ν_3 MAGNETIC MOMENT

Must vanish for Majorana neutrino or purely chiral massless Dirac neutrino. The value of the magnetic moment for the standard SU(2)×U(1) electroweak theory extended to include massive neutrinos (see FUJIKAWA 80) is $\mu_\nu = 3eG_F m_\nu/(8\pi^2\sqrt{2}) = (3.20 \times 10^{-19}) m_\nu \mu_B$ where m_ν is in eV and $\mu_B = e\hbar/2m_e$ is the Bohr magneton. Given the upper bound m_{ν_3} < 35 MeV, it follows that for the extended standard electroweak theory, $\mu(\nu_3) < 1.1 \times 10^{-11}\ \mu_B$.

VALUE (μ_B)	CL%	DOCUMENT ID		TECN	COMMENT
<5.4 × 10⁻⁷ → $\mathbf{<5.4 \times 10^{-7}}$	90	[44] COOPER-...	92	BEBC	$\nu_\tau e^- \rightarrow \nu_\tau e^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$\gtrsim 10^{-8}$		[45] KAWANO	92	ASTR	Primodial ^{4}He abundance
$<5.6 \times 10^{-6}$	90	DESHPANDE	91	RVUE	$e^+e^- \rightarrow \nu\overline{\nu}\gamma$
$<2 \times 10^{-12}$	95	[46] RAFFELT	90	ASTR	Red giant luminosity
$<1 \times 10^{-11}$		[47] RAFFELT	89B	ASTR	Cooling helium stars
$<4. \times 10^{-6}$	90	[48] GROTCH	88	RVUE	$e^+e^- \rightarrow \nu\overline{\nu}\gamma$
$<1.1 \times 10^{-11}$		[47,49] FUKUGITA	87	ASTR	Cooling helium stars
$<6 \times 10^{-14}$		[50] NUSSINOV	87	ASTR	Cosmic EM backgrounds
$<8.5 \times 10^{-11}$		[49] BEG	78	ASTR	Stellar plasmons

[44] COOPER-SARKAR 92 assume $f_{D_s}/f_\pi = 2$ and D_s, $\overline{D}_s$ production cross section = 2.6 μb to calculate ν_τ flux.

[45] KAWANO 92 lower limit is that needed to circumvent ^{4}He production if m_{ν_τ} is between 5 and $\sim$ 30 MeV/c^2.

[46] RAFFELT 90 limit valid if m_{ν_3} < 5 keV. It applies for a diagonal magnetic moment of a Dirac neutrino, or for a transition magnetic moment of a Majorana neutrino. In the latter case, the same analysis gives $< 1.4 \times 10^{-12}$. Limit at 95%CL obtained from δM_c.

[47] Significant dependence on details of stellar properties.

[48] GROTCH 88 combined data from MAC, ASP, CELLO, and Mark J.

[49] If m_{ν_3} < 10 keV.

[50] For m_{ν_3} = 8–200 eV. NUSSINOV 87 examines transition magnetic moments for $\nu_\tau \rightarrow \nu_e$ and obtain $< 3 \times 10^{-15}$ for m_{ν_3} < 16 eV and $< 6 \times 10^{-14}$ for m_{ν_3} > 4 eV.

LIMIT ON ν_τ PRODUCTION IN BEAM DUMP EXPERIMENT

VALUE	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •			
	[51] DORENBOS...	88	CHRM
	[52] BOFILL	87	CNTR
	[53] TALEBZADEH	87	BEBC
	[54] USHIDA	86C	EMUL
	[55] ASRATYAN	81	HLBC
	[56] FRITZE	80	BEBC

[51] DORENBOSCH 88 is CERN SPS beam dump experiment with the CHARM detector. $\nu_\tau + \overline{\nu}_\tau$ flux is <21% of the total prompt flux at 90% CL.

[52] BOFILL 87 is a Fermilab narrow-band ν beam with a fine-grained neutrino detector.

[53] TALEBZADEH 87 is a CERN SPS beam dump experiment with the BEBC detector. Mixing probability $P(\nu_e \rightarrow \nu_\tau)$ <18% at 90% CL.

[54] USHIDA 86C is a Fermilab wide-band ν beam with a hybrid emulsion spectrometer. Mixing probabilities $P(\nu_e \rightarrow \nu_\tau) < 7.3\%$ and $P(\nu_\mu \rightarrow \nu_\tau) < 0.2\%$ at 90% CL.

[55] ASRATYAN 81 is a Fermilab wide-band $\overline{\nu}$ beam with a 15 foot bubble chamber. Mixing probability $P(\overline{\nu}_\mu \rightarrow \overline{\nu}_\tau) < 2.2\%$ at 90% CL.

[56] FRITZE 80 is CERN SPS experiment with BEBC. Neutral-current/charged-current ratio corresponds to R = (prompt-ν_τ-induced events)/(all prompt-ν events) <0.1. Mixing probability $P(\nu_e \rightarrow \nu_\tau)$ <0.35 at CL = 90%.

ν_τ REFERENCES

BALEST	93	PR D47 R3671	+Daoudi, Ford, Johnson+	(CLEO Collab.)
CINABRO	93	PRL 70 3700	+Henderson, Kinoshita+	(CLEO Collab.)
DOLGOV	93	PRL 71 476	+Rothstein	(MICH)
ENQVIST	93	PL B301 376	+Uibo	(NORD)
MAYLE	93	PL B317 119	+Schramm, Turner, Wilson	(LLNL, CHIC)
RAJPOOT	93	MPL A8 1179		(CSULB)
ALBRECHT	92M	PL B292 221	+Ehrlichmann, Hamacher, Hofmann+	(ARGUS Collab.)
ALBRECHT	92Q	ZPHY C56 339	+Ehrlichmann, Hamacher+	(ARGUS Collab.)
BAI	92	PRL 69 3021	+Bardon, Becker-Szendy, Burnett+	(BES Collab.)
BLUDMAN	92	PR D45 4720		(CFPA)
BURROWS	92	PRL 68 3834	+Gandhi, Turner	(ARIZ, CHIC)
COOPER-...	92	PL B280 153	Cooper-Sarkar, Sarkar, Guy, Venus+	(BEBC WA66 Collab.)
DODELSON	92	PRL 68 2572	+Frieman, Turner	(FNAL, CHIC)
KAWANO	92	PL B275 487	+Fuller, Malaney, Savage	(CIT, UCSD, LLL, RUTG)
DESHPANDE	91	PR D43 943	+Sarma	(OREG, TATA)
FULLER	91	PR D43 3136	+Malaney	(UCSD)
GANDHI	91	PL B261 519E (erratum)	+Burrows	(ARIZ)
GRANEK	91	IJMP A6 2387	+McKellar	(MELB)
KOLB	91	PRL 67 533	+Turner, Chakravorty, Schramm	(FNAL, CHIC)
LAM	91	PR D44 3345	+Ng	(AST)
NATALE	91	PL B258 227		(SPIFT)
GANDHI	90	PL B246 149	+Burrows	(ARIZ)
Also	91	PL B261 519E (erratum)	Gandhi, Burrows	(ARIZ)
GRIFOLS	90B	PL B242 77	+Masso	(BARC, CERN)
RAFFELT	90	PRL 64 2856		(MPIM)
WALKER	90	PR D41 689		(HARV)
CHUPP	89	PRL 62 505	+Vestrand, Reppin	(UNH, MPIM)
GAEMERS	89	PR D40 309	+Gandhi, Lattimer	(ANIK, STON)
KOLB	89	PRL 62 509	+Turner	(CHIC, FNAL)
RAFFELT	89B	APJ 336 61	+Dearborn, Silk	(UCB, LLL)
ALBRECHT	88	PL B207 349	+Binder, Boeckmann+	(ARGUS Collab.)
ALBRECHT	88B	PL B202 149	+Binder, Boeckmann+	(ARGUS Collab.)
DORENBOS...	88	ZPHY C40 497	Dorenbosch, Allaby, Amaldi, Barbiellini+	(CHARM Collab.)
GROTCH	88	ZPHY C39 553	+Robinett	(PSU)
TERASAWA	88	NP B302 697	+Kawasaki, Sato	(TOKY)
ABACHI	87	PR D35 2880	+Baringer, Bylsma, DeBonte+	(HRS Collab.)
BOFILL	87	PR D36 3309	+Busza, Eldridge+	(MIT, FNAL, MSU)
CSORNA	87B	PR D35 2747	+Mestayer, Panvini, Word+	(CLEO Collab.)
FUKUGITA	87	PR D36 3817	+Yazaki	(KYOTY, TOKY)
NUSSINOV	87	PR D36 2278	+Rephaeli	(TELA)
TALEBZADEH	87	NP B291 503	+Guy, Venus+	(BEBC WA66 Collab.)
ABACHI	86	PRL 56 1039	+Akerlof, Baringer, Beltrami+	(HRS Collab.)
KAWASAKI	86	PL B178 71	+Terasawa, Sato	(TOKY)
USHIDA	86C	PRL 57 2897	+Kondo, Tasaka, Park, Song+	(FNAL E531 Collab.)
ALBRECHT	85I	PL 163B 404	+Binder, Drescher, Schubert+	(ARGUS Collab.)
BURCHAT	85	PRL 54 2489	+Schmidke, Yelton, Abrams+	(Mark II Collab.)
LINDLEY	85	APJ 294 1		(FNAL)
MATTEUZZI	85	PR D32 800	+Barklow+	(Mark II Collab.)
MILLS	85	PRL 54 624	+Pal, Atwood, Baillon+	(DELCO Collab.)
BINETRUY	84	PL 134B 174	+Girardi, Salati	(LAPP)
SARKAR	84	PL 148B 347	+Cooper	(OXF, CERN)
BLOCKER	82D	PL 109B 119	+Dorfan, Abrams, Alam+	(Mark II Collab.)
ASRATYAN	81	PL 105B 301	+Efremenko, Fedotov+	(ITEP, FNAL, SERP, MICH)
FELDMAN	81	SLAC-PUB-2839 Santa Cruz APS.		(SLAC, STAN)
HENRY	81	PRL 47 618	+Feldman	(JHU)
KIMBLE	81	PRL 46 80	+Bowyer, Jakobsen	(UCB)
REPHAELI	81	PL 106B 73	+Szalay	(UCSB, CHIC)
DERUJULA	80	PRL 45 942	+Glashow	(MIT, HARV)
FRITZE	80	PL 96B 427		(AACH3, BONN, CERN, LOIC, OXF, SACL)
FUJIKAWA	80	PRL 45 963	+Shrock	(STON)
STECKER	80	PRL 45 1460		(NASA)
BACINO	79B	PRL 42 749	+Ferguson, Nodulman, Slater+	(DELCO Collab.)
COWSIK	79	PR D19 2219		(TATA)
GOLDMAN	79	PR D19 2215	+Stephenson	(LASL)
LINDLEY	79	MNRAS 188 15P		(SUSS)
BACINO	78B	PRL 41 13	+Ferguson, Nodulman, Slater+	(DELCO Collab.)
BEG	78	PR D17 1395	+Marciano, Ruderman	(ROCK, COLU)
DICUS	78	PR D17 1529	+Kolb, Teplitz, Wagoner	(TEXA, VPI, STAN)
FALK	78	PL 79B 511	+Schramm	(CHIC)
COWSIK	77	PRL 39 784		(MPIM, TATA)
DICUS	77	PRL 39 168	+Kolb, Teplitz	(TEXA, VPI)

OTHER RELATED PAPERS

WEINSTEIN	93	ARNPS 43 457	+Stroynowski	(CIT, SMU)

$\boxed{e}$ $\quad J = \frac{1}{2}$

e MASS

The mass is known much more precisely in u (atomic mass units) than in MeV (see the footnote). The conversion from u to MeV, 1 u = 931.49432 ± 0.00028 MeV, involves the relatively poorly known electronic charge.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
0.51099906±0.00000015	[1] COHEN	87	RVUE	1986 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.5110034 ±0.0000014	COHEN	73	RVUE	1973 CODATA value

[1] The mass is known much more precisely in u: $m = (5.48579903 \pm 0.00000013) \times 10^{-4}$ u.

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

A test of *CPT* invariance.

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$\mathbf{<4 \times 10^{-8}}$	90	CHU	84	CNTR	Positronium spectroscopy

$|q_{e^+} + q_{e^-}|/e$

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

VALUE	DOCUMENT ID		TECN	COMMENT
$\mathbf{< 4 \times 10^{-8}}$	[2] HUGHES	92	RVUE	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<10^{-18}$	[3] MUELLER	92	THEO	Vacuum polarization

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

[3] 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.

Some older results have been omitted.

VALUE (units 10^{-6})	DOCUMENT ID		TECN	CHG	COMMENT
1159.652193 ±0.000010	[4] COHEN	87	RVUE		1986 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1159.6521884±0.0000043	VANDYCK	87	MRS	−	Single electron
1159.6521879±0.0000043	VANDYCK	87	MRS	+	Single positron
1159.652200 ±0.000040	VANDYCK	86	MRS	−	Single electron
1159.652222 ±0.000050	SCHWINBERG	81	MRS	+	Single positron

[4] The COHEN 87 value assumes the $g/2$ values for e^+ and e^- are equal, as required by *CPT*.