Heavy Neutral Leptons, Searches for

OMITTED FROM SUMMARY TABLE

We define searches for Heavy Neutral Leptons (HNLs) as searches for Dirac or Majorana fermions with sterile neutrino quantum numbers, that are heavy enough to not disrupt the simplest Big Bang Nucleosynthesis bounds and/or unstable on cosmological timescales: Typically HNLs have mass $\sim$ MeV or higher.

Searches for these particles generically set bounds on the mixing between the HNL and the active neutrinos, as parametrized by the extended 3×4 PMNS matrix elements $U_{\ell x}$ (see the "Neutrino mass, mixing and oscillations" review) where $\ell = e$, μ or τ, and we denote the HNL as ν_x. While many measurements may be interpreted to place bounds on various combinations of these matrix elements, we quote below limits only for those cases in which one matrix element is assumed to be much larger than the other two, i.e. $\left|U_{\ell x}\right| \gg \left|U_{\ell' x}\right|$ for $\ell' \neq \ell$.

Experimental searches make use of various different strategies, including e.g. resonance searches in missing mass decay distributions or specific final states, searches for lepton number violating decays, and trilepton signatures. The resulting bounds on $U_{\ell x}$ are typically dependent on the HNL mass. The quoted limits below are either the best limit near an experimental kinematic threshold, or a characteristic value in the mass range of the experimental sensitivity.

Limits on heavy neutral lepton mixing parameters

Limits on $\left|U_{ex}\right|^2$

Quoted limits are either the best limit near the kinematic threshold of the experiment, or a characteristic value in the mass range of the experimental sensitivity

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<5 \times 10^{-7}$	95	[1] AAD	23AO	ATLS	$m_{\nu_x} \sim$ 3–15 GeV, pp at 13 TeV
$<3 \times 10^{-4}$	90	[2] AGNES	23A	DS50	$m_{\nu_x} \sim$ 7–35 keV
$<3 \times 10^{-8}$	90	[3] BAROUKI	22	RVUE	Near $m_{D_s} - m_e$ kin. thres.
$<1 \times 10^{-6}$	95	[4] TUMASYAN	22AD	CMS	$m_{\nu_x} \sim$ 8–14 GeV, pp at 13 TeV
$<2 \times 10^{-4}$	95	[5] FRIEDRICH	21		Near $m_{^7\text{Be}} - m_{^7\text{Li}}$ kin. thres.
$<1 \times 10^{-9}$	90	[6] CORTINA-GIL	20	NA62	$m_{\nu_x} \sim$ 150–400 MeV
$<2 \times 10^{-5}$	95	[7] AAD	19F	ATLS	$m_{\nu_x} \sim$ 15–40 GeV
$<1 \times 10^{-9}$	90	[8] ABE	19B	T2K	Near $m_K - m_e$ kin. thres.
$<1 \times 10^{-4}$	90	[9] ABLIKIM	19AL	BES3	$m_{\nu_x} \sim$ 0.3–0.7 GeV
$<2 \times 10^{-7}$	90	[10] BRYMAN	19	RVUE	$m_{\nu_x} \sim$ 55 MeV
$<1 \times 10^{-8}$	90	[11] AGUILAR-AR...	18A	PIEN	$m_{\nu_x} \sim$ 60–120 MeV
$<3 \times 10^{-7}$	90	[12] CORTINA-GIL	18	NA62	$m_{\nu_x} \sim$ 200–400 MeV

$<1 \times 10^{-6}$	90	[13] PARK	16	BELL	$m_{\nu_x} \sim 1.4$ GeV
$<3 \times 10^{-5}$	90	[14] LIVENTSEV	13	BELL	Near $m_{\nu_x} \sim$ 2–2.5 GeV
$<3 \times 10^{-5}$	95	[15] ABREU	97I	DLPH	$m_{\nu_x} \sim$ 6–50 GeV
$<2 \times 10^{-5}$	95	[16] ABREU	97I	DLPH	Near $m_{\nu_x} \sim 3.5$ GeV
$<1 \times 10^{-5}$	90	[17] BARANOV	93		Near $m_\pi - m_e$ kin. thres.
$<2 \times 10^{-7}$	90	[17] BARANOV	93		Near $m_K - m_e$ kin. thres.
$<1 \times 10^{-7}$		[18,19] BERNARDI	88	CNTR	Near $m_\pi - m_e$ kin. thres.
$<2 \times 10^{-9}$		[19,20] BERNARDI	88	CNTR	Near $m_K - m_e$ kin. thres.
$<1 \times 10^{-7}$	90	[21] DORENBOS...	86	CHRM	Near $m_D - m_e$ kin. thres.
$<1 \times 10^{-7}$	90	[22] COOPER-...	85	BEBC	Near $m_D - m_e$ kin. thres.

[1] AAD 23AO search for $W \rightarrow \nu_x e$, for both Majorana and Dirac HNL scenarios. Also consider scenarios involving multiflavor mixing, with correspondingly weaker limits.

[2] Search for ionization signals in an LArTPC. Assumes the candidate particle is 100% of dark matter.

[3] Reanalysis of BEBC results (cf. COOPER-SARKAR 85) to update searches for $D_s^{\pm} \rightarrow \nu_x e^{\pm}$ using a corrected formula for the HNL decay probabilities, additional production channels, and an improved fit for the charm meson distributions. Assumes a Majorana HNL.

[4] TUMASYAN 22AD search for $W \rightarrow e\nu_x$, $\nu_x \rightarrow e\mu\nu_\mu$ and set limits for Dirac and Majorana Heavy Neutral Leptons. The data correspond to an integrated luminosity of 138 fb^{-1}.

[5] Search in electron capture decay ^{7}Be $\rightarrow$ ^{7}Liν_x. Kinematic threshold is $\sim$ 850 keV.

[6] Search for $K^+ \rightarrow e^+\nu_x$. Assumes lifetime of $\nu_x > 50$ ns.

[7] Limit from prompt lepton number violating trilepton search.

[8] $K^+ \rightarrow e^+\nu_x$, with ν_x decay through U_{ex}. ABE 19B also considers bounds on $|U_{\ell x}\, U_{\ell' x}|$ for combinations of lepton flavors in the ν_x decay final state.

[9] Searches for a Majorana Heavy Neutral Lepton producing a $\pi^- e^+$ resonance in the same sign dilepton decay $D \rightarrow K\pi^- e^+ e^+$.

[10] BRYMAN 19 sets best limits $|\mathrm{U}_{ex}|^2 < 1 \times 10^{-4}$–$2 \times 10^{-7}$ in the mass range $m_{\nu_x} \sim$ 2–55 MeV, respectively, using the precision branching ratio measurement in AGUILAR-AREVALO 15. See also BRYMAN 19A.

[11] Search for $\pi^+ \rightarrow e^+\nu_x$.

[12] Search for $K^+ \rightarrow e^+\nu_x$.

[13] PARK 16 quotes an approximate limit B($B^+ \rightarrow e^+\nu_x$) $< 3 \times 10^{-6}$ in the mass range $m_{\nu_x} \sim$ 0.2–1.4 GeV.

[14] Search for $B^+ \rightarrow e^+\nu_x$.

[15] Search for prompt ν_x decay signatures.

[16] Search for displaced ν_x decay signatures.

[17] Searches for K or $\pi \rightarrow e^+\nu_x$, $\nu_x \rightarrow e^+e^-\nu_e$ using a beam dump experiment at the 70 GeV Serpukhov proton synchrotron. BARANOV 93 also considers limits for $|U_{ex}\, U_{\mu x}|$ from K or $\pi \rightarrow \mu^+\nu_x$, $\nu_x \rightarrow e^+e^-\nu_e$.

[18] $\pi^+ \rightarrow e^+\nu_x$, with ν_x decay through U_{ex}.

[19] BERNARDI 88 also considers bounds on $|U_{ex}\, U_{\mu x}|$.

[20] $K^+ \rightarrow e^+\nu_x$, with ν_x decay through U_{ex}.

[21] $D^+ \rightarrow e^+\nu_x$, with $\nu_x \rightarrow e^-\ell^+\nu_\ell$.

[22] $D^+ \rightarrow e^+\nu_x$, with $\nu_x \rightarrow e^-\ell^+\nu_\ell$ or $\nu_x \rightarrow e^-\pi^+$.

Limits on $|U_{\mu x}|^2$

Quoted limits are either the best limit near the kinematic threshold of the experiment, or a characteristic value in the mass range of the experimental sensitivity

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<5 \times 10^{-7}$	95	[1] AAD	23AO	ATLS	$m_{\nu_x} \sim$ 3–15 GeV, pp at 13 TeV
<0.1	95	[2] AAD	23CE	ATLS	Near $m_{\nu_x} \sim$ 0.1–2 TeV
<0.1	95	[3] TUMASYAN	23AC	CMS	Near $m_{\nu_x} \sim$ 0.1–3 TeV
$<5 \times 10^{-9}$	90	[4] ABRATENKO	22A	MBNE	Near $m_K - m_\mu$ kin. thres.
$<3 \times 10^{-7}$	95	[5] TUMASYAN	22AD	CMS	$m_{\nu_x} \sim$ 8–14 GeV, pp at 13 TeV
$<1 \times 10^{-3}$	95	[6] AAIJ	21AA	LHCB	$m_{\nu_x} \sim$ 5–50 GeV, pp at 7, 8 TeV
$<2 \times 10^{-4}$	95	[7] AAIJ	21AA	LHCB	$m_{\nu_x} \sim$ 5–50 GeV, pp at 7, 8 TeV
$<5 \times 10^{-9}$	90	[8,9] CORTINA-GIL	21	NA62	Near $m_K - m_\mu$ kin. thres.
$<2 \times 10^{-2}$	90	[10] PRIM	20	BELL	$m_{\nu_x} \sim$ 1 GeV
$<2 \times 10^{-5}$	95	[11] AAD	19F	ATLS	$m_{\nu_x} \sim$ 10–50 GeV
$<2 \times 10^{-6}$	95	[12] AAD	19F	ATLS	$m_{\nu_x} \sim$ 10 GeV
$<1 \times 10^{-9}$	90	[13] ABE	19B	T2K	Near $m_K - m_\mu$ kin. thres.
$<5 \times 10^{-6}$	90	[14,15] AGUILAR-AR...	19B	PIEN	$m_{\nu_x} \sim$ 16–30 MeV
$<1 \times 10^{-5}$	90	[15] AGUILAR-AR...	19B	PIEN	Near $m_\pi - m_\mu$ kin. thres.
$<3 \times 10^{-7}$	90	[8] CORTINA-GIL	18	NA62	$m_{\nu_x} \sim$ 250–350 MeV
$<3 \times 10^{-6}$	90	[8] LAZZERONI	17A	NA62	Near $m_K - m_\mu$ kin. thres.
$<5 \times 10^{-2}$	90	[16] PARK	16	BELL	$m_{\nu_x} \sim$ 1.4 GeV
$<1 \times 10^{-8}$	90	[8] ARTAMONOV	15A	B949	$m_{\nu_x} \sim$ 200–300 MeV
$<3 \times 10^{-5}$	90	[17] LIVENTSEV	13	BELL	Near $m_{\nu_x} \sim$ 2–2.5 GeV
$<2.0 \times 10^{-8}$	95	[18] DAUM	00	KARM	$m_{\nu_x} = 33.905$ MeV
$<8 \times 10^{-8}$	90	[19] VAITAITIS	99	CCFR	Near $m_K - m_\mu$ kin. thres.
$<6 \times 10^{-8}$	90	[20] VAITAITIS	99	CCFR	Near $m_{D_s} - m_\mu$ kin. thres.
$<3 \times 10^{-5}$	95	[21] ABREU	97I	DLPH	$m_{\nu_x} \sim$ 6–50 GeV
$<2 \times 10^{-5}$	95	[22] ABREU	97I	DLPH	Near $m_{\nu_x} \sim$ 3.5 GeV
$<3 \times 10^{-5}$	90	[23] VILAIN	95C	CHM2	Near $m_K - m_\mu$ kin. thres.
$<3 \times 10^{-8}$		[24,25] BERNARDI	88	CNTR	Near $m_\mu + m_\pi$ kin. thres.
$<2 \times 10^{-9}$		[25,26] BERNARDI	88	CNTR	Near $m_K - m_\mu$ kin. thres.
$<1 \times 10^{-7}$	90	[27] DORENBOS...	86	CHRM	Near $m_D - m_\mu$ kin. thres.
$<1 \times 10^{-7}$	90	[28] COOPER-...	85	BEBC	Near $m_D - m_\mu$ kin. thres.
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<1 \times 10^{-7}$	90	[29] ABRATENKO	20	MBNE	Superseded by ABRATENKO 22A

[1] AAD 23AO search for $W \to \nu_x \mu$, for both Majorana and Dirac HNL scenarios. Also consider scenarios involving multiflavor mixing, with correspondingly weaker limits.

[2] AAD 23CE search for Majorana HNLs via vector boson fusion $W^\pm W^\pm \to \mu^\pm \mu^\pm$. Limits set in a m_{ν_x} mass range from 50 GeV up to 20 TeV, using the Phenomenological Type-I Seesaw model as a benchmark scenario.

[3] TUMASYAN 23AC search for Majorana HNLs via vector boson fusion $W^\pm W^\pm \to \mu^\pm \mu^\pm$. Limits set in a m_{ν_x} mass range from 50 GeV up to 25 TeV.

[4] ABRATENKO 22A search for $K^+ \rightarrow \mu^+ \nu_x$, with $\nu_x \rightarrow \mu^\mp \pi^\pm$, in the mass range $m_{\nu_x} \sim$ 246–385 MeV. Also considers limits from $\nu_x \rightarrow \mu^- \pi^+$ only, for the case of a Dirac HNL.
[5] TUMASYAN 22AD search for $W \rightarrow \mu \nu_x$, $\nu_x \rightarrow \mu e \nu_e$ and set limits for Dirac and Majorana Heavy Neutral Leptons. The data correspond to an integrated luminosity of 138 fb^{-1}.
[6] Limit from prompt lepton number conserving $W \rightarrow \mu \mu j$ search.
[7] Limit from prompt lepton number violating $W \rightarrow \mu \mu j$ search .
[8] Search for $K^+ \rightarrow \mu^+ \nu_x$.
[9] Assumes a lifetime exceeding 50 ns, and searches over m_{ν_x} range 200–384 MeV.
[10] Search for $B^+ \rightarrow \mu^+ \nu_x$ in the mass range $m_{\nu_x} \sim$ 0–1.5 GeV .
[11] Limit from prompt lepton number violating trilepton search.
[12] Limit from displaced lepton violating or conserving trilepton searches.
[13] $K^+ \rightarrow \mu^+ \nu_x$, with ν_x decay through $U_{\mu x}$. ABE 19B also considers bounds on $\left|U_{\ell x}\, U_{\ell' x}\right|$ for combinations of lepton flavors in the ν_x decay final state.
[14] Limit requires muon kinetic energy $>$ 1.2 MeV.
[15] Search for $\pi^+ \rightarrow \mu^+ \nu_x$.
[16] PARK 16 quotes an approximate limit $\text{B}(B^+ \rightarrow \mu^+ \nu_x) < 3 \times 10^{-6}$ in the mass range $m_{\nu_x} \sim$ 0.2–1.4 GeV.
[17] Search for $B^+ \rightarrow \mu^+ \nu_x$.
[18] DAUM 00 quotes a branching ratio bound $\text{B}(\pi^+ \rightarrow \mu^+ \nu_x) < 6.0 \times 10^{-10}$ at 95% CL.
[19] $K^+ \rightarrow \mu^+ \nu_x$, with $\nu_x \rightarrow \mu X$.
[20] $D_s \rightarrow \mu^+ \nu_x$, with $\nu_x \rightarrow \mu X$.
[21] Search for prompt ν_x decay signatures.
[22] Search for displaced ν_x decay signatures.
[23] Search for Heavy Neutral Leptons produced by neutral current muon neutrino interactions, with $\nu_x \rightarrow \mu^+ \mu^- \nu_\mu$.
[24] $K^+ \rightarrow \mu^+ \nu_x$, with ν_x decay through $U_{\mu x}$ and $m_{\nu_x} < m_\mu + m_\pi$.
[25] BERNARDI 88 also considers bounds on $\left|U_{e x}\, U_{\mu x}\right|$.
[26] $K^+ \rightarrow \mu^+ \nu_x$, with $\nu_x \rightarrow \mu^- \pi^+$.
[27] $D^+ \rightarrow \mu^+ \nu_x$, with $\nu_x \rightarrow \mu^- \ell^+ \nu_\ell$.
[28] $D^+ \rightarrow \mu^+ \nu_x$, with $\nu_x \rightarrow \mu^- \ell^+ \nu_\ell$ or $\nu_x \rightarrow \mu^- \pi^+$.
[29] $K^+ \rightarrow \mu^+ \nu_x$, with $\nu_x \rightarrow \mu^- \pi^+$, in the mass range $m_{\nu_x} \sim$ 260–385 MeV. ABRATENKO 20 also considers $\nu_x \rightarrow \mu^+ \pi^-$ for the case of a Majorana HNL.

Limits on $\left|U_{\tau x}\right|^2$

Quoted limits are either the best limit near the kinematic threshold of the experiment, or a characteristic value in the mass range of the experimental sensitivity

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<1 \times 10^{-5}$	95	[1] LEES	23A	BABR	Near $m_\tau - 3m_\pi$ kin. thres.
$<2 \times 10^{-6}$	90	[2] BAROUKI	22	RVUE	Near $m_\tau - m_\nu$ kin. thres.
$<3 \times 10^{-4}$	90	[3] ACCIARRI	21	ARNT	Near $m_{\nu_x} \lesssim$ 970 MeV
$<3 \times 10^{-6}$	90	[4] BOIARSKA	21	RVUE	Near $m_{\nu_x} \sim$ 0.8–1.6 GeV
$<2 \times 10^{-4}$	90	[5] ORLOFF	02	CHRM	Near $m_D - m_\tau$ kin. thres.
$<1 \times 10^{-4}$	90	[6] ORLOFF	02	CHRM	$m_{\nu_x} \sim$ 200–250 MeV
$<3 \times 10^{-5}$	95	[7] ABREU	97I	DLPH	$m_{\nu_x} \sim$ 6–50 GeV

$<2 \times 10^{-5}$	95	[8] ABREU	97I	DLPH	Near m_{ν_x} $\sim$ 3.5 GeV

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

		[9] LIVENTSEV	23	BELL	Near m_{ν_x} $\sim$ 0.8–1.2 GeV
		[10] TUMASYAN	22H	CMS	pp at 13 TeV

[1] Search for $\tau^{\pm} \rightarrow \pi^{\pm}\pi^{+}\pi^{-}\nu_x$.

[2] Reanalysis of BEBC results (cf. COOPER-SARKAR 85) to include searches for $D_s^{\pm} \rightarrow \nu_{\tau}\tau^{\pm}$, $\tau^{\pm} \rightarrow \nu_x \pi^{\pm}$, $\nu_x \rho^{\pm}$, or $\nu_x \nu_{\tau} \ell^{\pm}$ via $U_{\tau x}$. Assumes a Majorana HNL.

[3] Search for $\nu_x \rightarrow \mu^{+}\mu^{-}\nu$.

[4] Reanalysis of CHARM results (cf. ORLOFF 02) to include searches for $\nu_x \rightarrow \nu \ell^{+}\ell^{-}$ decays, and including the production of HNLs from τ decays.

[5] $D_s \rightarrow \tau^{+}\nu_x$, with ν_x decay via $U_{\tau x}$.

[6] $D_s \rightarrow \nu_{\tau}\tau^{+}$, $\tau^{+} \rightarrow \nu_x X$, with ν_x decay via $U_{\tau x}$.

[7] Search for prompt ν_x decay signatures.

[8] Search for displaced ν_x decay signatures. Kinematical suppression of $\nu_x \rightarrow \tau X$ at lower masses leads to rapid loosening of the $|U_{\tau x}|$ bound compared to that for $|U_{e x}|$ and $|U_{\mu x}|$.

[9] Search for $\tau \rightarrow \pi\nu_x$, $\nu_x \rightarrow \pi e$ or $\pi\mu$ in the range 0.2–1.6 GeV. LIVENTSEV 23 reports results for the sum $\Sigma_{\ell=e,\mu,\tau}|U_{\ell x}|^2$ in a model-dependent context, but which may be roughly reinterpreted as a limit $|U_{e x}\ U_{\tau x}|^2 + |U_{\mu x}\ U_{\tau x}|^2 \lesssim 5 \times 10^{-9}$ in either Majorana or Dirac HNL scenarios.

[10] TUMASYAN 22H sets limits on an approximately mass-degenerate vector-like lepton SU(2) doublet coupling to the τ. Some of the reported signal region distributions might be used to set limits for heavy neutral leptons coupled to the τ. The data correspond to an integrated luminosity of 138 fb^{-1}.

REFERENCES FOR Heavy Neutral Leptons, Searches for

AAD	23AO	PRL 131 061803	G. Aad *et al.*	(ATLAS Collab.)
AAD	23CE	EPJ C83 824	G. Aad *et al.*	(ATLAS Collab.)
AGNES	23A	PRL 130 101002	P. Agnes *et al.*	(DarkSide-50 Collab.)
LEES	23A	PR D107 052009	J.P. Lees *et al.*	(BABAR Collab.)
LIVENTSEV	23	PRL 131 211802	D. Liventsev *et al.*	(BELLE Collab.)
TUMASYAN	23AC	PRL 131 011803	A. Tumasyan *et al.*	(CMS Collab.)
ABRATENKO	22A	PR D106 092006	P. Abratenko *et al.*	(MicroBooNE Collab.)
BAROUKI	22	SCP 13 118	R. Barouki, G. Marocco, S. Sarkar	(OXF)
TUMASYAN	22AD	JHEP 2207 081	A. Tumasyan *et al.*	(CMS Collab.)
TUMASYAN	22H	PR D105 112007	A. Tumasyan *et al.*	(CMS Collab.)
AAIJ	21AA	EPJ C81 248	R. Aaij *et al.*	(LHCb Collab.)
ACCIARRI	21	PRL 127 121801	R. Acciarri *et al.*	(ArgoNeuT Collab.)
BOIARSKA	21	PR D104 095019	I. Boiarska *et al.*	(BOHR, LEID)
CORTINA-GIL	21	PL B816 136259	E. Cortina Gil *et al.*	(NA62 Collab.)
FRIEDRICH	21	PRL 126 021803	S. Friedrich *et al.*	(BeEST Collab.)
ABRATENKO	20	PR D101 052001	P. Abratenko *et al.*	(MiniBooNE Collab.)
CORTINA-GIL	20	PL B807 135599	E. Cortina Gil *et al.*	(NA62 Collab.)
PRIM	20	PR D101 032007	M.T. Prim *et al.*	(BELLE Collab.)
AAD	19F	JHEP 1910 265	G. Aad *et al.*	(ATLAS Collab.)
ABE	19B	PR D100 052006	K. Abe *et al.*	(T2K Collab.)
ABLIKIM	19AL	PR D99 112002	M. Ablikim *et al.*	(BESIII Collab.)
AGUILAR-AR...	19B	PL B798 134980	A. Aguilar-Arevalo *et al.*	(PIENU Collab.)
BRYMAN	19	PR D100 053006	D.A. Bryman, R. Shrock	(BRCO, TRIU, STON)
BRYMAN	19A	PR D100 073011	D.A. Bryman, R. Shrock	(BRCO, TRIU, STON)
AGUILAR-AR...	18A	PR D97 072012	A. Aguilar-Arevalo *et al.*	(PIENU Collab.)
CORTINA-GIL	18	PL B778 137	E. Cortina Gil *et al.*	(NA62 Collab.)
LAZZERONI	17A	PL B772 712	C. Lazzeroni *et al.*	(NA62 Collab.)
PARK	16	PR D94 012003	C.-S. Park *et al.*	(BELLE Collab.)
AGUILAR-AR...	15	PRL 115 071801	A. Aguilar-Arevalo *et al.*	(PIENU Collab.)
ARTAMONOV	15A	PR D91 052001	A.V. Artamanov *et al.*	(E949 Collab.)

LIVENTSEV	13	PR D87 071102	D. Liventsev *et al.*	(BELLE Collab.)
Also		PR D95 099903 (errat.)	D. Liventsev *et al.*	(BELLE Collab.)
ORLOFF	02	PL B550 8	J. Orloff *et al.*	(CHARM Collab.)
DAUM	00	PRL 85 1815	M. Daum *et al.*	(KARMEN Collab.)
VAITAITIS	99	PRL 83 4943	A. Vaitaitis *et al.*	(CCFR Collab.)
ABREU	97I	ZPHY C74 57	P. Abreu *et al.*	(DELPHI Collab.)
Also		ZPHY C75 580 (errat.)	P. Abreu *et al.*	(DELPHI Collab.)
VILAIN	95C	PL B351 387	P. Vilain *et al.*	(CHARM II Collab.)
Also		PL B343 453	P. Vilain *et al.*	(CHARM II Collab.)
BARANOV	93	PL B302 336	S.A. Baranov *et al.*	(JINR, SERP, BUDA)
BERNARDI	88	PL B203 332	G. Bernardi *et al.*	(PARIN, CERN, INFN+)
DORENBOS...	86	PL 166B 473	J. Dorenbosch *et al.*	(CHARM Collab.)
COOPER-...	85	PL 160B 207	A.M. Cooper-Sarkar *et al.*	(CERN, LOIC+)