ν_τ

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

The following results are obtained using neutrinos associated with τ^+ or τ^-. See Note on "Electron, muon, and tau neutrino listings."

The ν_τ was directly observed by the DONUT Collaboration (KODAMA 01). Existence indirectly established from τ decay data combined with ν reaction data. See for example FELDMAN 81. ALBRECHT 92Q rules out $J = 3/2$ by establishing that the ρ^- is not in a pure $H_\rho = -1$ helicity state in $\tau^- \to \rho^- \nu_\tau$.

ν MASS

In the context of some models, it is possible that this weighted sum over mass eigenstates is the same as for the neutrinos produced in μ decay.

In some of the ASTR and COSM papers listed below, the authors did not distinguish between weak and mass eigenstates.

VALUE (MeV)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
< 18.2	95		[1] BARATE	98F	ALEP	1991–1995 LEP runs
• • • We do not use the following data for averages, fits, limits, etc. • • •						
< 28	95		[2] ATHANAS	00	CLEO	E^{ee}_{cm}= 10.6 GeV
< 27.6	95		[3] ACKERSTAFF	98T	OPAL	1990–1995 LEP runs
< 30	95	473	[4] AMMAR	98	CLEO	E^{ee}_{cm} = 10.6 GeV
< 60	95		[5] ANASTASSOV	97	CLEO	E^{ee}_{cm}= 10.6 GeV
< 0.37 or >22			[6] FIELDS	97	COSM	Nucleosynthesis
< 68	95		[7] SWAIN	97	THEO	m_τ, τ_τ, τ partial widths
< 29.9	95		[8] ALEXANDER	96M	OPAL	1990–1994 LEP runs
<149			[9] BOTTINO	96	THEO	π, μ, τ leptonic decays
<1 or >25			[10] HANNESTAD	96C	COSM	Nucleosynthesis
< 71	95		[11] SOBIE	96	THEO	m_τ, τ_τ, B($\tau^- \to e^- \overline{\nu}_e \nu_\tau$)
< 24	95	25	[12] BUSKULIC	95H	ALEP	1991–1993 LEP runs
< 0.19			[13] DOLGOV	95	COSM	Nucleosynthesis
< 3			[14] SIGL	95	ASTR	SN 1987A
< 0.4 or > 30			[15] DODELSON	94	COSM	Nucleosynthesis
< 0.1 or > 50			[16] KAWASAKI	94	COSM	Nucleosynthesis
155–225			[17] PERES	94	THEO	π,K,μ,τ weak decays
< 32.6	95	113	[18] CINABRO	93	CLEO	$E^{ee}_{cm} \approx$ 10.6 GeV
< 0.3 or > 35			[19] DOLGOV	93	COSM	Nucleosynthesis
< 0.74			[20] ENQVIST	93	COSM	Nucleosynthesis
< 31	95	19	[21] ALBRECHT	92M	ARG	E^{ee}_{cm}= 9.4–10.6 GeV
< 0.3			[22] FULLER	91	COSM	Nucleosynthesis
< 0.5 or > 25			[23] KOLB	91	COSM	Nucleosynthesis
< 0.42			[22] LAM	91	COSM	Nucleosynthesis

[1] BARATE 98F result based on kinematics of 2939 $\tau^- \rightarrow 2\pi^- \pi^+ \nu_\tau$ and 52 $\tau^- \rightarrow 3\pi^- 2\pi^+ (\pi^0) \nu_\tau$ decays. If possible 2.5% excited a_1 decay is included in 3-prong sample analysis, limit increases to 19.2 MeV.

[2] ATHANAS 00 bound comes from analysis of $\tau^- \rightarrow \pi^- \pi^+ \pi^- \pi^0 \nu_\tau$ decays.

[3] ACKERSTAFF 98T use $\tau \rightarrow 5\pi^\pm \nu_\tau$ decays to obtain a limit of 43.2 MeV (95%CL). They combine this with ALEXANDER 96M value using $\tau \rightarrow 3h^\pm \nu_\tau$ decays to obtain quoted limit.

[4] AMMAR 98 limit comes from analysis of $\tau^- \rightarrow 3\pi^- 2\pi^+ \nu_\tau$ and $\tau^- \rightarrow 2\pi^- \pi^+ 2\pi^0 \nu_\tau$ decay modes.

[5] ANASTASSOV 97 derive limit by comparing their m_τ measurement (which depends on m_{ν_τ}) to BAI 96 m_τ threshold measurement.

[6] FIELDS 97 limit for a Dirac neutrino. For a Majorana neutrino the mass region < 0.93 or >31 MeV is excluded. These bounds assume $N_\nu <4$ from nucleosynthesis; a wider excluded region occurs with a smaller N_ν upper limit.

[7] SWAIN 97 derive their limit from the Standard Model relationships between the tau mass, lifetime, branching fractions for $\tau^- \rightarrow e^- \overline{\nu}_e \nu_\tau$, $\tau^- \rightarrow \mu^- \overline{\nu}_\mu \nu_\tau$, $\tau^- \rightarrow \pi^- \nu_\tau$, and $\tau^- \rightarrow K^- \nu_\tau$, and the muon mass and lifetime by assuming lepton universality and using world average values. Limit is reduced to 48 MeV when the CLEO τ mass measurement (BALEST 93) is included; see CLEO's more recent m_{ν_τ} limit (ANASTASSOV 97). Consideration of mixing with a fourth generation heavy neutrino yields $\sin^2\theta_L < 0.016$ (95%CL).

[8] ALEXANDER 96M bound comes from analyses of $\tau^- \rightarrow 3\pi^- 2\pi^+ \nu_\tau$ and $\tau^- \rightarrow h^- h^- h^+ \nu_\tau$ decays.

[9] BOTTINO 96 assumes three generations of neutrinos with mixing, finds consistency with massless neutrinos with no mixing based on 1995 data for masses, lifetimes, and leptonic partial widths.

[10] HANNESTAD 96C limit is on the mass of a Majorana neutrino. This bound assumes $N_\nu < 4$ from nucleosynthesis. A wider excluded region occurs with a smaller N_ν upper limit. This paper is the corrected version of HANNESTAD 96; see the erratum: HANNESTAD 96B.

[11] SOBIE 96 derive their limit from the Standard Model relationship between the tau mass, lifetime, and leptonic branching fraction, and the muon mass and lifetime, by assuming lepton universality and using world average values.

[12] BUSKULIC 95H bound comes from a two-dimensional fit of the visible energy and invariant mass distribution of $\tau \rightarrow 5\pi(\pi^0)\nu_\tau$ decays. Replaced by BARATE 98F.

[13] DOLGOV 95 removes earlier assumptions (DOLGOV 93) about thermal equilibrium below T_{QCD} for wrong-helicity Dirac neutrinos (ENQVIST 93, FULLER 91) to set more stringent limits. DOLGOV 96 argues that a possible window near 20 MeV is excluded.

[14] SIGL 95 exclude massive Dirac or Majorana neutrinos with lifetimes between 10^{-3} and 10^8 seconds if the decay products are predominantly γ or $e^+ e^-$.

[15] DODELSON 94 calculate constraints on ν_τ mass and lifetime from nucleosynthesis for 4 generic decay modes. Limits depend strongly on decay mode. Quoted limit is valid for all decay modes of Majorana neutrinos with lifetime greater than about 300 s. For Dirac neutrinos limits change to < 0.3 or > 33.

[16] KAWASAKI 94 excluded region is for Majorana neutrino with lifetime $>$1000 s. Other limits are given as a function of ν_τ lifetime for decays of the type $\nu_\tau \rightarrow \nu_\mu \phi$ where ϕ is a Nambu-Goldstone boson.

[17] PERES 94 used PDG 92 values for parameters to obtain a value consistent with mixing. Reexamination by BOTTINO 96 which included radiative corrections and 1995 PDG parameters resulted in two allowed regions, $m_3 < 70$ MeV and 140 MeV $m_3 < 149$ MeV.

[18] CINABRO 93 bound comes from analysis of $\tau^- \rightarrow 3\pi^- 2\pi^+ \nu_\tau$ and $\tau^- \rightarrow 2\pi^- \pi^+ 2\pi^0 \nu_\tau$ decay modes.

[19] DOLGOV 93 assumes neutrino lifetime >100 s. For Majorana neutrinos, the low mass limit is 0.5 MeV. KAWANO 92 points out that these bounds can be overcome for a Dirac neutrino if it possesses a magnetic moment. See also DOLGOV 96.
[20] ENQVIST 93 bases limit on the fact that thermalized wrong-helicity Dirac neutrinos would speed up expansion of early universe, thus reducing the primordial abundance. FULLER 91 exploits the same mechanism but in the older calculation obtains a larger production rate for these states, and hence a lower limit. Neutrino lifetime assumed to exceed nucleosynthesis time, ~ 1 s.
[21] ALBRECHT 92M reports measurement of a slightly lower τ mass, which has the effect of reducing the ν_τ mass reported in ALBRECHT 88B. Bound is from analysis of $\tau^- \rightarrow 3\pi^- 2\pi^+ \nu_\tau$ mode.
[22] Assumes neutrino lifetime >1 s. For Dirac neutrinos. See also ENQVIST 93.
[23] KOLB 91 exclusion region is for Dirac neutrino with lifetime >1 s; other limits are given.

ν (MEAN LIFE) / MASS

Measures $\left[\sum |U_{\ell j}|^2 \ \Gamma_j \ m_j\right]^{-1}$, where the sum is over mass eigenstates which cannot be resolved experimentally. Most of these limits apply to any ν within the indicated mass range.

VALUE (s/eV)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[24] DOLGOV	99	COSM	
	[25] BILLER	98	ASTR	$m_\nu = 0.05$–1 eV
$>1 \times 10^{14}$	[26] SIGL	95	ASTR	$m_\nu >$ few MeV
$>2.8 \times 10^{15}$	[27,28] BLUDMAN	92	ASTR	$m_\nu < 50$ eV
$< 10^{-12}$ or $> 5 \times 10^4$	[29] DODELSON	92	ASTR	m_ν=1–300 keV
	[30] GRANEK	91	COSM	Decaying L^0
	[31] WALKER	90	ASTR	$m_\nu = 0.03 - \sim 2$ MeV
$>6.3 \times 10^{15}$	[28,32] CHUPP	89	ASTR	$m_\nu < 20$ eV
$>1.7 \times 10^{15}$	[28] KOLB	89	ASTR	$m_\nu < 20$ eV
	[33] TERASAWA	88	COSM	$m_\mu = 30$–70 MeV
	[34] KAWASAKI	86	COSM	$m_\nu >10$ MeV
	[35] LINDLEY	85	COSM	$m_\nu > 10$ MeV
	[36] BINETRUY	84	COSM	$m_\nu \sim 1$ MeV
	[37] SARKAR	84	COSM	$m_\nu = 10$–100 MeV
	[38] HENRY	81	ASTR	$m_\nu = 16$–20 eV
	[39] KIMBLE	81	ASTR	$m_\nu = 10$–100 eV
	[40] REPHAELI	81	ASTR	$m_\nu = 30$–150 eV
	[41] DERUJULA	80	ASTR	$m_\nu = 10$–100 eV
$>2 \times 10^{21}$	[42] STECKER	80	ASTR	$m_\nu = 10$–100 eV
	[43] DICUS	78	COSM	$m_\nu = 0.5$–30 MeV
$<3 \times 10^{-11}$	[44] FALK	78	ASTR	$m_\nu <10$ MeV
	[45] COWSIK	77	ASTR	

[24] DOLGOV 99 places limits in the (Majorana) τ-associated ν mass-lifetime plane based on nucleosynthesis. Results would be considerably modified if neutrino oscillations exist.
[25] BILLER 98 use the observed TeV γ-ray spectra to set limits on the mean life of a radiatively decaying neutrino between 0.05 and 1 eV. Curve shows $\tau_\nu/\mathrm{B}_\gamma > 0.15 \times 10^{21}$ s at 0.05 eV, $> 1.2 \times 10^{21}$ s at 0.17 eV, $> 3 \times 10^{21}$ s at 1 eV, where B_γ is the branching ratio to photons.

[26] SIGL 95 exclude 1 s $\lesssim \tau \lesssim$ 10^8 s for MeV-mass τ neutrinos from SN 1987A decaying radiatively, and eliminates the lower limit using other published results.

[27] BLUDMAN 92 sets additional limits by this method for higher mass ranges. Cosmological limits are also obtained.

[28] Nonobservation of γ's in coincidence with ν's from SN 1987A. Results should be divided by the $\nu \rightarrow \gamma X$ branching ratio.

[29] DODELSON 92 range is for wrong-helicity keV mass Dirac ν's from the core of neutron star in SN 1987A decaying to ν's that would have interacted in KAM2 or IMB detectors.

[30] GRANEK 91 considers heavy neutrino decays to $\gamma\nu_L$ and $3\nu_L$, where m_{ν_L} <100 keV. Lifetime is calculated as a function of heavy neutrino mass, branching ratio into $\gamma\nu_L$, and m_{ν_L}.

[31] WALKER 90 uses SN 1987A γ flux limits after 289 days to find $\langle m/\tau \rangle > 1.1\times10^{15}$ eV s.

[32] CHUPP 89 should be multiplied by a branching ratio (about 1) and a detection efficiency (about 1/4), and pertains to radiative decay of any neutrino to a lighter or sterile neutrino.

[33] TERASAWA 88 finds only $10^2 < \tau < 10^4$ allowed for 30–70 MeV ν's from primordial nucleosynthesis.

[34] KAWASAKI 86 concludes that light elements in primordial nucleosynthesis would be destroyed by radiative decay of neutrinos with 10 MeV$<m_\nu<$1 GeV unless $\tau \lesssim 10^4$ s.

[35] LINDLEY 85 considers destruction of cosmologically-produced light elements, and finds $\tau < 2\times10^3$ s for 10 MeV $<m_\nu<$100 MeV. See also LINDLEY 79.

[36] BINETRUY 84 finds $\tau < 10^8$ s for neutrinos in a radiation-dominated universe.

[37] SARKAR 84 finds $\tau <$ 20 s at m_ν=10 MeV, with higher limits for other m_ν, and claims that all masses between 1 MeV and 50 MeV are ruled out.

[38] HENRY 81 uses UV flux from clusters of galaxies to find $\tau > 1.1\times10^{25}$ s for radiative decay.

[39] KIMBLE 81 uses extreme UV flux limits to find $\tau > 10^{22}$–10^{23} s.

[40] REPHAELI 81 consider ν decay γ effect on neutral *H* in early universe; based on M31 HI concludes $\tau > 10^{24}$ s.

[41] DERUJULA 80 finds $\tau > 3\times10^{23}$ s based on CDM neutrino decay contribution to UV background.

[42] STECKER 80 limit based on UV background; result given is $\tau > 4\times10^{22}$ s at $m = 20$ eV.

[43] DICUS 78 considers effect of ν decay photons on light-element production, and finds lifetime must be less than "hours." See also DICUS 77.

[44] FALK 78 finds lifetime constraints based on supernova energetics.

[45] COWSIK 77 considers variety of scenarios. For neutrinos produced in the big bang, present limits on optical photon flux require $\tau > 10^{23}$ s for $m_\nu \sim 1$ eV. See also COWSIK 79 and GOLDMAN 79.

ν MAGNETIC MOMENT

Must vanish for a purely chiral massless Dirac neutrino. A massive Dirac or Majorana neutrino can have a transition magnetic moment connecting one mass eigenstate to another one. The experimental limits below usually cannot distinguish between the true (diagonal, in mass) magnetic moment and a transition magnetic moment.

The value of the magnetic moment for the standard SU(2)×U(1) electroweak theory extended to include massive neutrinos (see FUJIKAWA 80) is $\mu_\nu = 3eG_F m_\nu/(8\pi^2\sqrt{2}) = (3.20\times10^{-19}) m_\nu \mu_B$ where m_ν is in eV and $\mu_B = e\hbar/2m_e$ is the Bohr magneton. Given the upper bound $m_\nu <$ 18 MeV, it follows that for the extended standard electroweak theory, $\mu_\nu < 6\times10^{-12}\ \mu_B$.

Most of the astrophysical limits pertain to any neutrino.

VALUE (μ_B)	CL%	DOCUMENT ID		TECN	COMMENT
<3.9 × 10^{-7}	90	[46] SCHWIENHO...	01	DONU	$\nu_\tau e^- \rightarrow \nu_\tau e^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<3.7 \times 10^{-9}$	95	[47] GRIFOLS	04	FIT	Solar ^{8}B ν (SNO NC)
$<3.6 \times 10^{-10}$	90	[48] LIU	04	SKAM	Solar ν spectrum shape
$<1.1 \times 10^{-10}$	90	[49] LIU	04	SKAM	Solar ν spectrum shape (LMA region)
$<2 \times 10^{-10}$	90	[50] GRIMUS	02	FIT	solar + reactor (Majorana ν)
$<8.0 \times 10^{-6}$	90	[51] TANIMOTO	00	RVUE	$e^+ e^- \rightarrow \nu\overline{\nu}\gamma$
$<3 \times 10^{-12}$		[52] RAFFELT	99	ASTR	Red giant luminosity
$<4 \times 10^{-10}$		[53] RAFFELT	99	ASTR	Solar cooling
$<4.4 \times 10^{-6}$	90	ABREU	97J	DLPH	$e^+ e^- \rightarrow \nu\overline{\nu}\gamma$ at LEP
$<3.3 \times 10^{-6}$	90	[54] ACCIARRI	97Q	L3	$e^+ e^- \rightarrow \nu\overline{\nu}\gamma$ at LEP
$<6.2 \times 10^{-11}$		[55] ELMFORS	97	COSM	Depolarization in early universe plasma
$<2.7 \times 10^{-6}$	95	[56] ESCRIBANO	97	RVUE	$\Gamma(Z \rightarrow \nu\nu)$ at LEP
$<5.5 \times 10^{-6}$	90	GOULD	94	RVUE	$e^+ e^- \rightarrow \nu\overline{\nu}\gamma$ at LEP
$<5.4 \times 10^{-7}$	90	[57] COOPER-...	92	BEBC	$\nu_\tau e^- \rightarrow \nu_\tau e^-$
$\gtrsim 10^{-8}$		[58] KAWANO	92	ASTR	Primodial ^{4}He abundance
$<5.6 \times 10^{-6}$	90	DESHPANDE	91	RVUE	$e^+ e^- \rightarrow \nu\overline{\nu}\gamma$
$<2 \times 10^{-12}$		[59] RAFFELT	90	ASTR	Red giant luminosity
$<1 \times 10^{-11}$		[60] RAFFELT	89B	ASTR	Cooling helium stars
$<4. \times 10^{-6}$	90	[61] GROTCH	88	RVUE	$e^+ e^- \rightarrow \nu\overline{\nu}\gamma$
$<1.1 \times 10^{-11}$		[60,62] FUKUGITA	87	ASTR	Cooling helium stars
$<6 \times 10^{-14}$		[63] NUSSINOV	87	ASTR	Cosmic EM backgrounds
$<8.5 \times 10^{-11}$		[62] BEG	78	ASTR	Stellar plasmons

[46] SCHWIENHORST 01 quote an experimental sensitivity of 4.9×10^{-7}.

[47] GRIFOLS 04 obtained this bound using the SNO data of the solar ^{8}B neutrino flux measured with deuteron breakup. This bound applies to $\mu_{\rm eff} = (\mu^2_{21} + \mu^2_{22} + \mu^2_{23})^{1/2}$.

[48] LIU 04 obtained this limit using the shape of the recoil electron energy spectrum from the Super-Kamiokande-I 1496 days of solar neutrino data. Neutrinos are assumed to have only diagonal magnetic moments, $\mu_{\nu 1} = \mu_{\nu 2}$. This limit corresponds to the oscillation parameters in the vacuum oscillation region.

[49] LIU 04 obtained this limit using the shape of the recoil electron energy spectrum from the Super-Kamiokande-I 1496 live-day solar neutrino data, by limiting the oscillation parameter region in the LMA region allowed by solar neutrino experiments plus KamLAND. $\mu_{\nu 1} = \mu_{\nu 2}$ is assumed. In the LMA region, the same limit would be obtained even if neutrinos have off-diagonal magnetic moments.

[50] GRIMUS 02 obtain stringent bounds on all Majorana neutrino transition moments from a simultaneous fit of LMA-MSW oscillation parameters and transition moments to global solar neutrino data + reactor data. Using only solar neutrino data, a 90% CL bound of $6.3 \times 10^{-10} \mu_B$ is obtained.

[51] TANIMOTO 00 combined $e^+ e^- \rightarrow \nu\overline{\nu}\gamma$ data from VENUS, TOPAZ, and AMY.

[52] RAFFELT 99 is an update of RAFFELT 90. This limit applies to all neutrino flavors which are light enough ($<$ 5 keV) to be emitted from globular-cluster red giants. This limit pertains equally to electric dipole moments and magnetic transition moments, and it applies to both Dirac and Majorana neutrinos.

[53] RAFFELT 99 is derived from the helioseismological limit on a new energy-loss channel of the Sun. This limit applies to all neutrino flavors which are light enough ($<$1 keV) to be emitted from the Sun. This limit pertains equally to electric dipole and magnetic transition moments, and it applies to both Dirac and Majorana neutrinos.

[54] ACCIARRI 97Q result applies to both direct and transition magnetic moments and for q^2=0.

[55] ELMFORS 97 calculate the rate of depolarization in a plasma for neutrinos with a magnetic moment and use the constraints from a big-bang nucleosynthesis on additional degrees of freedom.

[56] Applies to absolute value of magnetic moment.

[57] 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 flux.

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

[59] RAFFELT 90 limit valid if $m_\nu < 5$ 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.

[60] Significant dependence on details of stellar properties.

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

[62] If $m_\nu < 10$ keV.

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

ν ELECTRIC DIPOLE MOMENT

VALUE (*e* cm)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<5.2 \times 10^{-17}$	95	[64] ESCRIBANO	97	RVUE	$\Gamma(Z \rightarrow \nu\nu)$ at LEP

[64] Applies to absolute value of electric dipole moment.

ν CHARGE

VALUE (units: electron charge)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<2 \times 10^{-14}$	[65] RAFFELT	99	ASTR	Red giant luminosity
$<6 \times 10^{-14}$	[66] RAFFELT	99	ASTR	Solar cooling
$<4 \times 10^{-4}$	[67] BABU	94	RVUE	BEBC beam dump
$<3 \times 10^{-4}$	[68] DAVIDSON	91	RVUE	SLAC electron beam dump

[65] This RAFFELT 99 limit applies to all neutrino flavors which are light enough ($<$5 kEV) to be emitted from globular-cluster red giants.

[66] This RAFFELT 99 limit is derived from the helioseismological limit on a new energy-loss channel of the Sun, and applies to all neutrino flavors which are light enough ($<$1 keV) to be emitted from the sun.

[67] BABU 94 use COOPER-SARKAR 92 limit on ν magnetic moment to derive quoted result.

[68] DAVIDSON 91 use data from early SLAC electron beam dump experiment to derive charge limit as a function of neutrino mass.

NONSTANDARD CONTRIBUTIONS TO NEUTRINO SCATTERING

We report limits on the so-called neutrino charge radius squared. While the straight-forward definition of a neutrino charge radius has been proven to be gauge-dependent and, hence, unphysical (LEE 77C), there have been recent attempts to define a physically observable neutrino charge radius (BERNABEU 00, BERNABEU 02). The issue is still controversial (FUJIKAWA 03, BERNABEU 03). A more general interpretation of the experimental results is that they are limits on certain nonstandard contributions to neutrino scattering.

VALUE (10^{-32} cm^2)	*CL%*	*DOCUMENT ID*		*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<9.9 and > −8.2	90	[69] HIRSCH	03	anomalous $e^+ e^- \rightarrow \nu \overline{\nu} \gamma$

[69] Results of LEP-2 are interpreted as limits on the axial-vector charge radius squared of a Majorana ν_τ. Slightly weaker limits for both vector and axial-vector charge radius squared are obtained for the Dirac case, and somewhat weaker limits are obtained from the analysis of lower energy data (LEP-1.5 and TRISTAN).

ν_τ REFERENCES

GRIFOLS	04	PL B587 184	J.A. Grifols, E. Masso, S. Mohanty	(BARC, AHMED)
LIU	04	PRL 93 021802	D.W. Liu *et al.*	(Super-Kamiokande Collab.)
BERNABEU	03	hep-ph/0303202	J. Bernabeu, J. Papavassiliou, J. Vidal	
FUJIKAWA	03	hep-ph/0303188	K. Fujikawa, R. Shrock	
HIRSCH	03	PR D67 033005	M. Hirsch *et al.*	
BERNABEU	02	PRL 89 101802	J. Bernabeu, J. Papavassiliou, J. Vidal	
Also	02B	PRL 89 229902 (erratum)	J. Bernabeu, J. Papavassiliou, J. Vidal	
GRIMUS	02	NP B648 376	W. Grimus *et al.*	
KODAMA	01	PL B504 218	K. Kodama *et al.*	(DONUT Collab.)
SCHWIENHO...	01	PL B513 23	R. Schwienhorst *et al.*	(DONUT Collab.)
ATHANAS	00	PR D61 052002	M. Athanas *et al.*	(CLEO Collab.)
BERNABEU	00	PR D62 113012	J. Bernabeu *et al.*	
TANIMOTO	00	PL B478 1	N. Tanimoto *et al.*	
DOLGOV	99	NP B548 385	A.D. Dolgov *et al.*	
RAFFELT	99	PRPL 320 319	G.G. Raffelt	
ACKERSTAFF	98T	EPJ C5 229	K. Ackerstaff *et al.*	(OPAL Collab.)
AMMAR	98	PL B431 209	R. Ammar *et al.*	(CLEO Collab.)
BARATE	98F	EPJ C2 395	R. Barate *et al.*	(ALEPH Collab.)
BILLER	98	PRL 80 2992	S.D. Biller *et al.*	(WHIPPLE Collab.)
ABREU	97J	ZPHY C74 577	P. Abreu *et al.*	(DELPHI Collab.)
ACCIARRI	97Q	PL B412 201	M. Acciarri *et al.*	(L3 Collab.)
ANASTASSOV	97	PR D55 2559	A. Anastassov *et al.*	(CLEO Collab.)
Also	98B	PR D58 119903 (erratum)	A. Anastassov *et al.*	(CLEO Collab.)
ELMFORS	97	NP B503 3	P. Elmfors *et al.*	
ESCRIBANO	97	PL B395 369	R. Escribano, E. Masso	(BARC, PARIT)
FIELDS	97	ASP 6 169	B.D. Fields, K. Kainulainen, K.A. Olive	(NDAM+)
SWAIN	97	PR D55 R1	J. Swain, L. Taylor	(NEAS)
ALEXANDER	96M	ZPHY C72 231	G. Alexander *et al.*	(OPAL Collab.)
BAI	96	PR D53 20	J.Z. Bai *et al.*	(BES Collab.)
BOTTINO	96	PR D53 6361	A. Bottino *et al.*	
DOLGOV	96	PL B383 193	A.D. Dolgov, S. Pastor, J.W.F. Valle	(IFIC, VALE)
HANNESTAD	96	PRL 76 2848	S. Hannestad, J. Madsen	(AARH)
HANNESTAD	96B	PRL 77 5148 (erratum)	S. Hannestad, J. Madsen	(AARH)
HANNESTAD	96C	PR D54 7894	S. Hannestad, J. Madsen	(AARH)
SOBIE	96	ZPHY C70 383	R.J. Sobie, R.K. Keeler, I. Lawson	(VICT)
BUSKULIC	95H	PL B349 585	D. Buskulic *et al.*	(ALEPH Collab.)
DOLGOV	95	PR D51 4129	A.D. Dolgov, K. Kainulainen, I.Z. Rothstein	(MICH+)
SIGL	95	PR D51 1499	G. Sigl, M.S. Turner	(FNAL, EFI)
BABU	94	PL B321 140	K.S. Babu, T.M. Gould, I.Z. Rothstein	(BART+)
DODELSON	94	PR D49 5068	S. Dodelson, G. Gyuk, M.S. Turner	(FNAL, CHIC+)
GOULD	94	PL B333 545	T.M. Gould, I.Z. Rothstein	(JHU, MICH)
KAWASAKI	94	NP B419 105	M. Kawasaki *et al.*	(OSU)

PERES	94	PR D50 513	O.L.G. Peres, V. Pleitez, R. Zukanovich Funchal	
BALEST	93	PR D47 R3671	R. Balest *et al.*	(CLEO Collab.)
CINABRO	93	PRL 70 3700	D. Cinabro *et al.*	(CLEO Collab.)
DOLGOV	93	PRL 71 476	A.D. Dolgov, I.Z. Rothstein	(MICH)
ENQVIST	93	PL B301 376	K. Enqvist, H. Uibo	(NORD)
ALBRECHT	92M	PL B292 221	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	92Q	ZPHY C56 339	H. Albrecht *et al.*	(ARGUS Collab.)
BLUDMAN	92	PR D45 4720	S.A. Bludman	(CFPA)
COOPER-...	92	PL B280 153	A.M. Cooper-Sarkar *et al.*	(BEBC WA66 Collab.)
DODELSON	92	PRL 68 2572	S. Dodelson, J.A. Frieman, M.S. Turner	(FNAL+)
KAWANO	92	PL B275 487	L.H. Kawano *et al.*	(CIT, UCSD, LLL+)
PDG	92	PR D45, 1 June, Part II	K. Hikasa *et al.*	(KEK, LBL, BOST+)
DAVIDSON	91	PR D43 2314	S. Davidson, B.A. Campbell, D. Bailey	(ALBE+)
DESHPANDE	91	PR D43 943	N.G. Deshpande, K.V.L. Sarma	(OREG, TATA)
FULLER	91	PR D43 3136	G.M. Fuller, R.A. Malaney	(UCSD)
GRANEK	91	IJMP A6 2387	H. Granek, B.H.J. McKellar	(MELB)
KOLB	91	PRL 67 533	E.W. Kolb *et al.*	(FNAL, CHIC)
LAM	91	PR D44 3345	W.P. Lam, K.W. Ng	(AST)
RAFFELT	90	PRL 64 2856	G.G. Raffelt	(MPIM)
WALKER	90	PR D41 689	T.P. Walker	(HARV)
CHUPP	89	PRL 62 505	E.L. Chupp, W.T. Vestrand, C. Reppin	(UNH, MPIM)
KOLB	89	PRL 62 509	E.W. Kolb, M.S. Turner	(CHIC, FNAL)
RAFFELT	89B	APJ 336 61	G. Raffelt, D. Dearborn, J. Silk	(UCB, LLL)
ALBRECHT	88B	PL B202 149	H. Albrecht *et al.*	(ARGUS Collab.)
GROTCH	88	ZPHY C39 553	H. Grotch, R.W. Robinett	(PSU)
TERASAWA	88	NP B302 697	N. Terasawa, M. Kawasaki, K. Sato	(TOKY)
FUKUGITA	87	PR D36 3817	M. Fukugita, S. Yazaki	(KYOTU, TOKY)
NUSSINOV	87	PR D36 2278	S. Nussinov, Y. Rephaeli	(TELA)
KAWASAKI	86	PL B178 71	M. Kawasaki, N. Terasawa, K. Sato	(TOKY)
LINDLEY	85	APJ 294 1	D. Lindley	(FNAL)
BINETRUY	84	PL 134B 174	P. Binetruy, G. Girardi, P. Salati	(LAPP)
SARKAR	84	PL 148B 347	S. Sarkar, A.M. Cooper	(OXF, CERN)
FELDMAN	81	SLAC-PUB-2839	G.J. Feldman	(SLAC, STAN)
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HENRY	81	PRL 47 618	R.C. Henry, P.D. Feldman	(JHU)
KIMBLE	81	PRL 46 80	R. Kimble, S. Bowyer, P. Jakobsen	(UCB)
REPHAELI	81	PL 106B 73	Y. Rephaeli, A.S. Szalay	(UCSB, CHIC)
DERUJULA	80	PRL 45 942	A. De Rujula, S.L. Glashow	(MIT, HARV)
FUJIKAWA	80	PRL 45 963	K. Fujikawa, R. Shrock	(STON)
STECKER	80	PRL 45 1460	F.W. Stecker	(NASA)
COWSIK	79	PR D19 2219	R. Cowsik	(TATA)
GOLDMAN	79	PR D19 2215	T. Goldman, G.J. Stephenson	(LASL)
LINDLEY	79	MNRAS 188 15P	D. Lindley	(SUSS)
BEG	78	PR D17 1395	M.A.B. Beg, W.J. Marciano, M. Ruderman	(ROCK+)
DICUS	78	PR D17 1529	D.A. Dicus *et al.*	(TEXA, VPI, STAN)
FALK	78	PL 79B 511	S.W. Falk, D.N. Schramm	(CHIC)
COWSIK	77	PRL 39 784	R. Cowsik	(MPIM, TATA)
DICUS	77	PRL 39 168	D.A. Dicus, E.W. Kolb, V.L. Teplitz	(TEXA, VPI)
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