Neutral Heavy Lepton Production Cross Section (μN)

VALUE (cm^2)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$<4. \times 10^{-38}$	0	[61] CLARK	81	SPEC	0	μ_P^0
$<1.22 \times 10^{-34}$		[62] LEBRITTON	80	SPEC	0	$M^0 \rightarrow \mu^+ \mu^- \nu$

[61] CLARK 81 is FNAL experiment with 209 GeV muon. Looked for μ^+ nucleon $\rightarrow$ $\overline{\mu}_P^0$ X, $\overline{\mu}_P^0 \rightarrow \mu^+ \mu^- \overline{\nu}_\mu$ and $\mu^+ n \rightarrow \mu_P^{++}$X, $\mu_P^{++} \rightarrow 2\mu^+ \nu_\mu$. Above limits are for $\sigma \times$BR taken from their mass-dependence plot figure 2.

[62] LEBRITTON 80 is BNL experiment with 10.5 GeV muons. Trimuons are consistent with QED trident and diffractively produced ρ decay.

Neutral Heavy Lepton Production Cross Section

$\sigma \times$ B($\tau \rightarrow$ new neutral lepton) $\times$ B(neutral lepton $\rightarrow$ $e\pi$ or $\mu\pi$)

VALUE (10^{-5} nb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<450	90	[63] MEYER	77	MRK1	For m_L=0.5 GeV
<250	90	[63] MEYER	77	MRK1	For m_L=1.5 GeV

[63] MEYER 77 experiment looks for narrow neutral resonance in $e^- \pi$ and $\mu^- \pi$ channels. See "Heavy Lepton MASS LIMITS" section above.

$\sigma(L\overline{L}) \times \left[\text{B}(L \rightarrow e\nu X) + \text{B}(\overline{L} \rightarrow e\nu X)\right]$

VALUE (10^{-5} nb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 8	90	[64] ERREDE	84	HRS	For m_L=1 GeV
<18	90	[64] ERREDE	84	HRS	For m_L=2 GeV
<20	90	[64] ERREDE	84	HRS	For m_L=3 GeV
<11	90	[64] ERREDE	84	HRS	For m_L=4 or 5 GeV
<13	90	[64] ERREDE	84	HRS	For m_L=6 GeV
<17	90	[64] ERREDE	84	HRS	For m_L=7 GeV

[64] Assuming X = μ. If X = meson, limits are 20% higher. ERREDE 84 say these limits are comparable to those expected from naive theory. $e^+ e^-$, E_{cm} = 29 GeV. See also GRONAU 84, RIZZO 84.

$\sigma(L_1 + L_2) \times$ B($L_1 \rightarrow$ only light neutrinos)

VALUE (10^{-5} nb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 4.7	90	[65] AKERLOF	85	HRS	For m_L=2 GeV
<18.	90	[65] AKERLOF	85	HRS	For m_L=10 GeV

[65] AKERLOF 85 observe no monojets above background. They use standard couplings to Z to find $\sigma(L_1 + L_2)$ = 0.36 pb. Above data then imply B($L_1 \rightarrow$ light neutrinos) <13–50% for m_L = 2–10 GeV.

$\sigma(L\overline{L}) \times \text{BR}_1 \times \text{BR}_2$ / σ(standard via virtual Z)

where BR_1 and BR_2 are branching ratios leading to events with two or four charged particles, and σ(standard) = 0.35($\beta(3+\beta^2)$ / 4) pb with β = velocity/c of L.

VALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
< 0.1–0.2	90	0	[66] PERL	85	MRK2	For m_L <1 GeV

[66] PERL 85 examine a variety of models and processes. They search up to m_L = 14 GeV but are most sensitive for m_L <1 GeV. They require lepton lifetime $< m_L 10^{-11}$ s $[m_L$ in GeV$]$ which limits their ability to constrain the mixing of a 4th conventional generation.

REFERENCES FOR Heavy Lepton Searches

ABREU 92B PL B274 230 +Adams, Adami, Adye+ (DELPHI Collab.)
ADRIANI 92I PL B295 371 +Aguilar-Benitez, Ahlen, Akbari, Alcaraz+ (L3 Collab.)
MORI 92B PL B289 463 +Hikasa, Nojiri, Oyama+ (KAM2 Collab.)
ABREU 91F NP B367 511 +Adam, Adami, Adye, Akesson+ (DELPHI Collab.)
ALEXANDER 91F ZPHY C52 175 +Allison, Allport, Anderson, Arcelli+ (OPAL Collab.)
KIM 91B IJMP A6 2583 +Smith, Breedon, Ko+ (AMY Collab.)
REUSSER 91 PL B255 143 +Treichel, Boehm, Broggini+ (NEUC, CIT, VILL)
SATO 91 PR D44 2220 +Hirata, Kajita, Kifune, Kihara+ (Kamioka Collab.)
ADACHI 90C PL B244 352 +Aihara, Doser, Enomoto+ (TOPAZ Collab.)
ADEVA 90S PL B251 321 +Adriani, Aguilar-Benitez, Akbari+ (L3 Collab.)
AKRAWY 90G PL B240 250 +Alexander, Allison, Allport+ (OPAL Collab.)
AKRAWY 90L PL B247 448 +Alexander, Allison, Allport+ (OPAL Collab.)
AKRAWY 90O PL B252 290 +Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
BURCHAT 90 PR D41 3542 +King, Abrams, Adolphsen+ (Mark II Collab.)
DECAMP 90F PL B236 511 +Deschizeaux, Lees, Minard+ (ALEPH Collab.)
JUNG 90 PRL 64 1091 +Van Kooten, Abrams, Adolphsen+ (Mark II Collab.)
RILES 90 PR D42 1 +Perl, Barklow+ (Mark II Collab.)
SODERSTROM 90 PRL 64 2980 +McKenna, Abrams, Adolphsen, Averill+ (Mark II Collab.)
ABRAMS 89C PRL 63 2447 +Adolphsen, Averill, Ballam+ (Mark II Collab.)
ENQVIST 89 NP B317 647 +Kainulainen, Maalampi (HELS)
FISHER 89 PL B218 257 +Boehm, Bovet, Egger+ (CIT, NEUC, PSI)
SHAW 89 PRL 63 1342 +Blanis, Bodek, Budd+ (AMY Collab.)
STOKER 89 PR D39 1811 +Perl, Abrams+ (Mark II Collab.)
ABE 88 PRL 61 915 +Amako, Arai, Asano, Chiba (VENUS Collab.)
ADACHI 88B PR D37 1339 +Aihara, Dijkstra, Enomoto+ (TOPAZ Collab.)
AKERLOF 88 PR D37 577 +Chapman, Errede, Ken+ (HRS Collab.)
BEHREND 88C ZPHY C41 7 +Buerger, Criegee, Dainton+ (CELLO Collab.)
CALDWELL 88 PRL 61 510 +Eisberg, Grumm, Witherell+ (UCSB, UCB, LBL)
GAN 88 IJMP A3 531 +Perl (SLAC)
IGARASHI 88 PRL 60 2359 +Myung, Chiba, Hanaoka+ (AMY Collab.)
KIM 88 PRL 61 911 +Son, Bacala, Imlay+ (AMY Collab.)
OLIVE 88 PL B205 553 +Srednicki (MINN, UCSB)
SREDNICKI 88 NP B310 693 +Watkins, Olive (MINN, UCSB)
AHLEN 87 PL B195 603 +Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC)
ALBAJAR 87B PL B185 241 +Albrow, Allkofer, Arnison+ (UA1 Collab.)
GRIEST 87 NP B283 681 +Seckel (UCSC, CERN)
Also 88 NP B296 1034 erratum Griest, Seckel (UCSC, CERN)
MISHRA 87 PRL 59 1397 +Auchincloss+ (COLU, CIT, FNAL, CHIC, ROCH)
WENDT 87 PRL 58 1810 +Abrams, Amidei, Baden+ (Mark II Collab.)
YOSHIDA 87B PRL 59 2915 +Chiba, Endo+ (VENUS Collab.)
BADIER 86 ZPHY C31 21 +Bemporad, Boucrot, Callot+ (NA3 Collab.)
ADEVA 85 PL 152B 439 +Becker, Becker-Szendy+ (Mark-J Collab.)
Also 84C PRPL 109 131 Adeva, Barber, Becker+ (Mark-J Collab.)
AKERLOF 85 PL 156B 271 +Bonvicini, Chapman, Errede+ (HRS Collab.)
PERL 85 PR D32 2859 +Barklow, Boyarski+ (Mark II Collab.)
ERREDE 84 PL 149B 519 +Akerlof, Chapman, Harnew+ (HRS Collab.)
GRONAU 84 PR D29 2539 +Leung, Rosner (SYRA, FNAL, CHIC)
RIZZO 84 PL 136B 251 (ISU)
ADEVA 83B PRL 51 443 +Barber, Becker, Berdugo+ (Mark-J Collab.)
BARTEL 83 PL 123B 353 +Cords, Dietrich, Eichler+ (JADE Collab.)
ADEVA 82 PRL 48 967 +Barber, Becker, Berdugo+ (Mark-J Collab.)
BERGER 81B PL 99B 489 +Genzel, Grigull, Lackas+ (PLUTO Collab.)
BRANDELIK 81 PL 99B 163 +Braunschweig, Gather+ (TASSO Collab.)
CLARK 81 PRL 46 299 +Johnson, Kerth, Loken+ (UCB, LBL, FNAL, PRIN)
Also 82 PR D25 2762 Smith, Clark, Johnson, Kerth+ (LBL, FNAL, PRIN)
AZIMOV 80 JETPL 32 664 +Khoze (PNPI)
Translated from ZETFP 32 677.
BARBER 80B PRL 45 1904 +Becker, Bei, Berghoff+ (Mark-J Collab.)
BRANDELIK 80 PL 92B 199 +Braunschweig, Gather+ (TASSO Collab.)
LEBRITTON 80 PL 89B 271 +McCal, Melissinos+ (ROCH, BNL, NSF)
ASRATYAN 78 PL 76B 237 +Kubantsev (ITEP)
CNOPS 78 PRL 40 144 +Connolly, Kahn, Kirk+ (BNL, COLU)
ERRIQUEZ 78 PL 77B 227 (BARI, BIRM, BRUX, EPOL, RHEL, SACL, LOUC)
HOLDER 78 PL 74B 277 +Knobloch, May+ (CDHS Collab.)
BACCI 77B PL 71B 227 +Dezorzi, Penso, Stella+ (ROMA, FRAS)
HOLDER 77 PL 70B 393 +Knobloch, May+ (CDHS Collab.)
MEYER 77 PL 70B 469 +Nguyen, Abrams+ (SLAC, LBL, NWES, HAWA)
ASRATYAN 74 PL 49B 488 +Gershtein, Kaftanov, Kubantsev, Lapin+ (SERP)
BARISH 74 PRL 32 1387 +Bartlett, Buchholz, Merritt+ (CIT, FNAL)
GITTLESON 74 PR D10 1379 +Kirk+ (HARV, ROCH, COLU, FNAL)
ANSORGE 73B PR D7 26 +Baker, Krzesinski, Neale, Rushbrooke+ (CAVE)
BACCI 73 PL 44B 530 +Parisi, Penso, Salvini, Stella+ (ROMA, FRAS)
BARISH 73B PRL 31 410 +Bartlett, Buchholz, Humphrey+ (CIT, FNAL)
BUSHNIN 73 NP B58 476 +Dunaitzev, Golovkin, Kubarovsky+ (SERP)
Also 72 PL 42B 136 Golovkin, Grachev, Shodyrev+ (SERP)
EICHTEN 73 PL 46B 281 +Deden, Hasert, Krenz+ (Gargamelle Collab.)
LICHTENSTEIN 70 PR D1 825 +Ash, Berkelman, Hartill+ (CORN)
LIBERMAN 69 PRL 22 663 +Hoffman, Engels+ (HARV, CASE, MCGI, SLAC)
ROTHE 69 NP B10 241 +Wolsky (PENN)
BARNA 68 PR 173 1391 +Cox, Martin, Perl, Tan, Toner, Zipf+ (SLAC, STAN)
BOLEY 68 PR 167 1275 +Elias, Friedman, Hartmann, Kendall+ (MIT, CEA)
BUDNITZ 66 PR 141 1313 +Dunning, Goitein, Ramsey, Walker+ (HARV)
BEHREND 65 PRL 15 900 +Brasse, Engler, Ganssauge+ (DESY, KARL)
BETOURNE 65 PL 17 70 +Ngoc, Perez-y-Jorba+ (ORSAY)

OTHER RELATED PAPERS

PERL 81 SLAC-PUB-2752 (SLAC)
Physics in Collision Conference.

Searches for Massive Neutrinos and Lepton Mixing

Searches for the effects of nonzero neutrino masses are listed here. Direct searches for masses of dominantly coupled neutrinos are listed in the appropriate section on ν_e, ν_μ, or ν_τ. The results in the present section are correlated upper bounds on mixing matrix coefficients U_{aj} versus neutrino mass. These results are divided into three main sections:

1. Bounds from particle and nuclear decays;
2. Bounds from neutrino reactions, including reactor and accelerator neutrino oscillation experiments, and solar neutrino measurements (see the "Note on Neutrino Oscillations" below); and
3. Searches for neutrinoless double-β decay:

Discussion of the ν_e and ν_μ mass limits, the "17 keV neutrino," and solar neutrino observations are given in the "Note of Neutrinos" by R.E. Shrock in the ν_e section near the beginning of these data listings. Several reviews are also listed there. See also the "Note on the Muon Neutrino Mass" before the ν_μ Listings.

In addition, searches for mixing of $(\mu^- e^+)$ and $(\mu^+ e^-)$ are given in the muon Listings.