Citation: K. Nakamura *et al.* (Particle Data Group), JPG **37**, 075021 (2010) (URL: http://pdg.lbl.gov)

n

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

We have omitted some results that have been superseded by later experiments. See our earlier editions.

n MASS (atomic mass units u)

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

VALUE (u)	*DOCUMENT ID*		*TECN*	*COMMENT*
1.00866491597±0.00000000043	MOHR	08	RVUE	2006 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.00866491560±0.00000000055	MOHR	05	RVUE	2002 CODATA value
1.00866491578±0.00000000055	MOHR	99	RVUE	1998 CODATA value
1.008665904 ±0.000000014	COHEN	87	RVUE	1986 CODATA value

n MASS (MeV)

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

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
939.565346±0.000023	MOHR	08	RVUE	2006 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
939.565360±0.000081	MOHR	05	RVUE	2002 CODATA value
939.565331±0.000037	[1] KESSLER	99	SPEC	$np \to d\gamma$
939.565330±0.000038	MOHR	99	RVUE	1998 CODATA value
939.56565 ±0.00028	[2,3] DIFILIPPO	94	TRAP	Penning trap
939.56563 ±0.00028	COHEN	87	RVUE	1986 CODATA value
939.56564 ±0.00028	[3,4] GREENE	86	SPEC	$np \to d\gamma$
939.5731 ±0.0027	[3] COHEN	73	RVUE	1973 CODATA value

[1] We use the 1998 CODATA u-to-MeV conversion factor (see the heading above) to get this mass in MeV from the much more precisely measured KESSLER 99 value of 1.00866491637 ± 0.00000000082 u.

[2] The mass is known much more precisely in u: m = 1.0086649235 ± 0.0000000023 u. We use the 1986 CODATA conversion factor to get the mass in MeV.

[3] These determinations are not independent of the $m_n - m_p$ measurements below.

[4] The mass is known much more precisely in u: m = 1.008664919 ± 0.000000014 u.

$\overline{n}$ MASS

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
939.485±0.051	59	[5] CRESTI	86	HBC	$\overline{p}p \to \overline{n}n$

[5] This is a corrected result (see the erratum). The error is statistical. The maximum systematic error is 0.029 MeV.

$(m_n - m_{\overline{n}})/\, m_n$

A test of *CPT* invariance. Calculated from the n and $\overline{n}$ masses, above.

VALUE	*DOCUMENT ID*
$(9\pm6)\times10^{-5}$ OUR EVALUATION	

$m_n - m_p$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1.29333214±0.00000043	[6] MOHR	08	RVUE	2006 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.2933317 ±0.0000005	[7] MOHR	05	RVUE	2002 CODATA value
1.2933318 ±0.0000005	[8] MOHR	99	RVUE	1998 CODATA value
1.293318 ±0.000009	[9] COHEN	87	RVUE	1986 CODATA value
1.2933328 ±0.0000072	GREENE	86	SPEC	$np \rightarrow d\gamma$
1.293429 ±0.000036	COHEN	73	RVUE	1973 CODATA value

[6] Calculated by us from the MOHR 08 ratio m_n/m_p = 1.00137841918(46). In u, $m_n - m_p = 1.38844920(46)\times10^{-3}$ u.

[7] Calculated by us from the MOHR 05 ratio m_n/m_p = 1.00137841870 ± 0.00000000058. In u, $m_n - m_p = (1.3884487 \pm 0.0000006)\times10^{-3}$ u.

[8] Calculated by us from the MOHR 99 ratio m_n/m_p = 1.00137841887 ± 0.00000000058. In u, $m_n - m_p = (1.3884489 \pm 0.0000006)\times10^{-3}$ u.

[9] Calculated by us from the COHEN 87 ratio m_n/m_p = 1.001378404 ± 0.000000009. In u, $m_n - m_p$ = 0.001388434 ± 0.000000009 u.

n MEAN LIFE

We now compile only direct measurements of the lifetime, not those inferred from decay correlation measurements. For the average, we only use measurements with an error less than 10 s.

The most recent result, that of SEREBROV 05 (for a more detailed account, see SEREBROV 08A), is so far from other results that it makes no sense to include it in the average. It is up to workers in this field to resolve this issue. Until this major disagreement is understood our present average of 885.7 ± 0.8 s must be suspect.

For recent reviews of neutron physics, see NICO 05A, SEVERIJNS 06, ABELE 08, and NICO 09.

Limits on lifetimes for *bound* neutrons are given in the section "*p* PARTIAL MEAN LIVES."

VALUE (s)	*DOCUMENT ID*		*TECN*	*COMMENT*
885.7± 0.8 OUR AVERAGE				
886.3± 1.2± 3.2	NICO	05	CNTR	In-beam *n*, trapped *p*
885.4± 0.9± 0.4	ARZUMANOV	00	CNTR	UCN double bottle
889.2± 3.0± 3.8	BYRNE	96	CNTR	Penning trap
882.6± 2.7	[10] MAMPE	93	CNTR	Gravitational trap
888.4± 3.1± 1.1	NESVIZHEV...	92	CNTR	Gravitational trap
887.6± 3.0	MAMPE	89	CNTR	Gravitational trap
891 ± 9	SPIVAK	88	CNTR	Beam

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

878.5± 0.7± 0.3	[11] SEREBROV	05	CNTR	Gravitational trap
886.8± 1.2± 3.2	DEWEY	03	CNTR	See NICO 05
888.4± 2.9	ALFIMENKOV	90	CNTR	See NESVIZHEVSKII 92
893.6± 3.8± 3.7	BYRNE	90	CNTR	See BYRNE 96
878 ±27 ±14	KOSSAKOW...	89	TPC	Pulsed beam
877 ±10	PAUL	89	CNTR	Storage ring
876 ±10 ±19	LAST	88	SPEC	Pulsed beam
903 ±13	KOSVINTSEV	86	CNTR	Gravitational trap
937 ±18	[12] BYRNE	80	CNTR	
875 ±95	KOSVINTSEV	80	CNTR	
881 ± 8	BONDAREN...	78	CNTR	See SPIVAK 88
918 ±14	CHRISTENSEN	72	CNTR	

[10] IGNATOVICH 95 calls into question some of the corrections and averaging procedures used by MAMPE 93. The response, BONDARENKO 96, denies the validity of the criticisms.

[11] This SEREBROV 05 result is 6.5 standard deviations from our average of previous results and 5.6 standard deviations from the previous most precise result (that of ARZUMANOV 00).

[12] This measurement has been withdrawn (J. Byrne, private communication, 1990).

n MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the Λ Listings.

VALUE (μ_N)	*DOCUMENT ID*		*TECN*	*COMMENT*
−1.91304273±0.00000045	MOHR	08	RVUE	2006 CODATA value

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

−1.91304273±0.00000045	MOHR	05	RVUE	2002 CODATA value
−1.91304272±0.00000045	MOHR	99	RVUE	1998 CODATA value
−1.91304275±0.00000045	COHEN	87	RVUE	1986 CODATA value
−1.91304277±0.00000048	[13] GREENE	82	MRS	

[13] GREENE 82 measures the moment to be $(1.04187564 \pm 0.00000026) \times 10^{-3}$ Bohr magnetons. The value above is obtained by multiplying this by $m_p/m_e = 1836.152701 \pm 0.000037$ (the 1986 CODATA value from COHEN 87).

n ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both *T* invariance and *P* invariance. A number of early results have been omitted. See RAMSEY 90, GOLUB 94, and LAMOREAUX 09 for reviews.

VALUE (10^{-25} *e* cm)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
< 0.29	90	[14] BAKER	06	MRS	UCN's, $h\nu = 2\mu_n B \pm 2d_n E$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 0.63	90	[15] HARRIS	99	MRS	$d = (-0.1 \pm 0.36) \times 10^{-25}$
< 0.97	90	ALTAREV	96	MRS	$(+0.26 \pm 0.40 \pm 0.16) \times 10^{-25}$
< 1.1	95	ALTAREV	92	MRS	See ALTAREV 96
< 1.2	95	SMITH	90	MRS	See HARRIS 99
< 2.6	95	ALTAREV	86	MRS	$d = (-1.4 \pm 0.6) \times 10^{-25}$
0.3 ±4.8		PENDLEBURY	84	MRS	Ultracold neutrons
< 6	90	ALTAREV	81	MRS	$d = (2.1 \pm 2.4) \times 10^{-25}$
<16	90	ALTAREV	79	MRS	$d = (4.0 \pm 7.5) \times 10^{-25}$

[14] LAMOREAUX 07 faults BAKER 06 for not including in the estimate of systematic error an effect due to the Earth's rotation. BAKER 07 replies (1) that the effect was included implicitly in the analysis and (2) that further analysis confirms that the BAKER 06 limit is correct as is. See also SILENKO 07.

[15] This HARRIS 99 result includes the result of SMITH 90. However, the averaging of the results of these two experiments has been criticized by LAMOREAUX 00.

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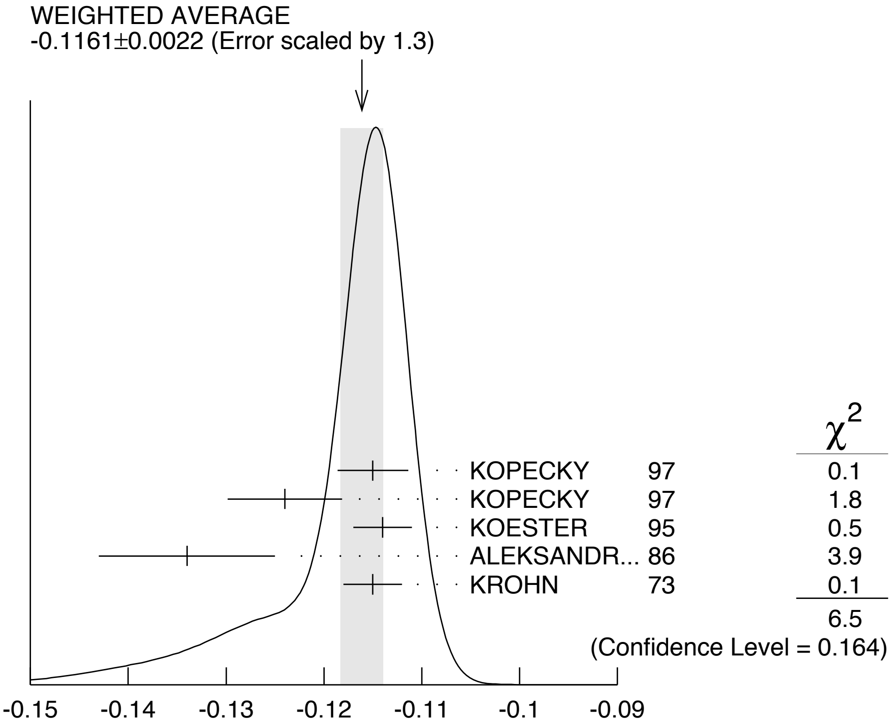
n MEAN-SQUARE CHARGE RADIUS

The mean-square charge radius of the neutron, $\langle r_n^2 \rangle$, is related to the neutron-electron scattering length b_{ne} by $\langle r_n^2 \rangle = 3(m_e a_0/m_n) b_{ne}$, where m_e and m_n are the masses of the electron and neutron, and a_0 is the Bohr radius. Numerically, $\langle r_n^2 \rangle = 86.34\ b_{ne}$, if we use a_0 for a nucleus with infinite mass.

VALUE (fm^2)	*DOCUMENT ID*		*COMMENT*
−0.1161±0.0022 OUR AVERAGE	Error includes scale factor of 1.3. See the ideogram below.		
−0.115 ±0.002 ±0.003	KOPECKY	97	*n e* scattering (Pb)
−0.124 ±0.003 ±0.005	KOPECKY	97	*n e* scattering (Bi)
−0.114 ±0.003	KOESTER	95	*n e* scattering (Pb, Bi)
−0.134 ±0.009	ALEKSANDR...	86	*n e* scattering (Bi)
−0.115 ±0.003	[16] KROHN	73	*n e* scattering (Ne, Ar, Kr, Xe)
• • • We do not use the following data for averages, fits, limits, etc. • • •			
−0.113 ±0.003 ±0.004	KOPECKY	95	*n e* scattering (Pb)
−0.114 ±0.003	KOESTER	86	*n e* scattering (Pb, Bi)
−0.118 ±0.002	KOESTER	76	*n e* scattering (Pb)
−0.120 ±0.002	KOESTER	76	*n e* scattering (Bi)
−0.116 ±0.003	KROHN	66	*n e* scattering (Ne, Ar, Kr, Xe)

[16] This value is as corrected by KOESTER 76.



n mean-square charge radius

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n ELECTRIC POLARIZABILITY α_n

Following is the electric polarizability α_n defined in terms of the induced electric dipole moment by $\mathbf{D} = 4\pi\epsilon_0\alpha_n\mathbf{E}$. For a review, see SCHMIEDMAYER 89.

For a very complete review of the "polarizability of the nucleon and Compton scattering," see SCHUMACHER 05. His recommended values for the neutron are $\alpha_n = (12.5 \pm 1.7) \times 10^{-4}$ fm^3 and $\beta_n = (2.7 \mp 1.8) \times 10^{-4}$ fm^3, which agree with our averages within errors.

VALUE (10^{-4} fm^3)	*DOCUMENT ID*		*TECN*	*COMMENT*
11.6± 1.5 OUR AVERAGE				
12.5± 1.8$^{+1.6}_{-1.3}$	[17] KOSSERT	03	CNTR	$\gamma d \rightarrow \gamma p n$
8.8± 2.4±3.0	[18] LUNDIN	03	CNTR	$\gamma d \rightarrow \gamma d$
12.0± 1.5±2.0	SCHMIEDM...	91	CNTR	*n* Pb transmission
10.7$^{+3.3}_{-10.7}$	ROSE	90B	CNTR	$\gamma d \rightarrow \gamma n p$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
13.6	[19] KOLB	00	CNTR	$\gamma d \rightarrow \gamma n p$
0.0± 5.0	[20] KOESTER	95	CNTR	*n* Pb, *n* Bi transmission
11.7$^{+4.3}_{-11.7}$	ROSE	90	CNTR	See ROSE 90B
8 ±10	KOESTER	88	CNTR	*n* Pb, *n* Bi transmission
12 ±10	SCHMIEDM...	88	CNTR	*n* Pb, *n* C transmission

[17] KOSSERT 03 gets $\alpha_n - \beta_n = (9.8 \pm 3.6^{+2.1}_{-1.1} \pm 2.2) \times 10^{-4}$ fm^3, and uses $\alpha_n + \beta_n = (15.2 \pm 0.5) \times 10^{-4}$ fm^3 from LEVCHUK 00. Thus the errors on α_n and β_n are anti-correlated.

[18] LUNDIN 03 measures $\alpha_N - \beta_N = (6.4 \pm 2.4) \times 10^{-4}$ fm^3 and uses accurate values for α_p and α_p and a precise sum-rule result for $\alpha_n + \beta_n$. The second error is a model uncertainty, and errors on α_n and β_n are anticorrelated.

[19] KOLB 00 obtains this value with a lower limit of 7.6×10^{-4} fm^3 but no upper limit from this experiment alone. Combined with results of ROSE 90, the 1-σ range is $(7.6\text{–}14.0) \times 10^{-4}$ fm^3.

[20] KOESTER 95 uses natural Pb and the isotopes 208, 207, and 206. See this paper for a discussion of methods used by various groups to extract α_n from data.

n MAGNETIC POLARIZABILITY β_n

VALUE (10^{-4} fm^3)	*DOCUMENT ID*		*TECN*	*COMMENT*
3.7±2.0 OUR AVERAGE				
$2.7 \pm 1.8^{+1.3}_{-1.6}$	[21] KOSSERT	03	CNTR	$\gamma d \rightarrow \gamma p n$
$6.5 \pm 2.4 \pm 3.0$	[22] LUNDIN	03	CNTR	$\gamma d \rightarrow \gamma d$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.6	[23] KOLB	00	CNTR	$\gamma d \rightarrow \gamma n p$

[21] KOSSERT 03 gets $\alpha_n - \beta_n = (9.8 \pm 3.6^{+2.1}_{-1.1} \pm 2.2) \times 10^{-4}$ fm^3, and uses $\alpha_n + \beta_n = (15.2 \pm 0.5) \times 10^{-4}$ fm^3 from LEVCHUK 00. Thus the errors on α_n and β_n are anti-correlated.

[22] LUNDIN 03 measures $\alpha_N - \beta_N = (6.4 \pm 2.4) \times 10^{-4}$ fm^3 and uses accurate values for α_p and α_p and a precise sum-rule result for $\alpha_n + \beta_n$. The second error is a model uncertainty, and errors on α_n and β_n are anticorrelated.

[23] KOLB 00 obtains this value with an upper limit of 7.6×10^{-4} fm^3 but no lower limit from this experiment alone. Combined with results of ROSE 90, the 1-σ range is $(1.2\text{–}7.6) \times 10^{-4}$ fm^3.

n CHARGE

See also "$|q_p + q_e|/e$" in the proton Listings.

VALUE (10^{-21} *e*)	*DOCUMENT ID*		*TECN*	*COMMENT*
− 0.4± 1.1	[24] BAUMANN	88		Cold *n* deflection
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−15 ±22	[25] GAEHLER	82	CNTR	Cold *n* deflection

[24] The BAUMANN 88 error ±1.1 gives the 68% CL limits about the the value −0.4.

[25] The GAEHLER 82 error ±22 gives the 90% CL limits about the the value −15.

LIMIT ON $n\overline{n}$ OSCILLATIONS

Mean Time for $n\overline{n}$ Transition in Vacuum

A test of ΔB=2 baryon number nonconservation. MOHAPATRA 80 and MOHAPATRA 89 discuss the theoretical motivations for looking for $n\overline{n}$ oscillations. DOVER 83 and DOVER 85 give phenomenological analyses. The best limits come from looking for the decay of neutrons bound in nuclei. However, these analyses require model-dependent corrections for nuclear effects. See KABIR 83, DOVER 89, ALBERICO 91, and GAL 00 for discussions. Direct searches for $n \rightarrow \overline{n}$ transitions using reactor neutrons are cleaner but give somewhat poorer limits. We include limits for both free and bound neutrons in the Summary Table. See MOHAPATRA 09 for a recent review.

VALUE (s)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{>1.3 \times 10^{8}}$	90	CHUNG	02B	SOU2	*n* bound in iron
$\mathbf{>8.6 \times 10^{7}}$	90	BALDO-...	94	CNTR	Reactor (free) neutrons
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$>1 \times 10^{7}$	90	BALDO-...	90	CNTR	See BALDO-CEOLIN 94
$>1.2 \times 10^{8}$	90	BERGER	90	FREJ	*n* bound in iron
$>4.9 \times 10^{5}$	90	BRESSI	90	CNTR	Reactor neutrons
$>4.7 \times 10^{5}$	90	BRESSI	89	CNTR	See BRESSI 90
$>1.2 \times 10^{8}$	90	TAKITA	86	CNTR	*n* bound in oxygen
$>1 \times 10^{6}$	90	FIDECARO	85	CNTR	Reactor neutrons
$>8.8 \times 10^{7}$	90	PARK	85B	CNTR	
$>3 \times 10^{7}$		BATTISTONI	84	NUSX	
$> 2.7 \times 10^{7}$–1.1×10^{8}		JONES	84	CNTR	
$>2 \times 10^{7}$		CHERRY	83	CNTR	

LIMIT ON nn' OSCILLATIONS

Lee and Yang (LEE 56) proposed the existence of mirror world in an attempt to restore global parity symmetry. See BEREZHIANI 06 for a recent discussion.

VALUE (s)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>414	90	SEREBROV	08	CNTR	UCN, B field on & off
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$>$ 12	95	[26] ALTAREV	09A	CNTR	UCN, scan $0 \leq B \leq 12.5$ μT
$>$103	95	BAN	07	CNTR	UCN, B field on & off

[26] Losses of neutrons due to oscillations to mirror neutrons would be maximal when the magnetic fields B and B' in the two worlds were equal. Hence the scan over B by ALTAREV 09A: the limit applies for any B' over the given range. At $B' = 0$, the limit is 141 s (95% CL).

n DECAY MODES

	Mode		Fraction (Γ_i/Γ)	Confidence level
Γ_1	$p e^- \overline{\nu}_e$		100 %	
Γ_2	hydrogen-atom $\overline{\nu}_e$			
Γ_3	$p e^- \overline{\nu}_e \gamma$	[*a*]	$(3.13 \pm 0.35) \times 10^{-3}$	

Charge conservation (Q) violating mode

Γ_4	$p \nu_e \overline{\nu}_e$	Q	< 8	$\times 10^{-27}$	68%

[a] This limit is for γ energies between 15 and 340 keV.

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n BRANCHING RATIOS

$\Gamma(\text{hydrogen-atom } \overline{\nu}_e)/\Gamma_{\text{total}}$ $\quad\Gamma_2/\Gamma$

VALUE	*CL%*	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<3 \times 10^{-2}$	95	[27] GREEN	90	RVUE

[27] GREEN 90 infers that $\tau(\text{hydrogen-atom}\overline{\nu}_e) > 3 \times 10^4$ s by comparing neutron lifetime measurements made in storage experiments with those made in β-decay experiments. However, the result depends sensitively on the lifetime measurements, and does not of course take into account more recent measurements of same.

$\Gamma(p e^- \overline{\nu}_e \gamma)/\Gamma_{\text{total}}$ $\quad\Gamma_3/\Gamma$

VALUE (units 10^{-3})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
3.13±0.11±0.33		[28] NICO	06	CNTR	γ, p, e^- coincidence
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<6.9	90	[29] BECK	02	CNTR	γ, p, e^- coincidence

[28] This NICO 06 result is for γ energies between 15 and 340 keV.

[29] This BECK 02 limit is for γ energies between 35 and 100 keV.

$\Gamma(p \nu_e \overline{\nu}_e)/\Gamma_{\text{total}}$ $\quad\Gamma_4/\Gamma$

Forbidden by charge conservation.

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{<8 \times 10^{-27}}$	68	[30] NORMAN	96	RVUE	^{71}Ga → ^{71}Ge neutrals
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<9.7 \times 10^{-18}$	90	ROY	83	CNTR	^{113}Cd → ^{113m}In neut.
$<7.9 \times 10^{-21}$		VAIDYA	83	CNTR	^{87}Rb → ^{87m}Sr neut.
$<9 \times 10^{-24}$	90	BARABANOV	80	CNTR	^{71}Ga → ^{71}Ge X
$<3 \times 10^{-19}$		NORMAN	79	CNTR	^{87}Rb → ^{87m}Sr neut.

[30] NORMAN 96 gets this limit by attributing SAGE and GALLEX counting rates to the charge-nonconserving transition ^{71}Ga → ^{71}Ge+neutrals rather than to solar-neutrino reactions.

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$n \rightarrow p e^- \overline{\nu}_e$ DECAY PARAMETERS

See the above "Note on Baryon Decay Parameters." For discussions of recent results, see the references cited at the beginning of the section on the neutron mean life. For discussions of the values of the weak coupling constants g_A and g_V obtained using the neutron lifetime and asymmetry parameter A, comparisons with other methods of obtaining these constants, and implications for particle physics and for astrophysics, see DUBBERS 91 and WOOLCOCK 91. For tests of the $V-A$ theory of neutron decay, see EROZOLIMSKII 91B, MOSTOVOI 96, NICO 05, SEVERIJNS 06, and ABELE 08.

$\lambda \equiv g_A / g_V$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
-1.2694 ± 0.0028 OUR AVERAGE				Error includes scale factor of 2.0. See the ideogram below.
-1.2739 ± 0.0019	[31] ABELE	02	SPEC	Cold n, polarized, A
$-1.2686 \pm 0.0046 \pm 0.0007$	[32] MOSTOVOI	01	CNTR	A and $B \times$ polarizations
-1.266 ± 0.004	LIAUD	97	TPC	Cold n, polarized, A
-1.2594 ± 0.0038	[33] YEROZLIM...	97	CNTR	Cold n, polarized, A
-1.262 ± 0.005	BOPP	86	SPEC	Cold n, polarized, A
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$-1.275 \pm 0.006 \pm 0.015$	SCHUMANN	08	CNTR	Cold n, polarized
-1.274 ± 0.003	ABELE	97D	SPEC	Cold n, polarized, A
-1.266 ± 0.004	SCHRECK...	95	TPC	See LIAUD 97
-1.2544 ± 0.0036	EROZOLIM...	91	CNTR	See YEROZOLIMSKY 97
-1.226 ± 0.042	MOSTOVOY	83	RVUE	
-1.261 ± 0.012	EROZOLIM...	79	CNTR	Cold n, polarized, A
-1.259 ± 0.017	[34] STRATOWA	78	CNTR	p recoil spectrum, a
-1.263 ± 0.015	EROZOLIM...	77	CNTR	See EROZOLIMSKII 79
-1.250 ± 0.036	[34] DOBROZE...	75	CNTR	See STRATOWA 78
-1.258 ± 0.015	[35] KROHN	75	CNTR	Cold n, polarized, A
-1.263 ± 0.016	[36] KROPF	74	RVUE	n decay alone
-1.250 ± 0.009	[36] KROPF	74	RVUE	n decay + nuclear ft

[31] This is the combined result of ABELE 02 and ABELE 97D.

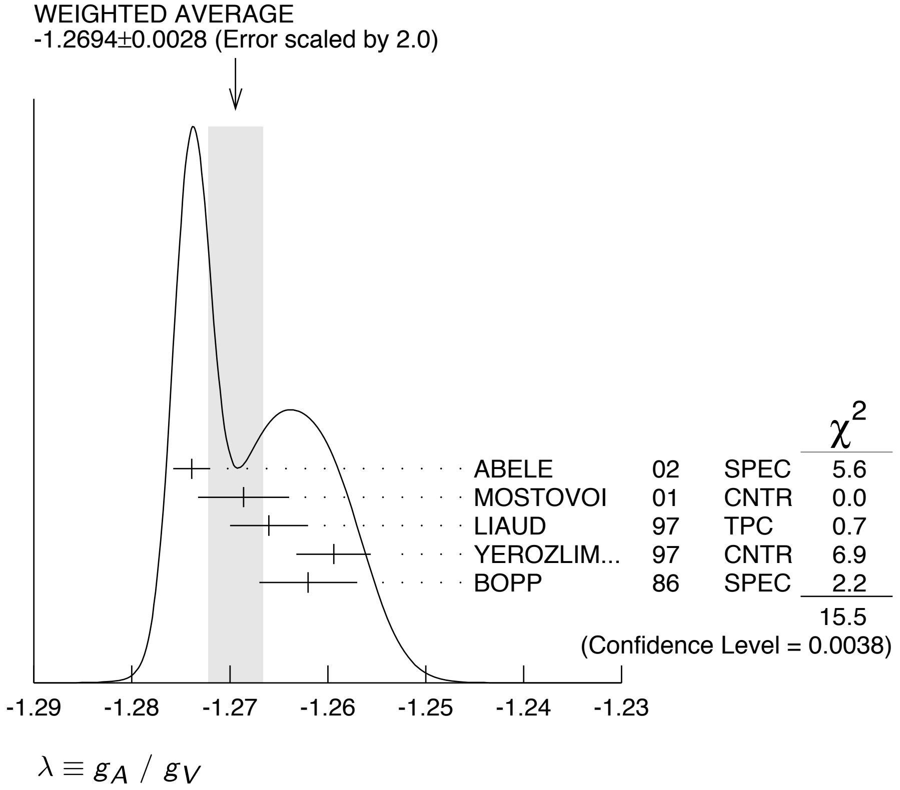
[32] MOSTOVOI 01 measures the two P-odd correlations A and B, or rather SA and SB, where S is the n polarization, in free neutron decay.

[33] YEROZOLIMSKY 97 makes a correction to the EROZOLIMSKII 91 value.

[34] These experiments measure the absolute value of g_A/g_V only.

[35] KROHN 75 includes events of CHRISTENSEN 70.

[36] KROPF 74 reviews all data through 1972.



e^- ASYMMETRY PARAMETER A

This is the neutron-spin electron-momentum correlation coefficient. Unless otherwise noted, the values are corrected for radiative effects and weak magnetism. In the Standard Model, A is related to $\lambda \equiv g_A/g_V$ by $A = -2\lambda(\lambda + 1) / (1 + 3\lambda^2)$; this assumes that g_A and g_V are real.

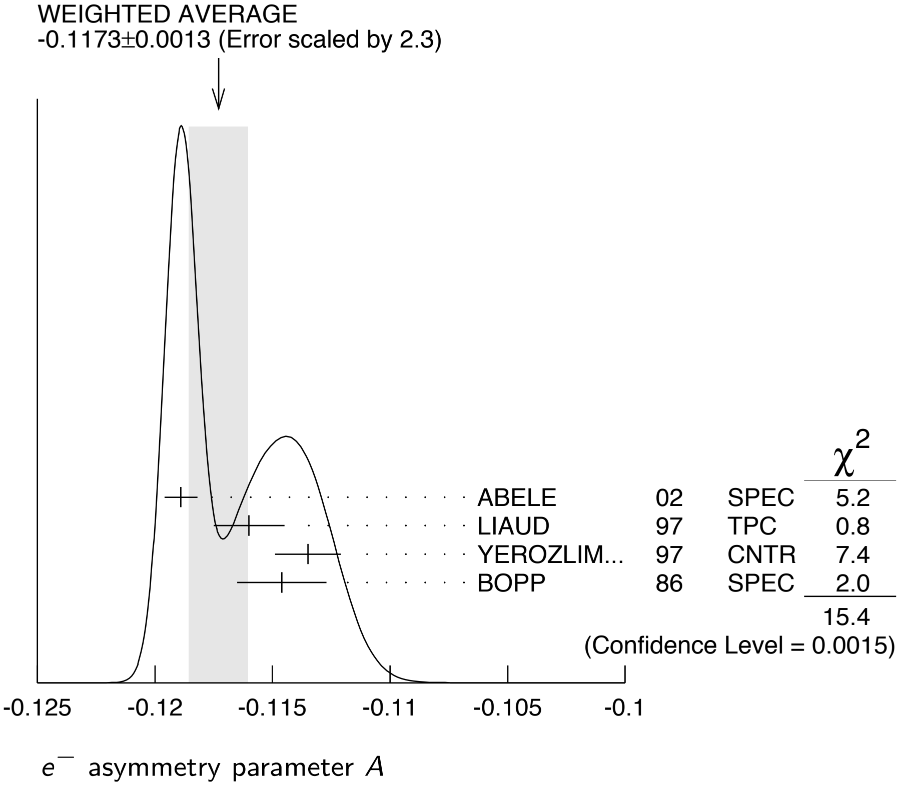
VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
−0.1173±0.0013 OUR AVERAGE	Error includes scale factor of 2.3. See the ideogram below.		
−0.1189±0.0007	[37] ABELE 02	SPEC	Cold *n*, polarized
−0.1160±0.0009±0.0012	LIAUD 97	TPC	Cold *n*, polarized
−0.1135±0.0014	[38] YEROZLIM... 97	CNTR	Cold *n*, polarized
−0.1146±0.0019	BOPP 86	SPEC	Cold *n*, polarized
• • • We do not use the following data for averages, fits, limits, etc. • • •			
−0.1138±0.0046±0.0021	PATTIE 09	SPEC	Ultracold *n*, polarized
−0.1168±0.0017	[39] MOSTOVOI 01	CNTR	Inferred
−0.1189±0.0012	ABELE 97D	SPEC	Cold *n*, polarized
−0.1160±0.0009±0.0011	SCHRECK... 95	TPC	See LIAUD 97
−0.1116±0.0014	EROZOLIM... 91	CNTR	See YEROZOLIMSKY 97
−0.114 ±0.005	[40] EROZOLIM... 79	CNTR	Cold *n*, polarized
−0.113 ±0.006	[40] KROHN 75	CNTR	Cold *n*, polarized

[37] This is the combined result of ABELE 02 and ABELE 97D.

[38] YEROZOLIMSKY 97 makes a correction to the EROZOLIMSKII 91 value.

[39] MOSTOVOI 01 calculates this from its measurement of $\lambda = g_A/g_V$ above.

[40] These results are not corrected for radiative effects and weak magnetism, but the corrections are small compared to the errors.



$\overline{\nu}_e$ ASYMMETRY PARAMETER B

This is the neutron-spin antineutrino-momentum correlation coefficient. In the Standard Model, B is related to $\lambda \equiv g_A/g_V$ by $B = 2\lambda(\lambda - 1) / (1 + 3\lambda^2)$; this assumes that g_A and g_V are real.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.9807±0.0030 OUR AVERAGE				
0.9802±0.0034±0.0036	SCHUMANN	07	CNTR	Cold n, polarized
0.967 ±0.006 ±0.010	KREUZ	05	CNTR	Cold n, polarized
0.9801±0.0046	SEREBROV	98	CNTR	Cold n, polarized
0.9894±0.0083	KUZNETSOV	95	CNTR	Cold n, polarized
1.00 ±0.05	CHRISTENSEN	70	CNTR	Cold n, polarized
0.995 ±0.034	EROZOLIM...	70C	CNTR	Cold n, polarized
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.9876±0.0004	[41] MOSTOVOI	01	CNTR	Inferred

[41] MOSTOVOI 01 calculates this from its measurement of $\lambda = g_A/g_V$ above.

PROTON ASYMMETRY PARAMETER C

Describes the correlation between the neutron spin and the proton momentum. In the Standard Model, C is related to $\lambda \equiv g_A/g_V$ by $C = -x_c\ (A + B) = x_c\ 4\lambda/(1 + 3\lambda^2)$, where $x_c = 0.27484$ is a kinematic factor; this assumes that g_A and g_V are real.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
−0.2377±0.0010±0.0024	SCHUMANN	08	CNTR	Cold n, polarized

e-$\overline{\nu}_e$ ANGULAR CORRELATION COEFFICIENT a

For a review of past experiments and plans for future measurements of the a parameter, see WIETFELDT 05. In the Standard Model, a is related to $\lambda \equiv g_A/g_V$ by $a = (1 - \lambda^2) / (1 + 3\lambda^2)$; this assumes that g_A and g_V are real.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
$-$0.103 $\pm$0.004 OUR AVERAGE				
$-$0.1054$\pm$0.0055	BYRNE	02	SPEC	Proton recoil spectrum
$-$0.1017$\pm$0.0051	STRATOWA	78	CNTR	Proton recoil spectrum
$-$0.091 $\pm$0.039	GRIGOREV	68	SPEC	Proton recoil spectrum
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$-$0.1045$\pm$0.0014	[42] MOSTOVOI	01	CNTR	Inferred

[42] MOSTOVOI 01 calculates this from its measurement of $\lambda=g_A/g_V$ above.

ϕ_{AV}, PHASE OF g_A RELATIVE TO g_V

Time reversal invariance requires this to be 0 or 180°. This is related to D given in the next data block and $\lambda \equiv g_A/g_V$ by $\sin(\phi_{AV}) = D(1+3\lambda^2)/2\lambda$; this assumes that g_A and g_V are real.

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
180.06$\pm$0.07 OUR AVERAGE				
180.04$\pm$0.09	SOLDNER	04	CNTR	Cold *n*, polarized
180.08$\pm$0.13	LISING	00	CNTR	Polarized >93%
179.71$\pm$0.39	EROZOLIM...	78	CNTR	Cold *n*, polarized
180.35$\pm$0.43	EROZOLIM...	74	CNTR	Cold *n*, polarized
180.14$\pm$0.22	STEINBERG	74	CNTR	Cold *n*, polarized
• • • We do not use the following data for averages, fits, limits, etc. • • •				
181.1 $\pm$1.3	[43] KROPF	74	RVUE	*n* decay

[43] KROPF 74 reviews all data through 1972.

TRIPLE CORRELATION COEFFICIENT D

These are measurements of the component of *n* spin perpendicular to the decay plane in β decay. Should be zero if T invariance is not violated.

VALUE (units 10^{-4})	*DOCUMENT ID*		*TECN*	*COMMENT*
$-$ 4 $\pm$ 6 OUR AVERAGE				
$-$ 2.8$\pm$ 6.4$\pm$3.0	SOLDNER	04	CNTR	Cold *n*, polarized
$-$ 6 $\pm$12 $\pm$5	LISING	00	CNTR	Polarized >93%
+22 $\pm$30	EROZOLIM...	78	CNTR	Cold *n*, polarized
$-$27 $\pm$50	[44] EROZOLIM...	74	CNTR	Cold *n*, polarized
$-$11 $\pm$17	STEINBERG	74	CNTR	Cold *n*, polarized

[44] EROZOLIMSKII 78 says asymmetric proton losses and nonuniform beam polarization may give a systematic error up to 30 × 10^{-4}, thus increasing the EROZOLIMSKII 74 error to 50 × 10^{-4}. STEINBERG 74 and STEINBERG 76 estimate these systematic errors to be insignificant in their experiment.

TRIPLE CORRELATION COEFFICIENT R

Another test of time-reversal invariance. R measures the polarization of the electron in the direction perpendicular to the plane defined by the neutron spin and the electron momentum. $R = 0$ for T invariance.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
+0.008$\pm$0.015$\pm$0.005	[45] KOZELA	09	CNTR	Mott polarimeter

[45] KOZELA 09 also measures the polarization of the electron along the direction of the neutron spin. This is nonzero in the Standard Model; the correlation coefficient is $N = +0.056 \pm 0.011 \pm 0.005$.

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LAMOREAUX	09	JPG 36 104002	S.K. Lamoreaux, R. Golub	(YALE, NCSU)
MOHAPATRA	09	JPG 36 104006	R.N. Mohapatra	(UMD)
NICO	09	JPG 36 104001	J.S. Nico	(NIST)
PATTIE	09	PRL 102 012301	R.W. Pattie Jr. *et al.*	(Los Alamos UCNA Collab.)
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MOHR	08	RMP 80 633	P.J. Mohr, B.N. Taylor, D.B. Newell	(NIST)
SCHUMANN	08	PRL 100 151801	M. Schumann *et al.*	(HEID, ILLG, KARL+)
SEREBROV	08	PL B663 181	A.P. Serebrov *et al.*	(PNPI, IOFF, ILLG+)
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