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Neutrino Mixing

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(A) Accelerator neutrino experiments

$\nu_e \to \nu_\tau$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
< 0.77	90	[1] ARMBRUSTER	98	KARM	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 5.9	90	[2] ASTIER	01B	NOMD	CERN SPS
< 7.5	90	[3] ESKUT	01	CHRS	CERN SPS
<17	90	NAPLES	99	CCFR	FNAL
<44	90	TALEBZADEH	87	HLBC	BEBC
< 9	90	USHIDA	86C	EMUL	FNAL

[1] ARMBRUSTER 98 use KARMEN detector with ν_e from muon decay at rest and observe $^{12}C(\nu_e,e^-)^{12}N_{gs}$. This is a disappearance experiment which is almost insensitive to $\nu_e \to \nu_\mu$ oscillation. Results are presented as limits to $\nu_e \to \nu_\tau$ oscillation, although the (non)oscillation could be to a non-visible flavor. A three-flavor analysis is also presented.

[2] ASTIER 01B searches for the appearance of ν_τ with the NOMAD detector at CERN's SPS. The limit is based on an oscillation probability $< 0.74 \times 10^{-2}$, whereas the quoted sensitivity was 1.1×10^{-2}. The limit was obtained following the statistical prescriptions of FELDMAN 98. See also the footnote to ESKUT 01.

[3] ESKUT 01 searches for the appearance of the ν_τ with the CHORUS detector at CERN's SPS. The limit is obtained following the statistical prescriptions in JUNK 99. The limit would have been 6 eV^2 if the prescriptions in FELDMAN 98 had been followed, as they were in ASTIER 01B.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.015	90	[4] ASTIER	01B	NOMD	CERN SPS
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.052	90	[5] ESKUT	01	CHRS	CERN SPS
<0.21	90	NAPLES	99	CCFR	FNAL
<0.338	90	[6] ARMBRUSTER	98	KARM	
<0.36	90	TALEBZADEH	87	HLBC	BEBC
<0.25	90	[7] USHIDA	86C	EMUL	FNAL

[4] ASTIER 01B limit is based on an oscillation probability $< 0.74 \times 10^{-2}$, whereas the quoted sensitivity was 1.1×10^{-2}. The limit was obtained following the statistical prescriptions of FELDMAN 98. See also the footnote to ESKUT 01.

[5] ESKUT 01 limit obtained following the statistical prescriptions in JUNK 99. The limit would have been 0.03 if the prescriptions in FELDMAN 98 had been followed, as they were in ASTIER 01B.

[6] See footnote in preceding table (ARMBRUSTER 98) for further details, and see the paper for a plot showing allowed regions. A three-flavor analysis is also presented here.

[7] USHIDA 86C published result is $\sin^2 2\theta < 0.12$. The quoted result is corrected for a numerical mistake incurred in calculating the expected number of ν_e CC events, normalized to the total number of neutrino interactions (3886) rather than to the total number of ν_μ CC events (1870).

$\overline{\nu}_e \to \overline{\nu}_\tau$

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.7	90	[8] FRITZE	80	HYBR	BEBC CERN SPS

[8] Authors give P($\nu_e \to \nu_\tau$) <0.35, equivalent to above limit.

$\nu_e \not\to \nu_e$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
< 0.18	90	[9] HAMPEL	98	GALX	^{51}Cr source
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<33	90	BATUSOV	04	CNTR	IHEP-JINR detector
<14.9	90	BRUCKER	86	HLBC	15-ft FNAL
< 8	90	BAKER	81	HLBC	15-ft FNAL
<56	90	DEDEN	81	HLBC	BEBC CERN SPS
<10	90	ERRIQUEZ	81	HLBC	BEBC CERN SPS
<2.3 OR >8	90	NEMETHY	81B	CNTR	LAMPF

[9] HAMPEL 98 analyzed the GALLEX calibration results with ^{51}Cr neutrino sources and updates the BAHCALL 95 analysis result. They also gave 95% and 99% CL limits of < 0.2 and < 0.22, respectively.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<7 $\times 10^{-2}$	90	[10] ERRIQUEZ	81	HLBC	BEBC CERN SPS
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.19	90	[11] BATUSOV	04	CNTR	IHEP-JINR detector
<0.4	90	[12] HAMPEL	98	GALX	^{51}Cr source
<0.54	90	BRUCKER	86	HLBC	15-ft FNAL
<0.6	90	BAKER	81	HLBC	15-ft FNAL
<0.3	90	[10] DEDEN	81	HLBC	BEBC CERN SPS

[10] Obtained from a Gaussian centered in the unphysical region.

[11] The limit becomes 0.09 in their most sensitive region ($\Delta m^2 \sim 150$ eV^2).

[12] HAMPEL 98 analyzed the GALLEX calibration results with ^{51}Cr neutrino sources and updates the BAHCALL 95 analysis result. They also gave 95% and 99% CL limits of < 0.45 and < 0.56, respectively.

$\nu_e \to (\overline{\nu}_e)_L$

This is a limit on lepton family-number violation and total lepton-number violation. $(\overline{\nu}_e)_L$ denotes a hypothetical left-handed $\overline{\nu}_e$. The bound is quoted in terms of $\Delta\ (m^2)$, $\sin(2\theta)$, and α, where α denotes the fractional admixture of $(V{+}A)$ charged current.

$\alpha\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.14	90	[13] FREEDMAN	93	CNTR	LAMPF
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<7	90	[14] COOPER	82	HLBC	BEBC CERN SPS

[13] FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ, $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e p \to e^+ n$.

[14] COOPER 82 states that existing bounds on V+A currents require α to be small.

$\alpha^2 \sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.032	90	[15] FREEDMAN	93	CNTR	LAMPF
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.05	90	[16] COOPER	82	HLBC	BEBC CERN SPS

[15] FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ, $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e p \to e^+ n$.

[16] COOPER 82 states that existing bounds on V+A currents require α to be small.

$\nu_\mu \to \nu_e$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.0008	90	AHN	04	K2K	Water Cherenkov
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.4	90	ASTIER	03	NOMD	CERN SPS
<2.4	90	AVVAKUNOV	02	NTEV	NUTEV FNAL
		[17] AGUILAR	01	LSND	$\nu \mu \to \nu_e$ osc.prob.
0.03 to 0.3	95	[18] ATHANASSO...	98	LSND	$\nu_\mu \to \nu_e$
<2.3	90	[19] LOVERRE	96		CHARM/CDHS
<0.9	90	VILAIN	94C	CHM2	CERN SPS
<0.1	90	BLUMENFELD	89	CNTR	
<1.3	90	AMMOSOV	88	HLBC	SKAT at Serpukhov
<0.19	90	BERGSMA	88	CHRM	
		[20] LOVERRE	88	RVUE	
<2.4	90	AHRENS	87	CNTR	BNL AGS
<1.8	90	BOFILL	87	CNTR	FNAL
<0.09	90	ANGELINI	86	HLBC	BEBC CERN PS
<2.2	90	[21] BRUCKER	86	HLBC	15-ft FNAL
<0.43	90	AHRENS	85	CNTR	BNL AGS E734
<0.20	90	BERGSMA	84	CHRM	
<1.7	90	ARMENISE	81	HLBC	GGM CERN PS
<0.6	90	BAKER	81	HLBC	15-ft FNAL
<1.7	90	ERRIQUEZ	81	HLBC	BEBC CERN PS
<1.2	95	BLIETSCHAU	78	HLBC	GGM CERN PS
<1.2	95	BELLOTTI	76	HLBC	GGM CERN PS

[17] AGUILAR 01 is the final analysis of the LSND full data set. Search is made for the $\nu_\mu \to \nu_e$ oscillations using ν_μ from π^+ decay in flight by observing beam-on electron events from $\nu_e \mathrm{C} \to e^- X$. Present analysis results in 8.1 ± 12.2 ± 1.7 excess events in the $60 < E_e < 200$ MeV energy range, corresponding to oscillation probability of 0.10 ± 0.16 ± 0.04%. This is consistent, though less significant, with the previous result of ATHANASSOPOULOS 98, which it supersedes. The present analysis uses selection criteria developed for the decay at rest region, and is less effective in removing the background above 60 MeV than ATHANASSOPOULOS 98.

[18] ATHANASSOPOULOS 98 is a search for the $\nu_\mu \rightarrow \nu_e$ oscillations using ν_μ from π^+ decay in flight. The 40 observed beam-on electron events are consistent with $\nu_e C \rightarrow e^- X$; the expected background is 21.9 ± 2.1. Authors interpret this excess as evidence for an oscillation signal corresponding to oscillations with probability $(0.26 \pm 0.10 \pm 0.05)\%$. Although the significance is only $2.3\,\sigma$, this measurement is an important and consistent cross check of ATHANASSOPOULOS 96 who reported evidence for $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ oscillations from μ^+ decay at rest. See also ATHANASSOPOULOS 98B.

[19] LOVERRE 96 uses the charged-current to neutral-current ratio from the combined CHARM (ALLABY 86) and CDHS (ABRAMOWICZ 86) data from 1986.

[20] LOVERRE 88 reports a less stringent, indirect limit based on theoretical analysis of neutral to charged current ratios.

[21] 15ft bubble chamber at FNAL.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE (units 10^{-3})	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
< 1.4	90	ASTIER 03	NOMD	CERN SPS
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<110	90	[22] AHN 04	K2K	Water Cherenkov
< 1.6	90	AVVAKUNOV 02	NTEV	NUTEV FNAL
		[23] AGUILAR 01	LSND	$\nu\mu \rightarrow \nu_e$ osc.prob.
0.5 to 30	95	[24] ATHANASSO...98	LSND	$\nu_\mu \rightarrow \nu_e$
< 3.0	90	[25] LOVERRE 96		CHARM/CDHS
< 9.4	90	VILAIN 94C	CHM2	CERN SPS
< 5.6	90	[26] VILAIN 94C	CHM2	CERN SPS
< 16	90	BLUMENFELD 89	CNTR	
< 2.5	90	AMMOSOV 88	HLBC	SKAT at Serpukhov
< 8	90	BERGSMA 88	CHRM	$\Delta(m^2) \geq 30$ eV^2
		[27] LOVERRE 88	RVUE	
< 10	90	AHRENS 87	CNTR	BNL AGS
< 15	90	BOFILL 87	CNTR	FNAL
< 20	90	[28] ANGELINI 86	HLBC	BEBC CERN PS
20 to 40		[29] BERNARDI 86B	CNTR	$\Delta(m^2)$=5–10
< 11	90	[30] BRUCKER 86	HLBC	15-ft FNAL
< 3.4	90	AHRENS 85	CNTR	BNL AGS E734
<240	90	BERGSMA 84	CHRM	
< 10	90	ARMENISE 81	HLBC	GGM CERN PS
< 6	90	BAKER 81	HLBC	15-ft FNAL
< 10	90	ERRIQUEZ 81	HLBC	BEBC CERN PS
< 4	95	BLIETSCHAU 78	HLBC	GGM CERN PS
< 10	95	BELLOTTI 76	HLBC	GGM CERN PS

[22] The limit becomes $\sin^2 2\theta < 0.15$ at $\Delta m^2 = 2.8 \times 10^{-3}$ eV^2, the bets-fit value of the ν_μ disappearance analysis in K2K.

[23] AGUILAR 01 is the final analysis of the LSND full data set of the search for the $\nu_\mu \rightarrow \nu_e$ oscillations. See footnote in preceding table for further details.

[24] ATHANASSOPOULOS 98 report $(0.26 \pm 0.10 \pm 0.05)\%$ for the oscillation probability; the value of $\sin^2 2\theta$ for large Δm^2 is deduced from this probability. See footnote in preceding table for further details, and see the paper for a plot showing allowed regions. If effect is due to oscillation, it is most likely to be intermediate $\sin^2 2\theta$ and Δm^2. See also ATHANASSOPOULOS 98B.

[25] LOVERRE 96 uses the charged-current to neutral-current ratio from the combined CHARM (ALLABY 86) and CDHS (ABRAMOWICZ 86) data from 1986.

[26] VILAIN 94C limit derived by combining the ν_μ and $\overline{\nu}_\mu$ data assuming *CP* conservation.

[27] LOVERRE 88 reports a less stringent, indirect limit based on theoretical analysis of neutral to charged current ratios.

[28] ANGELINI 86 limit reaches 13×10^{-3} at $\Delta(m^2) \approx 2$ eV^2.

[29] BERNARDI 86B is a typical fit to the data, assuming mixing between two species. As the authors state, this result is in conflict with earlier upper bounds on this type of neutrino oscillations.

[30] 15ft bubble chamber at FNAL.

$\overline{\nu}_\mu \to \overline{\nu}_e$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.055	90	[31] ARMBRUSTER	02	KAR2	Liquid Sci. calor.
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<2.6	90	AVVAKUNOV	02	NTEV	NUTEV FNAL
0.03–0.05		[32] AGUILAR	01	LSND	LAMPF
0.05–0.08	90	[33] ATHANASSO...	96	LSND	LAMPF
0.048–0.090	80	[34] ATHANASSO...	95		
<0.07	90	[35] HILL	95		
<0.9	90	VILAIN	94C	CHM2	CERN SPS
<0.14	90	[36] FREEDMAN	93	CNTR	LAMPF
<3.1	90	BOFILL	87	CNTR	FNAL
<2.4	90	TAYLOR	83	HLBC	15-ft FNAL
<0.91	90	[37] NEMETHY	81B	CNTR	LAMPF
<1	95	BLIETSCHAU	78	HLBC	GGM CERN PS

[31] ARMBRUSTER 02 is the final analysis of the KARMEN 2 data for 17.7 m distance from the ISIS stopped pion and muon neutrino source. It is a search for $\overline{\nu}_e$, detected by the inverse β-decay reaction on protons and ^{12}C. 15 candidate events are observed, and 15.8 ± 0.5 background events are expected, hence no oscillation signal is detected. The results exclude large regions of the parameter area favored by the LSND experiment.

[32] AGUILAR 01 is the final analysis of the LSND full data set. It is a search for $\overline{\nu}_e$ 30 m from LAMPF beam stop. Neutrinos originate mainly for π^+ decay at rest. $\overline{\nu}_e$ are detected through $\overline{\nu}_e p \to e^+ n$ ($20 < E_{e^+} < 60$ MeV) in delayed coincidence with $np \to d\gamma$. AUthors observe 87.9 ± 22.4 ± 6.0 total excess events. The observation is attributed to $\overline{\nu}_\mu \to \overline{\nu}_e$ oscillations with the oscillation probability of 0.264 ± 0.067 ± 0.045%, consistent with the previously published result. Taking into account all constraints, the most favored allowed region of oscillation parameters is a band of $\Delta(m^2)$ from 0.2–2.0 eV^2. Supersedes ATHANASSOPOULOS 95, ATHANASSOPOULOS 96, and ATHANASSOPOULOS 98.

[33] ATHANASSOPOULOS 96 is a search for $\overline{\nu}_e$ 30 m from LAMPF beam stop. Neutrinos originate mainly from π^+ decay at rest. $\overline{\nu}_e$ could come from either $\overline{\nu}_\mu \to \overline{\nu}_e$ or $\nu_e \to \overline{\nu}_e$; our entry assumes the first interpretation. They are detected through $\overline{\nu}_e p \to e^+ n$ (20 MeV $< E_{e^+} <$ 60 MeV) in delayed coincidence with $np \to d\gamma$. Authors observe 51 ± 20 ± 8 total excess events over an estimated background 12.5 ± 2.9. ATHANASSOPOULOS 96B is a shorter version of this paper.

[34] ATHANASSOPOULOS 95 error corresponds to the 1.6σ band in the plot. The expected background is 2.7 ± 0.4 events. Corresponds to an oscillation probability of $(0.34^{+0.20}_{-0.18} \pm 0.07)\%$. For a different interpretation, see HILL 95. Replaced by ATHANASSOPOULOS 96.

[35] HILL 95 is a report by one member of the LSND Collaboration, reporting a different conclusion from the analysis of the data of this experiment (see ATHANASSOPOULOS 95). Contrary to the rest of the LSND Collaboration, Hill finds no evidence for the neutrino oscillation $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ and obtains only upper limits.

[36] FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ, $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e p \rightarrow e^+ n$. FREEDMAN 93 replaces DURKIN 88.

[37] In reaction $\overline{\nu}_e p \rightarrow e^+ n$.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.0011	90	AVVAKUNOV	02	NTEV	NUTEV FNAL
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.0017	90	[38] ARMBRUSTER	02	KAR2	Liquid Sci. calor.
$0.0053 \pm 0.0013 \pm 0.009$		[39] AGUILAR	01	LSND	LAMPF
$0.0062 \pm 0.0024 \pm 0.0010$		[40] ATHANASSO...	96	LSND	LAMPF
0.003–0.012	80	[41] ATHANASSO...	95		
<0.006	90	[42] HILL	95		
<4.8	90	VILAIN	94C	CHM2	CERN SPS
<5.6	90	[43] VILAIN	94C	CHM2	CERN SPS
<0.024	90	[44] FREEDMAN	93	CNTR	LAMPF
<0.04	90	BOFILL	87	CNTR	FNAL
<0.013	90	TAYLOR	83	HLBC	15-ft FNAL
<0.2	90	[45] NEMETHY	81B	CNTR	LAMPF
<0.004	95	BLIETSCHAU	78	HLBC	GGM CERN PS

[38] ARMBRUSTER 02 is the final analysis of the KARMEN 2 data. See footnote in the preceding table for further details, and the paper for the exclusion plot.

[39] AGUILAR 01 is the final analysis of the LSND full data set. The deduced oscillation probability is $0.264 \pm 0.067 \pm 0.045\%$; the value of $\sin^2 2\theta$ for large $\Delta(m^2)$ is twice this probability (although these values are excluded by other constraints). See footnote in preceding table for further details, and the paper for a plot showing allowed regions. Supersedes ATHANASSOPOULOS 95, ATHANASSOPOULOS 96, and ATHANASSOPOULOS 98.

[40] ATHANASSOPOULOS 96 reports $(0.31 \pm 0.12 \pm 0.05)\%$ for the oscillation probability; the value of $\sin^2 2\theta$ for large $\Delta(m^2)$ should be twice this probability. See footnote in preceding table for further details, and see the paper for a plot showing allowed regions.

[41] ATHANASSOPOULOS 95 error corresponds to the 1.6σ band in the plot. The expected background is 2.7 ± 0.4 events. Corresponds to an oscillation probability of $(0.34^{+0.20}_{-0.18} \pm 0.07)\%$. For a different interpretation, see HILL 95. Replaced by ATHANASSOPOULOS 96.

[42] HILL 95 is a report by one member of the LSND Collaboration, reporting a different conclusion from the analysis of the data of this experiment (see ATHANASSOPOULOS 95). Contrary to the rest of the LSND Collaboration, Hill finds no evidence for the neutrino oscillation $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ and obtains only upper limits.

[43] VILAIN 94C limit derived by combining the ν_μ and $\overline{\nu}_\mu$ data assuming *CP* conservation.

[44] FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ, $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e p \rightarrow e^+ n$. FREEDMAN 93 replaces DURKIN 88.

[45] In reaction $\overline{\nu}_e p \rightarrow e^+ n$.

$\nu_\mu(\overline{\nu}_\mu) \rightarrow \nu_e(\overline{\nu}_e)$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.075	90	BORODOV...	92	CNTR	BNL E776
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<1.6	90	[46] ROMOSAN	97	CCFR	FNAL

[46] ROMOSAN 97 uses wideband beam with a 0.5 km decay region.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE (units 10^{-3})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<1.8	90	[47] ROMOSAN	97	CCFR	FNAL
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<3.8	90	[48] MCFARLAND	95	CCFR	FNAL
<3	90	BORODOV...	92	CNTR	BNL E776

[47] ROMOSAN 97 uses wideband beam with a 0.5 km decay region.

[48] MCFARLAND 95 state that "This result is the most stringent to date for $250 < \Delta(m^2) < 450$ eV^2 and also excludes at 90%CL much of the high $\Delta(m^2)$ region favored by the recent LSND observation." See ATHANASSOPOULOS 95 and ATHANASSOPOULOS 96.

$\nu_\mu \rightarrow \nu_\tau$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
< 0.6	90	[49] ESKUT	01	CHRS	CERN SPS
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<$ 0.7	90	[50] ASTIER	01B	NOMD	CERN SPS
$<$ 1.4	90	[51] ALTEGOER	98B	NOMD	CERN SPS
$<$ 1.5	90	[52] ESKUT	98	CHRS	CERN SPS
$<$ 1.1	90	[53] ESKUT	98B	CHRS	CERN SPS
$<$ 3.3	90	[54] LOVERRE	96		CHARM/CDHS
$<$ 1.4	90	MCFARLAND	95	CCFR	FNAL
$<$ 4.5	90	BATUSOV	90B	EMUL	FNAL
$<$10.2	90	BOFILL	87	CNTR	FNAL
$<$ 6.3	90	BRUCKER	86	HLBC	15-ft FNAL
$<$ 0.9	90	USHIDA	86C	EMUL	FNAL
$<$ 4.6	90	ARMENISE	81	HLBC	GGM CERN SPS
$<$ 3	90	BAKER	81	HLBC	15-ft FNAL
$<$ 6	90	ERRIQUEZ	81	HLBC	BEBC CERN SPS
$<$ 3	90	USHIDA	81	EMUL	FNAL

[49] ESKUT 01 limit obtained following the statistical prescriptions in JUNK 99. The limit would have been 0.5 eV^2 if the prescriptions in FELDMAN 98 had been followed, as they were in ASTIER 01B.

[50] ASTIER 01B limit is based on an oscillation probability $< 1.63 \times 10^{-4}$, whereas the quoted sensitivity was 2.5×10^{-4}. The limit was obtained following the statistical prescriptions of FELDMAN 98. See also the footnote to ESKUT 01.

[51] ALTEGOER 98B is the NOMAD 1995 data sample result, searching for events with $\tau^- \rightarrow e^- \nu_\tau \overline{\nu}_e$, hadron$^-$ ν_τ, or $\pi^- \pi^+ \pi^-$ decay modes using classical CL approach of FELDMAN 98.

[52] ESKUT 98 search for events with one μ^- with indication of a kink from τ^- decay in the nuclear emulsion. No candidates were found in a 31,423 event subsample.

[53] ESKUT 98B search for $\tau^- \rightarrow \mu^- \nu_\tau \overline{\nu}_\mu$ or $h^- \nu_\tau \overline{\nu}_\mu$, where h^- is a negatively charged hadron. The μ^- sample is somewhat larger than in ESKUT 98, which this result supersedes. Bayesian limit.

[54] LOVERRE 96 uses the charged-current to neutral-current ratio from the combined CHARM (ALLABY 86) and CDHS (ABRAMOWICZ 86) data from 1986.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.00033	90	[55] ASTIER	01B	NOMD	CERN SPS
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.00068	90	[56] ESKUT	01	CHRS	CERN SPS
<0.0042	90	[57] ALTEGOER	98B	NOMD	CERN SPS
<0.0035	90	[58] ESKUT	98	CHRS	CERN SPS
<0.0018	90	[59] ESKUT	98B	CHRS	CERN SPS
<0.006	90	[60] LOVERRE	96		CHARM/CDHS
<0.0081	90	MCFARLAND	95	CCFR	FNAL
<0.06	90	BATUSOV	90B	EMUL	FNAL
<0.34	90	BOFILL	87	CNTR	FNAL
<0.088	90	BRUCKER	86	HLBC	15-ft FNAL
<0.004	90	USHIDA	86C	EMUL	FNAL
<0.11	90	BALLAGH	84	HLBC	15-ft FNAL
<0.017	90	ARMENISE	81	HLBC	GGM CERN SPS
<0.06	90	BAKER	81	HLBC	15-ft FNAL
<0.05	90	ERRIQUEZ	81	HLBC	BEBC CERN SPS
<0.013	90	USHIDA	81	EMUL	FNAL

[55] ASTIER 01B limit is based on an oscillation probability $< 1.63 \times 10^{-4}$, whereas the quoted sensitivity was 2.5×10^{-4}. The limit was obtained following the statistical prescriptions of FELDMAN 98. See also the footnote to ESKUT 01.

[56] ESKUT 01 limit obtained following the statistical prescriptions in JUNK 99. The limit would have been 0.00040 if the prescriptions in FELDMAN 98 had been followed, as they were in ASTIER 01B.

[57] ALTEGOER 98B is the NOMAD 1995 data sample result, searching for events with $\tau^- \rightarrow e^- \nu_\tau \overline{\nu}_e$, hadron$^-$ ν_τ, or $\pi^- \pi^+ \pi^-$ decay modes using classical CL approach of FELDMAN 98.

[58] ESKUT 98 search for events with one μ^- with indication of a kink from τ^- decay in the nuclear emulsion. No candidates were found in a 31,423 event subsample.

[59] ESKUT 98B search for $\tau^- \rightarrow \mu^- \nu_\tau \overline{\nu}_\mu$ or $h^- \nu_\tau \overline{\nu}_\mu$, where h^- is a negatively charged hadron. The μ^- sample is somewhat larger than in ESKUT 98, which this result supersedes. Bayesian limit.

[60] LOVERRE 96 uses the charged-current to neutral-current ratio from the combined CHARM (ALLABY 86) and CDHS (ABRAMOWICZ 86) data from 1986.

$\overline{\nu}_\mu \rightarrow \overline{\nu}_\tau$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<2.2	90	ASRATYAN	81	HLBC	FNAL
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<1.4	90	MCFARLAND	95	CCFR	FNAL
<6.5	90	BOFILL	87	CNTR	FNAL
<7.4	90	TAYLOR	83	HLBC	15-ft FNAL

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<4.4 \times 10^{-2}$	90	ASRATYAN	81	HLBC	FNAL
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.0081	90	MCFARLAND	95	CCFR	FNAL
<0.15	90	BOFILL	87	CNTR	FNAL
$<8.8 \times 10^{-2}$	90	TAYLOR	83	HLBC	15-ft FNAL

$\nu_\mu(\overline{\nu}_\mu) \to \nu_\tau(\overline{\nu}_\tau)$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<1.5	90	[61] GRUWE	93	CHM2	CERN SPS

[61] GRUWE 93 is a search using the CHARM II detector in the CERN SPS wide-band neutrino beam for $\nu_\mu \to \nu_\tau$ and $\overline{\nu}_\mu \to \overline{\nu}_\tau$ oscillations signalled by quasi-elastic ν_τ and $\overline{\nu}_\tau$ interactions followed by the decay $\tau \to \nu_\tau \pi$. The maximum sensitivity in $\sin^2 2\theta$ ($< 6.4 \times 10^{-3}$ at the 90% CL) is reached for $\Delta(m^2) \simeq 50$ eV^2.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE (units 10^{-3})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<8	90	[62] GRUWE	93	CHM2	CERN SPS

[62] GRUWE 93 is a search using the CHARM II detector in the CERN SPS wide-band neutrino beam for $\nu_\mu \to \nu_\tau$ and $\overline{\nu}_\mu \to \overline{\nu}_\tau$ oscillations signalled by quasi-elastic ν_τ and $\overline{\nu}_\tau$ interactions followed by the decay $\tau \to \nu_\tau \pi$. The maximum sensitivity in $\sin^2 2\theta$ ($< 6.4 \times 10^{-3}$ at the 90% CL) is reached for $\Delta(m^2) \simeq 50$ eV^2.

$\nu_\mu \not\to \nu_\mu$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
> 0.0015 AND < 0.0039	90	[63] AHN	03	K2K	KEK to Super-K
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 0.29 OR >22	90	BERGSMA	88	CHRM	
<7	90	BELIKOV	85	CNTR	Serpukhov
<8.0 OR >1250	90	STOCKDALE	85	CNTR	
<0.29 OR >22	90	BERGSMA	84	CHRM	
<0.23 OR >100	90	DYDAK	84	CNTR	
<13 OR >1500	90	STOCKDALE	84	CNTR	
<8.0	90	BELIKOV	83	CNTR	

[63] K2K is a 250 km long-baseline disappearance experiment. The result indicates neutrino oscillations. The measured oscillation parameters are consistent with the ones suggested by atmospheric neutrino observations.

$\sin^2(2\theta)$ for $\Delta(m^2) = 0.003$ eV^2

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
> 0.35	90	[64] AHN	03	K2K	KEK to Super-K

[64] K2K is a 250 km long-baseline disappearance experiment. The result indicates neutrino oscillations. The measured oscillation parameters are consistent with the ones suggested by atmospheric neutrino observations.

$\sin^2(2\theta)$ for $\Delta(m^2) = 100\text{eV}^2$

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.02	90	[65] STOCKDALE 85	CNTR	FNAL
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.17	90	[66] BERGSMA 88	CHRM	
<0.07	90	[67] BELIKOV 85	CNTR	Serpukhov
<0.27	90	[66] BERGSMA 84	CHRM	CERN PS
<0.1	90	[68] DYDAK 84	CNTR	CERN PS
<0.02	90	[69] STOCKDALE 84	CNTR	FNAL
<0.1	90	[70] BELIKOV 83	CNTR	Serpukhov

[65] This bound applies for $\Delta(m^2) = 100$ eV^2. Less stringent bounds apply for other $\Delta(m^2)$; these are nontrivial for $8 < \Delta(m^2) < 1250$ eV^2.

[66] This bound applies for $\Delta(m^2) = 0.7$–$9.$ eV^2. Less stringent bounds apply for other $\Delta(m^2)$; these are nontrivial for $0.28 < \Delta(m^2) < 22$ eV^2.

[67] This bound applies for a wide range of $\Delta(m^2) > 7$ eV^2. For some values of $\Delta(m^2)$, the value is less stringent; the least restrictive, nontrivial bound occurs approximately at $\Delta(m^2) = 300$ eV^2 where $\sin^2(2\theta) < 0.13$ at CL = 90%.

[68] This bound applies for $\Delta(m^2) = 1.$–$10.$ eV^2. Less stringent bounds apply for other $\Delta(m^2)$; these are nontrivial for $0.23 < \Delta(m^2) < 90$ eV^2.

[69] This bound applies for $\Delta(m^2) = 110$ eV^2. Less stringent bounds apply for other $\Delta(m^2)$; these are nontrivial for $13 < \Delta(m^2) < 1500$ eV^2.

[70] Bound holds for $\Delta(m^2) = 20$–1000 eV^2.

$\overline{\nu}_\mu \not\to \overline{\nu}_\mu$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*	*TECN*
<7 OR >1200 OUR LIMIT			
< 7 OR > 1200	90	STOCKDALE 85	CNTR

$\sin^2(2\theta)$ for $190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2$

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.02	90	[71] STOCKDALE 85	CNTR	FNAL

[71] This bound applies for $\Delta(m^2)$ between 190 and 320 or = 530 eV^2. Less stringent bounds apply for other $\Delta(m^2)$; these are nontrivial for $7 < \Delta(m^2) < 1200$ eV^2.

$\nu_\mu \to (\overline{\nu}_e)_L$

See note above for $\nu_e \to (\overline{\nu}_e)_L$ limit

$\alpha\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.16	90	[72] FREEDMAN 93	CNTR	LAMPF
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.7	90	[73] COOPER 82	HLBC	BEBC CERN SPS

[72] FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ, $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e p \to e^+ n$. The limit on $\Delta(m^2)$ is better than the CERN BEBC experiment, but the limit on $\sin^2\theta$ is almost a factor of 100 less sensitive.

[73] COOPER 82 states that existing bounds on V+A currents require α to be small.

$\alpha^2\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.001	90	[74] COOPER	82	HLBC	BEBC CERN SPS
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.07	90	[75] FREEDMAN	93	CNTR	LAMPF

[74] COOPER 82 states that existing bounds on V+A currents require α to be small.

[75] FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ, $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e p \rightarrow e^+ n$. The limit on $\Delta(m^2)$ is better than the CERN BEBC experiment, but the limit on $\sin^2\theta$

(B) Reactor $\overline{\nu}_e$ disappearance experiments

In most cases, the reaction $\overline{\nu}_e p \rightarrow e^+ n$ is observed at different distances from one or more reactors in a complex.

Events (Observed/Expected) from Reactor $\overline{\nu}_e$ Experiments

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.611 \pm 0.085 \pm 0.041$	[76] EGUCHI	03	KLND	Japanese react ~ 180 km
$1.01 \pm 0.024 \pm 0.053$	[77] BOEHM	01		Palo Verde react. 0.75–0.89 km
$1.04 \pm 0.03 \pm 0.08$	[78] BOEHM	00C		Palo Verde react. 0.75–0.89 km
$1.01 \pm 0.028 \pm 0.027$	[79] APOLLONIO	99	CHOZ	Chooz reactors 1 km
$0.987 \pm 0.006 \pm 0.037$	[80] GREENWOOD	96		Savannah River, 18.2 m
$0.988 \pm 0.004 \pm 0.05$	ACHKAR	95	CNTR	Bugey reactor, 15 m
$0.994 \pm 0.010 \pm 0.05$	ACHKAR	95	CNTR	Bugey reactor, 40 m
$0.915 \pm 0.132 \pm 0.05$	ACHKAR	95	CNTR	Bugey reactor, 95 m
$0.987 \pm 0.014 \pm 0.027$	[81] DECLAIS	94	CNTR	Bugey reactor, 15 m
$0.985 \pm 0.018 \pm 0.034$	KUVSHINN...	91	CNTR	Rovno reactor
$1.05 \pm 0.02 \pm 0.05$	VUILLEUMIER	82		Gösgen reactor
$0.955 \pm 0.035 \pm 0.110$	[82] KWON	81		$\overline{\nu}_e p \rightarrow e^+ n$
0.89 ± 0.15	[82] BOEHM	80		$\overline{\nu}_e p \rightarrow e^+ n$
0.38 ± 0.21	[83,84] REINES	80		
0.40 ± 0.22	[83,84] REINES	80		

[76] EGUCHI 03 observe reactor neutrino disappearance at ~ 180 km baseline to various Japanese nuclear power reactors. See the footnote in the following table for further details, and the paper for the inclusion/exclusion plot.

[77] BOEHM 01 search for neutrino oscillations at 0.75 and 0.89 km distance from the Palo Verde reactors.

[78] BOEHM 00C search for neutrino oscillations at 0.75 and 0.89 km distance from the Palo Verde reactors.

[79] APOLLONIO 99, APOLLONIO 98 search for neutrino oscillations at 1.1 km fixed distance from Chooz reactors. They use $\overline{\nu}_e p \rightarrow e^+ n$ in Gd-loaded scintillator target. APOLLONIO 99 supersedes APOLLONIO 98. See also APOLLONIO 03 for detailed description.

[80] GREENWOOD 96 search for neutrino oscillations at 18 m and 24 m from the reactor at Savannah River.

[81] DECLAIS 94 result based on integral measurement of neutrons only. Result is ratio of measured cross section to that expected in standard *V-A* theory. Replaced by ACHKAR 95.

[82] KWON 81 represents an analysis of a larger set of data from the same experiment as BOEHM 80.

[83] REINES 80 involves comparison of neutral- and charged-current reactions $\overline{\nu}_e d \rightarrow n p \overline{\nu}_e$ and $\overline{\nu}_e d \rightarrow n n e^+$ respectively. Combined analysis of reactor $\overline{\nu}_e$ experiments was performed by SILVERMAN 81.

[84] The two REINES 80 values correspond to the calculated $\overline{\nu}_e$ fluxes of AVIGNONE 80 and DAVIS 79 respectively.

$\overline{\nu}_e \not\rightarrow \overline{\nu}_e$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>8 × 10^{-6}	95	[85] EGUCHI	03	KLND	Japanese react ∼ 180 km
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.0011	90	[86] BOEHM	01		Palo Verde react. 0.75–0.89 km
<0.0011	90	[87] BOEHM	00		Palo Verde react. 0.8 km
<0.0007	90	[88] APOLLONIO	99	CHOZ	Chooz reactors 1 km
<0.01	90	[89] ACHKAR	95	CNTR	Bugey reactor
<0.0075	90	[90] VIDYAKIN	94		Krasnoyarsk reactors
<0.04	90	[91] AFONIN	88	CNTR	Rovno reactor
<0.014	68	[92] VIDYAKIN	87		$\overline{\nu}_e p \rightarrow e^+ n$
<0.019	90	[93] ZACEK	86		Gösgen reactor

[85] EGUCHI 03 observe reactor neutrino disappearance at ∼ 180 km baseline to various Japanese nuclear power reactors. This is the lower limit on the mass difference spread, unlike all other entries in this table. Observation is consistent with neutrino oscillations, with mass-mixing and mixing-angle parameters in the Large Mixing Angle Solution region of the solar neutrino problem.

[86] BOEHM 01, a continuation of BOEHM 00, is a disappearance search for neutrino oscillations at 0.75 and 0.89 km distance from the Palo Verde reactors. Result is less restrictive than APOLLONIO 99.

[87] BOEHM 00 is a disappearance search for neutrino oscillations at 0.75 and 0.89 km distance from Palo Verde reactors. The detection reaction is $\overline{\nu}_e p \rightarrow e^+ n$ in a segmented Gd loaded scintillator target. Result is less restrictive than APOLLONIO 99.

[88] APOLLONIO 99 search for neutrino oscillations at 1.1 km fixed distance from Chooz reactors. They use $\overline{\nu}_e p \rightarrow e^+ n$ in Gd-loaded scintillator target. APOLLONIO 99 supersedes APOLLONIO 98. This is the most sensitive search in terms of $\Delta(m^2)$ for $\overline{\nu}_e$ disappearance. See also APOLLONIO 03 for detailed description.

[89] ACHKAR 95 bound is for L=15, 40, and 95 m.

[90] VIDYAKIN 94 bound is for L=57.0 m, 57.6 m, and 231.4 m. Supersedes VIDYAKIN 90.

[91] AFONIN 86 and AFONIN 87 also give limits on $\sin^2(2\theta)$ for intermediate values of $\Delta(m^2)$. (See also KETOV 92). Supersedes AFONIN 87, AFONIN 86, AFONIN 85, AFONIN 83, and BELENKII 83.

[92] VIDYAKIN 87 bound is for L = 32.8 and 92.3 m distance from two reactors.

[93] This bound is from data for L=37.9 m, 45.9 m, and 64.7 m.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>0.4	95	[94] EGUCHI	03	KLND	Japanese react ~ 180 km
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.17	90	[95] BOEHM	01		Palo Verde react. 0.75–0.89 km
<0.21	90	[96] BOEHM	00		Palo Verde react. 0.8 km
<0.10	90	[97] APOLLONIO	99	CHOZ	Chooz reactors 1 km
<0.24	90	[98] GREENWOOD	96		
<0.04	90	[98] GREENWOOD	96		For $\Delta(m^2) = 1.0$ eV^2
<0.02	90	[99] ACHKAR	95	CNTR	For $\Delta(m^2) = 0.6$ eV^2
<0.087	68	[100] VYRODOV	95	CNTR	For $\Delta(m^2)$ >2 eV^2
<0.15	90	[101] VIDYAKIN	94		For $\Delta(m^2) > 5.0 \times 10^{-2}$ eV^2
<0.2	90	[102] AFONIN	88	CNTR	$\overline{\nu}_e p \rightarrow e^+ n$
<0.14	68	[103] VIDYAKIN	87		$\overline{\nu}_e p \rightarrow e^+ n$
<0.21	90	[104] ZACEK	86		$\overline{\nu}_e p \rightarrow e^+ n$
<0.19	90	[105] ZACEK	85		Gösgen reactor
<0.16	90	[106] GABATHULER	84		$\overline{\nu}_e p \rightarrow e^+ n$

[94] EGUCHI 03 observe reactor neutrino disappearance at ~ 180 km baseline to various Japanese nuclear power reactors. This is the lower limit on $\sin^2 2\theta$, unlike all other entries in this table. It is based on the observed rate only; consideration of the spectrum shape results in somewhat more restrictive limit. Observation is consistent with neutrino oscillations, with mass-mixing and mixing-angle parameters in the Large Mixing Angle Solution region of the solar neutrino problem.

[95] BOEHM 01 search for neutrino oscillations at 0.75 and 0.89 km distance from the Palo Verde reactors. Continuation of BOEHM 00.

[96] BOEHM 00 search for neutrino oscillations at 0.75 and 0.89 km distance from Palo Verde reactors.

[97] APOLLONIO 99 search for neutrino oscillations at 1.1 km fixed distance from Chooz reactors. See also APOLLONIO 03 for detailed description.

[98] GREENWOOD 96 search for neutrino oscillations at 18 m and 24 m from the reactor at Savannah River by observing $\overline{\nu}_e p \rightarrow e^+ n$ in a Gd loaded scintillator target. Their region of sensitivity in $\Delta(m^2)$ and $\sin^2 2\theta$ is already excluded by ACHKAR 95.

[99] ACHKAR 95 bound is from data for L=15, 40, and 95 m distance from the Bugey reactor.

[100] The VYRODOV 95 bound is from data for L=15 m distance from the Bugey-5 reactor.

[101] The VIDYAKIN 94 bound is from data for L=57.0 m, 57.6 m, and 231.4 m from three reactors in the Krasnoyarsk Reactor complex.

[102] Several different methods of data analysis are used in AFONIN 88. We quote the most stringent limits. Different upper limits on $\sin^2 2\theta$ apply at intermediate values of $\Delta(m^2)$. Supersedes AFONIN 87, AFONIN 85, and BELENKII 83.

[103] VIDYAKIN 87 bound is for $L = 32.8$ and 92.3 m distance from two reactors.

[104] This bound is from data for L=37.9 m, 45.9 m, and 64.7 m distance from Gosgen reactor.

[105] ZACEK 85 gives two sets of bounds depending on what assumptions are used in the data analysis. The bounds in figure 3(a) of ZACEK 85 are progressively poorer for large $\Delta(m^2)$ whereas those of figure 3(b) approach a constant. We list the latter. Both sets of bounds use combination of data from 37.9, 45.9, and 64.7m distance from reactor. ZACEK 85 states "Our experiment excludes this area (the oscillation parameter region allowed by the Bugey data, CAVAIGNAC 84) almost completely, thus disproving the indications of neutrino oscillations of CAVAIGNAC 84 with a high degree of confidence."

[106] This bound comes from a combination of the VUILLEUMIER 82 data at distance 37.9m from Gosgen reactor and new data at 45.9m.

(C) Atmospheric neutrino observations

Neutrinos and antineutrinos produced in the atmosphere induce μ-like and e-like events in underground detectors. The ratio of the numbers of the two kinds of events is defined as μ/e. It has the advantage that systematic effects, such as flux uncertainty, tend to cancel, for both experimental and theoretical values of the ratio. The "ratio of the ratios" of experimental to theoretical μ/e, $R(\mu/e)$, or that of experimental to theoretical μ/total, $R(\mu/\text{total})$ with total = $\mu+e$, is reported below. If the actual value is not unity, the value obtained in a given experiment may depend on the experimental conditions.

R(μ/e) = (Measured Ratio μ/e) / (Expected Ratio μ/e)

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.69 \pm 0.10 \pm 0.06$	[107] SANCHEZ	03	SOU2	Calorimeter raw data
$0.61 \pm 0.03 \pm 0.05$	[108] FUKUDA	98	SKAM	sub-GeV
$0.66 \pm 0.06 \pm 0.08$	[109] FUKUDA	98E	SKAM	multi-GeV
	[110] FUKUDA	96B	KAMI	Water Cherenkov
$1.00 \pm 0.15 \pm 0.08$	[111] DAUM	95	FREJ	Calorimeter
$0.60^{+0.06}_{-0.05} \pm 0.05$	[112] FUKUDA	94	KAMI	sub-GeV
$0.57^{+0.08}_{-0.07} \pm 0.07$	[113] FUKUDA	94	KAMI	multi-Gev
	[114] BECKER-SZ...	92B	IMB	Water Cherenkov

[107] SANCHEZ 03 result is based on an exposure of 5.9 kton yr, and updates ALLISON 99 result. The analyzed data sample consists of fully-contained e-flavor and μ-flavor events having lepton momentum > 0.3 GeV/c.

[108] FUKUDA 98 result is based on an exposure of 25.5 kton yr. The analyzed data sample consists of fully-contained e-like events with $0.1\ \text{GeV}/c < p_e$ and μ-like events with $0.2\ \text{GeV}/c < p_\mu$, both having a visible energy < 1.33 GeV. These criteria match the definition used by FUKUDA 94.

[109] FUKUDA 98E result is based on an exposure of 25.5 kton yr. The analyzed data sample consists of fully-contained single-ring events with visible energy > 1.33 GeV and partially contained events. All partially contained events are classified as μ-like.

[110] FUKUDA 96B studied neutron background in the atmospheric neutrino sample observed in the Kamiokande detector. No evidence for the background contamination was found.

[111] DAUM 95 results are based on an exposure of 2.0 kton yr which includes the data used by BERGER 90B. This ratio is for the contained and semicontained events. DAUM 95 also report $R(\mu/e) = 0.99 \pm 0.13 \pm 0.08$ for the total neutrino induced data sample which includes upward going stopping muons and horizontal muons in addition to the contained and semicontained events.

[112] FUKUDA 94 result is based on an exposure of 7.7 kton yr and updates the HIRATA 92 result. The analyzed data sample consists of fully-contained e-like events with $0.1 < p_e < 1.33$ GeV/c and fully-contained μ-like events with $0.2 < p_\mu < 1.5$ GeV/c.

[113] FUKUDA 94 analyzed the data sample consisting of fully contained events with visible energy > 1.33 GeV and partially contained μ-like events.

[114] BECKER-SZENDY 92B reports the fraction of nonshowering events (mostly muons from atmospheric neutrinos) as $0.36 \pm 0.02 \pm 0.02$, as compared with expected fraction $0.51 \pm 0.01 \pm 0.05$. After cutting the energy range to the Kamiokande limits, BEIER 92 finds $R(\mu/e)$ very close to the Kamiokande value.

R(ν_μ) = (Measured Flux of ν_μ) / (Expected Flux of ν_μ)

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

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
$0.72 \pm 0.026 \pm 0.13$	[115] AMBROSIO	01	MCRO	upward through-going
$0.57 \pm 0.05 \pm 0.15$	[116] AMBROSIO	00	MCRO	upgoing partially contained
$0.71 \pm 0.05 \pm 0.19$	[117] AMBROSIO	00	MCRO	downgoing partially contained + upgoing stopping
$0.74 \pm 0.036 \pm 0.046$	[118] AMBROSIO	98	MCRO	Streamer tubes
	[119] CASPER	91	IMB	Water Cherenkov
	[120] AGLIETTA	89	NUSX	
0.95 ± 0.22	[121] BOLIEV	81		Baksan
0.62 ± 0.17	CROUCH	78		Case Western/UCI

[115] AMBROSIO 01 result is based on the upward through-going muon tracks with $E_\mu > 1$ GeV. The data came from three different detector configurations, but the statistics is largely dominated by the full detector run, from May 1994 to December 2000. The total live time, normalized to the full detector configuration, is 6.17 years. The first error is the statistical error, the second is the systematic error, dominated by the theoretical error in the predicted flux.

[116] AMBROSIO 00 result is based on the upgoing partially contained event sample. It came from 4.1 live years of data taking with the full detector, from April 1994 to February 1999. The average energy of atmospheric muon neutrinos corresponding to this sample is 4 GeV. The first error is statistical, the second is the systematic error, dominated by the 25% theoretical error in the rate (20% in the flux and 15% in the cross section, added in quadrature). Within statistics, the observed deficit is uniform over the zenith angle.

[117] AMBROSIO 00 result is based on the combined samples of downgoing partially contained events and upgoing stopping events. These two subsamples could not be distinguished due to the lack of timing information. The result came from 4.1 live years of data taking with the full detector, from April 1994 to February 1999. The average energy of atmospheric muon neutrinos corresponding to this sample is 4 GeV. The first error is statistical, the second is the systematic error, dominated by the 25% theoretical error in the rate (20% in the flux and 15% in the cross section, added in quadrature). Within statistics, the observed deficit is uniform over the zenith angle.

[118] AMBROSIO 98 result is for all nadir angles and updates AHLEN 95 result. The lower cutoff on the muon energy is 1 GeV. In addition to the statistical and systematic errors, there is a Monte Carlo flux error (theoretical error) of ±0.13. With a neutrino oscillation hypothesis, the fit either to the flux or zenith distribution independently yields $\sin^2 2\theta = 1.0$ and $\Delta(m^2) \sim$ a few times 10^{-3} eV^2. However, the fit to the observed zenith distribution gives a maximum probability for χ^2 of only 5% for the best oscillation hypothesis.

[119] CASPER 91 correlates showering/nonshowering signature of single-ring events with parent atmospheric-neutrino flavor. They find nonshowering ($\approx \nu_\mu$ induced) fraction is $0.41 \pm 0.03 \pm 0.02$, as compared with expected 0.51 ± 0.05 (syst).

[120] AGLIETTA 89 finds no evidence for any anomaly in the neutrino flux. They define ρ = (measured number of ν_e's)/(measured number of ν_μ's). They report $\rho(\text{measured}) = \rho(\text{expected}) = 0.96^{+0.32}_{-0.28}$.

[121] From this data BOLIEV 81 obtain the limit $\Delta(m^2) \leq 6 \times 10^{-3}$ eV^2 for maximal mixing, $\nu_\mu \not\to \nu_\mu$ type oscillation.

R(μ/total) = (Measured Ratio μ/total) / (Expected Ratio μ/total)

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

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
$1.1^{+0.07}_{-0.12} \pm 0.11$	[122] CLARK	97	IMB	multi-GeV

[122] CLARK 97 obtained this result by an analysis of fully contained and partially contained events in the IMB water-Cherenkov detector with visible energy > 0.95 GeV.

$N_{\mathrm{up}}(\mu)/N_{\mathrm{down}}(\mu)$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.52^{+0.07}_{-0.06}\pm0.01$	[123] FUKUDA	98E	SKAM	multi-GeV

[123] FUKUDA 98E result is based on an exposure of 25.5 kton yr. The analyzed data sample consists of fully-contained single-ring μ-like events with visible energy > 1.33 GeV and partially contained events. All partially contained events are classified as μ-like. Upward-going events are those with $-1 <$cos (zenith angle) < -0.2 and downward-going events with those with $0.2 <$cos (zenith angle) < 1. FUKUDA 98E result strongly deviates from an expected value of 0.98 ± 0.03 ± 0.02.

$N_{\mathrm{up}}(e)/N_{\mathrm{down}}(e)$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.84^{+0.14}_{-0.12}\pm0.02$	[124] FUKUDA	98E	SKAM	multi-GeV

[124] FUKUDA 98E result is based on an exposure of 25.5 kton yr. The analyzed data sample consists of fully-contained single-ring e-like events with visible energy > 1.33 GeV. Upward-going events are those with $-1 <$cos (zenith angle) < -0.2 and downward-going events are those with $0.2 <$cos (zenith angle) < 1. FUKUDA 98E result is compared to an expected value of 1.01 ± 0.06 ± 0.03.

$\sin^2(2\theta)$ for given $\Delta(m^2)$ ($\nu_e \leftrightarrow \nu_\mu$)

For a review see BAHCALL 89.

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.6	90	[125] OYAMA	98	KAMI	$\Delta(m^2) > 0.1$ eV^2
<0.5		[126] CLARK	97	IMB	$\Delta(m^2) > 0.1$ eV^2
>0.55	90	[127] FUKUDA	94	KAMI	$\Delta(m^2) = 0.007$–0.08 eV^2
<0.47	90	[128] BERGER	90B	FREJ	$\Delta(m^2) > 1$ eV^2
<0.14	90	LOSECCO	87	IMB	$\Delta(m^2)= 0.00011$ eV^2

[125] OYAMA 98 obtained this result by an analysis of upward-going muons in Kamiokande. The data sample used is essentially the same as that used by HATAKEYAMA 98.

[126] CLARK 97 obtained this result by an analysis of fully contained and partially contained events in the IMB water-Cherenkov detector with visible energy > 0.95 GeV.

[127] FUKUDA 94 obtained this result by a combined analysis of sub- and multi-GeV atmospheric neutrino events in Kamiokande.

[128] BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antineutrino oscillations.

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$ ($\nu_e \leftrightarrow \nu_\mu$)

VALUE (10^{-5} eV^2)	*CL%*	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<560	90	[129] OYAMA	98	KAMI
<980		[130] CLARK	97	IMB
$700 < \Delta(m^2) < 7000$	90	[131] FUKUDA	94	KAMI
<150	90	[132] BERGER	90B	FREJ

[129] OYAMA 98 obtained this result by an analysis of upward-going muons in Kamiokande. The data sample used is essentially the same as that used by HATAKEYAMA 98.

[130] CLARK 97 obtained this result by an analysis of fully contained and partially contained events in the IMB water-Cherenkov detector with visible energy > 0.95 GeV.

[131] FUKUDA 94 obtained this result by a combined analysis of sub- and multi-GeV atmospheric neutrino events in Kamiokande.

[132] BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antineutrino oscillations.

$\sin^2(2\theta)$ for given $\Delta(m^2)$ ($\overline{\nu}_e \leftrightarrow \overline{\nu}_\mu$)

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

VALUE (10^{-5} eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.9	99	[133] SMIRNOV	94	THEO	$\Delta(m^2) > 3 \times 10^{-4}$ eV^2
<0.7	99	[133] SMIRNOV	94	THEO	$\Delta(m^2) < 10^{-11}$ eV^2

[133] SMIRNOV 94 analyzed the data from SN 1987A using stellar-collapse models. They also give less stringent upper limits on $\sin^2 2\theta$ for $10^{-11} < \Delta(m^2) < 3 \times 10^{-7}$ eV^2 and $10^{-5} < \Delta(m^2) < 3 \times 10^{-4}$ eV^2. The same results apply to $\overline{\nu}_e \leftrightarrow \overline{\nu}_\tau$, ν_μ, and ν_τ.

$\sin^2(2\theta)$ for given $\Delta(m^2)$ ($\nu_\mu \leftrightarrow \nu_\tau$)

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

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>0.8	90	[134] AMBROSIO	04	MCRO	$\Delta(m^2) = 0.0006$–0.008 eV^2
>0.9	90	[135] ASHIE	04	SKAM	$\Delta(m^2) = 0.0019$–0.003 eV^2
>0.45	90	[136] AMBROSIO	03	MCRO	$\Delta(m^2)= 0.00025$–0.009 eV^2
>0.77	90	[137] AMBROSIO	03	MCRO	$\Delta(m^2)= 0.0006$–0.007 eV^2
>0.5	90	[138] SANCHEZ	03	SOU2	$\Delta(m^2) = 0.00015$–0.02 eV^2
>0.8	90	[139] AMBROSIO	01	MCRO	$\Delta(m^2)= 0.0006$–0.015 eV^2
>0.82	90	[140] AMBROSIO	01	MCRO	$\Delta(m^2)= 0.001$–0.006 ev^2
>0.25	90	[141] AMBROSIO	00	MCRO	$\Delta(m^2) > 3 \times 10^{-4}$ eV^2
>0.4	90	[142] FUKUDA	99C	SKAM	$\Delta(m^2)= 0.001$–0.1 eV^2
>0.7	90	[143] FUKUDA	99D	SKAM	$\Delta(m^2)= 0.0015$–0.015 eV^2
>0.82	90	[144] AMBROSIO	98	MCRO	$\Delta(m^2) \sim 0.0025$ eV^2
>0.82	90	[145] FUKUDA	98C	SKAM	$\Delta(m^2) = 0.0005$–0.006 eV^2
>0.3	90	[146] HATAKEYAMA	98	KAMI	$\Delta(m^2)= 0.00055$–0.14 eV^2
>0.73	90	[147] HATAKEYAMA	98	KAMI	$\Delta(m^2)= 0.004$–0.025 eV^2
<0.7		[148] CLARK	97	IMB	$\Delta(m^2) > 0.1$ eV^2
>0.65	90	[149] FUKUDA	94	KAMI	$\Delta(m^2) = 0.005$–0.03 eV^2
<0.5	90	[150] BECKER-SZ...	92	IMB	$\Delta(m^2)= 1$–2×10^{-4} eV^2
<0.6	90	[151] BERGER	90B	FREJ	$\Delta(m^2) > 1$ eV^2

[134] AMBROSIO 04 obtained this result, without using the absolute normalization of the neutrino flux, by combining the angular distribution of upward through-going muon tracks with $E_\mu > 1$ GeV, $N_{\rm low}$ and $N_{\rm high}$, and the numbers of *InDown* + *UpStop* and *InUp* events. Here, $N_{\rm low}$ and $N_{\rm high}$ are the number of events with reconstructed neutrino energy $<$30 and $>$130 GeV, respectively. *InDown* and *InUp* represent events with downward- and upward-going tracks starting inside the detector due to neutrino interactions, while *UpStop* represents entering upward-going tracks which stop inside the detector.

[135] ASHIE 04 obtained this result from the L(flight length) / E(estimated neutrino energy) distribution of ν_μ disappearance probability, using the Super-Kamiokande-I 1489 live-day atmospheric neutrino data.

[136] AMBROSIO 03 obtained this result on the basis of the ratio $R = N_{\text{low}}/N_{\text{high}}$, where N_{low} and N_{high} are the number of upward through-going muon events with reconstructed neutrino energy $<$30 GeV and $>$130 GeV, respectively. The data came from the full detector run started in 1994. The method of FELDMAN 98 is used to obtain the limits.

[137] AMBROSIO 03 obtained this result by using the ratio R and the angular distribution of the upward through-going muons. R is given by $N_{\text{low}}/N_{\text{high}}$, where N_{low} and N_{high} are the number of events with reconstructed neutrino energy $<$30 and $>$130 GeV, respectively. The angular distribution is reported in AMBROSIO 01. The method of FELDMAN 98 is used to obtain the limits.

[138] SANCHEZ 03 result is based on an exposure of 5.9 kton yr. The result is obtained using a likelihood analysis of the neutrino L/E distribution for a selected μ-flavor sample while the e-flavor sample provides flux normalization. The method of FELDMAN 98 is used to obtain the limits.

[139] AMBROSIO 01 result is based on the angular distribution of upward through-going muon tracks with $E_{\mu} > 1$ GeV. The data came from three different detector configurations, but the statistics is largely dominated by the full detector run, from May 1994 to December 2000. The total live time, normalized to the full detector configuration, is 6.17 years. The best fit is obtained outside the physical region. The method of FELDMAN 98 is used to obtain the limits.

[140] AMBROSIO 01 result is based on the angular distribution and normalization of upward through-going muon tracks with $E_{\mu} > 1$ GeV. The best fit is obtained outside the physical region. The method of FELDMAN 98 is used to obtain the limits. See the previous footnote.

[141] AMBROSIO 00 obtained this result by using the upgoing partially contained event sample and the combined samples of downgoing partially contained events and upgoing stopping events. These data came from 4.1 live years of data taking with the full detector, from April 1994 to February 1999. The average energy of atmospheric muon neutrinos corresponding to these samples is 4 GeV. The maximum of the χ^2 probability (97%) occurs at maximal mixing and $\Delta(m^2) = (1 \sim 20) \times 10^{-3}\ \text{eV}^2$.

[142] FUKUDA 99C obtained this result from a total of 537 live days of upward through-going muon data in Super-Kamiokande between April 1996 to January 1998. With a threshold of $E_{\mu} > 1.6$ GeV, the observed flux of upward through-going muons is $(1.74 \pm 0.07 \pm 0.02) \times 10^{-13}\ \text{cm}^{-2}\,\text{s}^{-1}\,\text{sr}^{-1}$. The zenith-angle dependence of the flux does not agree with no-oscillation predictions. For the $\nu_{\mu} \rightarrow \nu_{\tau}$ hypothesis, FUKUDA 99C obtained the best fit at $\sin^2 2\theta = 0.95$ and $\Delta(m^2) = 5.9 \times 10^{-3}\ \text{eV}^2$. FUKUDA 99C also reports 68% and 99% confidence-level allowed regions for the same hypothesis.

[143] FUKUDA 99D obtained this result from a simultaneous fitting to zenith angle distributions of upward-stopping and through-going muons. The flux of upward-stopping muons of minimum energy of 1.6 GeV measured between April 1996 and January 1998 is $(0.39 \pm 0.04 \pm 0.02) \times 10^{-13}\ \text{cm}^{-2}\,\text{s}^{-1}\,\text{sr}^{-1}$. This is compared to the expected flux of $(0.73 \pm 0.16\ \text{(theoretical error)}) \times 10^{-13}\ \text{cm}^{-2}\,\text{s}^{-1}\,\text{sr}^{-1}$. The flux of upward through-going muons is taken from FUKUDA 99C. For the $\nu_{\mu} \rightarrow \nu_{\tau}$ hypothesis, FUKUDA 99D obtained the best fit in the physical region at $\sin^2 2\theta = 1.0$ and $\Delta(m^2) = 3.9 \times 10^{-3}\ \text{eV}^2$. FUKUDA 99D also reports 68% and 99% confidence-level allowed regions for the same hypothesis. FUKUDA 99D further reports the result of the oscillation analysis using the zenith-angle dependence of upward-stopping/through-going flux ratio. The best fit in the physical region is obtained at $\sin^2 2\theta = 1.0$ and $\Delta(m^2) = 3.1 \times 10^{-3}\ \text{eV}^2$.

[144] AMBROSIO 98 result is only 17% probable at maximum because of relatively low flux for $\cos\theta < -0.8$.

[145] FUKUDA 98C obtained this result by an analysis of 33.0 kton yr atmospheric-neutrino data which include the 25.5 kton yr data used by FUKUDA 98 (sub-GeV) and FUKUDA 98E (multi-GeV). Inside the physical region, the best fit was obtained at $\sin^2 2\theta = 1.0$ and $\Delta(m^2) = 2.2 \times 10^{-3}\ \text{eV}^2$. In addition, FUKUDA 98C gave the 99% confidence interval, $\sin^2 2\theta > 0.73$ and $3 \times 10^{-4} < \Delta(m^2) < 8.5 \times 10^{-3}\ \text{eV}^2$. FUKUDA 98C also tested the $\nu_{\mu} \rightarrow \nu_{e}$ hypothesis, and concluded that it is not favored.

[146] HATAKEYAMA 98 obtained this result from a total of 2456 live days of upward-going muon data in Kamiokande between December 1985 and May 1995. With a threshold of $E_\mu > 1.6$ GeV, the observed flux of upward through-going muon is $(1.94 \pm 0.10^{+0.07}_{-0.06}) \times 10^{-13}$ cm^{-2} s^{-1} sr^{-1}. This is compared to the expected flux of (2.46 ± 0.54 (theoretical error)) $\times 10^{-13}$ cm^{-2} s^{-1} sr^{-1}. For the $\nu_\mu \rightarrow \nu_\tau$ hypothesis, the best fit inside the physical region was obtained at $\sin^2 2\theta$=1.0 and $\Delta(m^2)$=3.2 $\times 10^{-3}$ eV^2.

[147] HATAKEYAMA 98 obtained this result from a combined analysis of Kamiokande's contained events (FUKUDA 94) and upward-going muon events. The best fit was obtained at $\sin^2 2\theta$=0.95 and $\Delta(m^2)$=1.3 $\times 10^{-2}$ eV^2.

[148] CLARK 97 obtained this result by an analysis of fully contained and partially contained events in the IMB water-Cherenkov detector with visible energy > 0.95 GeV.

[149] FUKUDA 94 obtained this result by a combined analysis of sub-and multi-GeV atmospheric neutrino events in Kamiokande.

[150] BECKER-SZENDY 92 uses upward-going muons to search for atmospheric ν_μ oscillations. The fraction of muons which stop in the detector is used to search for deviations in the expected spectrum. No evidence for oscillations is found.

[151] BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antineutrino oscillations.

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$ ($\nu_\mu \leftrightarrow \nu_\tau$)

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

VALUE (10^{-5} eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$60 < \Delta(m^2) < 800$	90	[152] AMBROSIO	04	MCRO	
$190 < \Delta(m^2) < 300$	90	[153] ASHIE	04	SKAM	L/E distribution
$25 < \Delta(m^2) < 900$	90	[154] AMBROSIO	03	MCRO	
$60 < \Delta(m^2) < 700$	90	[155] AMBROSIO	03	MCRO	
$15 < \Delta(m^2) < 1500$	90	[156] SANCHEZ	03	SOU2	
$60 < \Delta(m^2) < 1500$	90	[157] AMBROSIO	01	MCRO	
$100 < \Delta(m^2) < 600$	90	[158] AMBROSIO	01	MCRO	
> 35	90	[159] AMBROSIO	00	MCRO	
$100 < \Delta(m^2) < 5000$	90	[160] FUKUDA	99C	SKAM	
$150 < \Delta(m^2) < 1500$	90	[161] FUKUDA	99D	SKAM	
$50 < \Delta(m^2) < 600$	90	[162] AMBROSIO	98	MCRO	
$50 < \Delta(m^2) < 600$	90	[163] FUKUDA	98C	SKAM	
$55 < \Delta(m^2) < 5000$	90	[164] HATAKEYAMA	98	KAMI	
$400 < \Delta(m^2) < 2300$	90	[165] HATAKEYAMA	98	KAMI	
<1500		[166] CLARK	97	IMB	
$500 < \Delta(m^2) < 2500$	90	[167] FUKUDA	94	KAMI	
< 350	90	[168] BERGER	90B	FREJ	

[152] AMBROSIO 04 obtained this result, without using the absolute normalization of the neutrino flux, by combining the angular distribution of upward through-going muon tracks with $E_\mu > 1$ GeV, N_{low} and N_{high}, and the numbers of *InDown* + *UpStop* and *InUp* events. Here, N_{low} and N_{high} are the number of events with reconstructed neutrino energy <30 and >130 GeV, respectively. *InDown* and *InUp* represent events with downward- and upward-going tracks starting inside the detector due to neutrino interactions,

[153] ASHIE 04 obtained this result from the L(flight length)/E(estimated neutrino energy) distribution of ν_μ disappearance probability, using the Super-Kamiokande-I 1489 live-day atmospheric neutrino data.

[154] AMBROSIO 03 obtained this result on the basis of the ratio $R = N_{\text{low}}/N_{\text{high}}$, where N_{low} and N_{high} are the number of upward through-going muon events with reconstructed neutrino energy <30 GeV and >130 GeV, respectively. The data came from the full detector run started in 1994. The method of FELDMAN 98 is used to obtain the limits.

[155] AMBROSIO 03 obtained this result by using the ratio R and the angular distribution of the upward through-going muons. R is given by $N_{\text{low}}/N_{\text{high}}$, where N_{low} and N_{high} are the number of events with reconstructed neutrino energy <30 and >130 GeV, respectively. The angular distribution is reported in AMBROSIO 01. The method of FELDMAN 98 is used to obtain the limits.

[156] SANCHEZ 03 result is based on an exposure of 5.9 kton yr. The result is obtained using a likelihood analysis of the neutrino L/E distribution for a selected μ-flavor sample while the e-flavor sample provides flux normalization. The method of FELDMAN 98 is used to obtain the limits.

[157] AMBROSIO 01 result is based on the angular distribution of upward through-going muon tracks with $E_\mu > 1$ GeV. The data came from three different detector configurations, but the statistics is largely dominated by the full detector run, from May 1994 to December 2000. The total live time, normalized to the full detector configuration, is 6.17 years. The best fit is obtained outside the physical region. The method of FELDMAN 98 is used to obtain the limits.

[158] AMBROSIO 01 result is based on the angular distribution and normalization of upward through-going muon tracks with $E_\mu > 1$ GeV. The best fit is obtained outside the physical region. The method of FELDMAN 98 is used to obtain the limits. See the previous footnote.

[159] AMBROSIO 00 obtained this result by using the upgoing partially contained event sample and the combined samples of downgoing partially contained events and upgoing stopping events. These data came from 4.1 live years of data taking with the full detector, from April 1994 to February 1999. The average energy of atmospheric muon neutrinos corresponding to these samples is 4 GeV. The maximum of the χ^2 probability (97%) occurs at maximal mixing and $\Delta(m^2)=(1\sim 20) \times 10^{-3}$ eV^2.

[160] FUKUDA 99C obtained this result from a total of 537 live days of upward through-going muon data in Super-Kamiokande between April 1996 to January 1998. With a threshold of $E_\mu > 1.6$ GeV, the observed flux of upward through-going muon is $(1.74 \pm 0.07 \pm 0.02) \times 10^{-13}$ cm^{-2} s^{-1} sr^{-1}. The zenith-angle dependence of the flux does not agree with no-oscillation predictions. For the $\nu_\mu \rightarrow \nu_\tau$ hypothesis, FUKUDA 99C obtained the best fit at $\sin^2 2\theta = 0.95$ and $\Delta(m^2) = 5.9 \times 10^{-3}$ eV^2. FUKUDA 99C also reports 68% and 99% confidence-level allowed regions for the same hypothesis.

[161] FUKUDA 99D obtained this result from a simultaneous fitting to zenith angle distributions of upward-stopping and through-going muons. The flux of upward-stopping muons of minimum energy of 1.6 GeV measured between April 1996 and January 1998 is $(0.39 \pm 0.04 \pm 0.02) \times 10^{-13}$ cm^{-2} s^{-1} sr^{-1}. This is compared to the expected flux of $(0.73 \pm 0.16$ (theoretical error)$) \times 10^{-13}$ cm^{-2} s^{-1} sr^{-1}. The flux of upward through-going muons is taken from FUKUDA 99C. For the $\nu_\mu \rightarrow \nu_\tau$ hypothesis, FUKUDA 99D obtained the best fit in the physical region at $\sin^2 2\theta = 1.0$ and $\Delta(m^2) = 3.9 \times 10^{-3}$ eV^2. FUKUDA 99D also reports 68% and 99% confidence-level allowed regions for the same hypothesis. FUKUDA 99D further reports the result of the oscillation analysis using the zenith-angle dependence of upward-stopping/through-going flux ratio. The best fit in the physical region is obtained at $\sin^2 2\theta = 1.0$ and $\Delta(m^2) = 3.1 \times 10^{-3}$ eV^2.

[162] AMBROSIO 98 result is only 17% probable at maximum because of relatively low flux for $\cos\theta < -0.8$.

[163] FUKUDA 98C obtained this result by an analysis of 33.0 kton yr atmospheric-neutrino data which include the 25.5 kton yr data used by FUKUDA 98 (sub-GeV) and FUKUDA 98E (multi-GeV). Inside the physical region, the best fit was obtained at $\sin^2 2\theta = 1.0$ and $\Delta(m^2) = 2.2 \times 10^{-3}$ eV^2. In addition, FUKUDA 98C gave the 99% confidence interval, $\sin^2 2\theta > 0.73$ and $3 \times 10^{-4} < \Delta(m^2) < 8.5 \times 10^{-3}$ eV^2. FUKUDA 98C also tested the $\nu_\mu \rightarrow \nu_e$ hypothesis, and concluded that it is not favored.

[164] HATAKEYAMA 98 obtained this result from a total of 2456 live days of upward-going muon data in Kamiokande between December 1985 and May 1995. With a threshold of $E_{\mu} > 1.6$ GeV, the observed flux of upward through-going muon is $(1.94 \pm 0.10^{+0.07}_{-0.06}) \times 10^{-13}$ cm^{-2} s^{-1} sr^{-1}. This is compared to the expected flux of (2.46 ± 0.54 (theoretical error)) $\times 10^{-13}$ cm^{-2} s^{-1} sr^{-1}. For the $\nu_{\mu} \rightarrow \nu_{\tau}$ hypothesis, the best fit inside the physical region was obtained at $\sin^2 2\theta$=1.0 and $\Delta(m^2)=3.2 \times 10^{-3}$ eV^2.

[165] HATAKEYAMA 98 obtained this result from a combined analysis of Kamiokande's contained events (FUKUDA 94) and upward-going muon events. The best fit was obtained at $\sin^2 2\theta$=0.95 and $\Delta(m^2)=1.3 \times 10^{-2}$ eV^2.

[166] CLARK 97 obtained this result by an analysis of fully contained and partially contained events in the IMB water-Cherenkov detector with visible energy > 0.95 GeV.

[167] FUKUDA 94 obtained this result by a combined analysis of sub-and multi-GeV atmospheric neutrino events in Kamiokande.

[168] BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antineutrino oscillations.

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$ ($\nu_{\mu} \rightarrow \nu_s$)

ν_s means ν_{τ} or any sterile (noninteracting) ν.

VALUE (10^{-5} eV^2)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<3000 (or <550)	90	[169] OYAMA	89	KAMI	Water Cherenkov
< 4.2 or > 54.	90	BIONTA	88	IMB	Flux has ν_{μ}, $\overline{\nu}_{\mu}$, ν_e, and $\overline{\nu}_e$

[169] OYAMA 89 gives a range of limits, depending on assumptions in their analysis. They argue that the region $\Delta(m^2)$ = (100–1000) $\times 10^{-5}$ eV^2 is not ruled out by any data for large mixing.

Search for $\nu_{\mu} \rightarrow \nu_s$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[170] AMBROSIO	01	MCRO	matter effects
	[171] FUKUDA	00	SKAM	neutral currents + matter effects

[170] AMBROSIO 01 tested the pure 2-flavor $\nu_{\mu} \rightarrow \nu_s$ hypothesis using matter effects which change the shape of the zenith-angle distribution of upward through-going muons. With maximum mixing and $\Delta(m^2)$ around 0.0024 eV^2, the $\nu_{\mu} \rightarrow \nu_s$ oscillation is disfavored with 99% confidence level with respect to the $\nu_{\mu} \rightarrow \nu_{\tau}$ hypothesis.

[171] FUKUDA 00 tested the pure 2-flavor $\nu_{\mu} \rightarrow \nu_s$ hypothesis using three complementary atmospheric-neutrino data samples. With this hypothesis, zenith-angle distributions are expected to show characteristic behavior due to neutral currents and matter effects. In the $\Delta(m^2)$ and $\sin^2 2\theta$ region preferred by the Super-Kamiokande data, the $\nu_{\mu} \rightarrow \nu_s$ hypothesis is rejected at the 99% confidence level, while the $\nu_{\mu} \rightarrow \nu_{\tau}$ hypothesis consistently fits all of the data sample.

(D) Solar ν Experiments

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ν_e Capture Rates from Radiochemical Experiments

1 SNU (Solar Neutrino Unit) = 10^{-36} captures per atom per second.

VALUE (SNU)	*DOCUMENT ID*		*TECN*	*COMMENT*
$70.8\ ^{+\ 5.3}_{-\ 5.2}\ ^{+3.7}_{-3.2}$	[172] ABDURASHI...	02	SAGE	$^{71}\text{Ga} \rightarrow {}^{71}\text{Ge}$
$65.8\ ^{+10.2}_{-\ 9.6}\ ^{+3.4}_{-3.6}$	[173] ALTMANN	00	GNO	$^{71}\text{Ga} \rightarrow {}^{71}\text{Ge}$
$74.1\ ^{+\ 6.7}_{-\ 6.8}$	[174] ALTMANN	00	GNO	GNO + GALX combined
$77.5 \pm 6.2\ ^{+4.3}_{-4.7}$	[175] HAMPEL	99	GALX	$^{71}\text{Ga} \rightarrow {}^{71}\text{Ge}$
$2.56 \pm 0.16 \pm 0.16$	[176] CLEVELAND	98	HOME	$^{37}\text{Cl} \rightarrow {}^{37}\text{Ar}$

[172] ABDURASHITOV 02 report a combined analysis of 92 runs of the SAGE solar-neutrino experiment during the period January 1990 through December 2001, and updates the ABDURASHITOV 99B result. A total of 406.4 ^{71}Ge events were observed. No evidence was found for temporal variations of the neutrino capture rate over the entire observation period.

[173] ALTMANN 00 report the first result from the GNO solar-neutrino experiment (GNO I), which is the successor project of GALLEX. Experimental technique of GNO is essentially the same as that of GALLEX. The run data cover the period 20 May 1998 through 12 January 2000.

[174] Combined result of GALLEX I+II+III+IV (HAMPEL 99) and GNO I. The indicated errors include systematic errors.

[175] HAMPEL 99 report the combined result for GALLEX I+II+III+IV (65 runs in total), which update the HAMPEL 96 result. The GALLEX IV result (12 runs) is 118.4 ± 17.8 ± 6.6 SNU. (HAMPEL 99 discuss the consistency of partial results with the mean.) The GALLEX experimental program has been completed with these runs. The total run data cover the period 14 May 1991 through 23 January 1997. A total of 300 ^{71}Ge events were observed.

[176] CLEVELAND 98 is a detailed report of the ^{37}Cl experiment at the Homestake Mine. The average solar neutrino-induced ^{37}Ar production rate from 108 runs between 1970 and 1994 updates the DAVIS 89 result.

ϕ_{ES} (^{8}B)

^{8}B solar-neutrino flux measured via νe elastic scattering. This process is sensitive to all active neutrino flavors, but with reduced sensitivity to ν_μ, ν_τ due to the cross-section difference, $\sigma(\nu_{\mu,\tau} e) \sim 0.16\sigma(\nu_e e)$. If the ^{8}B solar-neutrino flux involves nonelectron flavor active neutrinos, their contribution to the flux is ~ 0.16 times of ν_e.

VALUE (10^6 cm^{-2}s^{-1})	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$2.21^{+0.31}_{-0.26} \pm 0.10$	[177] AHMED	04A	SNO	Salty D_2O; ^{8}B shape not constrained

$2.13^{+0.29}_{-0.28}{}^{+0.15}_{-0.08}$	[177] AHMED 04A	SNO	Salty D_2O; ^{8}B shape constrained
$2.39^{+0.24}_{-0.23}\pm0.12$	[178] AHMAD 02	SNO	average flux
$2.35\pm0.03^{+0.07}_{-0.06}$	[179] FUKUDA 02	SKAM	average flux
$2.39\pm0.34^{+0.16}_{-0.14}$	[180] AHMAD 01	SNO	average flux
$2.80\pm0.19\pm0.33$	[181] FUKUDA 96	KAMI	average flux
2.70 ± 0.27	[181] FUKUDA 96	KAMI	day flux
$2.87^{+0.27}_{-0.26}$	[181] FUKUDA 96	KAMI	night flux

[177] AHMED 04A measurements were made with dissolved NaCl (0.195% by weight) in heavy water over the period between July 26, 2001 and October 10, 2002, corresponding to 254.2 live days. The CC, ES, and NC events were statistically separated. In one method, the spectral distributions of the ES and CC events were not constrained to the ^{8}B shape. In the other method, the constraint of an undistorted ^{8}B energy spectrum was added for comparison with AHMAD 02 results.

[178] AHMAD 02 reports the ^{8}B solar-neutrino flux measured via νe elastic scattering above the kinetic energy threshold of 5 MeV. The data correspond to 306.4 live days with SNO between November 2, 1999 and May 28, 2001, and updates AHMAD 01 results.

[179] FUKUDA 02 results are for 1496 live days with Super-Kamiokande between May 31, 1996 and July 15, 2001, and replace FUKUDA 01 results. The analysis threshold is 5 MeV except for the first 280 live days (6.5 MeV).

[180] AHMAD 01 reports the ^{8}B solar-neutrino flux measured via νe elastic scattering above the kinetic energy threshold of 6.75 MeV. The data correspond to 241 live days with SNO between November 2, 1999 and January 15, 2001.

[181] FUKUDA 96 results are for a total of 2079 live days with Kamiokande II and III from January 1987 through February 1995, covering the entire solar cycle 22, with threshold $E_e > 9.3$ MeV (first 449 days), > 7.5 MeV (middle 794 days), and > 7.0 MeV (last 836 days). These results update the HIRATA 90 result for the average ^{8}B solar-neutrino flux and HIRATA 91 result for the day-night variation in the ^{8}B solar-neutrino flux. The total data sample was also analyzed for short-term variations: within experimental errors, no strong correlation of the solar-neutrino flux with the sunspot numbers was found.

ϕ_{CC} (^{8}B)

^{8}B solar-neutrino flux measured with charged-current reaction which is sensitive exclusively to ν_e.

VALUE (10^6 cm^{-2}s^{-1})	*DOCUMENT ID*	*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
$1.59^{+0.08}_{-0.07}{}^{+0.06}_{-0.08}$	[182] AHMED 04A	SNO	Salty D_2O; ^{8}B shape not constrained
$1.70\pm0.07^{+0.09}_{-0.10}$	[182] AHMED 04A	SNO	Salty D_2O; ^{8}B shape constrained
$1.76^{+0.06}_{-0.05}\pm0.09$	[183] AHMAD 02	SNO	average flux
$1.75\pm0.07^{+0.12}_{-0.11}\pm0.05$	[184] AHMAD 01	SNO	average flux

[182] AHMED 04A measurements were made with dissolved NaCl (0.195% by weight) in heavy water over the period between July 26, 2001 and October 10, 2002, corresponding to 254.2 live days. The CC, ES, and NC events were statistically separated. In one method, the spectral distributions of the ES and CC events were not constrained to the ^{8}B shape. In the other method, the constraint of an undistorted ^{8}B energy spectrum was added for comparison with AHMAD 02 results.

[183] AHMAD 02 reports the SNO result of the ^{8}B solar-neutrino flux measured with charged-current reaction on deuterium, $\nu_e d \to ppe^-$, above the kinetic energy threshold of 5 MeV. The data correspond to 306.4 live days with SNO between November 2, 1999 and May 28, 2001, and updates AHMAD 01 results.

[184] AHMAD 01 reports the first SNO result of the ^{8}B solar-neutrino flux measured with the charged-current reaction on deuterium, $\nu_e d \to ppe^-$, above the kinetic energy threshold of 6.75 MeV. The data correspond to 241 live days with SNO between November 2, 1999 and January 15, 2001.

ϕ_{NC} (^{8}B)

^{8}B solar neutrino flux measured with neutral-current reaction, which is equally sensitive to ν_e, ν_μ, and ν_τ.

VALUE (10^6 cm^{-2}s^{-1})	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$5.21 \pm 0.27 \pm 0.38$	[185] AHMED	04A	SNO	Salty D_2O; ^{8}B shape not constrained
$4.90 \pm 0.24 ^{+0.29}_{-0.27}$	[185] AHMED	04A	SNO	Salty D_2O; ^{8}B shape constrained
$5.09 ^{+0.44}_{-0.43} {}^{+0.46}_{-0.43}$	[186] AHMAD	02	SNO	average flux; ^{8}B shape constrained
$6.42 \pm 1.57 ^{+0.55}_{-0.58}$	[186] AHMAD	02	SNO	average flux; ^{8}B shape not constrained

[185] AHMED 04A measurements were made with dissolved NaCl (0.195% by weight) in heavy water over the period between July 26, 2001 and October 10, 2002, corresponding to 254.2 live days. The CC, ES, and NC events were statistically separated. In one method, the spectral distributions of the ES and CC events were not constrained to the ^{8}B shape. In the other method, the constraint of an undistorted ^{8}B energy spectrum was added for comparison with AHMAD 02 results.

[186] AHMAD 02 reports the first SNO result of the ^{8}B solar-neutrino flux measured with the neutral-current reaction on deuterium, $\nu_\ell d \to np\nu_\ell$, above the neutral-current reaction threshold of 2.2 MeV. The data correspond to 306.4 live days with SNO between November 2, 1999 and May 28, 2001.

$\phi_{\nu_\mu + \nu_\tau}$ (^{8}B)

Nonelectron-flavor active neutrino component (ν_μ and ν_τ) in the ^{8}B solar-neutrino flux.

VALUE (10^6 cm^{-2}s^{-1})	*DOCUMENT ID*		*TECN*	*COMMENT*
$3.41 \pm 0.45 ^{+0.48}_{-0.45}$	[187] AHMAD	02	SNO	Derived from SNO ϕ_{CC}, ϕ_{ES}, and ϕ_{NC}
• • • We do not use the following data for averages, fits, limits, etc. • • •				
3.69 ± 1.13	[188] AHMAD	01		Derived from SNO+SuperKam, water Cherenkov

[187] AHMAD 02 deduced the nonelectron-flavor active neutrino component (ν_μ and ν_τ) in the ^{8}B solar-neutrino flux, by combining the charged-current result, the νe elastic-scattering result and the neutral-current result.

[188] AHMAD 01 deduced the nonelectron-flavor active neutrino component (ν_μ and ν_τ) in the ^{8}B solar-neutrino flux, by combining the SNO charged-current result (AHMAD 01) and the Super-Kamiokande νe elastic-scattering result (FUKUDA 01).

Total Flux of Active ^{8}B Solar Neutrinos

Total flux of active neutrinos (ν_e, ν_μ, and ν_τ).

VALUE (10^6 cm^{-2}s^{-1})		*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$5.21 \pm 0.27 \pm 0.38$		AHMED	04A	SNO	From Φ_{NC} ^{8}B shape not constrained
$4.90 \pm 0.24 ^{+0.29}_{-0.27}$		AHMED	04A	SNO	From Φ_{NC} ^{8}B shape constrained
$5.09 ^{+0.44}_{-0.43} {}^{+0.46}_{-0.43}$	[189]	AHMAD	02	SNO	Direct measurement from ϕ_{NC}
5.44 ± 0.99	[190]	AHMAD	01		Derived from SNO+SuperKam, water Cherenkov

[189] AHMAD 02 determined the total flux of active ^{8}B solar neutrinos by directly measuring the neutral-current reaction, $\nu_\ell d \rightarrow np\nu_\ell$, which is equally sensitive to ν_e, ν_μ, and ν_τ.

[190] AHMAD 01 deduced the total flux of active ^{8}B solar neutrinos by combining the SNO charged-current result (AHMAD 01) and the Super-Kamiokande νe elastic-scattering result (FUKUDA 01).

Day-Night Asymmetry (^{8}B)

$A = (\phi_{\text{night}} - \phi_{\text{day}}) / \phi_{\text{average}}$

VALUE		*DOCUMENT ID*		*TECN*	*COMMENT*
$0.14 \pm 0.063 ^{+0.015}_{-0.014}$	[191]	AHMAD	02B	SNO	Derived from SNO ϕ_{CC}
$0.021 \pm 0.020 ^{+0.013}_{-0.012}$	[192]	FUKUDA	02	SKAM	Based on ϕ_{ES}
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.018 \pm 0.016 ^{+0.013}_{-0.012}$	[193]	SMY	04	SKAM	Fitted result in the LMA region
$0.07 \pm 0.049 ^{+0.013}_{-0.012}$	[194]	AHMAD	02B	SNO	Constraint of no ϕ_{NC} asymmetry

[191] AHMAD 02B results are based on the charged-current interactions recorded between November 2, 1999 and May 28, 2001, with the day and night live times of 128.5 and 177.9 days, respectively.

[192] FUKUDA 02 results are for 1496 live days with Super-Kamiokande between May 31, 1996 and July 15, 2001, and replace FUKUDA 01 results. The analysis threshold is 5 MeV except for the first 280 live days (6.5 MeV).

[193] SMY 04 obtained this result for the best-fit LMA oscillation parameters determined by fitting the time variation of the solar neutrino flux measured via ν_e elastic scattering to the variations expected from neutrino oscillations. The directly measured result is given by FUKUDA 02.

[194] AHMAD 02B results are derived from the charged-current interactions, neutral-current interactions, and νe elastic scattering, with the total flux of active neutrinos constrained

to have no asymmetry. The data were recorded between November 2, 1999 and May 28, 2001, with the day and night live times of 128.5 and 177.9 days, respectively.

ϕ_{ES} (hep)

hep solar-neutrino flux measured via νe elastic scattering. This process is sensitive to all active neutrino flavors, but with reduced sensitivity to ν_μ, ν_τ due to the cross-section difference, $\sigma(\nu_{\mu,\tau} e) \sim 0.16\sigma(\nu_e e)$. If the hep solar-neutrino flux involves nonelectron flavor active neutrinos, their contribution to the flux is $\sim$ 0.16 times of ν_e.

VALUE (10^3 cm^{-2}s^{-1})	*CL%*	*DOCUMENT ID*		*TECN*
<40	90	[195] FUKUDA	01	SKAM

[195] FUKUDA 01 result is obtained from the recoil electron energy window of 18–21 MeV, and the obtained 90% confidence level upper limit is 4.3 times the BP2000 Standard-Solar-Model prediction.

$\phi_{\overline{\nu}_e}$ (^{8}B)

Searches are made for electron antineutrino flux from the Sun. Flux limits listed here are derived relative to the BP2000 Standard Solar Model ^{8}B solar neutrino flux, with an assumption that solar $\overline{\nu}_e$s follow an unoscillated ^{8}B neutrino spectrum.

VALUE (%)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.81	90	AHARMIM	04	SNO	$4.0 < E_{\overline{\nu}_e} < 14.8$ MeV
<0.028	90	EGUCHI	04	KLND	$8.3 < E_{\overline{\nu}_e} < 14.8$ MeV
<0.8	90	GANDO	03	SKAM	$8.0 < E_{\overline{\nu}_e} < 20.0$ MeV

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AHMED	04A	PRL 92 181301	S.N. Ahmed *et al.*	(SNO Collab.)
AHN	04	PRL 93 051801	M.H. Ahn *et al.*	(K2K)
AMBROSIO	04	EPJ C36 323	M. Ambrosio *et al.*	(MACRO Collab.)
ASHIE	04	PRL 93 101801	Y. Ashie *et al.*	(Super-Kamiokande Collab.)
BATUSOV	04	PPNL 1 192	Yu. A. Batusov *et al.*	(CNTR)
EGUCHI	04	PRL 92 071301	K. Eguchi *et al.*	(KamLAND Collab.)
SMY	04	PR D69 011104R	M.B. Smy *et al.*	(Super-Kamiokande Collab.)
AHN	03	PRL 90 041801	M.H. Ahn *et al.*	(K2K Collab.)
AMBROSIO	03	PL B566 35	M. Ambrosio *et al.*	(MACRO Collab.)
APOLLONIO	03	EPJ C27 331	M. Apollonio *et al.*	(CHOOZ Collab.)
ASTIER	03	PL B570 19	P. Astier *et al.*	(NOMAD Collab.)
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SANCHEZ	03	PR D68 113004	M. Sanchez *et al.*	(Soudan 2 Collab.)
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AHMAD	02	PRL 89 011301	Q.R. Ahmad *et al.*	(SNO Collab.)
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VIDYAKIN 87 JETP 66 243 G.S. Vidyakin *et al.* (KIAE)
Translated from ZETF 93 424.
ABRAMOWICZ 86 PRL 57 298 H. Abramowicz *et al.* (CDHS Collab.)
AFONIN 86 JETPL 44 142 A.I. Afonin *et al.* (KIAE)
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ALLABY 86 PL B177 446 J.V. Allaby *et al.* (CHARM Collab.)
ANGELINI 86 PL B179 307 C. Angelini *et al.* (PISA, ATHU, PADO+)
BERNARDI 86B PL B181 173 G. Bernardi *et al.* (CURIN, INFN, CDEF+)
BRUCKER 86 PR D34 2183 E.B. Brucker *et al.* (RUTG, BNL, COLU)
USHIDA 86C PRL 57 2897 N. Ushida *et al.* (FNAL E531 Collab.)
ZACEK 86 PR D34 2621 G. Zacek *et al.* (CIT-SIN-TUM Collab.)
AFONIN 85 JETPL 41 435 A.I. Afonin *et al.* (KIAE)
Translated from ZETFP 41 355.
Also 85B JETPL 42 285 A.I. Afonin *et al.* (KIAE)
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AHRENS 85 PR D31 2732 L.A. Ahrens *et al.* (BNL, BROW, KEK+)
BELIKOV 85 SJNP 41 589 S.V. Belikov *et al.* (SERP)
Translated from YAF 41 919.
STOCKDALE 85 ZPHY C27 53 I.E. Stockdale *et al.* (ROCH, CHIC, COLU+)
ZACEK 85 PL 164B 193 V. Zacek *et al.* (MUNI, CIT, SIN)
BALLAGH 84 PR D30 2271 H.C. Ballagh *et al.* (UCB, LBL, FNAL+)
BERGSMA 84 PL 142B 103 F. Bergsma *et al.* (CHARM Collab.)
CAVAIGNAC 84 PL 148B 387 J.F. Cavaignac *et al.* (ISNG, LAPP)
DYDAK 84 PL 134B 281 F. Dydak *et al.* (CERN, DORT, HEIDH, SACL+)
GABATHULER 84 PL 138B 449 K. Gabathuler *et al.* (CIT, SIN, MUNI)
STOCKDALE 84 PRL 52 1384 I.E. Stockdale *et al.* (ROCH, CHIC, COLU+)
AFONIN 83 JETPL 38 436 A.I. Afonin *et al.* (KIAE)
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BELENKII 83 JETPL 38 493 S.N. Belenky *et al.* (KIAE)
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Translated from ZETFP 38 547.
TAYLOR 83 PR D28 2705 G.N. Taylor *et al.* (HAWA, LBL, FNAL)
COOPER 82 PL 112B 97 A.M. Cooper *et al.* (RL)
VUILLEUMIER 82 PL 114B 298 J.L. Vuilleumier *et al.* (CIT, SIN, MUNI)
ARMENISE 81 PL 100B 182 N. Armenise *et al.* (BARI, CERN, MILA+)
ASRATYAN 81 PL 105B 301 A.E. Asratyan *et al.* (ITEP, FNAL, SERP+)
BAKER 81 PRL 47 1576 N.J. Baker *et al.* (BNL, COLU)
Also 78 PRL 40 144 A.M. Cnops *et al.* (BNL, COLU)
BOLIEV 81 SJNP 34 787 M.M. Boliev *et al.* (INRM)
Translated from YAF 34 1418.
DEDEN 81 PL 98B 310 H. Deden *et al.* (BEBC Collab.)
ERRIQUEZ 81 PL 102B 73 O. Erriquez *et al.* (BARI, BIRM, BRUX+)
KWON 81 PR D24 1097 H. Kwon *et al.* (CIT, ISNG, MUNI)
NEMETHY 81B PR D23 262 P. Nemethy *et al.* (YALE, LBL, LASL+)
SILVERMAN 81 PRL 46 467 D. Silverman, A. Soni (UCI, UCLA)
USHIDA 81 PRL 47 1694 N. Ushida *et al.* (AICH, FNAL, KOBE, SEOU+)
AVIGNONE 80 PR C22 594 F.T. Avignone, Z.D. Greenwood (SCUC)
BOEHM 80 PL 97B 310 F. Boehm *et al.* (ILLG, CIT, ISNG, MUNI)
FRITZE 80 PL 96B 427 P. Fritze (AACH3, BONN, CERN, LOIC, OXF+)
REINES 80 PRL 45 1307 F. Reines, H.W. Sobel, E. Pasierb (UCI)
Also 59 PR 113 273 F. Reines, C.L. Cowan (LASL)
Also 66 PR 142 852 F.A. Nezrick, F. Reines (CASE)
Also 76 PRL 37 315 F. Reines, H.S. Gurr, H.W. Sobel (UCI)

DAVIS 79 PR C19 2259 R. Davis *et al.* (CIT)
BLIETSCHAU 78 NP B133 205 J. Blietschau *et al.* (Gargamelle Collab.)
CROUCH 78 PR D18 2239 M.F. Crouch *et al.* (CASE, UCI, WITW)
BELLOTTI 76 LNC 17 553 E. Bellotti *et al.* (MILA)