Neutrino Mixing

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(A) Accelerator neutrino appearance 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. • • •					
< 7.5	90	[2] ESKUT	01	CHRS	CERN SPS
< 6.5	90	[3] ASTIER	00C	NOMD	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 $^{12}C(\nu_e,e^-)^{12}N_{gs}$ essentially free from this background. The reported limits on the parameters of ν_e disappearance are not competitive. A three-flavor analysis is also presented.

[2] ESKUT 01 limit 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 00C.

[3] ASTIER 00C limit is based on an oscillation probability $< 1.1\times10^{-2}$, whereas the quoted sensitivity was 2.0×10^{-2}. The limit was obtained following the statitical prescriptions of FELDMAN 98. See also the footnote to ESKUT 01.

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.022	90	[4] ASTIER	00C	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 00C limit is based on an oscillation probability $< 1.1\times10^{-2}$, whereas the quoted sensitivity was 2.0×10^{-2}. The limit was obtained following the statitical 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 00C.

[6] See foonote 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. • • •					
<40	90	[10] BORISOV	96	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.
[10] BORISOV 96 exclusion curve extrapolated to obtain this value; however, it does not have the right curvature in this region.

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<7 × 10^{-2}	90	[11] ERRIQUEZ	81	HLBC	BEBC CERN SPS
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.4	90	[12] HAMPEL	98	GALX	^{51}Cr source
<0.115	90	[13] BORISOV	96	CNTR	$\Delta(m^2) = 175$ eV^2
<0.54	90	BRUCKER	86	HLBC	15-ft FNAL
<0.6	90	BAKER	81	HLBC	15-ft FNAL
<0.3	90	[11] DEDEN	81	HLBC	BEBC CERN SPS

[11] Obtained from a Gaussian centered in the unphysical region.
[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.
[13] BORISOV 96 sets less stringent limits at large $\Delta(m^2)$, but exclusion curve does not have clear asymptotic behavior.

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

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	[14] FREEDMAN	93	CNTR	LAMPF
• • • We do not use the following data for averages, fits, limits, etc. • • •					

<7	90	[15] COOPER	82	HLBC	BEBC CERN SPS

[14] 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 $\overline{\nu}_e p \to e^+ n$.

[15] 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	[16] FREEDMAN	93	CNTR	LAMPF
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.05	90	[17] COOPER	82	HLBC	BEBC CERN SPS

[16] 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 $\overline{\nu}_e p \to e^+ n$.

[17] 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
<0.09	90	ANGELINI	86	HLBC	BEBC CERN PS
• • • We do not use the following data for averages, fits, limits, etc. • • •					
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
<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

[18] ATHANASSOPOULOS 98 is a search for the $\nu_\mu \to \nu_e$ oscillations using ν_μ from π^+ decay in flight. The 40 observed beam-on electron events are consistent with $\nu_e \mathrm{C} \to e^- \mathrm{X}$; 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 $\overline{\nu}_\mu \to \overline{\nu}_e$ 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
< 3.0	90	[22] LOVERRE	96		CHARM/CDHS
< 2.5	90	AMMOSOV	88	HLBC	SKAT at Serpukhov
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.0005 to 0.03	95	[23] ATHANASSO...	98	LSND	$\nu_\mu \rightarrow \nu_e$
< 9.4	90	VILAIN	94C	CHM2	CERN SPS
< 5.6	90	[24] VILAIN	94C	CHM2	CERN SPS
< 16	90	BLUMENFELD	89	CNTR	
< 8	90	BERGSMA	88	CHRM	$\Delta(m^2) \geq 30$ eV^2
		[25] LOVERRE	88	RVUE	
< 10	90	AHRENS	87	CNTR	BNL AGS
< 15	90	BOFILL	87	CNTR	FNAL
< 20	90	[26] ANGELINI	86	HLBC	BEBC CERN PS
20 to 40		[27] BERNARDI	86B	CNTR	$\Delta(m^2)$=5–10
< 11	90	[28] 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] LOVERRE 96 uses the charged-current to neutral-current ratio from the combined CHARM (ALLABY 86) and CDHS (ABRAMOWICZ 86) data from 1986.

[23] 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.

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

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

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

[27] 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.

[28] 15ft bubble chamber at FNAL.

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

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

VALUE (eV^2)	CL%	DOCUMENT ID		TECN	COMMENT
<0.14	90	[29] FREEDMAN	93	CNTR	LAMPF

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

0.05–0.08	90	[30] ATHANASSO...	96	LSND	LAMPF
0.048–0.090	80	[31] ATHANASSO...	95		
<0.07	90	[32] HILL	95		
<0.9	90	VILAIN	94C	CHM2	CERN SPS
<3.1	90	BOFILL	87	CNTR	FNAL
<2.4	90	TAYLOR	83	HLBC	15-ft FNAL
<0.91	90	[33] NEMETHY	81B	CNTR	LAMPF
<1	95	BLIETSCHAU	78	HLBC	GGM CERN PS

[29] 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.

[30] 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 $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ or $\nu_e \rightarrow \overline{\nu}_e$; our entry assumes the first interpretation. They are detected through $\overline{\nu}_e p \rightarrow e^+ n$ (20 MeV $< E_{e^+} <$60 MeV) in delayed coincidence with $np \rightarrow d\gamma$. Authors observe 51 $\pm$ 20 $\pm$ 8 total excess events over an estimated background 12.5 $\pm$ 2.9. ATHANASSOPOULOS 96B is a shorter version of this paper.

[31] ATHANASSOPOULOS 95 error corresponds to the 1.6σ band in the plot. The expected background is 2.7 $\pm$ 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.

[32] 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.

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

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.004	95	BLIETSCHAU	78	HLBC	GGM CERN PS

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

$0.0062 \pm 0.0024 \pm 0.0010$		[34] ATHANASSO...	96	LSND	LAMPF
0.003–0.012	80	[35] ATHANASSO...	95		
<0.006	90	[36] HILL	95		
<4.8	90	VILAIN	94C	CHM2	CERN SPS
<5.6	90	[37] VILAIN	94C	CHM2	CERN SPS
<0.024	90	[38] FREEDMAN	93	CNTR	LAMPF
<0.04	90	BOFILL	87	CNTR	FNAL
<0.013	90	TAYLOR	83	HLBC	15-ft FNAL
<0.2	90	[39] NEMETHY	81B	CNTR	LAMPF

[34] 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.

[35] ATHANASSOPOULOS 95 error corresponds to the 1.6σ band in the plot. The expected background is 2.7 $\pm$ 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.

[36] 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.

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

[38] 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.

[39] 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	[40] ROMOSAN	97	CCFR	FNAL

[40] 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	[41] ROMOSAN	97	CCFR	FNAL
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<3.8	90	[42] MCFARLAND	95	CCFR	FNAL
<3	90	BORODOV...	92	CNTR	BNL E776

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

[42] 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	[43] ESKUT	01	CHRS	CERN SPS
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 0.8	90	[44] ASTIER	00C	NOMD	CERN SPS
< 1.2	90	[45] ASTIER	99	NOMD	CERN SPS
< 1.4	90	[46] ALTEGOER	98B	NOMD	CERN SPS
< 1.5	90	[47] ESKUT	98	CHRS	CERN SPS
< 1.1	90	[48] ESKUT	98B	CHRS	CERN SPS
< 3.3	90	[49] 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

[43] 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 00C.

[44] ASTIER 00C limit is based on an oscillation probability $< 2.2\times10^{-4}$, whereas the quoted sensitivity was 4.3×10^{-4}. The limit was obtained following the statitical prescriptions of FELDMAN 98. See also the footnote to ESKUT 01.

[45] ASTIER 99 limits are based on data corresponding to $\sim$ 950000 ν_μCC interactions in the 1995, 1996, and (most) 1997 runs. This is a "blind" analysis using the FELDMAN 98 classical CL approach, and other algorithms have also been improved since ALTEGOER 98B.

[46] 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.

[47] 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.

[48] 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.

[49] 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
<0.00044	90	[50] ASTIER	00C	NOMD	CERN SPS
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.00068	90	[51] ESKUT	01	CHRS	CERN SPS
<0.0012	90	[52] ASTIER	99	NOMD	CERN SPS
<0.0042	90	[53] ALTEGOER	98B	NOMD	CERN SPS
<0.0035	90	[54] ESKUT	98	CHRS	CERN SPS
<0.0018	90	[55] ESKUT	98B	CHRS	CERN SPS
<0.006	90	[56] 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

[50] ASTIER 00C limit is based on an oscillation probability $< 2.2\times10^{-4}$, whereas the quoted sensitivity was 4.3×10^{-4}. The limit was obtained following the statitical prescriptions of FELDMAN 98. See also the footnote to ESKUT 01.

[51] 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 00C.

[52] ASTIER 99 limits are based on data corresponding to $\sim$ 950000 ν_μCC interactions in the 1995, 1996, and (most) 1997 runs. This is a "blind" analysis using the FELDMAN 98 classical CL approach, and other algorithms have also been improved since ALTEGOER 98B.

[53] 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.

[54] 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.

[55] 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.

[56] 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 × 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 × 10^{-2}	90	TAYLOR	83	HLBC	15-ft FNAL

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

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

VALUE (eV^2)	CL%	DOCUMENT ID		TECN	COMMENT
<1.5	90	[57] GRUWE	93	CHM2	CERN SPS

[57] GRUWE 93 is a search using the CHARM II detector in the CERN SPS wide-band neutrino beam for $\nu_\mu \rightarrow \nu_\tau$ and $\overline{\nu}_\mu \rightarrow \overline{\nu}_\tau$ oscillations signalled by quasi-elastic ν_τ and $\overline{\nu}_\tau$ interactions followed by the decay $\tau \rightarrow \nu_\tau \pi$. 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	[58] GRUWE	93	CHM2	CERN SPS

[58] GRUWE 93 is a search using the CHARM II detector in the CERN SPS wide-band neutrino beam for $\nu_\mu \rightarrow \nu_\tau$ and $\overline{\nu}_\mu \rightarrow \overline{\nu}_\tau$ oscillations signalled by quasi-elastic ν_τ and $\overline{\nu}_\tau$ interactions followed by the decay $\tau \rightarrow \nu_\tau \pi$. 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
<0.23 OR >1500 OUR LIMIT					
<0.23 OR >100	90	DYDAK	84	CNTR	
<13 OR >1500	90	STOCKDALE	84	CNTR	
• • • 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	
<8.0	90	BELIKOV	83	CNTR	

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.02	90	[59] STOCKDALE	85	CNTR	FNAL
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.17	90	[60] BERGSMA	88	CHRM	
<0.07	90	[61] BELIKOV	85	CNTR	Serpukhov
<0.27	90	[60] BERGSMA	84	CHRM	CERN PS
<0.1	90	[62] DYDAK	84	CNTR	CERN PS
<0.02	90	[63] STOCKDALE	84	CNTR	FNAL
<0.1	90	[64] BELIKOV	83	CNTR	Serpukhov

[59] 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.

[60] 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.

[61] 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%.

[62] 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.

[63] 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.

[64] 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 $eV^2 < \Delta(m^2) < 320$ eV^2

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.02	90	[65] STOCKDALE	85	CNTR	FNAL

[65] 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	[66] FREEDMAN	93	CNTR	LAMPF
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.7	90	[67] COOPER	82	HLBC	BEBC CERN SPS

[66] 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.
[67] 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	[68] COOPER	82	HLBC	BEBC CERN SPS
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.07	90	[69] FREEDMAN	93	CNTR	LAMPF

[68] COOPER 82 states that existing bounds on V+A currents require α to be small.
[69] 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 $\sin^2\theta$

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

In most cases, the reaction $\overline{\nu}_e p \to e^+ n$ 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. • • •				
1.04 ±0.03 ±0.08	[70] BOEHM	00C		Palo Verde react. 0.75–0.89 km
1.01 ±0.028±0.027	[71] APOLLONIO	99	CHOZ	Chooz reactors 1 km
0.987±0.006±0.037	[72] GREENWOOD	96		Savannah River, 18.2 m
0.988±0.004±0.05	ACHKAR	95	CNTR	Bugey reactor, 15 m
0.994±0.010±0.05	ACHKAR	95	CNTR	Bugey reactor, 40 m
0.915±0.132±0.05	ACHKAR	95	CNTR	Bugey reactor, 95 m
0.987±0.014±0.027	[73] DECLAIS	94	CNTR	Bugey reactor, 15 m
0.985±0.018±0.034	KUVSHINN...	91	CNTR	Rovno reactor
1.05 ±0.02 ±0.05	VUILLEUMIER	82		Gösgen reactor
0.955±0.035±0.110	[74] KWON	81		$\overline{\nu}_e p \to e^+ n$
0.89 ±0.15	[74] BOEHM	80		$\overline{\nu}_e p \to e^+ n$
0.38 ±0.21	[75,76] REINES	80		
0.40 ±0.22	[75,76] REINES	80		

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

[71] 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.

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

[73] 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.

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

[75] 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.

[76] 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
<0.0007	90	[77] APOLLONIO	99	CHOZ	Chooz reactors 1 km
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.0011	90	[78] BOEHM	00		Palo Verde react. 0.8 km
<0.01	90	[79] ACHKAR	95	CNTR	Bugey reactor
<0.0075	90	[80] VIDYAKIN	94		Krasnoyark reactors
<0.04	90	[81] AFONIN	88	CNTR	Rovno reactor
<0.014	68	[82] VIDYAKIN	87		$\overline{\nu}_e p \rightarrow e^+ n$
<0.019	90	[83] ZACEK	86		Gösgen reactor

[77] 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.

[78] 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.

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

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

[81] 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.

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

[83] 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
<0.02	90	[84] ACHKAR	95	CNTR	For $\Delta(m^2) = 0.6$ eV^2

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

<0.21	90	[85] BOEHM	00		Palo Verde react. 0.8 km
<0.10	90	[86] APOLLONIO	99	CHOZ	Chooz reactors 1 km
<0.24	90	[87] GREENWOOD	96		
<0.04	90	[87] GREENWOOD	96		For $\Delta(m^2) = 1.0$ eV^2
<0.087	68	[88] VYRODOV	95	CNTR	For $\Delta(m^2)$ >2 eV^2
<0.15	90	[89] VIDYAKIN	94		For $\Delta(m^2) > 5.0 \times 10^{-2}$ eV^2
<0.2	90	[90] AFONIN	88	CNTR	$\overline{\nu}_e p \rightarrow e^+ n$
<0.14	68	[91] VIDYAKIN	87		$\overline{\nu}_e p \rightarrow e^+ n$
<0.21	90	[92] ZACEK	86		$\overline{\nu}_e p \rightarrow e^+ n$
<0.19	90	[93] ZACEK	85		Gösgen reactor
<0.16	90	[94] GABATHULER	84		$\overline{\nu}_e p \rightarrow e^+ n$

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

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

[86] APOLLONIO 99 search for neutrino oscillations at 1.1 km fixed distance from Chooz reactors.

[87] 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.

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

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

[90] 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.

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

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

[93] 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."

[94] 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. • • •

$0.64 \pm 0.11 \pm 0.06$	[95] ALLISON	99	SOU2	Calorimeter
$0.61 \pm 0.03 \pm 0.05$	[96] FUKUDA	98	SKAM	sub-GeV
$0.66 \pm 0.06 \pm 0.08$	[97] FUKUDA	98E	SKAM	multi-GeV
	[98] FUKUDA	96B	KAMI	Water Cerenkov
$1.00 \pm 0.15 \pm 0.08$	[99] DAUM	95	FREJ	Calorimeter
$0.60^{+0.06}_{-0.05} \pm 0.05$	[100] FUKUDA	94	KAMI	sub-GeV
$0.57^{+0.08}_{-0.07} \pm 0.07$	[101] FUKUDA	94	KAMI	multi-Gev
	[102] BECKER-SZ...	92B	IMB	Water Cerenkov

[95] ALLISON 99 result is based on an exposure of 3.9 kton yr, 2.6 times the exposure reported in ALLISON 97, and replaces that result.

[96] 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.

[97] 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.

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

[99] 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.

[100] 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.

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

[102] BECKER-SZENDY 92B reports the fraction of nonshowering events (mostly muons from atomospheric 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.

$R(\nu_\mu)$ = (Measured Flux of ν_μ) / (Expected Flux of ν_μ)

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.57 \pm 0.05 \pm 0.15$	[103] AMBROSIO	00	MCRO	upgoing partially contained
$0.71 \pm 0.05 \pm 0.19$	[104] AMBROSIO	00	MCRO	downgoing partially contained + upgoing stopping
$0.74 \pm 0.036 \pm 0.046$	[105] AMBROSIO	98	MCRO	Streamer tubes
	[106] CASPER	91	IMB	Water Cherenkov
	[107] AGLIETTA	89	NUSX	
0.95 ± 0.22	[108] BOLIEV	81		Baksan
0.62 ± 0.17	CROUCH	78		Case Western/UCI

[103] 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.

[104] 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.

[105] 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.

[106] 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).

[107] 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 ρ(measured)=ρ(expected) = $0.96^{+0.32}_{-0.28}$.

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

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

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$1.1^{+0.07}_{-0.12} \pm 0.11$	[109] CLARK	97	IMB	multi-GeV

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

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

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.52^{+0.07}_{-0.06} \pm 0.01$	[110] FUKUDA	98E	SKAM	multi-GeV

[110] 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 $0.98 \pm 0.03 \pm 0.02$.

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

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.84^{+0.14}_{-0.12} \pm 0.02$	[111] FUKUDA	98E	SKAM	multi-GeV

[111] 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 conpared to an expected value of $1.01 \pm 0.06 \pm 0.03$.

$\sin^2(2\theta)$ 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	[112] OYAMA	98	KAMI	$\Delta(m^2) > 0.1$ eV^2
<0.5		[113] CLARK	97	IMB	$\Delta(m^2) > 0.1$ eV^2
>0.55	90	[114] FUKUDA	94	KAMI	$\Delta(m^2) = 0.007$–0.08 eV^2
<0.47	90	[115] BERGER	90B	FREJ	$\Delta(m^2) > 1$ eV^2
<0.14	90	LOSECCO	87	IMB	$\Delta(m^2) = 0.00011$ eV^2

[112] 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.

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

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

[115] BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antinuetrino 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	[116] OYAMA	98	KAMI
<980		[117] CLARK	97	IMB
$700 < \Delta(m^2) < 7000$	90	[118] FUKUDA	94	KAMI
<150	90	[119] BERGER	90B	FREJ

[116] 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.

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

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

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

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

VALUE (10^{-5} eV^2)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.9	99	[120] SMIRNOV	94	THEO	$\Delta(m^2) > 3 \times 10^{-4}$ eV^2
<0.7	99	[120] SMIRNOV	94	THEO	$\Delta(m^2) < 10^{-11}$ eV^2

[120] 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 $\Delta(m^2)$ ($\nu_\mu \leftrightarrow \nu_\tau$)

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>0.25	90	[121] AMBROSIO	00	MCRO	$\Delta(m^2) > 3 \times 10^{-4}$ eV^2
>0.4	90	[122] FUKUDA	99C	SKAM	$\Delta(m^2)$= 0.001–0.1 eV^2
>0.7	90	[123] FUKUDA	99D	SKAM	$\Delta(m^2)$= 0.0015–0.015 eV^2
>0.82	90	[124] AMBROSIO	98	MCRO	$\Delta(m^2) \sim 0.0025$ eV^2
>0.82	90	[125] FUKUDA	98C	SKAM	$\Delta(m^2)$ = 0.0005–0.006 eV^2
>0.3	90	[126] HATAKEYAMA	98	KAMI	$\Delta(m^2)$= 0.00055–0.14 eV^2
>0.73	90	[127] HATAKEYAMA	98	KAMI	$\Delta(m^2)$= 0.004–0.025 eV^2
<0.7		[128] CLARK	97	IMB	$\Delta(m^2) >$ 0.1 eV^2
>0.65	90	[129] FUKUDA	94	KAMI	$\Delta(m^2)$ = 0.005–0.03 eV^2
<0.5	90	[130] BECKER-SZ...	92	IMB	$\Delta(m^2)$= 1–2 $\times 10^{-4}$ eV^2
<0.6	90	[131] BERGER	90B	FREJ	$\Delta(m^2) > 1$ eV^2

[121] 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.

[122] 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 $(1.74 \pm 0.07 \pm 0.02) \times 10^{-13}$ 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 hypotheis.

[123] 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.

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

[125] 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.

[126] 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.

[127] 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.

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

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

[130] 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.

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

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

VALUE (10^{-5} eV^2)	*CL%*	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$>$ 35	90	[132] AMBROSIO	00	MCRO
100$<\Delta(m^2)<$ 5000	90	[133] FUKUDA	99C	SKAM
150$<\Delta(m^2)<$ 1500	90	[134] FUKUDA	99D	SKAM
50$<\Delta(m^2)<$ 600	90	[135] AMBROSIO	98	MCRO
50$<\Delta(m^2)<$ 600	90	[136] FUKUDA	98C	SKAM
55$<\Delta(m^2)<$ 5000	90	[137] HATAKEYAMA	98	KAMI
400$<\Delta(m^2)<$ 2300	90	[138] HATAKEYAMA	98	KAMI
$<$1500		[139] CLARK	97	IMB
500 $<\Delta(m^2)<$ 2500	90	[140] FUKUDA	94	KAMI
$<$ 350	90	[141] BERGER	90B	FREJ

[132] 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.

[133] 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 ± 0.07 ± 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 hypotheis.

[134] 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 ± 0.04 ± 0.02) $\times 10^{-13}$ cm^{-2} s^{-1} sr^{-1}. This is compared to the expected flux of (0.73 ± 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 × 10^{-3} eV^2.

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

[136] 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 $\Delta(m^2)$=2.2×10^{-3} eV^2. In addition, FUKUDA 98C gave the 99% confidence interval, $\sin^2 2\theta > 0.73$ and $3\times10^{-4} < \Delta(m^2) < 8.5\times10^{-3}$ eV^2. FUKUDA 98C also tested the $\nu_\mu \rightarrow \nu_e$ hypothesis, and concluded that it is not favored.

[137] 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_μ > 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)) × 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 × 10^{-3} eV^2.

[138] 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 × 10^{-2} eV^2.

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

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

[141] BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antinuetrino 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	[142] OYAMA	89	KAMI	Water Cerenkov
< 4.2 or > 54.	90	BIONTA	88	IMB	Flux has ν_μ, $\overline{\nu}_\mu$, ν_e, and $\overline{\nu}_e$

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

(D) Solar ν Experiments

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

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
$65.8^{+10.2}_{-\ 9.6}{}^{+3.4}_{-3.6}$ SNU	[143] ALTMANN	00	GNO	^{71}Ga → ^{71}Ge

$74.1^{+6.7}_{-6.8}$ SNU	[144] ALTMANN	00	GNO	GNO + GALX combined
$67.2^{+7.2}_{-7.0}{}^{+3.5}_{-3.0}$ SNU	[145] ABDURASHI...	99B	SAGE	^{71}Ga → ^{71}Ge
$(2.44 \pm 0.05^{+0.09}_{-0.07}) \times 10^6$ cm^{-2}s^{-1}	[146] FUKUDA	99	SKAM	^{8}B ν flux (all)
$(2.37 \pm 0.07) \times 10^6$ cm^{-2}s^{-1}	[146] FUKUDA	99	SKAM	^{8}B ν flux (day)
$(2.48^{+0.07}_{-0.06}) \times 10^6$ cm^{-2}s^{-1}	[146] FUKUDA	99	SKAM	^{8}B ν flux (night)
	[147] FUKUDA	99B	SKAM	Recoil e spectrum
$77.5 \pm 6.2^{+4.3}_{-4.7}$ SNU	[148] HAMPEL	99	GALX	^{71}Ga → ^{71}Ge
$2.56 \pm 0.16 \pm 0.16$ SNU	[149] CLEVELAND	98	HOME	^{37}Cl radiochem.
$(2.80 \pm 0.19 \pm 0.33)\times 10^6$cm^{-2}s^{-1}	[150] FUKUDA	96	KAMI	^{8}Bν flux
$(2.70 \pm 0.27)\times 10^6$cm^{-2}s^{-1}	[150] FUKUDA	96	KAMI	^{8}Bν flux (day)
$(2.87^{+0.27}_{-0.26})\times 10^6$cm^{-2}s^{-1}	[150] FUKUDA	96	KAMI	^{8}Bν flux (night)

[143] 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 essentilaly the same as that of GALLEX. The run data cover the period 20 May 1998 through 12 January 2000.

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

[145] ABDURASHITOV 99B is a detailed report of the SAGE solar-neutrino experiment during the period January 1990 through December 1997, and updates the ABDURASHITOV 94 result. However the data in the period November 1993 through June 1994 were not used in determining the neutrino capture rate due to some uncertainty with respect to experimental control. A total of 211 ^{71}Ge events were observed.

[146] FUKUDA 99 results are for a total of 503.8 live days with Super-Kamiokande between 31 May 1996 and 25 March 1998, with threshold $E_e > 6.5$ MeV, and replace FUKUDA 98B results. The day-night solar-neutrino flux asymmetry is given as N/D$-$1=0.047$\pm$0.042$\pm$0.008. The results are also given for night fluxes subdivided into five data sets according to nadir of the Sun at the time of the neutrino event. FUKUDA 99 set an absolute flux-independent exclusion region in the two-neutrino oscillation parameter space from the absence of a significant day-night variation. Except for +0.6%/$-$0.5%, the systematic errors are common to day and night fluxes.

[147] FUKUDA 99B reports the energy spectrum of recoil electrons from elastic scattering of solar neutrinos for a total of 503.8 live days of Super-Kamiokande observation. A comparison of the observed spectrum with the expectation is in poor agreement at the 4.6% confidence level.

[148] 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 $\pm$ 17.8 $\pm$ 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.

[149] 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.

[150] 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.

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		Translated from ZETFP 44 111.		
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)
		Translated from ZETFP 42 230.		
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)
		Translated from ZETFP 38 361.		
BELENKII	83	JETPL 38 493	S.N. Belenky *et al.*	(KIAE)
		Translated from ZETFP 38 406.		
BELIKOV	83	JETPL 38 661	S.V. Belikov *et al.*	(SERP)
		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)