Citation: K. Hagiwara *et al.* (Particle Data Group), Phys. Rev. D **66**, 010001 (2002) and 2003 partial update for edition 2004 (URL: http://pdg.lbl.gov)

e

$J = \frac{1}{2}$

e MASS (atomic mass units u)

The primary determination of an electron's mass comes from measuring the ratio of the mass to that of a nucleus, so that the result is obtained in u (atomic mass units). The conversion factor to MeV is more uncertain than the mass of the electron in u; indeed, the recent improvements in the mass determination are not evident when the result is given in MeV. In this datablock we give the result in u, and the following datablock in MeV.

VALUE (10^{-6} u)	*DOCUMENT ID*		*TECN*	*COMMENT*
548.5799110±0.0000012	MOHR	99	RVUE	1998 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
548.5799092±0.0000004	[1] BEIER	02	CNTR	Penning trap
548.5799111±0.0000012	[2] FARNHAM	95	CNTR	Penning trap
548.579903 ±0.000013	COHEN	87	RVUE	1986 CODATA value

[1] BEIER 02 compares Larmor frequency of the electron bound in a $^{12}\text{C}^{5+}$ ion with the cyclotron frequency of a single trapped $^{12}\text{C}^{5+}$ ion.

[2] FARNHAM 95 compares cyclotron frequency of trapped electrons with that of a single trapped $^{12}\text{C}^{6+}$ ion.

e MASS

The conversion from u (atomic mass units, see the above datablock) to MeV is 931.494013 ± 0.000037 MeV/u. The conversion error dominates the precision quoted in the following entries.

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
0.510998902±0.000000021	MOHR	99	RVUE	1998 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.510998901±0.000000020	[3,4] BEIER	02	CNTR	Penning trap
0.510998903±0.000000020	[3,5] FARNHAM	95	CNTR	Penning trap
0.510998895±0.000000024	[3] COHEN	87	RVUE	1986 CODATA value
0.5110034 ±0.0000014	COHEN	73	RVUE	1973 CODATA value

[3] Converted to MeV using the 1998 CODATA value of the conversion constant, 931.494013 ± 0.0000037 MeV/u.

[4] BEIER 02 compares Larmor frequency of the electron bound in a $^{12}\text{C}^{5+}$ ion with the cyclotron frequency of a single trapped $^{12}\text{C}^{5+}$ ion.

[5] FARNHAM 95 compares cyclotron frequency of trapped electrons with that of a single trapped $^{12}\text{C}^{6+}$ ion.

$(m_{e^+} - m_{e^-})\ /\ m_{\text{average}}$

A test of *CPT* invariance.

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{<8 \times 10^{-9}}$	90	[6] FEE	93	CNTR	Positronium spectroscopy
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<4 \times 10^{-8}$	90	CHU	84	CNTR	Positronium spectroscopy

[6] FEE 93 value is obtained under the assumption that the positronium Rydberg constant is exactly half the hydrogen one.

$\left|q_{e^+} + q_{e^-}\right|/e$

A test of *CPT* invariance. See also similar tests involving the proton.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{<4 \times 10^{-8}}$	[7] HUGHES	92	RVUE	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<2 \times 10^{-18}$	[8] SCHAEFER	95	THEO	Vacuum polarization
$<1 \times 10^{-18}$	[9] MUELLER	92	THEO	Vacuum polarization

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

[8] SCHAEFER 95 removes model dependency of MUELLER 92.

[9] MUELLER 92 argues that an inequality of the charge magnitudes would, through higher-order vacuum polarization, contribute to the net charge of atoms.

e MAGNETIC MOMENT ANOMALY

$\mu_e/\mu_B - 1 = (g-2)/2$

For the most accurate theoretical calculation, see KINOSHITA 81.

VALUE (units 10^{-6})	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
1159.6521869±0.0000041	[10] MOHR	99	RVUE		1998 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1159.652193 ±0.000010	[10] COHEN	87	RVUE		1986 CODATA value
1159.6521884±0.0000043	VANDYCK	87	MRS	−	Single electron
1159.6521879±0.0000043	VANDYCK	87	MRS	+	Single positron

[10] The CODATA value assumes the $g/2$ values for e^+ and e^- are equal, as required by *CPT*.

$(g_{e^+} - g_{e^-})$ / g_{average}

A test of *CPT* invariance.

VALUE (units 10^{-12})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
− 0.5± 2.1		[11] VANDYCK	87	MRS	Penning trap
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 12	95	[12] VASSERMAN	87	CNTR	Assumes $m_{e^+} = m_{e^-}$
22 ±64		SCHWINBERG	81	MRS	Penning trap

[11] VANDYCK 87 measured $(g_-/g_+)-1$ and we converted it.

[12] VASSERMAN 87 measured $(g_+ - g_-)/(g-2)$. We multiplied by $(g-2)/g = 1.2 \times 10^{-3}$.

e ELECTRIC DIPOLE MOMENT

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

VALUE (10^{-26} *e* cm)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.069± 0.074		REGAN	02	MRS	^{205}Tl beams
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.18 ± 0.12 ±0.10		[13] COMMINS	94	MRS	^{205}Tl beams
− 0.27 ± 0.83		[13] ABDULLAH	90	MRS	^{205}Tl beams
− 14 ± 24		CHO	89	NMR	Tl F molecules
− 1.5 ± 5.5 ±1.5		MURTHY	89		Cesium, no *B* field
− 50 ±110		LAMOREAUX	87	NMR	^{199}Hg
190 ±340	90	SANDARS	75	MRS	Thallium
70 ±220	90	PLAYER	70	MRS	Xenon
< 300	90	WEISSKOPF	68	MRS	Cesium

[13] ABDULLAH 90, COMMINS 94, and REGAN 02 use the relativistic enhancement of a valence electron's electric dipole moment in a high-Z atom.

e^- MEAN LIFE / BRANCHING FRACTION

A test of charge conservation. See the "Note on Testing Charge Conservation and the Pauli Exclusion Principle" following this section in our 1992 edition (Physical Review **D45,** 1 June, Part II (1992), p. VI.10).

Most of these experiments are one of three kinds: Attempts to observe (a) the 255.5 keV gamma ray produced in $e^- \rightarrow \nu_e \gamma$, (b) the (K) shell x ray produced when an electron decays without additional energy deposit, e.g., $e^- \rightarrow \nu_e \overline{\nu}_e \nu_e$ ("disappearance" experiments), and (c) nuclear deexcitation gamma rays after the electron disappears from an atomic shell and the nucleus is left in an excited state. The last can include both weak boson and photon mediating processes. We use the best $e^- \rightarrow \nu_e \gamma$ limit for the Summary Tables.

Note that we use the mean life rather than the half life, which is often reported.

$e \rightarrow \nu_e \gamma$ and astrophysical limits

VALUE (yr)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$>4.6 \times 10^{26}$	90	BACK	02	BORX	$e^- \rightarrow \nu \gamma$

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

$>3.4 \times 10^{26}$	68	BELLI	00B	DAMA	$e^- \to \nu\gamma$, liquid Xe
$>3.7 \times 10^{25}$	68	AHARONOV	95B	CNTR	$e^- \to \nu\gamma$
$>2.35 \times 10^{25}$	68	BALYSH	93	CNTR	$e^- \to \nu\gamma$, ^{76}Ge detector
$>1.5 \times 10^{25}$	68	AVIGNONE	86	CNTR	$e^- \to \nu\gamma$
$>1 \times 10^{39}$		[14] ORITO	85	ASTR	Astrophysical argument
$>3 \times 10^{23}$	68	BELLOTTI	83B	CNTR	$e^- \to \nu\gamma$

[14] ORITO 85 assumes that electromagnetic forces extend out to large enough distances and that the age of our galaxy is 10^{10} years.

Disappearance and nuclear-de-excitation experiments

VALUE (yr)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{>6.4 \times 10^{24}}$	68	[15] BELLI	99B	DAMA	De-excitation of ^{129}Xe
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$>4.2 \times 10^{24}$	68	BELLI	99	DAMA	Iodine L-shell disappearance
$>2.4 \times 10^{23}$	90	[16] BELLI	99D	DAMA	De-excitation of ^{127}I (in NaI)
$>4.3 \times 10^{23}$	68	AHARONOV	95B	CNTR	Ge K-shell disappearance
$>2.7 \times 10^{23}$	68	REUSSER	91	CNTR	Ge K-shell disappearance
$>2 \times 10^{22}$	68	BELLOTTI	83B	CNTR	Ge K-shell disappearance

[15] BELLI 99B limit on charge nonconserving e^- capture involving excitation of the 236.1 keV nuclear state of ^{129}Xe; the 90% CL limit is 3.7×10^{24} yr. Less stringent limits for other states are also given.

[16] BELLI 99D limit on charge nonconserving e^- capture involving excitation of the 57.6 keV nuclear state of ^{127}I. Less stringent limits for the other states and for the state of ^{23}Na are also given.

---

e REFERENCES

BACK	02	PL B525 29	H.O. Back *et al.*	(BOREXINO/SASSO Collab.)
BEIER	02	PRL 88 011603	T. Beier *et al.*	
REGAN	02	PRL 88 071805	B.C. Regan *et al.*	
BELLI	00B	PR D61 117301	P. Belli *et al.*	(DAMA Collab.)
BELLI	99	PL B460 236	P. Belli *et al.*	(DAMA Collab.)
BELLI	99B	PL B465 315	P. Belli *et al.*	(DAMA Collab.)
BELLI	99D	PR C60 065501	P. Belli *et al.*	(DAMA Collab.)
MOHR	99	JPCRD 28 1713	P.J. Mohr, B.N. Taylor	(NIST)
Also	00	RMP 72 351	P.J. Mohr, B.N. Taylor	(NIST)
AHARONOV	95B	PR D52 3785	Y. Aharonov *et al.*	(SCUC, PNL, ZARA+)
Also	95	PL B353 168	Y. Aharonov *et al.*	(SCUC, PNL, ZARA+)
FARNHAM	95	PRL 75 3598	D.L. Farnham, R.S. van Dyck, P.B. Schwinberg	(WASH)
SCHAEFER	95	PR A51 838	A. Schaefer, J. Reinhardt	(FRAN)
COMMINS	94	PR A50 2960	E.D. Commins *et al.*	
BALYSH	93	PL B298 278	A. Balysh *et al.*	(KIAE, MPIH, SASSO)
FEE	93	PR A48 192	M.S. Fee *et al.*	
HUGHES	92	PRL 69 578	R.J. Hughes, B.I. Deutch	(LANL, AARH)
MUELLER	92	PRL 69 3432	B. Muller, M.H. Thoma	(DUKE)
PDG	92	PR D45, 1 June, Part II	K. Hikasa *et al.*	(KEK, LBL, BOST+)
REUSSER	91	PL B255 143	D. Reusser *et al.*	(NEUC, CIT, PSI)
ABDULLAH	90	PRL 65 2347	K. Abdullah *et al.*	(LBL, UCB)
CHO	89	PRL 63 2559	D. Cho, K. Sangster, E.A. Hinds	(YALE)
MURTHY	89	PRL 63 965	S.A. Murthy *et al.*	(AMHT)
COHEN	87	RMP 59 1121	E.R. Cohen, B.N. Taylor	(RISC, NBS)
LAMOREAUX	87	PRL 59 2275	S.K. Lamoreaux *et al.*	(WASH)
VANDYCK	87	PRL 59 26	R.S. van Dyck, P.B. Schwinberg, H.G. Dehmelt	(WASH)

VASSERMAN	87	PL B198 302	I.B. Vasserman *et al.*	(NOVO)
Also	87B	PL B187 172	I.B. Vasserman *et al.*	(NOVO)
AVIGNONE	86	PR D34 97	F.T. Avignone *et al.*	(PNL, SCUC)
ORITO	85	PRL 54 2457	S. Orito, M. Yoshimura	(TOKY, KEK)
CHU	84	PRL 52 1689	S. Chu, A.P. Mills, J.L. Hall	(BELL, NBS, COLO)
BELLOTTI	83B	PL 124B 435	E. Bellotti *et al.*	(MILA)
KINOSHITA	81	PRL 47 1573	T. Kinoshita, W.B. Lindquist	(CORN)
SCHWINBERG	81	PRL 47 1679	P.B. Schwinberg, R.S. van Dyck, H.G. Dehmelt	(WASH)
SANDARS	75	PR A11 473	P.G.H. Sandars, D.M. Sternheimer	(OXF, BNL)
COHEN	73	JPCRD 2 664	E.R. Cohen, B.N. Taylor	(RISC, NBS)
PLAYER	70	JPB 3 1620	M.A. Player, P.G.H. Sandars	(OXF)
WEISSKOPF	68	PRL 21 1645	M.C. Weisskopf *et al.*	(BRAN)