NODE=S016

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

p MASS (atomic mass units u)

NODE=S016AMU

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

NODE=S016AMU

NODE=S016AMU

VALUE (u)	DOCUMENT ID		TECN	COMMENT
1.007276466621±0.000000000053 OUR EVALUATION	2018 CODATA			
1.007276466574±0.000000000010	[1] FINK	21	SPEC	Penning trap
1.007276466621±0.000000000053	[2] TIESINGA	21	RVUE	2018 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.007276466598±0.000000000033	[3] HEISSE	19	SPEC	Penning Trap
1.007276466583±0.000000000032	[4] HEISSE	17	SPEC	See HEISSE 19
1.007276466879±0.000000000091	MOHR	16	RVUE	2014 CODATA value
1.007276466812±0.000000000090	MOHR	12	RVUE	2010 CODATA value
1.00727646677 ±0.00000000010	MOHR	08	RVUE	2006 CODATA value
1.00727646688 ±0.00000000013	MOHR	05	RVUE	2002 CODATA value
1.00727646688 ±0.00000000013	MOHR	99	RVUE	1998 CODATA value
1.007276470 ±0.000000012	COHEN	87	RVUE	1986 CODATA value

→ UNCHECKED ←

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

NODE=S016AMU;LINKAGE=E

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2018 CODATA combination in TIESINGA 21 includes data from HEISSE 17, but does not include updates in HEISSE 19, which superseded HEISSE 17.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

NODE=S016AMU;LINKAGE=C

[3] The value is an update of HEISSE 17; the result is shifted by 1.5×10^{-11} u, corresponding to 0.45 σ due to the corrected motional temperatures of the particles. The statistical and total systematic uncertainties are given as 16 and 29 in the last two digits.

NODE=S016AMU;LINKAGE=B

[4] The statistical and systematic errors are 15 and 29 in the last two places of the value. Superseded by HEISSE 19.

NODE=S016AMU;LINKAGE=A

p MASS (MeV)

NODE=S016M

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

NODE=S016M

NODE=S016M

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
938.27208816±0.00000029 OUR EVALUATION	2018 CODATA			
938.27208812±0.00000029	[1] FINK	21	SPEC	Penning trap
938.27208816±0.00000029	TIESINGA	21	RVUE	2018 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
938.2720813 ±0.0000058	MOHR	16	RVUE	2014 CODATA value
938.272046 ±0.000021	MOHR	12	RVUE	2010 CODATA value
938.272013 ±0.000023	MOHR	08	RVUE	2006 CODATA value
938.272029 ±0.000080	MOHR	05	RVUE	2002 CODATA value
938.271998 ±0.000038	MOHR	99	RVUE	1998 CODATA value
938.27231 ±0.00028	COHEN	87	RVUE	1986 CODATA value
938.2796 ±0.0027	COHEN	73	RVUE	1973 CODATA value

→ UNCHECKED ←

[1] FINK 21 quote the more precise mass in atomic mass units.

NODE=S016M;LINKAGE=B

$\left|m_p - m_{\overline{p}}\right|/m_p$

NODE=S016DM

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=S016DM

NODE=S016DM

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

[1] HORI 01, HORI 03, HORI 06, and HORI 11 use the more-precisely-known constraint on the $\overline{p}$ charge-to-mass ratio of GABRIELSE 99 (see below) to get their results. Their results are not independent of the HORI 01, HORI 03, HORI 06, and HORI 11 values for $|q_p+q_{\overline{p}}|/e$, below. 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, $\left|\frac{q_{\overline{p}}}{m_{\overline{p}}}\right|/(\frac{q_p}{m_p})$

NODE=S016CMR

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=S016CMR

NODE=S016CMR

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

[1] Equation (2) of GABRIELSE 95 should read $M(\overline{p})/M(p) = 0.999\,999\,99\underline{8}5\,(11)$ (G. Gabrielse, private communication). NODE=S016CMR;LINKAGE=B

[2] GABRIELSE 90 also measures $m_{\overline{p}}/m_{e^-} = 1836.152660 \pm 0.000083$ and $m_p/m_{e^-} = 1836.152680 \pm 0.000088$. Both are completely consistent with the 1986 CODATA (COHEN 87) value for m_p/m_{e^-} of 1836.152701 ± 0.000037. NODE=S016CMR;LINKAGE=A

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

NODE=S016DMM

A test of *CPT* invariance. Taken from the $\overline{p}/p$ charge-to-mass ratio, above. NODE=S016DMM

NODE=S016DMM

VALUE	*DOCUMENT ID*
$(0.3\pm1.6)\times10^{-11}$ OUR EVALUATION	

→ UNCHECKED ←

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

NODE=S016DQ2

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=S016DQ2

NODE=S016DQ2

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

[1] HORI 01, HORI 03, HORI 06, and HORI 11 use the more-precisely-known constraint on the $\overline{p}$ charge-to-mass ratio of GABRIELSE 99 (see above) to get their results. Their results are not independent of the HORI 01, HORI 03, HORI 06, and HORI 11 values for $|m_p-m_{\overline{p}}|/m_p$, above. NODE=S016DQ2;LINKAGE=C

[2] TORII 99 uses the more-precisely-known constraint on the $\overline{p}$ charge-to-mass ratio of GABRIELSE 95 (see above) to get this result. This is not independent of the TORII 99 value for $|m_p-m_{\overline{p}}|/m_p$, above. NODE=S016DQ2;LINKAGE=B

[3] HUGHES 92 uses recent measurements of Rydberg-energy and cyclotron-frequency ratios. NODE=S016DQ2;LINKAGE=A

$|q_p + q_e|/e$

NODE=S016DQ

See BRESSI 11 for a summary of experiments on the neutrality of matter. See also "*n* CHARGE" in the neutron Listings. NODE=S016DQ

NODE=S016DQ

VALUE	*DOCUMENT ID*		*COMMENT*
$<1 \times 10^{-21}$	[1] BRESSI	11	Neutrality of SF_6

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

$<3.2 \times 10^{-20}$	[2] SENGUPTA	00	binary pulsar
$<0.8 \times 10^{-21}$	MARINELLI	84	Magnetic levitation
$<1.0 \times 10^{-21}$	[1] DYLLA	73	Neutrality of SF_6

[1] BRESSI 11 uses the method of DYLLA 73 but finds serious errors in that experiment that greatly reduce its accuracy. The BRESSI 11 limit assumes that $n \rightarrow p e^- \nu_e$ conserves charge. Thus the limit applies equally to the charge of the neutron. NODE=S016DQ;LINKAGE=BR

[2] SENGUPTA 00 uses the difference between the observed rate of of rotational energy loss by the binary pulsar PSR B1913+16 and the rate predicted by general relativity to set this limit. See the paper for assumptions. NODE=S016DQ;LINKAGE=SE

p MAGNETIC MOMENT

NODE=S016MM

See the "Quark Model" review.

NODE=S016MM

NODE=S016MM

VALUE (μ_N)	*DOCUMENT ID*		*TECN*	*COMMENT*
2.79284734463±0.00000000082	TIESINGA	21	RVUE	2018 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.79284734462±0.00000000082	SCHNEIDER	17	TRAP	Double Penning trap
2.7928473508 ±0.0000000085	MOHR	16	RVUE	2014 CODATA value
2.792847356 ±0.000000023	MOHR	12	RVUE	2010 CODATA value
2.792847356 ±0.000000023	MOHR	08	RVUE	2006 CODATA value
2.792847351 ±0.000000028	MOHR	05	RVUE	2002 CODATA value
2.792847337 ±0.000000029	MOHR	99	RVUE	1998 CODATA value
2.792847386 ±0.000000063	COHEN	87	RVUE	1986 CODATA value

$\overline{p}$ MAGNETIC MOMENT

NODE=S016MM1

A few early results have been omitted.

NODE=S016MM1

NODE=S016MM1

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

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

NODE=S016MMD

A test of *CPT* invariance.

NODE=S016MMD

NODE=S016MMD

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

p ELECTRIC DIPOLE MOMENT

NODE=S016EDM

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

NODE=S016EDM

NODE=S016EDM

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

OCCUR=2

[1] SAHOO 17 and DMITRIEV 03 are not direct measurements of the proton electric dipole moment. They use theory to calculate this limit from the limit on the electric dipole moment of the ^{199}Hg atom. NODE=S016EDM;LINKAGE=D

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

[3] 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 α_p

NODE=S016EPL

For a very complete review of the "polarizability of the nucleon and Compton scattering," see SCHUMACHER 05, updated in SCHUMACHER 19. NODE=S016EPL

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

NODE=S016EPL

VALUE (10^{-4} fm^3)	*DOCUMENT ID*		*TECN*	*COMMENT*
11.5 ±0.4 OUR AVERAGE	Error includes scale factor of 1.1.			
12.7 ±0.8 ±0.1	[1] MORNACCHI	22	FIT	Fit of RCS data sets
10.65±0.35±0.36	MCGOVERN	13	RVUE	χEFT + Compton scattering
12.1 ±1.1 ±0.5	[2] BEANE	03		EFT + γp
$11.82\pm0.98^{+0.52}_{-0.98}$	[3] BLANPIED	01	LEGS	$p(\vec{\gamma},\gamma)$, $p(\vec{\gamma},\pi^0)$, $p(\vec{\gamma},\pi^+)$
11.9 ±0.5 ±1.3	[4] OLMOSDEL...	01	CNTR	γp Compton scattering
12.1 ±0.8 ±0.5	[5] MACGIBBON	95	RVUE	global average (OCCUR=2)
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$12.03^{+0.48}_{-0.54}$	[6] PASQUINI	19		fit of RCS data sets
11.7 ±0.8 ±0.7	[7] BARANOV	01	RVUE	Global average
12.5 ±0.6 ±0.9	MACGIBBON	95	CNTR	γp Compton scattering
9.8 ±0.4 ±1.1	HALLIN	93	CNTR	γp Compton scattering
$10.62^{+1.25}_{-1.19}{}^{+1.07}_{-1.03}$	ZIEGER	92	CNTR	γp Compton scattering
10.9 ±2.2 ±1.3	[8] FEDERSPIEL	91	CNTR	γp Compton scattering

[1] MORNACCHI 22 perform the first simultaneous extraction of the six leading-order proton polarizabilities using fixed-t subtracted dispersion relations and a bootstrap-based fitting technique. NODE=S016EPL;LINKAGE=C

[2] BEANE 03 uses effective field theory and low-energy γp and γd Compton-scattering data. It also gets for the isoscalar polarizabilities (see the erratum) $\alpha_N = (13.0 \pm 1.9^{+3.9}_{-1.5}) \times 10^{-4}$ fm^3 and $\beta_N = (-1.8 \pm 1.9^{+2.1}_{-0.9}) \times 10^{-4}$ fm^3. NODE=S016EPL;LINKAGE=B3

[3] BLANPIED 01 gives $\alpha_p + \beta_p$ and $\alpha_p - \beta_p$. The separate α_p and β_p are provided to us by A. Sandorfi. The first error above is statistics plus systematics; the second is from the model. NODE=S016EPL;LINKAGE=SF

[4] 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

[5] 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

[6] PASQUINI 19 fit data sets for the unpolarized proton RCS cross section, using fixed-t subtracted dispersion relations and a bootstrap-based fitting technique. NODE=S016EPL;LINKAGE=B

[7] 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

[8] FEDERSPIEL 91 obtains for the (static) electric polarizability α_p, defined in terms of the induced electric dipole moment by $\mathbf{D} = 4\pi\epsilon_0\alpha_p\mathbf{E}$, the value $(7.0\pm2.2\pm1.3)\times10^{-4}$ fm^3. NODE=S016EPL;LINKAGE=A

p MAGNETIC POLARIZABILITY β_p

NODE=S016MPL

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=S016MPL

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

NODE=S016MPL

VALUE (10^{-4} fm^3)	DOCUMENT ID		TECN	COMMENT
2.31±0.29 OUR AVERAGE	Error includes scale factor of 1.1.			
2.4 ±0.6 ±0.1	[1] MORNACCHI	22	FIT	Fit of RCS data sets
$1.77^{+0.52}_{-0.54}$	[2] PASQUINI	19	FIT	fit of RCS data sets
3.15±0.35±0.36	MCGOVERN	13	RVUE	χEFT + Compton scattering
3.4 ±1.1 ±0.1	[3] BEANE	03		EFT + γp
$1.43\pm0.98^{+0.52}_{-0.98}$	[4] BLANPIED	01	LEGS	$p(\vec{\gamma},\gamma)$, $p(\vec{\gamma},\pi^0)$, $p(\vec{\gamma},\pi^+)$
1.2 ±0.7 ±0.5	[5] OLMOSDEL...	01	CNTR	γp Compton scattering
2.1 ±0.8 ±0.5	[6] MACGIBBON	95	RVUE	global average
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.3 ±0.9 ±0.7	[7] BARANOV	01	RVUE	Global average
1.7 ±0.6 ±0.9	MACGIBBON	95	CNTR	γp Compton scattering
4.4 ±0.4 ±1.1	HALLIN	93	CNTR	γp Compton scattering
$3.58^{+1.19}_{-1.25}{}^{+1.03}_{-1.07}$	ZIEGER	92	CNTR	γp Compton scattering
3.3 ±2.2 ±1.3	FEDERSPIEL	91	CNTR	γp Compton scattering

OCCUR=2

[1] MORNACCHI 22 perform the first simultaneous extraction of the six leading-order proton polarizabilities using fixed-t subtracted dispersion relations and a bootstrap-based fitting technique. NODE=S016MPL;LINKAGE=B

[2] PASQUINI 19 fit data sets for the unpolarized proton RCS cross section, using fixed-t subtracted dispersion relations and a bootstrap-based fitting technique. NODE=S016MPL;LINKAGE=A

[3] BEANE 03 uses effective field theory and low-energy γp and γd Compton-scattering data. It also gets for the isoscalar polarizabilities (see the erratum) $\alpha_N = (13.0 \pm 1.9^{+3.9}_{-1.5}) \times 10^{-4}$ fm^3 and $\beta_N = (-1.8 \pm 1.9^{+2.1}_{-0.9}) \times 10^{-4}$ fm^3. NODE=S016MPL;LINKAGE=B3

[4] BLANPIED 01 gives $\alpha_p + \beta_p$ and $\alpha_p - \beta_p$. The separate α_p and β_p are provided to us by A. Sandorfi. The first error above is statistics plus systematics; the second is from the model. NODE=S016MPL;LINKAGE=SF

[5] 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

[6] 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

[7] 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 SPIN POLARIZABILITY γ_{E1E1}

NODE=S016A00
NODE=S016A00

VALUE (10^{-4} fm^4)	DOCUMENT ID		TECN	COMMENT
−3.0±0.6±0.4	[1] MORNACCHI	22	FIT	Fit of RCS data sets

[1] MORNACCHI 22 perform the first simultaneous extraction of the six leading-order proton polarizabilities using fixed-t subtracted dispersion relations and a bootstrap-based fitting technique. NODE=S016A00;LINKAGE=A

p SPIN POLARIZABILITY γ_{M1M1}

NODE=S016A01
NODE=S016A01

VALUE (10^{-4} fm^4)	DOCUMENT ID		TECN	COMMENT
3.7±0.5±0.1	[1] MORNACCHI	22	FIT	Fit of RCS data sets

[1] MORNACCHI 22 perform the first simultaneous extraction of the six leading-order proton polarizabilities using fixed-t subtracted dispersion relations and a bootstrap-based fitting technique. NODE=S016A01;LINKAGE=A

p SPIN POLARIZABILITY γ_{E1M2}

NODE=S016A02
NODE=S016A02

VALUE (10^{-4} fm^4)	DOCUMENT ID		TECN	COMMENT
−1.2±1.0±0.3	[1] MORNACCHI	22	FIT	Fit of RCS data sets

[1] MORNACCHI 22 perform the first simultaneous extraction of the six leading-order proton polarizabilities using fixed-t subtracted dispersion relations and a bootstrap-based fitting technique. NODE=S016A02;LINKAGE=A

p SPIN POLARIZABILITY γ_{M1E2}

NODE=S016A03
NODE=S016A03

VALUE (10^{-4} fm^4)	DOCUMENT ID		TECN	COMMENT
2.0±0.7±0.4	[1] MORNACCHI	22	FIT	Fit of RCS data sets

[1] MORNACCHI 22 perform the first simultaneous extraction of the six leading-order proton polarizabilities using fixed-t subtracted dispersion relations and a bootstrap-based fitting technique. NODE=S016A03;LINKAGE=A

p CHARGE RADIUS

NODE=S016CR

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

NODE=S016CR

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

The MOHR 16 value (2014 CODATA), obtained from the electronic results available at the time, was 0.8751(61) fm. This differs by 5.6 standard deviations from the muonic hydrogen value, leading to the so-called proton charge radius puzzle. See our 2018 edition (Physical Review **D98** 030001 (2018)) for a further discussion of interpretations of this puzzle. However, reflecting the new electronic measurements, the 2018 CODATA, TIESINGA 21, recommended value is 0.8414(19) fm, and the puzzle appears to be resolved.

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

NODE=S016CR

VALUE (fm)			*DOCUMENT ID*		*TECN*	*COMMENT*
0.8409	**±0.0004**	**OUR AVERAGE**				
0.833	±0.010		[1] BEZGINOV	19	LASR	2S-2P transition in H
0.831	±0.007	±0.012	[2] XIONG	19	SPEC	$e p \to e p$ form factor
0.84087	±0.00026	±0.00029	ANTOGNINI	13	LASR	μp-atom Lamb shift
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.847	±0.008		[3] CUI	21	FIT	use existing $e p$ data
0.878	±0.011	±0.031	[4] MIHOVILOVIC	21		ISR $e p \to e p$ reanalysis
0.877	±0.013		[5] FLEURBAEY	18	LASR	1S-3S transition in H
0.8335	±0.0095		[6] BEYER	17	LASR	2S-4P transition in H
0.8751	±0.0061		MOHR	16	RVUE	2014 CODATA value
0.895	±0.014	±0.014	[7] LEE	15	SPEC	Just 2010 Mainz data
0.916	±0.024		LEE	15	SPEC	World data, no Mainz
0.8775	±0.0051		MOHR	12	RVUE	2010 CODATA, $e p$ data
0.875	±0.008	±0.006	ZHAN	11	SPEC	Recoil polarimetry
0.879	±0.005	±0.006	BERNAUER	10	SPEC	$e p \to e p$ form factor
0.912	±0.009	±0.007	BORISYUK	10		reanalyzes old $e p$ data
0.871	±0.009	±0.003	HILL	10		z-expansion reanalysis
0.84184	±0.00036	±0.00056	POHL	10	LASR	See ANTOGNINI 13
0.8768	±0.0069		MOHR	08	RVUE	2006 CODATA value
0.844	$^{+0.008}_{-0.004}$		BELUSHKIN	07		Dispersion analysis
0.897	±0.018		BLUNDEN	05		SICK 03 + 2γ correction
0.8750	±0.0068		MOHR	05	RVUE	2002 CODATA value
0.895	±0.010	±0.013	SICK	03		$e p \to e p$ reanalysis

OCCUR=2

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

NODE=S016CR;LINKAGE=E

[2] The XIONG 19 value from $e p \to e p$ scattering and supports the muonic hydrogen Lamb shift value.

NODE=S016CR;LINKAGE=F

[3] CUI 21 employ a new mathematical procedure (statistical SPM, Schlessinger point method) based on form-unbiased interpolations of existing $e p$ scattering data.

NODE=S016CR;LINKAGE=G

[4] MIHOVILOVIC 21 reports a value of 0.878 ± 0.011 ± 0.031 ± 0.002 fm where the last uncertainty comes from the dependence on the model form factor function.

NODE=S016CR;LINKAGE=H

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

NODE=S016CR;LINKAGE=D

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

NODE=S016CR;LINKAGE=C

[7] Authors also provide values for combinations of all available data.

NODE=S016CR;LINKAGE=A

p MAGNETIC RADIUS

NODE=S016MCR

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

NODE=S016MCR

NODE=S016MCR

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

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

NODE=S016MCR;LINKAGE=A

[2] CUI 21B employ a new mathematical procedure (statistical SPM, Schlessinger point method) based on form-unbiased interpolations of existing $e p$ scattering data.

NODE=S016MCR;LINKAGE=B

p MEAN LIFE

NODE=S016T

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

NODE=S016T

NODE=S016T

LIMIT (years)	PARTICLE	CL%	DOCUMENT ID		TECN	COMMENT
>0.96 × 10^30	***p***	90	[1] ALLEGA	22	SNO+	$p \to$ invisible
>0.9 × 10^30	***n***	90	[2] ALLEGA	22	SNO+	$n \to$ invisible
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$>1.3 \times 10^{24}$	p	90	[3] AGOSTINI	24A	HPGE	$p \to$ invisible
$>1.5 \times 10^{24}$	n	90	[4] AGOSTINI	24A	HPGE	$n \to$ invisible
$>3.6 \times 10^{29}$	p	90	[5] ANDERSON	19A	SNO+	$p \to$ invisible
$>2.5 \times 10^{29}$	n	90	[5] ANDERSON	19A	SNO+	$n \to$ invisible
$>5.8 \times 10^{29}$	n	90	[6] ARAKI	06	KLND	$n \to$ invisible
$>2.1 \times 10^{29}$	p	90	[5] AHMED	04	SNO	$p \to$ invisible
$>1.9 \times 10^{29}$	n	90	[5] AHMED	04	SNO	$n \to$ invisible
$>1.8 \times 10^{25}$	n	90	[7] BACK	03	BORX	
$>1.1 \times 10^{26}$	p	90	[7] BACK	03	BORX	
$>3.5 \times 10^{28}$	p	90	[8] ZDESENKO	03		$p \to$ invisible
$>1 \times 10^{28}$	p	90	[9] AHMAD	02	SNO	$p \to$ invisible
$>4 \times 10^{23}$	p	95	TRETYAK	01		$d \to n + ?$
$>1.9 \times 10^{24}$	p	90	[10] BERNABEI	00B	DAMA	
$>1.6 \times 10^{25}$	p, n		[11,12] EVANS	77		
$>3 \times 10^{23}$	p		[12] DIX	70	CNTR	
$>3 \times 10^{23}$	p, n		[12,13] FLEROV	58		

OCCUR=2

OCCUR=2

OCCUR=2

OCCUR=2

OCCUR=2

[1] ALLEGA 22 look for γ rays from the de-excitation of a residual $^{15}N^*$ following the disappearance of p in ^{16}O.

NODE=S016T;LINKAGE=A

[2] ALLEGA 22 look for γ rays from the de-excitation of a residual $^{15}O^*$ following the disappearance of n in ^{16}O.

NODE=S016T;LINKAGE=B

[3] AGOSTINI 24A look for γ rays from the de-excitation of a residual $^{75}As^*$ following the disappearance of p in ^{76}Ge (through the transition chain $^{76}Ge \to {}^{75}Ga \to {}^{75}Ge \to {}^{75}As$).

NODE=S016T;LINKAGE=C

[4] AGOSTINI 24A look for γ rays from the de-excitation of a residual $^{75}As^*$ following the disappearance of n in ^{76}Ge (through the transition chain $^{76}Ge \to {}^{75}Ge \to {}^{75}As$).

NODE=S016T;LINKAGE=D

[5] AHMED 04 and ANDERSON 19A look for γ rays from the de-excitation of a residual $^{15}O^*$ or $^{15}N^*$ following the disappearance of a neutron or proton in ^{16}O.

NODE=S016T;LINKAGE=A4

[6] 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

[7] 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

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

NODE=S016T;LINKAGE=ZO

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

NODE=S016T;LINKAGE=KH

[10] 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

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

[12] 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

[13] 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=S016TA

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

NODE=S016TA

NODE=S016TA

LIMIT (years)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>5.0	90		SELLNER	17	TRAP	Penning trap
$>8 \times 10^5$	90		[1] GEER	00D		$\overline{p}/p$ ratio, cosmic rays
>0.28			GABRIELSE	90	TRAP	Penning trap
>0.08	90	1	BELL	79	CNTR	Storage ring
$>1 \times 10^7$			GOLDEN	79	SPEC	$\overline{p}/p$ ratio, cosmic rays
$>3.7 \times 10^{-3}$			BREGMAN	78	CNTR	Storage ring

[1] GEER 00D uses agreement between a model of galactic $\overline{p}$ production and propagation and the observed $\overline{p}/p$ cosmic-ray spectrum to set this limit. 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 τ/B_i, where τ is the total mean life and B_i is the branching fraction for the mode in question. For N decays, p and n indicate proton and neutron partial lifetimes.

	Mode	Partial mean life (10^{30} years)	Confidence level	
	Antilepton + meson			NODE=S016;CLUMP=B
τ_1	$N \to e^+ \pi$	> 5300 (n), > 24000 (p)	90%	DESIG=6;OUR LIM;→ UNCHECKED ←
τ_2	$N \to \mu^+ \pi$	> 3500 (n), > 16000 (p)	90%	DESIG=7;OUR LIM;→ UNCHECKED ←
τ_3	$N \to \nu \pi$	> 1100 (n), > 390 (p)	90%	DESIG=10;OUR LIM;→ UNCHECKED ←
τ_4	$p \to e^+ \eta$	> 10000	90%	DESIG=22;OUR LIM;→ UNCHECKED ←
τ_5	$p \to \mu^+ \eta$	> 4700	90%	DESIG=23;OUR LIM;→ UNCHECKED ←
τ_6	$n \to \nu \eta$	> 158	90%	DESIG=24;OUR LIM;→ UNCHECKED ←
τ_7	$N \to e^+ \rho$	> 217 (n), > 720 (p)	90%	DESIG=14;OUR LIM;→ UNCHECKED ←
τ_8	$N \to \mu^+ \rho$	> 228 (n), > 570 (p)	90%	DESIG=15;OUR LIM;→ UNCHECKED ←
τ_9	$N \to \nu \rho$	> 19 (n), > 162 (p)	90%	DESIG=25;OUR LIM;→ UNCHECKED ←
τ_{10}	$p \to e^+ \omega$	> 1600	90%	DESIG=12;OUR LIM;→ UNCHECKED ←
τ_{11}	$p \to \mu^+ \omega$	> 2800	90%	DESIG=13;OUR LIM;→ UNCHECKED ←
τ_{12}	$n \to \nu \omega$	> 108	90%	DESIG=26;OUR LIM;→ UNCHECKED ←
τ_{13}	$N \to e^+ K$	> 17 (n), > 1000 (p)	90%	DESIG=8;OUR LIM;→ UNCHECKED ←
τ_{14}	$p \to e^+ K^0_S$			DESIG=50
τ_{15}	$p \to e^+ K^0_L$			DESIG=51
τ_{16}	$N \to \mu^+ K$	> 26 (n), > 4500 (p)	90%	DESIG=9;OUR LIM;→ UNCHECKED ←
τ_{17}	$p \to \mu^+ K^0_S$			DESIG=52
τ_{18}	$p \to \mu^+ K^0_L$			DESIG=53
τ_{19}	$N \to \nu K$	> 86 (n), > 5900 (p)	90%	DESIG=11;OUR LIM;→ UNCHECKED ←
τ_{20}	$n \to \nu K^0_S$	> 260	90%	DESIG=99;OUR LIM;→ UNCHECKED ←
τ_{21}	$p \to e^+ K^*(892)^0$	> 84	90%	DESIG=34;OUR LIM;→ UNCHECKED ←
τ_{22}	$N \to \nu K^*(892)$	> 78 (n), > 51 (p)	90%	DESIG=18;OUR LIM;→ UNCHECKED ←

	Antilepton + mesons			NODE=S016;CLUMP=E
τ_{23}	$p \to e^+ \pi^+ \pi^-$	> 82	90%	DESIG=56;OUR LIM;→ UNCHECKED ←
τ_{24}	$p \to e^+ \pi^0 \pi^0$	> 147	90%	DESIG=57;OUR LIM;→ UNCHECKED ←
τ_{25}	$n \to e^+ \pi^- \pi^0$	> 52	90%	DESIG=58;OUR LIM;→ UNCHECKED ←
τ_{26}	$p \to \mu^+ \pi^+ \pi^-$	> 133	90%	DESIG=48;OUR LIM;→ UNCHECKED ←
τ_{27}	$p \to \mu^+ \pi^0 \pi^0$	> 101	90%	DESIG=59;OUR LIM;→ UNCHECKED ←
τ_{28}	$n \to \mu^+ \pi^- \pi^0$	> 74	90%	DESIG=60;OUR LIM;→ UNCHECKED ←
τ_{29}	$n \to e^+ K^0 \pi^-$	> 18	90%	DESIG=61;OUR LIM;→ UNCHECKED ←
	Lepton + meson			NODE=S016;CLUMP=F
τ_{30}	$n \to e^- \pi^+$	> 65	90%	DESIG=29;OUR LIM;→ UNCHECKED ←
τ_{31}	$n \to \mu^- \pi^+$	> 49	90%	DESIG=30;OUR LIM;→ UNCHECKED ←
τ_{32}	$n \to e^- \rho^+$	> 62	90%	DESIG=31;OUR LIM;→ UNCHECKED ←
τ_{33}	$n \to \mu^- \rho^+$	> 7	90%	DESIG=32;OUR LIM;→ UNCHECKED ←
τ_{34}	$n \to e^- K^+$	> 32	90%	DESIG=33;OUR LIM;→ UNCHECKED ←
τ_{35}	$n \to \mu^- K^+$	> 57	90%	DESIG=35;OUR LIM;→ UNCHECKED ←
	Lepton + mesons			NODE=S016;CLUMP=G
τ_{36}	$p \to e^- \pi^+ \pi^+$	> 30	90%	DESIG=47;OUR LIM;→ UNCHECKED ←
τ_{37}	$n \to e^- \pi^+ \pi^0$	> 29	90%	DESIG=39;OUR LIM;→ UNCHECKED ←
τ_{38}	$p \to \mu^- \pi^+ \pi^+$	> 17	90%	DESIG=49;OUR LIM;→ UNCHECKED ←
τ_{39}	$n \to \mu^- \pi^+ \pi^0$	> 34	90%	DESIG=40;OUR LIM;→ UNCHECKED ←
τ_{40}	$p \to e^- \pi^+ K^+$	> 75	90%	DESIG=41;OUR LIM;→ UNCHECKED ←
τ_{41}	$p \to \mu^- \pi^+ K^+$	> 245	90%	DESIG=42;OUR LIM;→ UNCHECKED ←
	Antilepton + photon(s)			NODE=S016;CLUMP=C
τ_{42}	$p \to e^+ \gamma$	> 670	90%	DESIG=3;OUR LIM;→ UNCHECKED ←
τ_{43}	$p \to \mu^+ \gamma$	> 478	90%	DESIG=4;OUR LIM;→ UNCHECKED ←
τ_{44}	$n \to \nu \gamma$	> 550	90%	DESIG=5;OUR LIM;→ UNCHECKED ←
τ_{45}	$p \to e^+ \gamma \gamma$	> 100	90%	DESIG=54;OUR LIM;→ UNCHECKED ←
τ_{46}	$n \to \nu \gamma \gamma$	> 219	90%	DESIG=93;OUR LIM;→ UNCHECKED ←
	Antilepton + single massless			NODE=S016;CLUMP=H
τ_{47}	$p \to e^+ X$	> 790	90%	DESIG=194;OUR LIM;→ UNCHECKED ←
τ_{48}	$p \to \mu^+ X$	> 410	90%	DESIG=195;OUR LIM;→ UNCHECKED ←
	Three (or more) leptons			NODE=S016;CLUMP=D
τ_{49}	$p \to e^+ e^+ e^-$	> 34000	90%	DESIG=16;OUR LIM;→ UNCHECKED ←
τ_{50}	$p \to e^+ \mu^+ \mu^-$	> 9200	90%	DESIG=45;OUR LIM;→ UNCHECKED ←
τ_{51}	$p \to e^+ \nu \nu$	> 170	90%	DESIG=36;OUR LIM;→ UNCHECKED ←
τ_{52}	$n \to e^+ e^- \nu$	> 257	90%	DESIG=27;OUR LIM;→ UNCHECKED ←
τ_{53}	$n \to \mu^+ e^- \nu$	> 83	90%	DESIG=37;OUR LIM;→ UNCHECKED ←
τ_{54}	$n \to \mu^+ \mu^- \nu$	> 79	90%	DESIG=28;OUR LIM;→ UNCHECKED ←
τ_{55}	$p \to \mu^+ e^+ e^-$	> 23000	90%	DESIG=55;OUR LIM;→ UNCHECKED ←
τ_{56}	$p \to \mu^- e^+ e^+$	> 19000	90%	DESIG=196;OUR LIM;→ UNCHECKED ←
τ_{57}	$p \to \mu^+ \mu^+ \mu^-$	> 10000	90%	DESIG=17;OUR LIM;→ UNCHECKED ←
τ_{58}	$p \to \mu^+ \nu \nu$	> 220	90%	DESIG=38;OUR LIM;→ UNCHECKED ←
τ_{59}	$p \to e^- \mu^+ \mu^+$	> 11000	90%	DESIG=46;OUR LIM;→ UNCHECKED ←
τ_{60}	$n \to 3\nu$	$> 5 \times 10^{-4}$	90%	DESIG=21;OUR LIM;→ UNCHECKED ←
τ_{61}	$n \to 5\nu$			DESIG=86
	Inclusive modes			NODE=S016;CLUMP=A
τ_{62}	$N \to e^+$ anything	> 0.6 (n, p)	90%	DESIG=1;OUR LIM;→ UNCHECKED ←
τ_{63}	$N \to \mu^+$ anything	> 12 (n, p)	90%	DESIG=2;OUR LIM;→ UNCHECKED ←
τ_{64}	$N \to \nu$ anything			DESIG=20
τ_{65}	$N \to e^+ \pi^0$ anything	> 0.6 (n, p)	90%	DESIG=19;OUR LIM;→ UNCHECKED ←
τ_{66}	$N \to$ 2 bodies, ν-free			DESIG=191

$\Delta B = 2$ dinucleon modes

NODE=S016;CLUMP=I

The following are lifetime limits per iron nucleus.

NODE=S016

	Mode	Partial mean life	Confidence level	
τ_{67}	$pp \rightarrow \pi^+ \pi^+$	> 72.2	90%	DESIG=62;OUR LIM;→ UNCHECKED ←
τ_{68}	$pn \rightarrow \pi^+ \pi^0$	> 170	90%	DESIG=63;OUR LIM;→ UNCHECKED ←
τ_{69}	$nn \rightarrow \pi^+ \pi^-$	> 0.7	90%	DESIG=64;OUR LIM;→ UNCHECKED ←
τ_{70}	$nn \rightarrow \pi^0 \pi^0$	> 404	90%	DESIG=65;OUR LIM;→ UNCHECKED ←
τ_{71}	$pp \rightarrow K^+ K^+$	> 170	90%	DESIG=193;OUR LIM;→ UNCHECKED ←
τ_{72}	$pp \rightarrow e^+ e^+$	> 5.8	90%	DESIG=66;OUR LIM;→ UNCHECKED ←
τ_{73}	$pp \rightarrow e^+ \mu^+$	> 3.6	90%	DESIG=67;OUR LIM;→ UNCHECKED ←
τ_{74}	$pp \rightarrow \mu^+ \mu^+$	> 1.7	90%	DESIG=68;OUR LIM;→ UNCHECKED ←
τ_{75}	$pn \rightarrow e^+ \overline{\nu}$	> 260	90%	DESIG=69;OUR LIM;→ UNCHECKED ←
τ_{76}	$pn \rightarrow \mu^+ \overline{\nu}$	> 200	90%	DESIG=70;OUR LIM;→ UNCHECKED ←
τ_{77}	$pn \rightarrow \tau^+ \overline{\nu}_\tau$	> 29	90%	DESIG=192;OUR LIM;→ UNCHECKED ←
τ_{78}	$nn \rightarrow$ invisible	> 1.4	90%	DESIG=199;OUR LIM;→ UNCHECKED ←
τ_{79}	$nn \rightarrow \nu_e \overline{\nu}_e$	> 1.4	90%	DESIG=71;OUR LIM;→ UNCHECKED ←
τ_{80}	$nn \rightarrow \nu_\mu \overline{\nu}_\mu$	> 1.4	90%	DESIG=72;OUR LIM;→ UNCHECKED ←
τ_{81}	$pn \rightarrow$ invisible	> 0.06	90%	DESIG=101;OUR LIM;→ UNCHECKED ←
τ_{82}	$pp \rightarrow$ invisible	> 0.11	90%	DESIG=100;OUR LIM;→ UNCHECKED ←

$\overline{p}$ DECAY MODES

NODE=S016;CLUMP=M
NODE=S016

	Mode	Partial mean life (years)	Confidence level	
τ_{83}	$\overline{p} \rightarrow e^- \gamma$	$> 7 \times 10^5$	90%	DESIG=81;OUR LIM;→ UNCHECKED ←
τ_{84}	$\overline{p} \rightarrow \mu^- \gamma$	$> 5 \times 10^4$	90%	DESIG=87;OUR LIM;→ UNCHECKED ←
τ_{85}	$\overline{p} \rightarrow e^- \pi^0$	$> 4 \times 10^5$	90%	DESIG=82;OUR LIM;→ UNCHECKED ←
τ_{86}	$\overline{p} \rightarrow \mu^- \pi^0$	$> 5 \times 10^4$	90%	DESIG=88;OUR LIM;→ UNCHECKED ←
τ_{87}	$\overline{p} \rightarrow e^- \eta$	$> 2 \times 10^4$	90%	DESIG=83;OUR LIM;→ UNCHECKED ←
τ_{88}	$\overline{p} \rightarrow \mu^- \eta$	$> 8 \times 10^3$	90%	DESIG=89;OUR LIM;→ UNCHECKED ←
τ_{89}	$\overline{p} \rightarrow e^- K^0_S$	> 900	90%	DESIG=84;OUR LIM;→ UNCHECKED ←
τ_{90}	$\overline{p} \rightarrow \mu^- K^0_S$	$> 4 \times 10^3$	90%	DESIG=90;OUR LIM;→ UNCHECKED ←
τ_{91}	$\overline{p} \rightarrow e^- K^0_L$	$> 9 \times 10^3$	90%	DESIG=85;OUR LIM;→ UNCHECKED ←
τ_{92}	$\overline{p} \rightarrow \mu^- K^0_L$	$> 7 \times 10^3$	90%	DESIG=91;OUR LIM;→ UNCHECKED ←
τ_{93}	$\overline{p} \rightarrow e^- \gamma\gamma$	$> 2 \times 10^4$	90%	DESIG=94;OUR LIM;→ UNCHECKED ←
τ_{94}	$\overline{p} \rightarrow \mu^- \gamma\gamma$	$> 2 \times 10^4$	90%	DESIG=92;OUR LIM;→ UNCHECKED ←
τ_{95}	$\overline{p} \rightarrow e^- \omega$	> 200	90%	DESIG=96;OUR LIM;→ UNCHECKED ←

p PARTIAL MEAN LIVES

NODE=S016230

The "partial mean life" limits tabulated here are the limits on τ/B_i, where τ is the total mean life for the proton and B_i is the branching fraction for the mode in question.

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

$\tau(N \rightarrow e^+ \pi)$ τ_1

NODE=S016T06
NODE=S016T06

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	
>24000	***p***	**90**	**0**	**0.59**	[1] TAKENAKA	20	SKAM	
> 5300	***n***	**90**	**0**	**0.41**	ABE	17D	SKAM	
• • • We do not use the following data for averages, fits, limits, etc. • • •								
>16000	*p*	90	0	0.61	ABE	17	SKAM	
> 2000	*n*	90	0	0.27	NISHINO	12	SKAM	
> 8200	*p*	90	0	0.3	NISHINO	09	SKAM	
> 540	*p*	90	0	0.2	MCGREW	99	IMB3	
> 158	*n*	90	3	5	MCGREW	99	IMB3	OCCUR=2
> 1600	*p*	90	0	0.1	SHIOZAWA	98	SKAM	
> 70	*p*	90	0	0.5	BERGER	91	FREJ	

> 70	*n*	90	0	≤ 0.1	BERGER	91	FREJ	OCCUR=2
> 550	*p*	90	0	0.7	[2] 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	[3] BARTELT	83	SOUD	
> 0.5	*n*	90	1	0.3	[3] BARTELT	83	SOUD	OCCUR=2
> 5.8	*p*	90	2		[4] KRISHNA...	82	KOLR	
> 5.8	*n*	90	2		[4] KRISHNA...	82	KOLR	OCCUR=2
> 0.1	*n*	90			[5] GURR	67	CNTR	

[1] TAKENAKA 20 includes data of ABE 17, and thus supersedes ABE 17. NODE=S016T06;LINKAGE=A
[2] This BECKER-SZENDY 90 result includes data from SEIDEL 88. NODE=S016T06;LINKAGE=L
[3] Limit based on zero events. NODE=S016T06;LINKAGE=B
[4] We have calculated 90% CL limit from 1 confined event. NODE=S016T06;LINKAGE=K
[5] We have converted half-life to 90% CL mean life. NODE=S016T06;LINKAGE=G

$\tau(N \to \mu^+ \pi)$ τ_2

NODE=S016T07
NODE=S016T07

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	
>16000	***p***	**90**	**1**	**0.94**	[1] TAKENAKA	20	SKAM	
> 3500	***n***	**90**	**1**	**0.77**	ABE	17D	SKAM	
• • • We do not use the following data for averages, fits, limits, etc. • • •								
> 7700	*p*	90	2	0.87	ABE	17	SKAM	
> 1000	*n*	90	1	0.43	NISHINO	12	SKAM	
> 6600	*p*	90	0	0.3	NISHINO	09	SKAM	
> 473	*p*	90	0	0.6	MCGREW	99	IMB3	
> 90	*n*	90	1	1.9	MCGREW	99	IMB3	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	
> 100	*n*	90	0	<0.2	HIRATA	89C	KAMI	OCCUR=2
> 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	

[1] TAKENAKA 20 includes the data of ABE 17 and thus supersedes ABE 17. NODE=S016T07;LINKAGE=A

$\tau(N \to \nu \pi)$ τ_3

NODE=S016T10
NODE=S016T10

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	
> 390	***p***	**90**	**52.8**		ABE	14E	SKAM	
>1100	***n***	**90**	**19.1**		ABE	14E	SKAM	OCCUR=2
• • • We do not use the following data for averages, fits, limits, etc. • • •								
> 16	*p*	90	6	6.7	WALL	00B	SOU2	
> 39	*n*	90	4	3.8	WALL	00B	SOU2	OCCUR=2
> 10	*p*	90	15	20.3	MCGREW	99	IMB3	
> 112	*n*	90	6	6.6	MCGREW	99	IMB3	OCCUR=2
> 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	[1] 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	≤ 3		BATTISTONI	84	NUSX	OCCUR=2
> 5.8	p	90	1		[2] KRISHNA...	82	KOLR	
> 0.3	p	90	2		[3] CHERRY	81	HOME	
> 0.1	p	90			[4] GURR	67	CNTR	

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

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

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

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

$\tau(p \to e^+ \eta)$ τ_4

NODE=S016T22
NODE=S016T22

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	
>14000	***p***	**90**	**0**	**0.42**	[1] TANIUCHI	24	SKAM	
• • • We do not use the following data for averages, fits, limits, etc. • • •								
>10000	p	90	0	0.78	ABE	17D	SKAM	
> 4200	p	90	0	0.44	NISHINO	12	SKAM	
> 81	p	90	1	1.7	WALL	00B	SOU2	
> 313	p	90	0	0.2	MCGREW	99	IMB3	
> 44	p	90	0	0.1	BERGER	91	FREJ	
> 140	p	90	0	<0.04	HIRATA	89C	KAMI	
> 100	p	90	0	0.6	SEIDEL	88	IMB	
> 200	p	90	5	3.3	HAINES	86	IMB	
> 64	p	90	0	<0.8	ARISAKA	85	KAMI	
> 64	p (free)	90	5	6.5	BLEWITT	85	IMB	
> 200	p	90	5	4.7	BLEWITT	85	IMB	OCCUR=2
> 1.2	p	90	2		[2] CHERRY	81	HOME	

[1] TANIUCHI 24 includes the ABE 17D dataset and thus supersedes ABE 17D entries. NODE=S016T22;LINKAGE=A

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

$\tau(p \to \mu^+ \eta)$ τ_5

NODE=S016T23
NODE=S016T23

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	
>7300	***p***	**90**	**2**	**0.93**	[1] TANIUCHI	24	SKAM	
• • • We do not use the following data for averages, fits, limits, etc. • • •								
>4700	p	90	2	0.85	ABE	17D	SKAM	
>1300	p	90	2	0.49	NISHINO	12	SKAM	
> 89	p	90	0	1.6	WALL	00B	SOU2	
> 126	p	90	3	2.8	MCGREW	99	IMB3	
> 26	p	90	1	0.8	BERGER	91	FREJ	
> 69	p	90	1	<0.08	HIRATA	89C	KAMI	
> 1.3	p	90	0	0.7	PHILLIPS	89	HPW	
> 34	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

[1] TANIUCHI 24 includes the ABE 17D dataset and thus supersedes ABE 17D entries. NODE=S016T23;LINKAGE=A

$\tau(n \to \nu \eta)$ τ_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		[1] CHERRY	81	HOME

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

NODE=S016T24;LINKAGE=C

$\tau(N \to e^+ \rho)$ τ_7

NODE=S016T14
NODE=S016T14

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	
>720	***p***	**90**	**2**	**0.64**	ABE	17D	SKAM	
>217	***n***	**90**	**4**	**4.8**	MCGREW	99	IMB3	
• • • We do not use the following data for averages, fits, limits, etc. • • •								
> 30	*n*	90	4	0.87	ABE	17D	SKAM	OCCUR=2
>710	*p*	90	0	0.35	NISHINO	12	SKAM	
> 70	*n*	90	1	0.38	NISHINO	12	SKAM	OCCUR=2
> 29	*p*	90	0	2.2	BERGER	91	FREJ	
> 41	*n*	90	0	1.4	BERGER	91	FREJ	OCCUR=2
> 75	*p*	90	2	2.7	HIRATA	89C	KAMI	
> 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	[1] BARTELT	83	SOUD	
> 0.5	*p*	90	1	0.3	[1] BARTELT	83	SOUD	OCCUR=2
> 9.8	*p*	90	1		[2] KRISHNA...	82	KOLR	
> 0.8	*p*	90	2		[3] CHERRY	81	HOME	

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

$\tau(N \to \mu^+ \rho)$ τ_8

NODE=S016T15
NODE=S016T15

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	
>570	***p***	**90**	**1**	**1.30**	ABE	17D	SKAM	
>228	***n***	**90**	**3**	**9.5**	MCGREW	99	IMB3	
• • • We do not use the following data for averages, fits, limits, etc. • • •								
> 60	*n*	90	1	0.96	ABE	17D	SKAM	OCCUR=2
>160	*p*	90	1	0.42	NISHINO	12	SKAM	
> 36	*n*	90	0	0.29	NISHINO	12	SKAM	OCCUR=2
> 12	*p*	90	0	0.5	BERGER	91	FREJ	
> 22	*n*	90	0	1.1	BERGER	91	FREJ	OCCUR=2
>110	*p*	90	0	1.7	HIRATA	89C	KAMI	
> 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

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

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

$\tau(p \to e^+\omega)$ τ_{10}

NODE=S016T12
NODE=S016T12

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	
>1600	***p***	**90**	**1**	**1.35**	ABE	17D	SKAM	
• • • We do not use the following data for averages, fits, limits, etc. • • •								
> 320	p	90	1	0.53	NISHINO	12	SKAM	
> 107	p	90	7	10.8	MCGREW	99	IMB3	
> 17	p	90	0	1.1	BERGER	91	FREJ	
> 45	p	90	2	1.45	HIRATA	89C	KAMI	
> 26	p	90	1	1.0	SEIDEL	88	IMB	
> 1.5	p	90	0		BARTELT	87	SOUD	
> 37	p	90	6	5.3	HAINES	86	IMB	
> 25	p	90	1	<1.4	ARISAKA	85	KAMI	
> 12	p (free)	90	6	7.5	BLEWITT	85	IMB	
> 37	p	90	6	5.7	BLEWITT	85	IMB	OCCUR=2
> 0.6	p	90	1	0.3	[1] BARTELT	83	SOUD	
> 9.8	p	90	1		[2] KRISHNA...	82	KOLR	
> 2.8	p	90	2		[3] CHERRY	81	HOME	

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

$\tau(p \to \mu^+\omega)$ τ_{11}

NODE=S016T13
NODE=S016T13

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	
>2800	***p***	**90**	**0**	**1.09**	ABE	17D	SKAM	
• • • We do not use the following data for averages, fits, limits, etc. • • •								
> 780	p	90	0	0.48	NISHINO	12	SKAM	
> 117	p	90	11	12.1	MCGREW	99	IMB3	
> 11	p	90	0	1.0	BERGER	91	FREJ	
> 57	p	90	2	1.9	HIRATA	89C	KAMI	
> 4.4	p	90	0	0.7	PHILLIPS	89	HPW	
> 10	p	90	2	1.3	SEIDEL	88	IMB	
> 23	p	90	2	1	HAINES	86	IMB	
> 6.5	p (free)	90	9	8.7	BLEWITT	85	IMB	
> 23	p	90	8	7	BLEWITT	85	IMB	OCCUR=2

$\tau(n \to \nu\omega)$ τ_{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		[1] CHERRY	81	HOME

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

$\tau(N \to e^+ K)$ τ_{13}

NODE=S016T08
NODE=S016T08

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	
>1000	**p**	**90**	**6**	**4.7**	KOBAYASHI	05	SKAM	
> 17	**n**	**90**	**35**	**29.4**	MCGREW	99	IMB3	OCCUR=2

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

> 85	p	90	3	4.9	WALL	00	SOU2	
> 31	p	90	23	25.2	MCGREW	99	IMB3	
> 60	p	90	0		BERGER	91	FREJ	
> 150	p	90	0	<0.27	HIRATA	89C	KAMI	
> 70	p	90	0	1.8	SEIDEL	88	IMB	
> 77	p	90	5	4.5	HAINES	86	IMB	
> 38	p	90	0	<0.8	ARISAKA	85	KAMI	
> 24	p (free)	90	7	8.5	BLEWITT	85	IMB	
> 77	p	90	5	4	BLEWITT	85	IMB	OCCUR=2
> 1.3	p	90	0		ALEKSEEV	81	BAKS	
> 1.3	n	90	0		ALEKSEEV	81	BAKS	OCCUR=2

$\tau(p \to e^+ K^0_S)$ τ_{14}

NODE=S016T42
NODE=S016T42

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

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

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

$\tau(p \to e^+ K^0_L)$ τ_{15}

NODE=S016T43
NODE=S016T43

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

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

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

$\tau(N \to \mu^+ K)$ τ_{16}

NODE=S016T09
NODE=S016T09

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	
>4500	**p**	**90**	**1**	**3.08**	[1] MATSUMOTO	22	SKAM	
> 26	**n**	**90**	**20**	**28.4**	MCGREW	99	IMB3	OCCUR=2

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

>3600	p	90	14	16.3	[2] MATSUMOTO	22	SKAM	OCCUR=2
>1600	p	90	13	13.2	REGIS	12	SKAM	
>1300	p	90	3	3.9	KOBAYASHI	05	SKAM	
> 120	p	90	0	<1.2	WALL	00	SOU2	
> 120	p	90	4	7.2	MCGREW	99	IMB3	
> 54	p	90	0		BERGER	91	FREJ	
> 120	p	90	1	0.4	HIRATA	89C	KAMI	
> 3.0	p	90	0	0.7	PHILLIPS	89	HPW	OCCUR=2
> 19	p	90	3	2.5	SEIDEL	88	IMB	
> 1.5	p	90	0		[3] 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		[4] BARTELT	83	SOUD	
> 0.4	n	90	0		[4] BARTELT	83	SOUD	OCCUR=2
> 5.8	p	90	2		[5] KRISHNA...	82	KOLR	
> 2.0	p	90	0		CHERRY	81	HOME	
> 0.2	n	90			[6] GURR	67	CNTR	

[1] MATSUMOTO 22 limit $> 4500 \times 10^{30}$ is derived from the latest dataset SKA IV phase (from 2008 to 2018) with 0.20 Mton·years of exposure. NODE=S016T09;LINKAGE=A

[2] MATSUMOTO 22 limit $> 3600 \times 10^{30}$ is derived from a combination of all datasets SKA I,II, III and IV phase (from 1996 to 2018) with a total of 0.37 Mton·years of exposure. Note, the limit from only SKA IV is stronger, because there were some events observed in SKA II. NODE=S016T09;LINKAGE=C

[3] BARTELT 87 limit applies to $p \to \mu^+ K^0_S$. NODE=S016T09;LINKAGE=S

[4] Limit based on zero events. NODE=S016T09;LINKAGE=B

[5] We have calculated 90% CL limit from 1 confined event. NODE=S016T09;LINKAGE=K

[6] We have converted half-life to 90% CL mean life. NODE=S016T09;LINKAGE=G

$\tau(p \to \mu^+ K^0_S)$ — τ_{17}

NODE=S016T44

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>150	p	90	0	<0.8	WALL	00	SOU2
> 64	p	90	0	1.2	BERGER	91	FREJ

$\tau(p \to \mu^+ K^0_L)$ — τ_{18}

NODE=S016T45

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

$\tau(N \to \nu K)$ — τ_{19}

NODE=S016T11

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

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

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

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

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

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

$\tau(n \to \nu K^0_S)$ — τ_{20}

NODE=S016T75

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>260	**n**	**90**	**34**	**30**	[1] KOBAYASHI	05	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 51	n	90	16	9.1	WALL	00	SOU2

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

$\tau(p \to e^+ K^*(892)^0)$ — τ_{21}

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

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

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

NODE=S016T18;LINKAGE=B

——— Antilepton + mesons ———

NODE=S016310

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

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

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

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

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

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

$\tau(n \to e^+ K^0 \pi^-)$ τ_{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

$\tau(n \to e^- \pi^+)$ τ_{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

$\tau(n \to \mu^- \pi^+)$ τ_{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

$\tau(n \to e^- \rho^+)$ τ_{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

$\tau(n \to \mu^- \rho^+)$ τ_{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

$\tau(n \to e^- K^+)$ τ_{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

$\tau(n \to \mu^- K^+)$ τ_{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

$\tau(p \to e^- \pi^+ \pi^+)$ τ_{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

$\tau(n \to e^- \pi^+ \pi^0)$ τ_{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

$\tau(p \to \mu^- \pi^+ \pi^+)$ τ_{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

$\tau(n \to \mu^- \pi^+ \pi^0)$ τ_{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

$\tau(p \to e^- \pi^+ K^+)$ τ_{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

$\tau(p \to \mu^- \pi^+ K^+)$ τ_{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

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

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

NODE=S016T03;LINKAGE=C

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

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

NODE=S016T04;LINKAGE=C

$\tau(n \to \nu \gamma)$ τ_{44}

NODE=S016T05
NODE=S016T05

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>550		**90**			TAKHISTOV	15	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 28	*n*	90	163	144.7	MCGREW	99	IMB3
> 24	*n*	90	10	6.86	BERGER	91B	FREJ
> 9	*n*	90	73	60	HAINES	86	IMB
> 11	*n*	90	28	19	PARK	85	IMB

$\tau(p \to e^+ \gamma\gamma)$ τ_{45}

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

$\tau(n \to \nu\gamma\gamma)$ τ_{46}

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

Antilepton + single massless

NODE=S016345

$\tau(p \to e^+ X)$ τ_{47}

NODE=S016T00
NODE=S016T00

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

$\tau(p \to \mu^+ X)$ τ_{48}

NODE=S016T61
NODE=S016T61

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

Three (or more) leptons

NODE=S016330

$\tau(p \to e^+ e^+ e^-)$ τ_{49}

NODE=S016T16
NODE=S016T16

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>34000	***p***	**90**	**0**	**0.58**	TANAKA	20	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 793	*p*	90	0	0.5	MCGREW	99	IMB3
> 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

$\tau(p \to e^+ \mu^+ \mu^-)$ τ_{50}

NODE=S016T35
NODE=S016T35

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>9200	***p***	**90**	**1**	**0.27**	TANAKA	20	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 359	*p*	90	1	0.9	MCGREW	99	IMB3
> 81	*p*	90	0	0.16	BERGER	91	FREJ
> 5.0	*p*	90	0	0.7	PHILLIPS	89	HPW

$\tau(p \to e^+ \nu\nu)$ τ_{51}

NODE=S016T54
NODE=S016T54

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

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

NODE=S016T54;LINKAGE=A

$\tau(n \to e^+ e^- \nu)$ τ_{52}

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

$\tau(n \to \mu^+ e^- \nu)$ τ_{53}

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

$\tau(n \to \mu^+ \mu^- \nu)$ τ_{54}

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

$\tau(p \to \mu^+ e^+ e^-)$ τ_{55}

NODE=S016T47

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>23000	***p***	**90**	**0**	**0.5**	TANAKA	20	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 529	*p*	90	0	1.0	MCGREW	99	IMB3
> 91	*p*	90	0	≤ 0.1	BERGER	91	FREJ

$\tau(p \to \mu^- e^+ e^+)$ τ_{56}

NODE=S016T80

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>19000	***p***	**90**	**0**	**0.5**	TANAKA	20	SKAM

$\tau(p \to \mu^+ \mu^+ \mu^-)$ τ_{57}

NODE=S016T17

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>10000	***p***	**90**	**1**	**0.4**	TANAKA	20	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 675	*p*	90	0	0.3	MCGREW	99	IMB3
> 119	*p*	90	0	0.2	BERGER	91	FREJ
> 10.5	*p*	90	0	0.7	PHILLIPS	89	HPW
> 190	*p*	90	1	0.1	HAINES	86	IMB
> 44	*p* (free)	90	1	0.7	BLEWITT	85	IMB
> 190	*p*	90	1	0.9	BLEWITT	85	IMB
> 2.1	*p*	90	1		[1] BATTISTONI	82	NUSX

OCCUR=2

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

NODE=S016T17;LINKAGE=B

$\tau(p \to \mu^+ \nu \nu)$ τ_{58}

NODE=S016T56

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

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

NODE=S016T56;LINKAGE=A

$\tau(p \to e^- \mu^+ \mu^+)$ τ_{59}

NODE=S016T36

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

$\tau(n \to 3\nu)$ τ_{60}

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

LIMIT (10^{30} years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>0.00049	***n***	**90**	**2**	**2**	[1] SUZUKI	93B	KAMI
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.0023	*n*	90			[2] GLICENSTEIN	97	KAMI
>0.00003	*n*	90	11	6.1	[3] BERGER	91B	FREJ
>0.00012	*n*	90	7	11.2	[3] BERGER	91B	FREJ
>0.0005	*n*	90	0		LEARNED	79	RVUE

OCCUR=2

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

NODE=S016T21;LINKAGE=B

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

NODE=S016T21;LINKAGE=C

[3] 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

$\tau(n \to 5\nu)$ — τ_{61}

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			[1] GLICENSTEIN	97	KAMI

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

NODE=S016T73;LINKAGE=C

Inclusive modes

NODE=S016335

$\tau(N \to e^+ \text{anything})$ — τ_{62}

NODE=S016T01
NODE=S016T01

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

[1] The electron may be primary or secondary.

NODE=S016T01;LINKAGE=D

$\tau(N \to \mu^+ \text{anything})$ — τ_{63}

NODE=S016T02
NODE=S016T02

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

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

NODE=S016T02;LINKAGE=C

[2] The muon may be primary or secondary.

NODE=S016T02;LINKAGE=D

$\tau(N \to \nu \text{anything})$ — τ_{64}

NODE=S016T20

Anything = π, ρ, 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

$\tau(N \to e^+ \pi^0 \text{anything})$ — τ_{65}

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

$\tau(N \to 2 \text{ bodies}, \nu\text{-free})$ — τ_{66}

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

$\tau(pp \to \pi^+ \pi^+)$ — τ_{67}

NODE=S016T62
NODE=S016T62

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>72.2	**90**	**2**	**4.45**	GUSTAFSON	15	SKAM	per oxygen nucleus
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 0.7	90	4	2.34	BERGER	91B	FREJ	per iron nucleus

$\tau(pn \to \pi^+ \pi^0)$ — τ_{68}

NODE=S016T63
NODE=S016T63

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>170	**90**			GUSTAFSON	15	SKAM	per oxygen nucleus
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 2.0	90	0	0.31	BERGER	91B	FREJ	per iron nucleus

$\tau(nn \to \pi^+ \pi^-)$ — τ_{69}

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	τ per iron nucleus

$\tau(n n \to \pi^0 \pi^0)$ — τ_{70}

NODE=S016T65

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>404	**90**			GUSTAFSON	15	SKAM	per oxygen nucleus
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 3.4	90	0	0.78	BERGER	91B	FREJ	per iron nucleus

$\tau(p p \to K^+ K^+)$ — τ_{71}

NODE=S016T79

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

$\tau(p p \to e^+ e^+)$ — τ_{72}

NODE=S016T66

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

$\tau(p p \to e^+ \mu^+)$ — τ_{73}

NODE=S016T67

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

$\tau(p p \to \mu^+ \mu^+)$ — τ_{74}

NODE=S016T68

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

$\tau(p n \to e^+ \overline{\nu})$ — τ_{75}

NODE=S016T69

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>260	**90**			TAKHISTOV	15	SKAM	
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 2.8	90	5	9.67	BERGER	91B	FREJ	τ per iron nucleus

$\tau(p n \to \mu^+ \overline{\nu})$ — τ_{76}

NODE=S016T70

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>200	**90**			TAKHISTOV	15	SKAM	
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 1.6	90	4	4.37	BERGER	91B	FREJ	τ per iron nucleus

$\tau(p n \to \tau^+ \overline{\nu}_\tau)$ — τ_{77}

NODE=S016T78

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>29	**90**			TAKHISTOV	15	SKAM
• • • We do not use the following data for averages, fits, limits, etc. • • •						
> 1	90			[1] BRYMAN	14	CHER

[1] BRYMAN 14 uses a MCGREW 99 limit on the $p \to e^+ \nu \nu$ lifetime to extract this value. NODE=S016T78;LINKAGE=A

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

NODE=S016T83

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>1.4	**90**			[1] ARAKI	06	KLND	$n n \to$ invisible
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.015	90			[2,3] ALLEGA	22	SNO+	$n n \to$ invisible
>0.013	90			[2] ANDERSON	19A	SNO+	$n n \to$ invisible
>0.000042	90			[4] TRETYAK	04	CNTR	$n n \to$ invisible
>0.000049	90			[5] BACK	03	BORX	$n n \to$ invisible
>0.000012	90			[6] BERNABEI	00B	DAMA	$n n \to$ invisible

[1] ARAKI 06 looks for signs of de-excitation of the residual nucleus after disappearance of two neutrons from the s shell of ^{12}C. NODE=S016T83;LINKAGE=AR

[2] ALLEGA 22 and ANDERSON 19A look for γ rays from the de-excitation of a residual ^{14}O* following the disappearance of $n n$ in ^{16}O. NODE=S016T83;LINKAGE=A

[3] ALLEGA 22 replaces the previous SNO+ value of ANDERSON 19A. NODE=S016T83;LINKAGE=B

[4] TRETYAK 04 uses data from an old Homestake-mine radiochemical experiment on limits for invisible decays of ^{39}K to ^{37}Ar. NODE=S016T83;LINKAGE=TR

[5] BACK 03 looks for decays of unstable nuclides left after $N N$ decays of parent ^{12}C, ^{13}C, ^{16}O nuclei. These are "invisible channel" limits. NODE=S016T83;LINKAGE=BK

[6] BERNABEI 00B looks for the decay of a $^{127}_{54}$Xe nucleus following the disappearance of an $n n$ pair in the otherwise-stable $^{129}_{54}$Xe nucleus. The limit here applies as well to $n n \to \nu_\mu \overline{\nu}_\mu$, $n n \to \nu_\tau \overline{\nu}_\tau$, or any "disappearance" mode. NODE=S016T83;LINKAGE=BN

$\tau(n n \to \nu_e \overline{\nu}_e)$ τ_{79}

NODE=S016T71

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
>0.000012	**90**	**5**	**9.7**	BERGER	91B	FREJ	τ per iron nucleus

$\tau(n n \to \nu_\mu \overline{\nu}_\mu)$ τ_{80}

NODE=S016T72

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

LIMIT (10^{30} years)	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	COMMENT
> 1.4 (CL=90%) OUR LIMIT							
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.000006	90	4	4.4	BERGER	91B	FREJ	τ per iron nucleus

→ UNCHECKED ←

$\tau(p n \to \text{invisible})$ τ_{81}

NODE=S016T77

This violates charge conservation as well as baryon number conservation.

VALUE (10^{30} years)	CL%	DOCUMENT ID		TECN
>0.06	90	[1,2] ALLEGA	22	SNO+
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>0.026	90	[1] ANDERSON	19A	SNO+
>0.000021	90	[3] TRETYAK	04	CNTR

[1] ALLEGA 22 and ANDERSON 19A look for γ rays from the de-excitation of a residual $^{14}N^*$ following the disappearance of $p n$ in ^{16}O.

NODE=S016T77;LINKAGE=A

[2] ALLEGA 22 replaces the previous SNO+ value of ANDERSON 19A.

NODE=S016T77;LINKAGE=B

[3] 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

$\tau(p p \to \text{invisible})$ τ_{82}

NODE=S016T76

This violates charge conservation as well as baryon number conservation.

VALUE (10^{30} years)	CL%	DOCUMENT ID		TECN
>0.11	90	[1] ALLEGA	22	SNO+
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>0.047	90	[1] ANDERSON	19A	SNO+
>0.00005	90	[2] BACK	03	BORX
>0.00000055	90	[3] BERNABEI	00B	DAMA

OCCUR=2

[1] ALLEGA 22 look for γ rays from the de-excitation of a residual $^{14}C^*$ following the disappearance of $p p$ in ^{16}O. Supersedes ANDERSON 19A result.

NODE=S016T76;LINKAGE=A

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

NODE=S016T76;LINKAGE=BK

[3] BERNABEI 00B looks for the decay of a $^{127}_{52}Te$ nucleus following the disappearance of a $p p$ pair in the otherwise-stable $^{129}_{54}Xe$ nucleus.

NODE=S016T76;LINKAGE=BN

$\Delta B = 1$

NODE=S016350

$\overline{p}$ 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

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

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

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

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

$\tau(\overline{p} \to e^- \pi^0)$ τ_{85}

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

$\tau(\overline{p} \to \mu^- \pi^0)$ τ_{86}

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 × 10^4	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- \eta)$ τ_{87}

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

$\tau(\overline{p} \to \mu^- \eta)$ τ_{88}

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 × 10^3	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- K^0_S)$ τ_{89}

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

$\tau(\overline{p} \to \mu^- K^0_S)$ τ_{90}

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 × 10^3	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- K^0_L)$ τ_{91}

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

$\tau(\overline{p} \to \mu^- K^0_L)$ τ_{92}

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 × 10^3	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- \gamma\gamma)$ τ_{93}

NODE=S016TC3

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

$\tau(\overline{p} \to \mu^- \gamma\gamma)$ τ_{94}

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 × 10^4	90	HU	98B	APEX	8.9 GeV/c $\overline{p}$ beam

$\tau(\overline{p} \to e^- \omega)$ τ_{95}

NODE=S016TC5

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

p REFERENCES

NODE=S016

AGOSTINI	24A	EPJ C84 940	M. Agostini *et al.*	(GERDA Collab.)	REFID=63146
TANIUCHI	24	PR D110 112011	N. Taniuchi *et al.*	(Super-Kamiokande Collab.)	REFID=63109
ALLEGA	22	PR D105 112012	A. Allega *et al.*	(SNO+ Collab.)	REFID=61752
BORCHERT	22	NAT 601 53	M.J. Borchert *et al.*	(BASE Collab.)	REFID=61494
LI	22D	NAT 611 265	R. Li *et al.*		REFID=61996
MATSUMOTO	22	PR D106 072003	R. Matsumoto *et al.*	(Super-Kamiokande Collab.)	REFID=61946
MORNACCHI	22	PRL 129 102501	E. Mornacchi *et al.*	(MAINZ, REGE, PAVI+)	REFID=63009
CUI	21	PRL 127 092001	Z.-F. Cui *et al.*	(NJU, ECT, HZDR)	REFID=61354
CUI	21B	CPL 38 121401	Z.-F. Cui *et al.*	(NJU, ECT, HZDR)	REFID=61616
FINK	21	PRL 127 243001	D.J. Fink, E.G. Myers	(FSU)	REFID=61605
MIHOVILOVIC	21	EPJ A57 107	M. Mihovilovic *et al.*	(LJUB, MAINZ, MIT+)	REFID=61600
TIESINGA	21	RMP 93 025010	E. Tiesinga *et al.*	(NIST)	REFID=61422
TAKENAKA	20	PR D102 112011	A. Takenaka *et al.*	(Super-Kamiokande Collab.)	REFID=60746
TANAKA	20	PR D101 052011	M. Tanaka *et al.*	(Super-Kamiokande Collab.)	REFID=60274
ANDERSON	19A	PR D99 032008	M. Anderson *et al.*	(SNO+ Collab.)	REFID=59829
BEZGINOV	19	SCI 365 1007	N. Bezginov *et al.*	(YORKC, TNTO)	REFID=59978
HEISSE	19	PR A100 022518	F. Heisse *et al.*	(MPIK, GSI, MAINZ)	REFID=60248
PASQUINI	19	JP G46 104001	B. Pasquini, P. Pedroni, S. Sconfietti	(PAVI)	REFID=60249
SCHUMACHER	19	LHEP 4 4	M. Schumacher	(GOET)	REFID=61618
XIONG	19	NAT 575 147	W. Xiong *et al.*	(PRad Collab.)	REFID=59984
FLEURBAEY	18	PRL 120 183001	H. Fleurbaey *et al.*	(SORB)	REFID=59203
PDG	18	PR D98 030001	M. Tanabashi *et al.*	(PDG Collab.)	REFID=59304
ABE	17	PR D95 012004	K. Abe *et al.*	(Super-Kamiokande Collab.)	REFID=57638
ABE	17D	PR D96 012003	K. Abe *et al.*	(Super-Kamiokande Collab.)	REFID=58011
BEYER	17	SCI 358 79	A. Beyer *et al.*	(MPQG Collab.)	REFID=58371
HEISSE	17	PRL 119 033001	F. Heisse *et al.*	(MPIK, GSI, MAINZ, RIKEN)	REFID=57785
NAGAHAMA	17	NATC 8 14084	H. Nagahama *et al.*	(RIKEN, TOKY, CERN+)	REFID=57759
SAHOO	17	PR D95 013002	B.K. Sahoo	(AHMEB)	REFID=57749
SCHNEIDER	17	SCI 358 1081	G. Schneider *et al.*	(MAINZ, RIKEN, +)	REFID=58373
SELLNER	17	NJP 19 083023	S. Sellner *et al.*	(RIKEN, MPIK, +)	REFID=58796
SMORRA	17	NAT 550 371	C. Smorra *et al.*	(RIKEN, CERN, +)	REFID=58374
MOHR	16	RMP 88 035009	P.J. Mohr, D.B. Newell, B.N. Taylor	(NIST)	REFID=57148
ASAKURA	15	PR D92 052006	K. Asakura *et al.*	(KamLAND Collab.)	REFID=56882
GUSTAFSON	15	PR D91 072009	J. Gustafson *et al.*	(Super-Kamiokande Collab.)	REFID=56559
LEE	15	PR D92 013013	G. Lee, J.R. Arrington, R.J. Hill	(ANL, EFI+)	REFID=56603
TAKHISTOV	15	PRL 115 121803	V. Takhistov *et al.*	(Super-Kamiokande Collab.)	REFID=56918
ULMER	15	NAT 524 196	S. Ulmer *et al.*	(RIKEN, CERN, MPIK, +)	REFID=57769
ABE	14E	PRL 113 121802	K. Abe *et al.*	(Super-Kamiokande Collab.)	REFID=55892
ABE	14G	PR D90 072005	K. Abe *et al.*	(Super-Kamiokande Collab.)	REFID=56136
BRYMAN	14	PL B733 190	D. Bryman	(BRCO)	REFID=56146
EPSTEIN	14	PR D90 074027	Z. Epstein, G. Paz, J. Roy	(UMD, WAYN)	REFID=56141
LITOS	14	PRL 112 131803	M. Litos *et al.*	(Super-Kamiokande Collab.)	REFID=55847
PDG	14	CP C38 070001	K. Olive *et al.*	(PDG Collab.)	REFID=55687
TAKHISTOV	14	PRL 113 101801	V. Takhistov *et al.*	(Super-Kamiokande Collab.)	REFID=55894
ANTOGNINI	13	SCI 339 417	A. Antognini *et al.*	(MPIM, ETH, UPMC+)	REFID=54969
DISCIACCA	13	PRL 110 130801	J. DiSciacca *et al.*	(ATRAP Collab.)	REFID=54971
MCGOVERN	13	EPJ A49 12	J.A. McGovern, D.R. Phillips, H.W. Griesshammer		REFID=54970;ERROR=1
MOHR	12	RMP 84 1527	P.J. Mohr, B.N. Taylor, D.B. Newell	(NIST)	REFID=53956
NISHINO	12	PR D85 112001	H. Nishino *et al.*	(Super-Kamiokande Collab.)	REFID=54410
REGIS	12	PR D86 012006	C. Regis *et al.*	(Super-Kamiokande Collab.)	REFID=54418
BRESSI	11	PR A83 052101	G. Bressi *et al.*	(LEGN, PAVII, PADO, TRST+)	REFID=53785
HORI	11	NAT 475 484	M. Hori *et al.*	(MPIG, TOKY, BUDA, +)	REFID=53784
ZHAN	11	PL B705 59	X. Zhan *et al.*	(JLAB-Hall A Collab.)	REFID=57160
BERNAUER	10	PRL 105 242001	J.C. Bernauer *et al.*	(MAMI A1 Collab.)	REFID=53570
Also		PR C90 015206	J.C. Bernauer *et al.*	(MAMI A1 Collab.)	REFID=55778
BORISYUK	10	NP A843 59	D. Borisyuk	(KIEV)	REFID=53322
HILL	10	PR D82 113005	R.J. Hill, G. Paz	(CHIC)	REFID=53580
POHL	10	NAT 466 213	R. Pohl *et al.*	(MPIQ, ENSP, COIM, +)	REFID=53681
NISHINO	09	PRL 102 141801	H. Nishino *et al.*	(Super-Kamiokande Collab.)	REFID=52876
PASK	09	PL B678 55	T. Pask *et al.*	(Stefan Meyer Inst., Vienna, TOKY+)	REFID=52911
MOHR	08	RMP 80 633	P.J. Mohr, B.N. Taylor, D.B. Newell	(NIST)	REFID=52197
BELUSHKIN	07	PR C75 035202	M.A. Belushkin, H.W. Hammer, U.-G. Meissner	(BONN+)	REFID=53687
ARAKI	06	PRL 96 101802	T. Araki *et al.*	(KamLAND Collab.)	REFID=51206
HORI	06	PRL 96 243401	M. Hori *et al.*	(CERN, TOKYO+)	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 (errat.)	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
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 (errat.)	S. Geer *et al.*	(FNAL APEX Collab.)	REFID=47798

GEER	00D	APJ 532 648	S.H. Geer, D.C. Kennedy		REFID=47799
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
GABRIELSE	95	PRL 74 3544	G. Gabrielse *et al.*	(HARV, MAINZ, 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
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 (errat.)	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
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, MAINZ, 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 (errat.)	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 Translated from ZETFP 33 664.	E.N. Alekseev *et al.*	(PNPI)	REFID=11630
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
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
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
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
FLEROV	58	DOKL 3 79	G.N. Flerov *et al.*	(ASCI)	REFID=11655