ν_e

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

Not in general a mass eigenstate. See note on neutrino properties above.

MINIREVIEW GOES HERE

ν_e MASS

Most of the data from which these limits are derived are from β^- decay experiments in which a $\overline{\nu}_e$ is produced, so that they really apply to $m_{\overline{\nu}_1}$. Assuming *CPT* invariance, a limit on $m_{\overline{\nu}_1}$ is the same as a limit on m_{ν_1}. Results from studies of electron capture transitions, given below "$m_{\nu_1} - m_{\overline{\nu}_1}$", give limits on m_{ν_1} itself. See also the Listings in the Neutrino Bounds from Astrophysics and Cosmology section.

VALUE (eV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
OUR LIMIT		[1] PDG	94	RVUE	See the note below.
< 7.2	95	[2] WEINHEIMER	93	SPEC	^{3}H β decay
< 11.7	95	[3] HOLZSCHUH	92B	SPEC	^{3}H β decay
< 13.1	95	[4] KAWAKAMI	91	SPEC	^{3}H β decay
< 9.3	95	[5] ROBERTSON	91	SPEC	^{3}H β decay
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<460	68	[6] YASUMI	94	CNTR	*e* capture in ^{163}Ho
		[7] VANDYCK	93		$m_{^3\text{H}} - m_{^3\text{He}}$
< 8.0	95	[8] DECMAN	92	CNTR	^{3}H β decay
< 14	95	AVIGNONE	90	ASTR	Supernova SN 1987A
< 23		LOREDO	89	ASTR	SN 1987A
		ABBOTT	88	ASTR	Supernova SN 1987A
< 29	95	[9] KAWAKAMI	88	SPEC	Repl. by KAWAKAMI 91
		[10] SPERGEL	88	ASTR	Supernova SN 1987A
17 to 40		[11] BORIS	87	SPEC	$\overline{\nu}_e$, ^{3}H β decay
< 27	95	[12] WILKERSON	87	SPEC	$\overline{\nu}_e$, ^{3}H β decay
< 18	95	[13] FRITSCHI	86	SPEC	Repl. by HOLZSCHUH 92B

[1] PDG 94 formal upper limit, as obtained from the m^2 average in the next section, is 5.1 eV at the 95%CL. Caution is urged in interpreting this result, since the m^2 average is positive with only a 3.5% probability. If the weighted average m^2 were forced to zero, the limit would increase to 7.0 eV.

[2] WEINHEIMER 93 is a measurement of the endpoint of the tritium β spectrum using an electrostatic spectrometer with a magnetic guiding field. The source is molecular tritium frozen onto an aluminum substrate.

[3] HOLZSCHUH 92B result is obtained from the measurement $m^2_{\nu_e} = -24 \pm 48 \pm 61$ (1σ errors), in eV^2, using the PDG prescription for conversion to a limit in m_{ν_e}.

[4] KAWAKAMI 91 experiment uses tritium-labeled arachidic acid. This result may be obtained from the $m^2_{\nu_1}$ limit by combining the errors in quadrature and using the method described in the Probability, Statistics, and Monte Carlo section in Chapter III of this *Review*. This was also done in ROBERTSON 91, although the authors report a different procedure.

[5] ROBERTSON 91 experiment uses gaseous molecular tritium. The result is in strong disagreement with the earlier claims by the ITEP group [LUBIMOV 80, BORIS 87 (+ BORIS 88 erratum)] that m_{ν_1} lies between 17 and 40 eV. However, the probability of a positive m^2 is only 3% if statistical and systematic error are combined in quadrature.

[6] The YASUMI 94 limit results from their measurement $m_{\nu_e} = 110^{+350}_{-110}$ eV.

[7] VANDYCK 93 is a new measurement of the atomic masses of ^{3}H and ^{3}He. The authors note that "The excellent agreement with recent results from beta spectrometers lends strong support for new (upper) limits on the (electron) neutrio's rest mass."

[8] DECMAN 92 was not published in a refereed journal, so we do not use it in our compilation, but we include it for the reader's convenience. If it were included our limit would be reduced to 4.9 eV, but the average m^2 would be positive with only a 1.1% probability.

[9] KAWAKAMI 88 multiply their statistical error by the appropriate factor for 95% CL when $m^2 > 0$ is required (1.74), add this linearly to their unmultiplied systematic error (173 eV^2) and add the m^2 value (223 eV^2) to obtain their 95% CL limit ($m<29$ eV). To adjust for our quadratic addition of errors and our multiplication of both the statistical and systematic errors by the factor 1.645 we set the systematic error to 269 eV^2 to yield the same limit.

[10] SPERGEL 88 rule out masses greater than 16 eV.

[11] See also comment in BORIS 87B and erratum in BORIS 88.

[12] WILKERSON 87 multiply both statistical and systematic errors by 1.645 (for 95% CL), add them in quadrature and add the (negative) m^2 value ($-57\,\mathrm{eV}^2$) to obtain their 95% CL limit ($m<27\,\mathrm{eV}$).

[13] FRITSCHI 86 multiply their statistical error by 1.645 (for 95% CL), add this linearly to their unmultiplied systematic error ($204\,\mathrm{eV}^2$) and do NOT add in the m^2 value ($-11\,\mathrm{eV}^2$) to obtain their 95% CL limit ($m<18\,\mathrm{eV}$). To adjust for our quadratic addition of errors, and our multiplication of both the statistical and systematic errors by the factor 1.645, we set the systematic error to $178\,\mathrm{eV}^2$.

ν_e MASS SQUARED

The tritium experiments actually measure mass squared. A combined limit on mass must therefore be obtained from the weighted average of the results shown here. The recent results are in strong disagreement with the earlier claims by the ITEP group [LUBIMOV 80, BORIS 87 (+ BORIS 88, erratum)] that m_{ν_1} lies between 17 and 40 eV. The BORIS 87 result is excluded because of the controversy over the possibly large unreported systematic errors; see BERGKVIST 85B, BERGKVIST 86, SIMPSON 84, and REDONDO 89. However, the average for the new experiments given below implies only a 3.5% probability that m^2 is positive. See HOLZSCHUH 92 for a review of the recent direct m_{ν_1} measurements.

VALUE (eV^2)	*DOCUMENT ID*		*TECN*	*COMMENT*
− 54± 30 OUR AVERAGE				
− 39± 34± 15	[14] WEINHEIMER	93	SPEC	$^3\mathrm{H}\,\beta$ decay
− 24± 48± 61	[15] HOLZSCHUH	92B	SPEC	$^3\mathrm{H}\,\beta$ decay
− 65± 85± 65	[16] KAWAKAMI	91	SPEC	$\overline{\nu}_e$, tritium
−147± 68± 41	[17] ROBERTSON	91	SPEC	$\overline{\nu}_e$, tritium
• • • We do not use the following data for averages, fits, limits, etc. • • •				
− 72± 41± 30	[18] DECMAN	92	SPEC	$^3\mathrm{H}\,\beta$ decay
223±244±269	[19] KAWAKAMI	88	SPEC	Repl. by KAWAKAMI 91
− 57±453±118	[20] WILKERSON	87	SPEC	Repl. by ROBERTSON 91
− 11± 63±178	[21] FRITSCHI	86	SPEC	Repl. by HOLZSCHUH 92B

[14] WEINHEIMER 93 is a measurement of the endpoint of the tritium β spectrum using an electrostatic spectrometer with a magnetic guiding field. The source is molecular tritium frozen onto an aluminum substrate.

[15] HOLZSCHUH 92B source is a monolayer of tritiated hydrocarbon.

[16] KAWAKAMI 91 experiment uses tritium-labeled arachidic acid.

[17] ROBERTSON 91 experiment uses gaseous molecular tritium. The result is in strong disagreement with the earlier claims by the ITEP group [LUBIMOV 80, BORIS 87 (+ BORIS 88 erratum)] that m_{ν_1} lies between 17 and 40 eV. However, the probability of a positive m^2 is only 3% if statistical and systematic error are combined in quadrature.

[18] DECMAN 92 was not published in a refereed journal, so we do not use it in our compilation, but we include it for the reader's convenience. If it were included, our average would be $-58 \pm 26\,\mathrm{eV}^2$.

[19] KAWAKAMI 88 multiply their statistical error by the appropriate factor for 95% CL when $m^2 > 0$ is required (1.74), add this linearly to their unmultiplied systematic error ($173\,\mathrm{eV}^2$) and add the m^2 value ($223\,\mathrm{eV}^2$) to obtain their 95% CL limit ($m<29\,\mathrm{eV}$). To adjust for our quadratic addition of errors and our multiplication of both the statistical and systematic errors by the factor 1.645 we set the systematic error to $269\,\mathrm{eV}^2$ to yield the same limit.

[20] WILKERSON 87 multiply both statistical and systematic errors by 1.645 (for 95% CL), add them in quadrature and add the (negative) m^2 value ($-57\,\mathrm{eV}^2$) to obtain their 95% CL limit ($m<27\,\mathrm{eV}$).

[21] FRITSCHI 86 multiply their statistical error by 1.645 (for 95% CL), add this linearly to their unmultiplied systematic error ($204\,\mathrm{eV}^2$) and do NOT add in the m^2 value ($-11\,\mathrm{eV}^2$) to obtain their 95% CL limit ($m<18\,\mathrm{eV}$). To adjust for our quadratic addition of errors, and our multiplication of both the statistical and systematic errors by the factor 1.645, we set the systematic error to $178\,\mathrm{eV}^2$.

$m_{\nu_1} - m_{\overline{\nu}_1}$

These are measurement of m_{ν_1} (in contrast to $m_{\overline{\nu}_1}$, given above). The masses can be different for a Dirac neutrino in the absense of CPT invariance. The test is not very strong.

VALUE (eV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
< 225	95	SPRINGER	87	CNTR	ν, ^{163}Ho
< 550	68	YASUMI	86	CNTR	ν, ^{163}Ho
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<1250		[22] YASUMI	83	CNTR	ν, ^{163}Ho
<1300		ANDERSEN	82	CNTR	ν, ^{163}Ho
$< 4.5 \times 10^5$	90	CLARK	74	ASPK	K_{e3} decay
<4100	67	BECK	68	CNTR	ν, ^{22}Na

[22] Assumes upper limit on Q-value reported by ANDERSEN 82. Replaced by YASUMI 86.

ν_1 CHARGE

VALUE (units: electron charge)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<2 \times 10^{-15}$	[23] BARBIELLINI	87	ASTR	Supernova SN 1987A
$<1 \times 10^{-13}$	BERNSTEIN	63	ASTR	Solar energy losses

[23] Precise limit depends on assumptions about the intergalactic or galactic magnetic fields and about the direct distance and time through the field.

ν_1 MEAN LIFE

VALUE (s)	*CL%*	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>278	90	[24] LOSECCO	87B	IMB

[24] LOSECCO 87B assumes observed rate of 2.1 SNU (solar neutrino units) comes from sun while 7.0 ± 3.0 is theory.

ν_1 (MEAN LIFE) / MASS

VALUE (s/eV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>300	90	[25] REINES	74	CNTR	$\overline{\nu}$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$> 2.8 \times 10^{15}$		[26,27] BLUDMAN	92	ASTR	$m_\nu < 50$ eV
> 6.4	90	[28] KRAKAUER	91	CNTR	$\overline{\nu}$ at LAMPF
$> 6.3 \times 10^{15}$		[27,29] CHUPP	89	ASTR	$m_\nu < 20$ eV
		[30] COWSIK	89	ASTR	
$> 1.7 \times 10^{15}$		[27] KOLB	89	ASTR	$m_\nu < 20$ eV
		[31] RAFFELT	89	RVUE	$\overline{\nu}$ (Dirac, Majorana)
		[32] RAFFELT	89B	ASTR	
		[33] BOUCHEZ	88	CNTR	$\overline{\nu}$ (Dirac, Majorana)
		[34] FRIEMAN	88	ASTR	
$> 8.3 \times 10^{14}$		[34] VONFEILIT...	88	ASTR	
> 22	68	[35] OBERAUER	87		$\overline{\nu}_R$ (Dirac)
> 38	68	[35] OBERAUER	87		$\overline{\nu}$ (Majorana)
> 59	68	[35] OBERAUER	87		$\overline{\nu}_L$ (Dirac)
> 30	68	KETOV	86	CNTR	$\overline{\nu}$ (Dirac)
> 20	68	KETOV	86	CNTR	$\overline{\nu}$ (Majorana)
$> 7 \times 10^9$		[36] RAFFELT	85	ASTR	
		[37] HENRY	81	ASTR	m_ν= 16–20 eV
		[38] KIMBLE	81	ASTR	m_ν= 10–100 eV
$> 2 \times 10^{21}$		[39] STECKER	80	ASTR	m_ν= 10–100 eV

[25] REINES 74 looked for ν_e of nonzero mass decaying to a neutral of lesser mass + γ. Used liquid scintillator detector near fission reactor. Finds lab lifetime $6. \times 10^7$ s or more. Above value of (mean life)/mass assumes average effective neutrino energy of 0.2 MeV. To obtain the limit $6. \times 10^7$ s REINES 74 assumed that the full $\overline{\nu}_e$ reactor flux could be responsible for yielding decays with photon energies in the interval 0.1 MeV – 0.5 MeV. This represents some overestimate so their lower limit is an over-estimate of the lab lifetime (P. Vogel, private communication, 1984).

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

[27] Nonobservation of γ's in coincidence with ν's from SN 1987A.

[28] KRAKAUER 91 quotes the limit $\tau/m_{\nu_1} > (0.3a^2 + 9.8a + 15.9)$ s/eV, where a is a parameter describing the asymmetry in the neutrino decay defined as $dN_\gamma/d\cos\theta = (1/2)(1 + a\cos\theta)$ $a = 0$ for a Majorana neutrino, but can vary from -1 to 1 for a Dirac neutrino. The bound given by the authors is the most conservative (which applies for $a = -1$).

[29] 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.

[30] COWSIK 89 use observations of supernova SN 1987A to set the limit for the lifetime of a neutrino with $1 < m < 50$ MeV decaying through $\nu_H \rightarrow \nu_1 e e$ to be $\tau > 4 \times 10^{15}$ $\exp(-m/5\ \text{MeV})$ s.

[31] RAFFELT 89 uses KYULDJIEV 84 to obtain $\tau m^3 > 3 \times 10^{18}$ s eV^3 (based on $\overline{\nu}_e e^-$ cross sections). The bound is not valid if electric and magnetic transition moments are equal for Dirac neutrinos.

[32] RAFFELT 89B analyze stellar evolution and exclude the region $3 \times 10^{12} < \tau m^3 < 3 \times 10^{21}$ s eV^3.

[33] BOUCHEZ 88 reports limits in the nearly degenerate mass case.

[34] Model-dependent theoretical analysis of SN 1987A neutrinos.

[35] OBERAUER 87 bounds are from comparison of observed and expected rate of reactor neutrinos.

[36] RAFFELT 85 limit is from solar x- and γ-ray fluxes.

[37] HENRY 81 uses UV flux from clusters of galaxies to find $\tau > 1.1 \times 10^{25}$ s for radiative decay.

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

[39] STECKER 80 limit based on UV background; result given is $\tau > 4 \times 10^{22}$ s at $m_\nu = 20$ eV.

$|(v - c)/c|$ ($v \equiv \nu_1$ VELOCITY)

Expected to be zero for massless neutrino, but tests also whether photons and neutrinos have the same limiting velocity in vacuum.

VALUE (units 10^{-8})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
<1	17	[40] STODOLSKY	88	ASTR	SN 1987A

[40] STODOLSKY 88 result based on <10 hr between $\overline{\nu}_e$ detection in IMB and KAMI detectors and beginning of light signal. Inclusion of the problematic 5 neutrino events from FREJ (four hours later) does not change the result.

ν_1 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 $m_{\nu_1} < 7.3$ eV, it follows that for the extended standard electroweak theory, $\mu(\nu_1) < 2.3 \times 10^{-18}\ \mu_B$. Current experiments are not yet challenging this limit. There is considerable controversy over the validity of many of the claimed upper limits on the magnetic moment from the astrophysical data. For example, VOLOSHIN 90 states that "in connection with the astrophysical limits on μ_ν, ... there is by now a general consensus that contrary to the initial claims (BARBIERI 88, LATTIMER 88, GOLDMAN 88, NOTZOLD 88), essentially no better than quoted limits (from previous constraints) can be derived from detection of the neutrino flux from the supernova SN1987A." See VOLOSHIN 88 and VOLOSHIN 88C.

VALUE (μ_B)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<1.8 \times 10^{-10}$	90	[41] DERBIN	94	CNTR	Reactor $\overline{\nu}_e e \rightarrow \overline{\nu}_e e$
$<1.08 \times 10^{-9}$	90	[42] KRAKAUER	90	CNTR	LAMPF $\nu_e e \rightarrow \nu_e e$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<7.7 \times 10^{-10}$	95	MOURAO	92	ASTR	HOME/KAM2 ν rates
$<2.4 \times 10^{-10}$	90	[43] VIDYAKIN	92	CNTR	Reactor $\overline{\nu}_e e \rightarrow \overline{\nu}_e e$
		[44] FIORENTINI	91	ASTR	
$<2 \times 10^{-12}$	95	[45] RAFFELT	90	ASTR	Red giant luminosity
$<1 \times 10^{-11}$		[46] RAFFELT	89B	ASTR	Cooling helium stars
$<(2–8) \times 10^{-12}$		[46,47,48] BARBIERI	88	ASTR	Supernova SN 1987A
		[49] FUKUGITA	88	COSM	Primordial magn. fields
$<1 \times 10^{-12}$		[47,48,50] GOLDMAN	88	ASTR	Supernova SN 1987A
$<5 \times 10^{-13}$		[46,48] LATTIMER	88	ASTR	Supernova SN 1987A

$\leq 1.5 \times 10^{-12}$		[46,48] NOETZOLD	88	ASTR	Supernova SN 1987A
$\leq 3 \times 10^{-11}$		[46] RAFFELT	88B	ASTR	He burning stars
$<1.1 \times 10^{-11}$		[46] FUKUGITA	87	ASTR	Cooling helium stars
$<4 \times 10^{-11}$		LYNN	81	ASTR	
$< 1\text{–}2 \times 10^{-11}$		MORGAN	81	COSM	^{4}He abundance
$<8.5 \times 10^{-11}$		BEG	78	ASTR	Stellar plasmons
$<6 \times 10^{-11}$		[51] SUTHERLAND	76	ASTR	Red giants + degen. dwarfs
$<1 \times 10^{-10}$		BERNSTEIN	63	ASTR	Cooling white dwarfs
$<1.4 \times 10^{-9}$		COWAN	57	CNTR	Reactor $\overline{\nu}_e$

[41] DERBIN 94 supersedes DERBIN 93.

[42] KRAKAUER 90 experiment fully reported in ALLEN 93.

[43] VIDYAKIN 92 limit is from a $e\overline{\nu}_e$ elastic scattering experiment. No experimental details are given except for the cross section from which this limit is derived. Signal/noise was 1/10. The limit uses $\sin^2\theta_W = 0.23$ as input.

[44] FIORENTINI 91 is a study of the statistical significance of possible correlation of solar neutrino flux with sunspot cycle. Data do not imply any evidence for a nonzero neutrino magnetic moment, although they are consistent with a moment of order $1 \times 10^{-10}/\mu_B$.

[45] RAFFELT 90 limit 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.

[46] Significant dependence on details of stellar models.

[47] A limit of 10^{-13} is obtained with even more model-dependence.

[48] These papers have assumed that the right-handed neutrino is inert; see BARBIERI 88B.

[49] FUKUGITA 88 find magnetic dipole moments of any two neutrino species are bounded by $\mu < 10^{-16}$ $[10^{-9}\ G/B_0]$ where B_0 is the present-day intergalactic field strength.

[50] Some dependence on details of stellar models.

[51] We obtain above limit from SUTHERLAND 76 using their limit $f < 1/3$.

NONSTANDARD CONTRIBUTIONS TO NEUTRINO SCATTERING

We report limits on the so-called neutrino charge radius squared in this section. This quantity is not an observable, physical quantity and this is reflected in the fact that it is gauge dependent (see LEE 77C). It is not necessarily positive. 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*		*TECN*	*COMMENT*
0.9±2.7		ALLEN	93	CNTR	LAMPF $\nu_e e \rightarrow \nu_e e$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<2.3 \times 10^{-32}$	95	MOURAO	92	ASTR	HOME/KAM2 ν rates
<7.3	90	[52] VIDYAKIN	92	CNTR	Reactor $\overline{\nu}_e e \rightarrow \overline{\nu}_e e$
1.1±2.3		ALLEN	91	CNTR	Repl. by ALLEN 93
		[53] GRIFOLS	89B	ASTR	SN 1987A

[52] VIDYAKIN 92 limit is from a $e\overline{\nu}_e$ elastic scattering experiment. No experimental details are given except for the cross section from which this limit is derived. Signal/noise was 1/10. The limit uses $\sin^2\theta_W = 0.23$ as input.

[53] GRIFOLS 89B sets a limit of $\langle r^2 \rangle < 0.2 \times 10^{-32}$ cm^2 for right-handed neutrinos.

ν_e REFERENCES

DERBIN	94	PAN 57 222		(PNPI)
		Translated from YAF 57 236.		
PDG	94	PR D50 1173	Montanet+	(CERN, LBL, BOST, IFIC+)
YASUMI	94	PL B334 229	+Maezawa, Shima, Inagaki+	(KEK, TSUK, KYOT+)
ALLEN	93	PR D47 11	+Chen, Doe, Hausammann+	(UCI, LANL, ANL, UMD)
DERBIN	93	JETPL 57 768	+Chernyi, Popeko, Muratova+	(PNPI)
		Translated from ZETFP 57 755.		
VANDYCK	93	PRL 70 2888	Van Dyck, Farnham, Schwinberg	(WASH)
WEINHEIMER	93	PL B300 210	+Przyrembel, Backe+	(MANZ)
BLUDMAN	92	PR D45 4720		(CFPA)
DECMAN	92	BAPS 37 1286	+Stoeffl	(LLNL)
HOLZSCHUH	92	RPP 55 1035		(ZURI)
HOLZSCHUH	92B	PL B287 381	+Fritschi, Kuendig	(ZURI)
MOURAO	92	PL B285 364	+Pulido, Ralston	(LISB, LISBT, CERN, KANS)
VIDYAKIN	92	JETPL 55 206	+Vyrodov, Gurevich, Koslov+	(KIAE)
		Translated from ZETFP 55 212.		

ALLEN	91	PR D43 R1	+Chen, Doe, Hausammann	(UCI, LANL, UMD)
FIORENTINI	91	PL B253 181	+Mezzorani	(CAGL, INFN)
KAWAKAMI	91	PL B256 105	+Kato, Ohshima+	(INUS, TOHOK, TINT, KOBE, KEK)
KRAKAUER	91	PR D44 R6	+Talaga, Allen, Chen+	(LAMPF E225 Collab.)
ROBERTSON	91	PRL 67 957	+Bowles, Stephenson, Wark, Wilkerson, Knapp	(LASL, LLL)
AVIGNONE	90	PR D41 682	+Collar	(SCUC)
KRAKAUER	90	PL B252 177	+Talaga, Allen, Chen+	(LAMPF E225 Collab.)
RAFFELT	90	PRL 64 2856		(MPIM)
VOLOSHIN	90	NP B (Proc. Suppl) 19 433		(ITEP)
Neutrino 90 Conference				
CHUPP	89	PRL 62 505	+Vestrand, Reppin	(UNH, MPIM)
COWSIK	89	PL B218 91	+Schramm, Hoflich	(WUSL, TATA, CHIC, MPIM)
GRIFOLS	89B	PR D40 3819	+Masso	(BARC)
KOLB	89	PRL 62 509	+Turner	(CHIC, FNAL)
LOREDO	89	ANYAS 571 601	+Lamb	(CHIC)
RAFFELT	89	PR D39 2066		(PRIN, UCB)
RAFFELT	89B	APJ 336 61	+Dearborn, Silk	(UCB, LLL)
REDONDO	89	PR C40 368	+Robertson	(LANL)
ABBOTT	88	NP B299 734	+De Rujula, Walker	(BRAN, CERN, BOST)
BARBIERI	88	PRL 61 27	+Mohapatra	(PISA, UMD)
BARBIERI	88B	PL B213 69	+Mohapatra, Yanagida	(PISA, UMD, MICH)
BORIS	88	PRL 61 245 erratum	+Golutvin, Laptin+	(ITEP, ASCI)
BOUCHEZ	88	PL B207 217	+Pichard, Soirat, Spiro, Declais	(SACL, MARS)
FRIEMAN	88	PL B200 115	+Haber, Freese	(SLAC, UCSC, UCSBT)
FUKUGITA	88	PRL 60 879	+Notzold, Raffelt, Silk	(KYOTY, MPIM, UCB)
GOLDMAN	88	PRL 60 1789	+Aharanov, Alexander, Nussinov	(TELA)
KAWAKAMI	88	JPSJ 57 2873	+Kato, Naito, Nisimura+	(INUS, TOKY, TINT, KEK)
LATTIMER	88	PRL 61 23	+Cooperstein	(STON, BNL)
Also	88B	PRL 61 2633 erratum	Lattimer, Cooperstein	(STON, BNL)
NOETZOLD	88	PR D38 1658		(MPIM)
NOTZOLD	88	PR D38 1658		(MPIM)
RAFFELT	88B	PR D37 549	+Dearborn	(UCB, LLL)
SPERGEL	88	PL B200 366	+Bahcall	(IAS)
STODOLSKY	88	PL B201 353		(MPIM)
VOLOSHIN	88	PL B209 360		(ITEP)
Also	88B	JETPL 47 501	Voloshin	(ITEP)
		Translated from ZETFP 47 421.		
VOLOSHIN	88C	JETPL 68 690		(ITEP)
VONFEILIT...	88	PL B200 580	Von Feilitzsch, Oberauer	(MUNT)
BARBIELLINI	87	Nature 329 21	+Cocconi	(CERN)
BORIS	87	PRL 58 2019	+Golutvin, Laptin+	(ITEP, ASCI)
Also	88	PRL 61 245 erratum	Boris, Golutvin, Laptin+	(ITEP, ASCI)
BORIS	87B	JETPL 45 333	+Golutvin, Laptin+	(ITEP)
		Translated from ZETFP 45 267.		
FUKUGITA	87	PR D36 3817	+Yazaki	(KYOTY, TOKY)
LOSECCO	87B	PR D35 2073	+Bionta, Blewitt, Bratton+	(IMB Collab.)
OBERAUER	87	PL B198 113	+von Feilitzsch, Mossbauer	(MUNT)
SPRINGER	87	PR A35 679	+Bennet, Baisden+	(LLNL)
WILKERSON	87	PRL 58 2023	+Bowles, Browne+	(LANL, PRIN, UCSD)
BERGKVIST	86	Moriond Conf., Vol. M48, 465		(STOH)
FRITSCHI	86	PL B173 485	+Holzschuh, Kundig+	(ZURI, SIN)
KETOV	86	JETPL 44 146	+Klimov, Nikolaev, Mikaelyan+	(KIAE)
		Translated from ZETFP 44 114.		
YASUMI	86	PL B181 169	+Ando+	(KEK, OSAK, TOHOK, TSUK, KYOT, INUS+)
BERGKVIST	85B	PL 159B 408		(STOH)
RAFFELT	85	PR D31 3002		(MPIM)
KYULDJIEV	84	NP B243 387		(SOFI)
SIMPSON	84	PR D30 1110		(GUEL)
YASUMI	83	PL 122B 461	+Rajasekaran+	(KEK, OSAK, TINT, TOHOK, TSUK)
ANDERSEN	82	PL 113B 72	+Beyer, Charpak, Derujula+	(AARH, CERN, RISO)
HENRY	81	PRL 47 618	+Feldman	(JHU)
KIMBLE	81	PRL 46 80	+Bowyer, Jakobsen	(UCB)
LYNN	81	PR D23 2151		(COLU)
MORGAN	81	PL 102B 247	Morgan	(SUSS)
FUJIKAWA	80	PRL 45 963	+Shrock	(STON)
LUBIMOV	80	PL 94B 266	+Novikov, Nozik, Tretyakov, Kosik	(ITEP)
Also	80	SJNP 32 154	Kozik, Lubimov, Novikov+	(ITEP)
		Translated from YAF 32 301.		
Also	81	JETP 54 616	Lubimov, Novikov, Nozik+	(ITEP)
		Translated from ZETF 81 1158.		
STECKER	80	PRL 45 1460		(NASA)
BEG	78	PR D17 1395	+Marciano, Ruderman	(ROCK, COLU)
LEE	77C	PR D16 1444	+Shrock	(STON)
SUTHERLAND	76	PR D13 2700	+Ng, Flowers+	(PENN, COLU, NYU)
CLARK	74	PR D9 533	+Elioff, Frisch, Johnson, Kerth, Shen+	(LBL)
REINES	74	PRL 32 180	+Sobel, Gurr	(UCI)
Also	78	Private Comm.	Barnes	(PURD)
BECK	68	ZPHY 216 229	+Daniel	(MPIH)
BERNSTEIN	63	PR 132 1227	+Ruderman, Feinberg	(NYU, COLU)
COWAN	57	PR 107 528	+Reines	(LANL)