ν_τ

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

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 $\tau^- \rightarrow \rho^- \nu_\tau$.

Not in general a mass eigenstate. Pending better understanding, it is assumed that ν_τ couples predominately with ν_3. See Note on "Neutrino Mass" above.

ν_τ MASS

Applies to ν_3, the primary mass eigenstate in ν_τ. Would also apply to any other ν_j which mixes strongly in ν_τ and has sufficiently small mass that it can occur in the respective decays. (This would be nontrivial only for a hypothetical $j \geq 4$, given the ν_e and ν_μ mass limits above.) See also the Listings in the Neutrino Bounds from Astrophysics and Cosmology section.

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($\tau^- \rightarrow e^- \overline{\nu}_e \nu_\tau$)
$<$ 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
$<$ 0.003			[21,22] MAYLE	93	ASTR	SN 1987A cooling

$<$ 31	95	19	[23] ALBRECHT	92M	ARG	$E^{ee}_{\rm cm}$= 9.4–10.6 GeV
$<$ 0.025–0.030			[22,24] BURROWS	92	ASTR	SN 1987A cooling
$<$ 0.3			[25] FULLER	91	COSM	Nucleosynthesis
$<$ 0.5 or $>$ 25			[26] KOLB	91	COSM	Nucleosynthesis
$<$ 0.42			[25] LAM	91	COSM	Nucleosynthesis
$<$ 0.028–0.15			[27] NATALE	91	ASTR	SN 1987A
$<$ 0.028			[22] GANDHI	90	ASTR	SN 1987A
$<$ 0.014 or $>$ 34			[22,28] GRIFOLS	90B	ASTR	SN 1987A
$<$ 0.06			[22,29] GAEMERS	89		SN 1987A

[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_ν $<$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 $T_{\rm QCD}$ 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] MAYLE 93 recalculates cooling rate enhancement by escape of wrong-helicity Dirac neutrinos using the Livermore Supernova Explosion Code, obtains more restrictive result than the "very conservative" BURROWS 92 limit because of higher core temperature.

[22] There would be an increased SN 1987A cooling rate if Dirac neutrino mass is included; this does not apply for Majorana neutrinos. Limit is on $\sqrt{m^2_{\nu_\mu} + m^2_{\nu_\tau}}$, and error becomes very large if ν_τ is nonrelativistic, which occurs near the lab limit of 31 MeV. RAJPOOT 93 notes that limit could be evaded with new physics.

[23] 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.

[24] BURROWS 92 limit for Dirac neutrinos only.

[25] Assumes neutrino lifetime >1 s. For Dirac neutrinos. See also ENQVIST 93.

[26] KOLB 91 exclusion region is for Dirac neutrino with lifetime >1 s; other limits are given.

[27] NATALE 91 published result multiplied by $\sqrt{8}\sqrt{4}$ at the advice of the author.

[28] GRIFOLS 90B estimated error is a factor of 3.

[29] GAEMERS 89 published result (< 0.03) corrected via the GANDHI 91 erratum.

ν_3 (MEAN LIFE) / MASS

These limits often apply to ν_μ (ν_2) also.

VALUE (s/eV)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[30] DOLGOV	99	COSM	
	[31] BILLER	98	ASTR	m_ν= 0.05–1 eV
$>1 \quad \times 10^{14}$	[32] SIGL	95	ASTR	$m_\nu >$ few MeV
$>2.8 \times 10^{15}$	[33,34] BLUDMAN	92	ASTR	$m_\nu <$ 50 eV
$< \ 10^{-12}$ or $> \ 5 \times 10^4$	[35] DODELSON	92	ASTR	m_ν=1–300 keV
	[36] GRANEK	91	COSM	Decaying L^0
	[37] WALKER	90	ASTR	m_ν= 0.03 – $\sim$ 2 MeV
$>6.3 \times 10^{15}$	[34,38] CHUPP	89	ASTR	$m_\nu <$ 20 eV
$>1.7 \times 10^{15}$	[34] KOLB	89	ASTR	$m_\nu <$ 20 eV
	[39] TERASAWA	88	COSM	m_μ= 30–70 MeV
	[40] KAWASAKI	86	COSM	m_ν >10 MeV
	[41] LINDLEY	85	COSM	$m_\nu >$ 10 MeV
	[42] BINETRUY	84	COSM	$m_\nu \sim$ 1 MeV
	[43] SARKAR	84	COSM	m_ν= 10–100 MeV
	[44] HENRY	81	ASTR	m_ν= 16–20 eV
	[45] KIMBLE	81	ASTR	m_ν= 10–100 eV
	[46] REPHAELI	81	ASTR	m_ν= 30–150 eV
	[47] DERUJULA	80	ASTR	m_ν= 10–100 eV
$>2 \quad \times 10^{21}$	[48] STECKER	80	ASTR	m_ν= 10–100 eV
	[49] DICUS	78	COSM	m_ν= 0.5–30 MeV
$<3 \quad \times 10^{-11}$	[50] FALK	78	ASTR	m_ν <10 MeV
	[51] COWSIK	77	ASTR	

[30] DOLGOV 99 places limits in the (Majorana) ν_τ mass-lifetime plane based on nucleosynthesis. Results would be consideribly modified if neutrino oscillations exist.

[31] 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 $\tau_\nu/\mathrm{B}_\gamma > 0.15\times10^{21}$ 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.

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

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

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

[35] 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.

[36] 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}.

[37] WALKER 90 uses SN 1987A γ flux limits after 289 days to find $m_\tau > 1.1 \times 10^{15}$ eV s.

[38] 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.

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

[40] KAWASAKI 86 concludes that light elements in primordal nucleosynthesis would be destroyed by radiative decay of neutrinos with 10 MeV$<m_\nu<$1 GeV unless $\tau \lesssim 10^4$ s.
[41] LINDLEY 85 considers destruction of cosmologically-produced light elements, and finds $\tau < 2 \times 10^3$ s for 10 MeV $<m_\nu<$100 MeV. See also LINDLEY 79.
[42] BINETRUY 84 finds $\tau < 10^8$ s for neutrinos in a radiation-dominated universe.
[43] 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.
[44] HENRY 81 uses UV flux from clusters of galaxies to find $\tau > 1.1 \times 10^{25}$ s for radiative decay.
[45] KIMBLE 81 uses extreme UV flux limits to find $\tau > 10^{22}$–10^{23} s.
[46] REPHAELI 81 consider ν decay γ effect on neutral *H* in early universe; based on M31 HI concludes $\tau > 10^{24}$ s.
[47] DERUJULA 80 finds $\tau > 3 \times 10^{23}$ s based on CDM neutrino decay contribution to UV background.
[48] STECKER 80 limit based on UV background; result given is $\tau > 4 \times 10^{22}$ s at $m_\nu = 20$ eV.
[49] DICUS 78 considers effect of ν decay photons on light-element production, and finds lifetime must be less than "hours." See also DICUS 77.
[50] FALK 78 finds lifetime constraints based on supernova energetics.
[51] COWSIK 77 considers varity 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_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 $m_{\nu_3} < 35$ 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
$<5.4 \times 10^{-7}$	90	[52] COOPER-...	92	BEBC	$\nu_\tau e^- \rightarrow \nu_\tau e^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<3 \times 10^{-12}$		[53] RAFFELT	99	ASTR	Red giant luminosity
$<4 \times 10^{-10}$		[54] 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	[55] ACCIARRI	97Q	L3	$e^+e^- \rightarrow \nu\overline{\nu}\gamma$ at LEP
$<6.2 \times 10^{-11}$		[56] ELMFORS	97	COSM	Depolarization in early universe plasma
$<2.7 \times 10^{-6}$	95	[57] 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
$\gtrsim 10^{-8}$		[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

[52] 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.
[53] 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.
[54] 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.
[55] ACCIARRI 97Q result applies to both direct and transition magnetic moments and for q^2=0.
[56] 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.
[57] Applies to absolute value of magnetic moment.
[58] 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.
[59] RAFFELT 90 limit valid if $m_{\nu_3} < 5$ 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.
[60] Significant dependence on details of stellar properties.
[61] GROTCH 88 combined data from MAC, ASP, CELLO, and Mark J.
[62] If $m_{\nu_3} < 10$ keV.
[63] 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 $m_{\nu_3} < 16$ eV and $< 6 \times 10^{-14}$ for $m_{\nu_3} > 4$ eV.

ν_3 ELECTRIC DIPOLE MOMENT

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

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

ν_3 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_3 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.

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. • • •			
	[69] DORENBOS...	88	CHRM
	[70] BOFILL	87	CNTR
	[71] TALEBZADEH	87	BEBC
	[72] USHIDA	86C	EMUL
	[73] ASRATYAN	81	HLBC
	[74] FRITZE	80	BEBC

[69] 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.

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

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

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

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

[74] 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 $P(\nu_e \to \nu_\tau) < 0.35$ at CL = 90%.

ν_τ REFERENCES

ATHANAS	00	PR D61 052002	M. Athanas *et al.*	(CLEO Collab.)
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)
MAYLE	93	PL B317 119	R. Mayle *et al.*	(LLNL, CHIC)

RAJPOOT	93	MPL A8 1179	S. Rajpoot	(CSULB)
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)
BURROWS	92	PRL 68 3834	A. Burrows, R. Gandhi, M. Turner	(ARIZ, CHIC)
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)
GANDHI	91	PL B261 519E (erratum)	R. Gandhi, A. Burrows	(ARIZ)
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)
NATALE	91	PL B258 227	A.A. Natale	(SPIFT)
GANDHI	90	PL B246 149	R. Gandhi, A. Burrows	(ARIZ)
Also	91	PL B261 519E (erratum)	R. Gandhi, A. Burrows	(ARIZ)
GRIFOLS	90B	PL B242 77	J.A. Grifols, E. Masso	(BARC, CERN)
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)
GAEMERS	89	PR D40 309	K.J.F. Gaemers, R. Gandhi, J.M. Lattimer	(ANIK+)
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.)
DORENBOS...	88	ZPHY C40 497	J. Dorenbosch *et al.*	(CHARM Collab.)
GROTCH	88	ZPHY C39 553	H. Grotch, R.W. Robinett	(PSU)
TERASAWA	88	NP B302 697	N. Terasawa, M. Kawasaki, K. Sato	(TOKY)
BOFILL	87	PR D36 3309	J. Bofill *et al.*	(MIT, FNAL, MSU)
FUKUGITA	87	PR D36 3817	M. Fukugita, S. Yazaki	(KYOTU, TOKY)
NUSSINOV	87	PR D36 2278	S. Nussinov, Y. Rephaeli	(TELA)
TALEBZADEH	87	NP B291 503	M. Talebzadeh *et al.*	(BEBC WA66 Collab.)
KAWASAKI	86	PL B178 71	M. Kawasaki, N. Terasawa, K. Sato	(TOKY)
USHIDA	86C	PRL 57 2897	N. Ushida *et al.*	(FNAL E531 Collab.)
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)
ASRATYAN	81	PL 105B 301	A.E. Asratyan *et al.*	(ITEP, FNAL, SERP+)
FELDMAN	81	SLAC-PUB-2839	G.J. Feldman	(SLAC, STAN)
Santa Cruz APS.				
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)
FRITZE	80	PL 96B 427	P. Fritze	(AACH3, BONN, CERN, LOIC, OXF+)
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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