ | $N \to \mu^+ \rho$ | $> 228$ ($n$), $> 110$ ($p$) | 90% | DESIG=15;OUR LIM;→ NOT CHECKED ← |
| $\tau_9$ | $N \to \nu \rho$ | $> 19$ ($n$), $> 162$ ($p$) | 90% | DESIG=25;OUR LIM;→ NOT CHECKED ← |
| $\tau_{10}$ | $p \to e^+ \omega$ | $> 107$ | 90% | DESIG=12;OUR LIM;→ NOT CHECKED ← |
| $\tau_{11}$ | $p \to \mu^+ \omega$ | $> 117$ | 90% | DESIG=13;OUR LIM;→ NOT CHECKED ← |
| $\tau_{12}$ | $n \to \nu \omega$ | $> 108$ | 90% | DESIG=26;OUR LIM;→ NOT CHECKED ← |
| $\tau_{13}$ | $N \to e^+ K$ | $> 17$ ($n$), $> 150$ ($p$) | 90% | DESIG=8;OUR LIM;→ NOT CHECKED ← |
| $\tau_{14}$ | $p \to e^+ K^0_S$ | $> 120$ | 90% | DESIG=50;OUR LIM;→ NOT CHECKED ← |
| $\tau_{15}$ | $p \to e^+ K^0_L$ | $> 51$ | 90% | DESIG=51;OUR LIM;→ NOT CHECKED ← |
| $\tau_{16}$ | $N \to \mu^+ K$ | $> 26$ ($n$), $> 120$ ($p$) | 90% | DESIG=9;OUR LIM;→ NOT CHECKED ← |
| $\tau_{17}$ | $p \to \mu^+ K^0_S$ | $> 150$ | 90% | DESIG=52;OUR LIM;→ NOT CHECKED ← |
| $\tau_{18}$ | $p \to \mu^+ K^0_L$ | $> 83$ | 90% | DESIG=53;OUR LIM;→ NOT CHECKED ← |
| $\tau_{19}$ | $N \to \nu K$ | $> 86$ ($n$), $> 670$ ($p$) | 90% | DESIG=11;OUR LIM;→ NOT CHECKED ← |
| $\tau_{20}$ | $n \to \nu K^0_S$ | $> 51$ | 90% | DESIG=99;OUR LIM;→ NOT CHECKED ← |
| $\tau_{21}$ | $p \to e^+ K^*(892)^0$ | $> 84$ | 90% | DESIG=34;OUR LIM;→ NOT CHECKED ← |
| $\tau_{22}$ | $N \to \nu K^*(892)$ | $> 78$ ($n$), $> 51$ ($p$) | 90% | DESIG=18;OUR LIM;→ NOT CHECKED ← |

## Antilepton + mesons

NODE=S016;CLUMP=E

| | | | | |
|---|---|---|---|---|
| $\tau_{23}$ | $p \to e^+ \pi^+ \pi^-$ | $> 82$ | 90% | DESIG=56;OUR LIM;→ NOT CHECKED ← |
| $\tau_{24}$ | $p \to e^+ \pi^0 \pi^0$ | $> 147$ | 90% | DESIG=57;OUR LIM;→ NOT CHECKED ← |
| $\tau_{25}$ | $n \to e^+ \pi^- \pi^0$ | $> 52$ | 90% | DESIG=58;OUR LIM;→ NOT CHECKED ← |
| $\tau_{26}$ | $p \to \mu^+ \pi^+ \pi^-$ | $> 133$ | 90% | DESIG=48;OUR LIM;→ NOT CHECKED ← |
| $\tau_{27}$ | $p \to \mu^+ \pi^0 \pi^0$ | $> 101$ | 90% | DESIG=59;OUR LIM;→ NOT CHECKED ← |
| $\tau_{28}$ | $n \to \mu^+ \pi^- \pi^0$ | $> 74$ | 90% | DESIG=60;OUR LIM;→ NOT CHECKED ← |
| $\tau_{29}$ | $n \to e^+ K^0 \pi^-$ | $> 18$ | 90% | DESIG=61;OUR LIM;→ NOT CHECKED ← |

## Lepton + meson

NODE=S016;CLUMP=F

| | | | | |
|---|---|---|---|---|
| $\tau_{30}$ | $n \to e^- \pi^+$ | $> 65$ | 90% | DESIG=29;OUR LIM;→ NOT CHECKED ← |
| $\tau_{31}$ | $n \to \mu^- \pi^+$ | $> 49$ | 90% | DESIG=30;OUR LIM;→ NOT CHECKED ← |
| $\tau_{32}$ | $n \to e^- \rho^+$ | $> 62$ | 90% | DESIG=31;OUR LIM;→ NOT CHECKED ← |
| $\tau_{33}$ | $n \to \mu^- \rho^+$ | $> 7$ | 90% | DESIG=32;OUR LIM;→ NOT CHECKED ← |
| $\tau_{34}$ | $n \to e^- K^+$ | $> 32$ | 90% | DESIG=33;OUR LIM;→ NOT CHECKED ← |
| $\tau_{35}$ | $n \to \mu^- K^+$ | $> 57$ | 90% | DESIG=35;OUR LIM;→ NOT CHECKED ← |

## Lepton + mesons

NODE=S016;CLUMP=G

| | | | | |
|---|---|---|---|---|
| $\tau_{36}$ | $p \to e^- \pi^+ \pi^+$ | $> 30$ | 90% | DESIG=47;OUR LIM;→ NOT CHECKED ← |
| $\tau_{37}$ | $n \to e^- \pi^+ \pi^0$ | $> 29$ | 90% | DESIG=39;OUR LIM;→ NOT CHECKED ← |
| $\tau_{38}$ | $p \to \mu^- \pi^+ \pi^+$ | $> 17$ | 90% | DESIG=49;OUR LIM;→ NOT CHECKED ← |
| $\tau_{39}$ | $n \to \mu^- \pi^+ \pi^0$ | $> 34$ | 90% | DESIG=40;OUR LIM;→ NOT CHECKED ← |
| $\tau_{40}$ | $p \to e^- \pi^+ K^+$ | $> 75$ | 90% | DESIG=41;OUR LIM;→ NOT CHECKED ← |
| $\tau_{41}$ | $p \to \mu^- \pi^+ K^+$ | $> 245$ | 90% | DESIG=42;OUR LIM;→ NOT CHECKED ← |

## Antilepton + photon(s)

NODE=S016;CLUMP=C

| | | | | |
|---|---|---|---|---|
| $\tau_{42}$ | $p \to e^+ \gamma$ | $> 670$ | 90% | DESIG=3;OUR LIM;→ NOT CHECKED ← |
| $\tau_{43}$ | $p \to \mu^+ \gamma$ | $> 478$ | 90% | DESIG=4;OUR LIM;→ NOT CHECKED ← |
| $\tau_{44}$ | $n \to \nu \gamma$ | $> 28$ | 90% | DESIG=5;OUR LIM;→ NOT CHECKED ← |
| $\tau_{45}$ | $p \to e^+ \gamma \gamma$ | $> 100$ | 90% | DESIG=54;OUR LIM;→ NOT CHECKED ← |
| $\tau_{46}$ | $n \to \nu \gamma \gamma$ | $> 219$ | 90% | DESIG=93;OUR LIM;→ NOT CHECKED ← |

## Three (or more) leptons

NODE=S016;CLUMP=D

| | | | | |
|---|---|---|---|---|
| $\tau_{47}$ | $p \to e^+ e^+ e^-$ | $> 793$ | 90% | DESIG=16;OUR LIM;→ NOT CHECKED ← |
| $\tau_{48}$ | $p \to e^+ \mu^+ \mu^-$ | $> 359$ | 90% | DESIG=45;OUR LIM;→ NOT CHECKED ← |
| $\tau_{49}$ | $p \to e^+ \nu \nu$ | $> 17$ | 90% | DESIG=36;OUR LIM;→ NOT CHECKED ← |
| $\tau_{50}$ | $n \to e^+ e^- \nu$ | $> 257$ | 90% | DESIG=27;OUR LIM;→ NOT CHECKED ← |
| $\tau_{51}$ | $n \to \mu^+ e^- \nu$ | $> 83$ | 90% | DESIG=37;OUR LIM;→ NOT CHECKED ← |
| $\tau_{52}$ | $n \to \mu^+ \mu^- \nu$ | $> 79$ | 90% | DESIG=28;OUR LIM;→ NOT CHECKED ← |
| $\tau_{53}$ | $p \to \mu^+ e^+ e^-$ | $> 529$ | 90% | DESIG=55;OUR LIM;→ NOT CHECKED ← |
| $\tau_{54}$ | $p \to \mu^+ \mu^+ \mu^-$ | $> 675$ | 90% | DESIG=17;OUR LIM;→ NOT CHECKED ← |
| $\tau_{55}$ | $p \to \mu^+ \nu \nu$ | $> 21$ | 90% | DESIG=38;OUR LIM;→ NOT CHECKED ← |
| $\tau_{56}$ | $p \to e^- \mu^+ \mu^+$ | $> 6$ | 90% | DESIG=46;OUR LIM;→ NOT CHECKED ← |
| $\tau_{57}$ | $n \to 3\nu$ | $> 0.0005$ | 90% | DESIG=21;OUR LIM;→ NOT CHECKED ← |
| $\tau_{58}$ | $n \to 5\nu$ | | | DESIG=86 |

## Inclusive modes

NODE=S016;CLUMP=A

| | | | | |
|---|---|---|---|---|
| $\tau_{59}$ | $N \to e^+$ anything | $> 0.6$ ($n$, $p$) | 90% | DESIG=1;OUR LIM;→ NOT CHECKED ← |
| $\tau_{60}$ | $N \to \mu^+$ anything | $> 12$ ($n$, $p$) | 90% | DESIG=2;OUR LIM;→ NOT CHECKED ← |
| $\tau_{61}$ | $N \to \nu$ anything | | | DESIG=20 |
| $\tau_{62}$ | $N \to e^+ \pi^0$ anything | $> 0.6$ ($n$, $p$) | 90% | DESIG=19;OUR LIM;→ NOT CHECKED ← |
| $\tau_{63}$ | $N \to$ 2 bodies, $\nu$-free | | | DESIG=191 |

## $\Delta B = 2$ dinucleon modes

NODE=S016;CLUMP=I

The following are lifetime limits per iron nucleus.

NODE=S016

| | | | | |
|---|---|---|---|---|
| $\tau_{64}$ | $pp \to \pi^+ \pi^+$ | $> 0.7$ | 90% | DESIG=62;OUR LIM;→ NOT CHECKED ← |
| $\tau_{65}$ | $pn \to \pi^+ \pi^0$ | $> 2$ | 90% | DESIG=63;OUR LIM;→ NOT CHECKED ← |
| $\tau_{66}$ | $nn \to \pi^+ \pi^-$ | $> 0.7$ | 90% | DESIG=64;OUR LIM;→ NOT CHECKED ← |
| $\tau_{67}$ | $nn \to \pi^0 \pi^0$ | $> 3.4$ | 90% | DESIG=65;OUR LIM;→ NOT CHECKED ← |
| $\tau_{68}$ | $pp \to e^+ e^+$ | $> 5.8$ | 90% | DESIG=66;OUR LIM;→ NOT CHECKED ← |
| $\tau_{69}$ | $pp \to e^+ \mu^+$ | $> 3.6$ | 90% | DESIG=67;OUR LIM;→ NOT CHECKED ← |
| $\tau_{70}$ | $pp \to \mu^+ \mu^+$ | $> 1.7$ | 90% | DESIG=68;OUR LIM;→ NOT CHECKED ← |
| $\tau_{71}$ | $pn \to e^+ \overline{\nu}$ | $> 2.8$ | 90% | DESIG=69;OUR LIM;→ NOT CHECKED ← |
| $\tau_{72}$ | $pn \to \mu^+ \overline{\nu}$ | $> 1.6$ | 90% | DESIG=70;OUR LIM;→ NOT CHECKED ← |
| $\tau_{73}$ | $nn \to \nu_e \overline{\nu}_e$ | $> 0.000049$ | 90% | DESIG=71;OUR LIM;→ NOT CHECKED ← |
| $\tau_{74}$ | $nn \to \nu_\mu \overline{\nu}_\mu$ | | | DESIG=72 |
| $\tau_{75}$ | $pn \to$ invisible | $>2.1 \times 10^{-5}$ | 90% | DESIG=101 |
| $\tau_{76}$ | $pp \to$ invisible | $> 0.00005$ | 90% | DESIG=100;OUR LIM;→ NOT CHECKED ← |

## $\overline{p}$ DECAY MODES

NODE=S016;CLUMP=M
NODE=S016

| | Mode | Partial mean life (years) | Confidence level | |
|---|---|---|---|---|
| $\tau_{77}$ | $\overline{p} \to e^- \gamma$ | $> 7 \times 10^5$ | 90% | DESIG=81;OUR LIM;→ NOT CHECKED ← |
| $\tau_{78}$ | $\overline{p} \to \mu^- \gamma$ | $> 5 \times 10^4$ | 90% | DESIG=87;OUR LIM;→ NOT CHECKED ← |
| $\tau_{79}$ | $\overline{p} \to e^- \pi^0$ | $> 4 \times 10^5$ | 90% | DESIG=82;OUR LIM;→ NOT CHECKED ← |
| $\tau_{80}$ | $\overline{p} \to \mu^- \pi^0$ | $> 5 \times 10^4$ | 90% | DESIG=88;OUR LIM;→ NOT CHECKED ← |
| $\tau_{81}$ | $\overline{p} \to e^- \eta$ | $> 2 \times 10^4$ | 90% | DESIG=83;OUR LIM;→ NOT CHECKED ← |
| $\tau_{82}$ | $\overline{p} \to \mu^- \eta$ | $> 8 \times 10^3$ | 90% | DESIG=89;OUR LIM;→ NOT CHECKED ← |
| $\tau_{83}$ | $\overline{p} \to e^- K^0_S$ | $> 900$ | 90% | DESIG=84;OUR LIM;→ NOT CHECKED ← |
| $\tau_{84}$ | $\overline{p} \to \mu^- K^0_S$ | $> 4 \times 10^3$ | 90% | DESIG=90;OUR LIM;→ NOT CHECKED ← |
| $\tau_{85}$ | $\overline{p} \to e^- K^0_L$ | $> 9 \times 10^3$ | 90% | DESIG=85;OUR LIM;→ NOT CHECKED ← |
| $\tau_{86}$ | $\overline{p} \to \mu^- K^0_L$ | $> 7 \times 10^3$ | 90% | DESIG=91;OUR LIM;→ NOT CHECKED ← |
| $\tau_{87}$ | $\overline{p} \to e^- \gamma\gamma$ | $> 2 \times 10^4$ | 90% | DESIG=94;OUR LIM;→ NOT CHECKED ← |
| $\tau_{88}$ | $\overline{p} \to \mu^- \gamma\gamma$ | $> 2 \times 10^4$ | 90% | DESIG=92;OUR LIM;→ NOT CHECKED ← |
| $\tau_{89}$ | $\overline{p} \to e^- \rho$ | | | DESIG=95 |
| $\tau_{90}$ | $\overline{p} \to e^- \omega$ | $> 200$ | 90% | DESIG=96;OUR LIM;→ NOT CHECKED ← |
| $\tau_{91}$ | $\overline{p} \to e^- K^*(892)^0$ | | | DESIG=97 |

## *p* PARTIAL MEAN LIVES

NODE=S016230

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.

NODE=S016230

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 ———

NODE=S016305

### $\tau(N \to e^+ \pi)$ $\tau_1$

NODE=S016T06
NODE=S016T06

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| **> 158** | ***n*** | **90** | **3** | **5** | MCGREW | 99 | IMB3 | OCCUR=2 |
| **>1600** | ***p*** | **90** | **0** | **0.1** | SHIOZAWA | 98 | SKAM | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | | | |
| > 540 | *p* | 90 | 0 | 0.2 | MCGREW | 99 | IMB3 | |
| > 70 | *p* | 90 | 0 | 0.5 | BERGER | 91 | FREJ | |
| > 70 | *n* | 90 | 0 | ≤ 0.1 | BERGER | 91 | FREJ | OCCUR=2 |
| > 550 | *p* | 90 | 0 | 0.7 | [35] BECKER-SZ... | 90 | IMB3 | |
| > 260 | *p* | 90 | 0 | <0.04 | HIRATA | 89C | KAMI | |
| > 130 | *n* | 90 | 0 | <0.2 | HIRATA | 89C | KAMI | OCCUR=2 |
| > 310 | *p* | 90 | 0 | 0.6 | SEIDEL | 88 | IMB | |
| > 100 | *n* | 90 | 0 | 1.6 | SEIDEL | 88 | IMB | OCCUR=2 |
| > 1.3 | *n* | 90 | 0 | | BARTELT | 87 | SOUD | |
| > 1.3 | *p* | 90 | 0 | | BARTELT | 87 | SOUD | OCCUR=2 |
| > 250 | *p* | 90 | 0 | 0.3 | HAINES | 86 | IMB | |
| > 31 | *n* | 90 | 8 | 9 | HAINES | 86 | IMB | OCCUR=2 |
| > 64 | *p* | 90 | 0 | <0.4 | ARISAKA | 85 | KAMI | |
| > 26 | *n* | 90 | 0 | <0.7 | ARISAKA | 85 | KAMI | OCCUR=2 |
| > 82 | *p* (free) | 90 | 0 | 0.2 | BLEWITT | 85 | IMB | |
| > 250 | *p* | 90 | 0 | 0.2 | BLEWITT | 85 | IMB | OCCUR=2 |
| > 25 | *n* | 90 | 4 | 4 | PARK | 85 | IMB | OCCUR=2 |
| > 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 | OCCUR=2 |
| > 5.8 | *p* | 90 | 2 | | [37] KRISHNA... | 82 | KOLR | |
| > 5.8 | *n* | 90 | 2 | | [37] KRISHNA... | 82 | KOLR | OCCUR=2 |
| > 0.1 | *n* | 90 | | | [38] GURR | 67 | CNTR | |

[35] This BECKER-SZENDY 90 result includes data from SEIDEL 88. NODE=S016T06;LINKAGE=L
[36] Limit based on zero events. NODE=S016T06;LINKAGE=B
[37] We have calculated 90% CL limit from 1 confined event. NODE=S016T06;LINKAGE=K
[38] We have converted half-life to 90% CL mean life. NODE=S016T06;LINKAGE=G

### $\tau(N \to \mu^+ \pi)$ $\tau_2$

NODE=S016T07
NODE=S016T07

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

## $\tau(N \rightarrow \nu\pi)$ $\tau_3$

NODE=S016T10
NODE=S016T10

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| **> 16** | ***p*** | **90** | **6** | **6.7** | WALL | 00B | SOU2 | |
| **>112** | ***n*** | **90** | **6** | **6.6** | MCGREW | 99 | IMB3 | OCCUR=2 |

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

| LIMIT | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| > 39 | *n* | 90 | 4 | 3.8 | WALL | 00B | SOU2 | OCCUR=2 |
| > 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 | OCCUR=2 |
| > 25 | *p* | 90 | 32 | 32.8 | [39] HIRATA | 89C | KAMI | |
| >100 | *n* | 90 | 1 | 3 | HIRATA | 89C | KAMI | OCCUR=2 |
| > 6 | *n* | 90 | 73 | 60 | HAINES | 86 | IMB | |
| > 2 | *p* | 90 | 16 | 13 | KAJITA | 86 | KAMI | |
| > 40 | *n* | 90 | 0 | 1 | KAJITA | 86 | KAMI | OCCUR=2 |
| > 7 | *n* | 90 | 28 | 19 | PARK | 85 | IMB | |
| > 7 | *n* | 90 | 0 | | BATTISTONI | 84 | NUSX | |
| > 2 | *p* | 90 | $\leq 3$ | | BATTISTONI | 84 | NUSX | OCCUR=2 |
| > 5.8 | *p* | 90 | 1 | | [40] KRISHNA... | 82 | KOLR | |
| > 0.3 | *p* | 90 | 2 | | [41] CHERRY | 81 | HOME | |
| > 0.1 | *p* | 90 | | | [42] GURR | 67 | CNTR | |

[39] In estimating the background, this HIRATA 89C limit (as opposed to the later limits of WALL 00B and MCGREW 99) does not take into account present understanding that the flux of $\nu_\mu$ originating in the upper atmosphere is depleted. Doing so would reduce the background and thus also would reduce the limit here. NODE=S016T10;LINKAGE=HI

[40] We have calculated 90% CL limit from 1 confined event. NODE=S016T10;LINKAGE=K

[41] We have converted 2 possible events to 90% CL limit. NODE=S016T10;LINKAGE=C

[42] We have converted half-life to 90% CL mean life. NODE=S016T10;LINKAGE=G

## $\tau(p \rightarrow e^+\eta)$ $\tau_4$

NODE=S016T22
NODE=S016T22

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| **>313** | ***p*** | **90** | **0** | **0.2** | MCGREW | 99 | IMB3 | |

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

| LIMIT | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| > 81 | *p* | 90 | 1 | 1.7 | WALL | 00B | SOU2 | |
| > 44 | *p* | 90 | 0 | 0.1 | BERGER | 91 | FREJ | |
| >140 | *p* | 90 | 0 | <0.04 | HIRATA | 89C | KAMI | |
| >100 | *p* | 90 | 0 | 0.6 | SEIDEL | 88 | IMB | |
| >200 | *p* | 90 | 5 | 3.3 | HAINES | 86 | IMB | |
| > 64 | *p* | 90 | 0 | <0.8 | ARISAKA | 85 | KAMI | |
| > 64 | *p* (free) | 90 | 5 | 6.5 | BLEWITT | 85 | IMB | |
| >200 | *p* | 90 | 5 | 4.7 | BLEWITT | 85 | IMB | OCCUR=2 |
| > 1.2 | *p* | 90 | 2 | | [43] CHERRY | 81 | HOME | |

[43] We have converted 2 possible events to 90% CL limit. NODE=S016T22;LINKAGE=C

## $\tau(p \rightarrow \mu^+\eta)$ $\tau_5$

NODE=S016T23
NODE=S016T23

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| **>126** | ***p*** | **90** | **3** | **2.8** | MCGREW | 99 | IMB3 | |

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

| LIMIT | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| > 89 | *p* | 90 | 0 | 1.6 | WALL | 00B | SOU2 | |
| > 26 | *p* | 90 | 1 | 0.8 | BERGER | 91 | FREJ | |
| > 69 | *p* | 90 | 1 | <0.08 | HIRATA | 89C | KAMI | |
| > 1.3 | *p* | 90 | 0 | 0.7 | PHILLIPS | 89 | HPW | |
| > 34 | *p* | 90 | 1 | 1.5 | SEIDEL | 88 | IMB | |
| > 46 | *p* | 90 | 7 | 6 | HAINES | 86 | IMB | |
| > 26 | *p* | 90 | 1 | <0.8 | ARISAKA | 85 | KAMI | |
| > 17 | *p* (free) | 90 | 6 | 6 | BLEWITT | 85 | IMB | |
| > 46 | *p* | 90 | 7 | 8 | BLEWITT | 85 | IMB | OCCUR=2 |

## $\tau(n \rightarrow \nu\eta)$ $\tau_6$

NODE=S016T24
NODE=S016T24

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

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

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

[44] We have converted 2 possible events to 90% CL limit. NODE=S016T24;LINKAGE=C

## $\tau(N \rightarrow e^+ \rho)$ $\tau_7$

NODE=S016T14
NODE=S016T14

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

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

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

[45] Limit based on zero events. NODE=S016T14;LINKAGE=B
[46] We have calculated 90% CL limit from 0 confined events. NODE=S016T14;LINKAGE=K
[47] We have converted 2 possible events to 90% CL limit. NODE=S016T14;LINKAGE=C

## $\tau(N \rightarrow \mu^+ \rho)$ $\tau_8$

NODE=S016T15
NODE=S016T15

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

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

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| > 12 | *p* | 90 | 0 | 0.5 | BERGER | 91 | FREJ | |
| > 22 | *n* | 90 | 0 | 1.1 | BERGER | 91 | FREJ | OCCUR=2 |
| > 23 | *n* | 90 | 1 | 1.8 | HIRATA | 89C | KAMI | OCCUR=2 |
| > 4.3 | *p* | 90 | 0 | 0.7 | PHILLIPS | 89 | HPW | |
| > 30 | *p* | 90 | 0 | 0.5 | SEIDEL | 88 | IMB | |
| > 11 | *n* | 90 | 1 | 1.1 | SEIDEL | 88 | IMB | OCCUR=2 |
| > 16 | *p* | 90 | 4 | 4.5 | HAINES | 86 | IMB | |
| > 7 | *n* | 90 | 6 | 5 | HAINES | 86 | IMB | OCCUR=2 |
| > 12 | *p* | 90 | 0 | <0.7 | ARISAKA | 85 | KAMI | |
| > 5 | *n* | 90 | 1 | <1.2 | ARISAKA | 85 | KAMI | OCCUR=2 |
| > 5.5 | *p* (free) | 90 | 4 | 5 | BLEWITT | 85 | IMB | |
| > 16 | *p* | 90 | 4 | 5 | BLEWITT | 85 | IMB | OCCUR=2 |
| > 9 | *n* | 90 | 1 | 2 | PARK | 85 | IMB | OCCUR=2 |

## $\tau(N \rightarrow \nu \rho)$ $\tau_9$

NODE=S016T25
NODE=S016T25

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|---|---|
| **>162** | ***p*** | **90** | **18** | **21.7** | MCGREW | 99 | IMB3 |
| **> 19** | ***n*** | **90** | **0** | **0.5** | SEIDEL | 88 | IMB |

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

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| > 9 | *n* | 90 | 4 | 2.4 | BERGER | 89 | FREJ | |
| > 24 | *p* | 90 | 0 | 0.9 | BERGER | 89 | FREJ | OCCUR=2 |
| > 27 | *p* | 90 | 5 | 1.5 | HIRATA | 89C | KAMI | |
| > 13 | *n* | 90 | 4 | 3.6 | HIRATA | 89C | KAMI | OCCUR=2 |
| > 13 | *p* | 90 | 1 | 1.1 | SEIDEL | 88 | IMB | OCCUR=2 |
| > 8 | *p* | 90 | 6 | 5 | HAINES | 86 | IMB | |
| > 2 | *n* | 90 | 15 | 10 | HAINES | 86 | IMB | OCCUR=2 |
| > 11 | *p* | 90 | 2 | 1 | KAJITA | 86 | KAMI | |
| > 4 | *n* | 90 | 2 | 2 | KAJITA | 86 | KAMI | OCCUR=2 |
| > 4.1 | *p* (free) | 90 | 6 | 7 | BLEWITT | 85 | IMB | |
| > 8.4 | *p* | 90 | 6 | 5 | BLEWITT | 85 | IMB | OCCUR=2 |
| > 2 | *n* | 90 | 7 | 3 | PARK | 85 | IMB | OCCUR=2 |
| > 0.9 | *p* | 90 | 2 | | [48] CHERRY | 81 | HOME | |
| > 0.6 | *n* | 90 | 2 | | [48] CHERRY | 81 | HOME | OCCUR=2 |

[48] We have converted 2 possible events to 90% CL limit. NODE=S016T25;LINKAGE=C

## $\tau(p \to e^+ \omega)$ $\tau_{10}$

NODE=S016T12
NODE=S016T12

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

[49] Limit based on zero events. NODE=S016T12;LINKAGE=B
[50] We have calculated 90% CL limit from 0 confined events. NODE=S016T12;LINKAGE=K
[51] We have converted 2 possible events to 90% CL limit. NODE=S016T12;LINKAGE=C

## $\tau(p \to \mu^+ \omega)$ $\tau_{11}$

NODE=S016T13
NODE=S016T13

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

## $\tau(n \to \nu \omega)$ $\tau_{12}$

NODE=S016T26
NODE=S016T26

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

[52] We have converted 2 possible events to 90% CL limit. NODE=S016T26;LINKAGE=C

### $\tau(N \rightarrow e^+ K)$ $\tau_{13}$

NODE=S016T08
NODE=S016T08

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| **> 17** | ***n*** | **90** | **35** | **29.4** | MCGREW | 99 | IMB3 | OCCUR=2 |
| **>150** | ***p*** | **90** | **0** | **<0.27** | HIRATA | 89C | KAMI | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | | | |
| > 85 | *p* | 90 | 3 | 4.9 | WALL | 00 | SOU2 | |
| > 31 | *p* | 90 | 23 | 25.2 | MCGREW | 99 | IMB3 | |
| > 60 | *p* | 90 | 0 | | BERGER | 91 | FREJ | |
| > 70 | *p* | 90 | 0 | 1.8 | SEIDEL | 88 | IMB | |
| > 77 | *p* | 90 | 5 | 4.5 | HAINES | 86 | IMB | |
| > 38 | *p* | 90 | 0 | <0.8 | ARISAKA | 85 | KAMI | |
| > 24 | *p* (free) | 90 | 7 | 8.5 | BLEWITT | 85 | IMB | |
| > 77 | *p* | 90 | 5 | 4 | BLEWITT | 85 | IMB | OCCUR=2 |
| > 1.3 | *p* | 90 | 0 | | ALEKSEEV | 81 | BAKS | |
| > 1.3 | *n* | 90 | 0 | | ALEKSEEV | 81 | BAKS | OCCUR=2 |

### $\tau(p \rightarrow e^+ K^0_S)$ $\tau_{14}$

NODE=S016T42
NODE=S016T42

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

[53] We have doubled the $p \rightarrow e^+ K^0$ limit given in KOBAYASHI 05 to obtain this $p \rightarrow e^+ K^0_S$ limit. NODE=S016T42;LINKAGE=KO

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

NODE=S016T43
NODE=S016T43

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

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

NODE=S016T09
NODE=S016T09

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

[54] BARTELT 87 limit applies to $p \rightarrow \mu^+ K^0_S$. NODE=S016T09;LINKAGE=S
[55] Limit based on zero events. NODE=S016T09;LINKAGE=B
[56] We have calculated 90% CL limit from 1 confined event. NODE=S016T09;LINKAGE=K
[57] We have converted half-life to 90% CL mean life. NODE=S016T09;LINKAGE=G

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

NODE=S016T44
NODE=S016T44

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

[58] We have doubled the $p \rightarrow \mu^+ K^0$ limit given in KOBAYASHI 05 to obtain this $p \rightarrow \mu^+ K^0_S$ limit. NODE=S016T44;LINKAGE=KO

## $\tau(p \rightarrow \mu^+ K^0_L)$ $\tau_{18}$

NODE=S016T45
NODE=S016T45

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

## $\tau(N \rightarrow \nu K)$ $\tau_{19}$

NODE=S016T11
NODE=S016T11

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| **>2300** | **p** | **90** | **0** | **1.3** | KOBAYASHI | 05 | SKAM | |
| **> 86** | ***n*** | **90** | **0** | **2.4** | HIRATA | 89C | KAMI | OCCUR=2 |
| • • • 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 | OCCUR=2 |
| > 43 | *p* | 90 | 1 | 1.54 | [59] ALLISON | 98 | SOU2 | |
| > 15 | *n* | 90 | 1 | 1.8 | BERGER | 89 | FREJ | |
| > 15 | *p* | 90 | 1 | 1.8 | BERGER | 89 | FREJ | OCCUR=2 |
| > 100 | *p* | 90 | 9 | 7.3 | HIRATA | 89C | KAMI | |
| > 0.28 | *p* | 90 | 0 | 0.7 | PHILLIPS | 89 | HPW | |
| > 0.3 | *p* | 90 | 0 | | BARTELT | 87 | SOUD | |
| > 0.75 | *n* | 90 | 0 | | [60] BARTELT | 87 | SOUD | OCCUR=2 |
| > 10 | *p* | 90 | 6 | 5 | HAINES | 86 | IMB | |
| > 15 | *n* | 90 | 3 | 5 | HAINES | 86 | IMB | OCCUR=2 |
| > 28 | *p* | 90 | 3 | 3 | KAJITA | 86 | KAMI | |
| > 32 | *n* | 90 | 0 | 1.4 | KAJITA | 86 | KAMI | OCCUR=2 |
| > 1.8 | *p* (free) | 90 | 6 | 11 | BLEWITT | 85 | IMB | |
| > 9.6 | *p* | 90 | 6 | 5 | BLEWITT | 85 | IMB | OCCUR=2 |
| > 10 | *n* | 90 | 2 | 2 | PARK | 85 | IMB | OCCUR=2 |
| > 5 | *n* | 90 | 0 | | BATTISTONI | 84 | NUSX | |
| > 2 | *p* | 90 | 0 | | BATTISTONI | 84 | NUSX | OCCUR=2 |
| > 0.3 | *n* | 90 | 0 | | [61] BARTELT | 83 | SOUD | |
| > 0.1 | *p* | 90 | 0 | | [61] BARTELT | 83 | SOUD | OCCUR=2 |
| > 5.8 | *p* | 90 | 1 | | [62] KRISHNA... | 82 | KOLR | |
| > 0.3 | *n* | 90 | 2 | | [63] CHERRY | 81 | HOME | |

[59] This ALLISON 98 limit is with no background subtraction; with subtraction the limit becomes $> 46 \times 10^{30}$ years. NODE=S016T11;LINKAGE=A

[60] BARTELT 87 limit applies to $n \rightarrow \nu K^0_S$. NODE=S016T11;LINKAGE=S

[61] Limit based on zero events. NODE=S016T11;LINKAGE=B

[62] We have calculated 90% CL limit from 1 confined event. NODE=S016T11;LINKAGE=K

[63] We have converted 2 possible events to 90% CL limit. NODE=S016T11;LINKAGE=C

## $\tau(n \rightarrow \nu K^0_S)$ $\tau_{20}$

NODE=S016T75
NODE=S016T75

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

[64] We have doubled the $n \rightarrow \nu K^0$ limit given in KOBAYASHI 05 to obtain this $n \rightarrow \nu K^0_S$ limit. NODE=S016T75;LINKAGE=KO

### $\tau(p \to e^+ K^*(892)^0)$ $\tau_{21}$

NODE=S016T34
NODE=S016T34

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

### $\tau(N \to \nu K^*(892))$ $\tau_{22}$

NODE=S016T18
NODE=S016T18

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| **>51** | ***p*** | **90** | **7** | **9.1** | MCGREW | 99 | IMB3 | |
| **>78** | ***n*** | **90** | **40** | **50** | MCGREW | 99 | IMB3 | OCCUR=2 |
| • • • 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 | OCCUR=2 |
| >20 | *p* | 90 | 5 | 2.1 | HIRATA | 89C | KAMI | |
| >21 | *n* | 90 | 4 | 2.4 | HIRATA | 89C | KAMI | OCCUR=2 |
| >10 | *p* | 90 | 7 | 6 | HAINES | 86 | IMB | |
| > 5 | *n* | 90 | 8 | 7 | HAINES | 86 | IMB | OCCUR=2 |
| > 8 | *p* | 90 | 3 | 2 | KAJITA | 86 | KAMI | |
| > 6 | *n* | 90 | 2 | 1.6 | KAJITA | 86 | KAMI | OCCUR=2 |
| > 5.8 | *p* (free) | 90 | 10 | 16 | BLEWITT | 85 | IMB | |
| > 9.6 | *p* | 90 | 7 | 6 | BLEWITT | 85 | IMB | OCCUR=2 |
| > 7 | *n* | 90 | 1 | 4 | PARK | 85 | IMB | OCCUR=2 |
| > 2.1 | *p* | 90 | 1 | | [65] BATTISTONI | 82 | NUSX | |

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

NODE=S016T18;LINKAGE=B

## Antilepton + mesons

NODE=S016310

### $\tau(p \to e^+ \pi^+ \pi^-)$ $\tau_{23}$

NODE=S016T48
NODE=S016T48

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

### $\tau(p \to e^+ \pi^0 \pi^0)$ $\tau_{24}$

NODE=S016T49
NODE=S016T49

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

### $\tau(n \to e^+ \pi^- \pi^0)$ $\tau_{25}$

NODE=S016T50
NODE=S016T50

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

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

NODE=S016T38
NODE=S016T38

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

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

NODE=S016T51
NODE=S016T51

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

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

NODE=S016T52
NODE=S016T52

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

### $\tau(n \to e^+ K^0 \pi^-)$ $\tau_{29}$

NODE=S016T53
NODE=S016T53

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

## Lepton + meson

NODE=S016315

### $\tau(n \to e^- \pi^+)$ $\tau_{30}$

NODE=S016T29
NODE=S016T29

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

### $\tau(n \to \mu^- \pi^+)$ $\tau_{31}$

NODE=S016T30
NODE=S016T30

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

### $\tau(n \to e^- \rho^+)$ $\tau_{32}$

NODE=S016T31
NODE=S016T31

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

### $\tau(n \to \mu^- \rho^+)$ $\tau_{33}$

NODE=S016T32
NODE=S016T32

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

OCCUR=2

### $\tau(n \to e^- K^+)$ $\tau_{34}$

NODE=S016T40
NODE=S016T40

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

### $\tau(n \to \mu^- K^+)$ $\tau_{35}$

NODE=S016T41
NODE=S016T41

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

## Lepton + mesons

NODE=S016320

### $\tau(p \to e^- \pi^+ \pi^+)$ — $\tau_{36}$

NODE=S016T37
NODE=S016T37

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

### $\tau(n \to e^- \pi^+ \pi^0)$ — $\tau_{37}$

NODE=S016T57
NODE=S016T57

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

### $\tau(p \to \mu^- \pi^+ \pi^+)$ — $\tau_{38}$

NODE=S016T39
NODE=S016T39

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

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

NODE=S016T58
NODE=S016T58

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

### $\tau(p \to e^- \pi^+ K^+)$ — $\tau_{40}$

NODE=S016T59
NODE=S016T59

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

### $\tau(p \to \mu^- \pi^+ K^+)$ — $\tau_{41}$

NODE=S016T60
NODE=S016T60

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

## Antilepton + photon(s)

NODE=S016325

### $\tau(p \to e^+ \gamma)$ — $\tau_{42}$

NODE=S016T03
NODE=S016T03

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| **>670** | ***p*** | **90** | **0** | **0.1** | MCGREW | 99 | IMB3 | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | | | |
| >133 | *p* | 90 | 0 | 0.3 | BERGER | 91 | FREJ | |
| >460 | *p* | 90 | 0 | 0.6 | SEIDEL | 88 | IMB | |
| >360 | *p* | 90 | 0 | 0.3 | HAINES | 86 | IMB | |
| > 87 | *p* (free) | 90 | 0 | 0.2 | BLEWITT | 85 | IMB | |
| >360 | *p* | 90 | 0 | 0.2 | BLEWITT | 85 | IMB | OCCUR=2 |
| > 0.1 | *p* | 90 | | | [66] GURR | 67 | CNTR | |

[66] We have converted half-life to 90% CL mean life. NODE=S016T03;LINKAGE=C

### $\tau(p \to \mu^+ \gamma)$ — $\tau_{43}$

NODE=S016T04
NODE=S016T04

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

[67] We have converted half-life to 90% CL mean life. NODE=S016T04;LINKAGE=C

## $\tau(n \to \nu\gamma)$ τ44

NODE=S016T05
NODE=S016T05

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|---|---|
| **>28** | ***n*** | **90** | **163** | **144.7** | MCGREW | 99 | IMB3 |

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| >24 | *n* | 90 | 10 | 6.86 | BERGER | 91B | FREJ |
| > 9 | *n* | 90 | 73 | 60 | HAINES | 86 | IMB |
| >11 | *n* | 90 | 28 | 19 | PARK | 85 | IMB |

## $\tau(p \to e^+\gamma\gamma)$ τ45

NODE=S016T46
NODE=S016T46

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

## $\tau(n \to \nu\gamma\gamma)$ τ46

NODE=S016T74
NODE=S016T74

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

## Three (or more) leptons

NODE=S016330

## $\tau(p \to e^+e^+e^-)$ τ47

NODE=S016T16
NODE=S016T16

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|---|---|
| **>793** | ***p*** | **90** | **0** | **0.5** | MCGREW | 99 | IMB3 |

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

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| >147 | *p* | 90 | 0 | 0.1 | BERGER | 91 | FREJ | |
| >510 | *p* | 90 | 0 | 0.3 | HAINES | 86 | IMB | |
| > 89 | *p* (free) | 90 | 0 | 0.5 | BLEWITT | 85 | IMB | |
| >510 | *p* | 90 | 0 | 0.7 | BLEWITT | 85 | IMB | OCCUR=2 |

## $\tau(p \to e^+\mu^+\mu^-)$ τ48

NODE=S016T35
NODE=S016T35

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|---|---|
| **>359** | ***p*** | **90** | **1** | **0.9** | MCGREW | 99 | IMB3 |

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| > 81 | *p* | 90 | 0 | 0.16 | BERGER | 91 | FREJ |
| > 5.0 | *p* | 90 | 0 | 0.7 | PHILLIPS | 89 | HPW |

## $\tau(p \to e^+\nu\nu)$ τ49

NODE=S016T54
NODE=S016T54

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|---|---|
| **>17** | ***p*** | **90** | **152** | **153.7** | MCGREW | 99 | IMB3 |

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| >11 | *p* | 90 | 11 | 6.08 | BERGER | 91B | FREJ |

## $\tau(n \to e^+e^-\nu)$ τ50

NODE=S016T27
NODE=S016T27

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|---|---|
| **>257** | ***n*** | **90** | **5** | **7.5** | MCGREW | 99 | IMB3 |

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| > 74 | *n* | 90 | 0 | < 0.1 | BERGER | 91B | FREJ |
| > 45 | *n* | 90 | 5 | 5 | HAINES | 86 | IMB |
| > 26 | *n* | 90 | 4 | 3 | PARK | 85 | IMB |

## $\tau(n \to \mu^+e^-\nu)$ τ51

NODE=S016T55
NODE=S016T55

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|---|---|
| **>83** | ***n*** | **90** | **25** | **29.4** | MCGREW | 99 | IMB3 |

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| >47 | *n* | 90 | 0 | < 0.1 | BERGER | 91B | FREJ |

### $\tau(n \to \mu^+ \mu^- \nu)$ — $\tau_{52}$

NODE=S016T28
NODE=S016T28

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

### $\tau(p \to \mu^+ e^+ e^-)$ — $\tau_{53}$

NODE=S016T47
NODE=S016T47

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

### $\tau(p \to \mu^+ \mu^+ \mu^-)$ — $\tau_{54}$

NODE=S016T17
NODE=S016T17

| LIMIT ($10^{30}$ years) | PARTICLE | CL% | EVTS | BKGD EST | DOCUMENT ID | | TECN | |
|---|---|---|---|---|---|---|---|---|
| **>675** | ***p*** | **90** | **0** | **0.3** | MCGREW | 99 | IMB3 | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | | | |
| >119 | *p* | 90 | 0 | 0.2 | BERGER | 91 | FREJ | |
| > 10.5 | *p* | 90 | 0 | 0.7 | PHILLIPS | 89 | HPW | |
| >190 | *p* | 90 | 1 | 0.1 | HAINES | 86 | IMB | |
| > 44 | *p* (free) | 90 | 1 | 0.7 | BLEWITT | 85 | IMB | |
| >190 | *p* | 90 | 1 | 0.9 | BLEWITT | 85 | IMB | OCCUR=2 |
| > 2.1 | *p* | 90 | 1 | | [68] BATTISTONI | 82 | NUSX | |

[68] We have converted 1 possible event to 90% CL limit. NODE=S016T17;LINKAGE=B

### $\tau(p \to \mu^+ \nu \nu)$ — $\tau_{55}$

NODE=S016T56
NODE=S016T56

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

### $\tau(p \to e^- \mu^+ \mu^+)$ — $\tau_{56}$

NODE=S016T36
NODE=S016T36

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

### $\tau(n \to 3\nu)$ — $\tau_{57}$

NODE=S016T21

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. NODE=S016T21

NODE=S016T21

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

[69] The SUZUKI 93B limit applies to any of $\nu_e \nu_e \overline{\nu}_e$, $\nu_\mu \nu_\mu \overline{\nu}_\mu$, or $\nu_\tau \nu_\tau \overline{\nu}_\tau$. NODE=S016T21;LINKAGE=B

[70] GLICENSTEIN 97 uses Kamioka data and the idea that the disappearance of the neutron's magnetic moment should produce radiation. NODE=S016T21;LINKAGE=C

[71] The first BERGER 91B limit is for $n \to \nu_e \nu_e \overline{\nu}_e$, the second is for $n \to \nu_\mu \nu_\mu \overline{\nu}_\mu$. NODE=S016T21;LINKAGE=A

### $\tau(n \to 5\nu)$ — $\tau_{58}$

NODE=S016T73

See the note on $\tau(n \to 3\nu)$ on the previous data block. NODE=S016T73

NODE=S016T73

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

[72] GLICENSTEIN 97 uses Kamioka data and the idea that the disappearance of the neutron's magnetic moment should produce radiation. NODE=S016T73;LINKAGE=C

## Inclusive modes

NODE=S016335

### $\tau(N \rightarrow e^{+}\text{anything})$ — $\tau_{59}$

NODE=S016T01
NODE=S016T01

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

[73] The electron may be primary or secondary.

NODE=S016T01;LINKAGE=D

### $\tau(N \rightarrow \mu^{+}\text{anything})$ — $\tau_{60}$

NODE=S016T02
NODE=S016T02

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

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

NODE=S016T02;LINKAGE=C
NODE=S016T02;LINKAGE=D

### $\tau(N \rightarrow \nu\,\text{anything})$ — $\tau_{61}$

NODE=S016T20

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

NODE=S016T20
NODE=S016T20

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

### $\tau(N \rightarrow e^{+}\pi^{0}\text{anything})$ — $\tau_{62}$

NODE=S016T19
NODE=S016T19

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

### $\tau(N \rightarrow 2\text{ bodies}, \nu\text{-free})$ — $\tau_{63}$

NODE=S016T33
NODE=S016T33

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

## $\Delta B = 2$ dinucleon modes

NODE=S016340

### $\tau(pp \rightarrow \pi^{+}\pi^{+})$ — $\tau_{64}$

NODE=S016T62
NODE=S016T62

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

### $\tau(pn \rightarrow \pi^{+}\pi^{0})$ — $\tau_{65}$

NODE=S016T63
NODE=S016T63

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

### $\tau(nn \rightarrow \pi^{+}\pi^{-})$ — $\tau_{66}$

NODE=S016T64
NODE=S016T64

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

### $\tau(nn \rightarrow \pi^{0}\pi^{0})$ — $\tau_{67}$

NODE=S016T65
NODE=S016T65

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

### $\tau(pp \rightarrow e^{+}e^{+})$ — $\tau_{68}$

NODE=S016T66
NODE=S016T66

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

### $\tau(pp \rightarrow e^{+}\mu^{+})$ — $\tau_{69}$

NODE=S016T67
NODE=S016T67

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

## $\tau(pp \to \mu^+\mu^+)$ T70

NODE=S016T68

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

## $\tau(pn \to e^+\overline{\nu})$ T71

NODE=S016T69

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

## $\tau(pn \to \mu^+\overline{\nu})$ T72

NODE=S016T70

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

## $\tau(nn \to \nu_e\overline{\nu}_e)$ T73

NODE=S016T71

We include "invisible" modes here.

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

[76] ARAKI 06 looks for signs of de-excitation of the residual nucleus after disappearance of two neutrons from the $s$ shell of $^{12}$C. NODE=S016T71;LINKAGE=AR

[77] TRETYAK 04 uses data from an old Homestake-mine radiochemical experiment on limits for invisible decays of $^{39}$K to $^{37}$Ar. NODE=S016T71;LINKAGE=TR

[78] BACK 03 looks for decays of unstable nuclides left after $NN$ decays of parent $^{12}$C, $^{13}$C, $^{16}$O nuclei. These are "invisible channel" limits. NODE=S016T71;LINKAGE=BK

[79] BERNABEI 00B looks for the decay of a $^{127}_{54}$Xe nucleus following the disappearance of an $nn$ pair in the otherwise-stable $^{129}_{54}$Xe nucleus. The limit here applies as well to $nn \to \nu_\mu\overline{\nu}_\mu$, $nn \to \nu_\tau\overline{\nu}_\tau$, or any "disappearance" mode. NODE=S016T71;LINKAGE=BN

## $\tau(nn \to \nu_\mu\overline{\nu}_\mu)$ T74

NODE=S016T72

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

## $\tau(pn \to \text{invisible})$ T75

NODE=S016T77

This violates charge conservation as well as baryon number conservation.

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

[80] TRETYAK 04 uses data from an old Homestake-mine radiochemical experiment on limits for invisible decays of $^{39}$K to $^{37}$Ar. NODE=S016T77;LINKAGE=TR

## $\tau(pp \to \text{invisible})$ T76

NODE=S016T76

This violates charge conservation as well as baryon number conservation.

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

[81] BACK 03 looks for decays of unstable nuclides left after $NN$ decays of parent $^{12}$C, $^{13}$C, $^{16}$O nuclei. These are "invisible channel" limits. NODE=S016T76;LINKAGE=BK

[82] BERNABEI 00B looks for the decay of a $^{127}_{52}$Te nucleus following the disappearance of a $pp$ pair in the otherwise-stable $^{129}_{54}$Xe nucleus. NODE=S016T76;LINKAGE=BN

## $\overline{p}$ PARTIAL MEAN LIVES

NODE=S016232

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

NODE=S016232

### $\tau(\overline{p} \to e^- \gamma)$ — $\tau_{77}$

NODE=S016TB1
NODE=S016TB1

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

### $\tau(\overline{p} \to \mu^- \gamma)$ — $\tau_{78}$

NODE=S016TB6
NODE=S016TB6

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

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

NODE=S016TB2
NODE=S016TB2

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

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

NODE=S016TB7
NODE=S016TB7

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

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

NODE=S016TB3
NODE=S016TB3

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

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

NODE=S016TB8
NODE=S016TB8

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

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

NODE=S016TB4
NODE=S016TB4

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

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

NODE=S016TB9
NODE=S016TB9

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

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

NODE=S016TB5
NODE=S016TB5

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

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

NODE=S016TC1
NODE=S016TC1

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

### $\tau(\overline{p} \to e^- \gamma\gamma)$ — τ87

NODE=S016TC3

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

### $\tau(\overline{p} \to \mu^- \gamma\gamma)$ — τ88

NODE=S016TC2

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

### $\tau(\overline{p} \to e^- \rho)$ — τ89

NODE=S016TC4

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

[83] This GEER 00 measurement has been withdrawn; see GEER 00C. NODE=S016TC4;LINKAGE=A

### $\tau(\overline{p} \to e^- \omega)$ — τ90

NODE=S016TC5

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

### $\tau(\overline{p} \to e^- K^*(892)^0)$ — τ91

NODE=S016TC6

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

[84] This GEER 00 measurement has been withdrawn; see GEER 00C. NODE=S016TC6;LINKAGE=A

## *p* REFERENCES

NODE=S016


| | | | | | |
|---|---|---|---|---|---|
| MOHR | 08 | RMP 80 633 | P.J. Mohr, B.N. Taylor, D.B. Newell | (NIST) | REFID=52197 |
| ARAKI | 06 | PRL 96 101802 | T. Araki *et al.* | (KamLAND Collab.) | REFID=51206 |
| HORI | 06 | PRL 96 243401 | M. Hori *et al.* | | REFID=52189 |
| BLUNDEN | 05 | PR C72 057601 | P.G. Blunden, I. Sick | (MANI, BASL) | REFID=51419 |
| KOBAYASHI | 05 | PR D72 052007 | K. Kobayashi *et al.* | (Super-Kamiokande Collab.) | REFID=50905 |
| MOHR | 05 | RMP 77 1 | P.J. Mohr, B.N. Taylor | (NIST) | REFID=49695 |
| SCHUMACHER | 05 | PPNP 55 567 | M. Schumacher | (GOET) | REFID=51658 |
| AHMED | 04 | PRL 92 102004 | S.N. Ahmed *et al.* | (SNO Collab.) | REFID=49661 |
| TRETYAK | 04 | JETPL 79 106 | V.I. Tretyak, V.Yu. Denisov, Yu.G. Zdesenko | (KIEV) | REFID=49964 |
| | | Translated from ZETFP 79 136. | | | |
| BACK | 03 | PL B563 23 | H.O. Back *et al.* | (BOREXINO Collab.) | REFID=49448 |
| BEANE | 03 | PL B567 200 | S.R. Beane *et al.* | | REFID=49517 |
| Also | | PL B607 320 (erratum) | S.R. Beane *et al.* | | REFID=50472 |
| DMITRIEV | 03 | PRL 91 212303 | V.F. Dmitriev, R.A. Senkov | (NOVO) | REFID=49696 |
| HORI | 03 | PRL 91 123401 | M. Hori *et al.* | (CERN ASACUSA Collab.) | REFID=49678 |
| SICK | 03 | PL B576 62 | I. Sick | (BASL) | REFID=49807 |
| ZDESENKO | 03 | PL B553 135 | Yu.G. Zdesenko, V.I. Tretyak | (KIEV) | REFID=49662 |
| AHMAD | 02 | PRL 89 011301 | Q.R. Ahmad *et al.* | (SNO Collab.) | REFID=48642 |
| BARANOV | 01 | PPN 32 376 | P.S. Baranov *et al.* | | REFID=48156 |
| | | Translated from FECAY 32 699. | | | |
| BLANPIED | 01 | PR C64 025203 | G. Blanpied *et al.* | (BNL LEGS Collab.) | REFID=48192 |
| ESCHRICH | 01 | PL B522 233 | I. Eschrich *et al.* | (FNAL SELEX Collab.) | REFID=48455 |
| HORI | 01 | PRL 87 093401 | M. Hori *et al.* | (CERN ASACUSA Collab.) | REFID=48249 |
| OLMOSDEL... | 01 | EPJ A10 207 | V. Olmos de Leon *et al.* | (MAMI TAPS Collab.) | REFID=48151 |
| TRETYAK | 01 | PL B505 59 | V.I. Tretyak, Yu.G. Zdesenko | (KIEV) | REFID=48128 |
| BERNABEI | 00B | PL B493 12 | R. Bernabei *et al.* | (Gran Sasso DAMA Collab.) | REFID=47829 |
| GEER | 00 | PRL 84 590 | S. Geer *et al.* | (FNAL APEX Collab.) | REFID=47441 |
| Also | | PR D62 052004 | S. Geer *et al.* | (FNAL APEX Collab.) | REFID=47696 |
| Also | | PRL 85 3546 (erratum) | S. Geer *et al.* | (FNAL APEX Collab.) | REFID=47798 |
| GEER | 00C | PRL 85 3546 (erratum) | S. Geer *et al.* | (FNAL APEX Collab.) | REFID=47798 |
| GEER | 00D | APJ 532 648 | S.H. Geer, D.C. Kennedy | | REFID=47799 |
| MELNIKOV | 00 | PRL 84 1673 | K. Melnikov *et al.* | (SLAC, KARL) | REFID=48481 |
| ROSENFELDR... | 00 | PL B479 381 | R. Rosenfelder | | REFID=48482 |
| SENGUPTA | 00 | PL B484 275 | S. Sengupta | | REFID=47662 |
| WALL | 00 | PR D61 072004 | D. Wall *et al.* | (Soudan-2 Collab.) | REFID=47598 |
| WALL | 00B | PR D62 092003 | D. Wall *et al.* | (Soudan-2 Collab.) | REFID=47870 |
| GABRIELSE | 99 | PRL 82 3198 | G. Gabrielse *et al.* | | REFID=46985 |
| HAYATO | 99 | PRL 83 1529 | Y. Hayato *et al.* | (Super-Kamiokande Collab.) | REFID=47054 |
| MCGREW | 99 | PR D59 052004 | C. McGrew *et al.* | (IMB-3 Collab.) | REFID=46723 |
| MOHR | 99 | JPCRD 28 1713 | P.J. Mohr, B.N. Taylor | (NIST) | REFID=47256 |
| Also | | RMP 72 351 | P.J. Mohr, B.N. Taylor | (NIST) | REFID=47373 |
| TORII | 99 | PR A59 223 | H.A. Torii *et al.* | (CERN PS-205 Collab.) | REFID=47327 |
| ALLISON | 98 | PL B427 217 | W.W.M. Allison *et al.* | (Soudan-2 Collab.) | REFID=46058 |
| HU | 98B | PR D58 111101 | M. Hu *et al.* | (FNAL APEX Collab.) | REFID=46432 |
| SHIOZAWA | 98 | PRL 81 3319 | M. Shiozawa *et al.* | (Super-Kamiokande Collab.) | REFID=46213 |
| GLICENSTEIN | 97 | PL B411 326 | J.F. Glicenstein | (SACL) | REFID=45731 |
| MERGELL | 96 | NP A596 367 | P. Mergell *et al.* | (MANZ, BONN) | REFID=48483 |
| GABRIELSE | 95 | PRL 74 3544 | G. Gabrielse *et al.* | (HARV, MANZ, SEOUL) | REFID=44202 |
| MACGIBBON | 95 | PR C52 2097 | B.E. MacGibbon *et al.* | (ILL, SASK, INRM) | REFID=44534 |
| GEER | 94 | PRL 72 1596 | S. Geer *et al.* | (FNAL, UCLA, PSU) | REFID=43796 |
| WONG | 94 | IJMP E3 821 | C.W. Wong | (UCLA) | REFID=48484 |
| HALLIN | 93 | PR C48 1497 | E.L. Hallin *et al.* | (SASK, BOST, ILL) | REFID=43513 |
| SUZUKI | 93B | PL B311 357 | Y. Suzuki *et al.* | (KAMIOKANDE Collab.) | REFID=43436 |
| HUGHES | 92 | PRL 69 578 | R.J. Hughes, B.I. Deutch | (LANL, AARH) | REFID=42139 |
| ZIEGER | 92 | PL B278 34 | A. Zieger *et al.* | (MPCM) | REFID=43636 |
| Also | | PL B281 417 (erratum) | A. Zieger *et al.* | (MPCM) | REFID=43717 |

| | | | | | |
|---|---|---|---|---|---|
| BERGER | 91 | ZPHY C50 385 | C. Berger *et al.* | (FREJUS Collab.) | REFID=41514 |
| BERGER | 91B | PL B269 227 | C. Berger *et al.* | (FREJUS Collab.) | REFID=41762 |
| FEDERSPIEL | 91 | PRL 67 1511 | F.J. Federspiel *et al.* | (ILL) | REFID=41597 |
| MCCORD | 91 | NIM B56/57 496 | M. McCord *et al.* | | REFID=48485 |
| BECKER-SZ... | 90 | PR D42 2974 | R.A. Becker-Szendy *et al.* | (IMB-3 Collab.) | REFID=41460 |
| ERICSON | 90 | EPL 11 295 | T.E.O. Ericson, A. Richter | (CERN, DARM) | REFID=41233 |
| GABRIELSE | 90 | PRL 65 1317 | G. Gabrielse *et al.* | (HARV, MANZ, WASH+) | REFID=41302 |
| BERGER | 89 | NP B313 509 | C. Berger *et al.* | (FREJUS Collab.) | REFID=40768 |
| CHO | 89 | PRL 63 2559 | D. Cho, K. Sangster, E.A. Hinds | (YALE) | REFID=41081 |
| HIRATA | 89C | PL B220 308 | K.S. Hirata *et al.* | (Kamiokande Collab.) | REFID=40813 |
| PHILLIPS | 89 | PL B224 348 | T.J. Phillips *et al.* | (HPW Collab.) | REFID=40822 |
| KREISSL | 88 | ZPHY C37 557 | A. Kreissl *et al.* | (CERN PS176 Collab.) | REFID=40594 |
| SEIDEL | 88 | PRL 61 2522 | S. Seidel *et al.* | (IMB Collab.) | REFID=40623 |
| BARTELT | 87 | PR D36 1990 | J.E. Bartelt *et al.* | (Soudan Collab.) | REFID=40487 |
| Also | | PR D40 1701 (erratum) | J.E. Bartelt *et al.* | (Soudan Collab.) | REFID=40850 |
| COHEN | 87 | RMP 59 1121 | E.R. Cohen, B.N. Taylor | (RISC, NBS) | REFID=11616 |
| HAINES | 86 | PRL 57 1986 | T.J. Haines *et al.* | (IMB Collab.) | REFID=40302 |
| KAJITA | 86 | JPSJ 55 711 | T. Kajita *et al.* | (Kamiokande Collab.) | REFID=40301 |
| ARISAKA | 85 | JPSJ 54 3213 | K. Arisaka *et al.* | (Kamiokande Collab.) | REFID=40300 |
| BLEWITT | 85 | PRL 55 2114 | G.B. Blewitt *et al.* | (IMB Collab.) | REFID=11617 |
| DZUBA | 85 | PL 154B 93 | V.A. Dzuba, V.V. Flambaum, P.G. Silvestrov | (NOVO) | REFID=11618 |
| PARK | 85 | PRL 54 22 | H.S. Park *et al.* | (IMB Collab.) | REFID=11619 |
| BATTISTONI | 84 | PL 133B 454 | G. Battistoni *et al.* | (NUSEX Collab.) | REFID=11714 |
| MARINELLI | 84 | PL 137B 439 | M. Marinelli, G. Morpurgo | (GENO) | REFID=11621 |
| WILKENING | 84 | PR A29 425 | D.A. Wilkening, N.F. Ramsey, D.J. Larson | (HARV+) | REFID=11622 |
| BARTELT | 83 | PRL 50 651 | J.E. Bartelt *et al.* | (MINN, ANL) | REFID=11623 |
| BATTISTONI | 82 | PL 118B 461 | G. Battistoni *et al.* | (NUSEX Collab.) | REFID=11627 |
| KRISHNA... | 82 | PL 115B 349 | M.R. Krishnaswamy *et al.* | (TATA, OSKC+) | REFID=11628 |
| ALEKSEEV | 81 | JETPL 33 651 | E.N. Alekseev *et al.* | (PNPI) | REFID=11630 |
| | | Translated from ZETFP 33 664. | | | |
| CHERRY | 81 | PRL 47 1507 | M.L. Cherry *et al.* | (PENN, BNL) | REFID=11631 |
| COWSIK | 80 | PR D22 2204 | R. Cowsik, V.S. Narasimham | (TATA) | REFID=11632 |
| SIMON | 80 | NP A333 381 | G.G. Simon *et al.* | | REFID=48486 |
| BELL | 79 | PL 86B 215 | M. Bell *et al.* | (CERN) | REFID=11633 |
| GOLDEN | 79 | PRL 43 1196 | R.L. Golden *et al.* | (NASA, PSLL) | REFID=11634 |
| LEARNED | 79 | PRL 43 907 | J.G. Learned, F. Reines, A. Soni | (UCI) | REFID=11635 |
| BREGMAN | 78 | PL 78B 174 | M. Bregman *et al.* | (CERN) | REFID=11636 |
| ROBERTS | 78 | PR D17 358 | B.L. Roberts | (WILL, RHEL) | REFID=11638 |
| EVANS | 77 | SCI 197 989 | J.C. Evans Jr., R.I. Steinberg | (BNL, PENN) | REFID=11639 |
| HU | 75 | NP A254 403 | E. Hu *et al.* | (COLU, YALE) | REFID=11642 |
| BORKOWSKI | 74 | NP A222 269 | F. Borkowski *et al.* | | REFID=48487 |
| COHEN | 73 | JPCRD 2 664 | E.R. Cohen, B.N. Taylor | (RISC, NBS) | REFID=10098 |
| DYLLA | 73 | PR A7 1224 | H.F. Dylla, J.G. King | (MIT) | REFID=11646 |
| AKIMOV | 72 | JETP 35 651 | Yu.K. Akimov *et al.* | (YERE) | REFID=48488 |
| | | Translated from ZETF 62 1231. | | | |
| DIX | 70 | Thesis Case | F.W. Dix | (CASE) | REFID=11649 |
| HARRISON | 69 | PRL 22 1263 | G.E. Harrison, P.G.H. Sandars, S.J. Wright | (OXF) | REFID=11650 |
| GURR | 67 | PR 158 1321 | H.S. Gurr *et al.* | (CASE, WITW) | REFID=11652 |
| FREREJACQ... | 66 | PR 141 1308 | D. Frerejacque *et al.* | | REFID=48489 |
| HAND | 63 | RMP 35 335 | L.N. Hand *et al.* | | REFID=48490 |
| FLEROV | 58 | DOKL 3 79 | G.N. Flerov *et al.* | (ASCI) | REFID=11655 |