Heavy Charged Lepton Searches

Charged Heavy Lepton MASS LIMITS

Sequential Charged Heavy Lepton ($L^{\pm}$) MASS LIMITS

These experiments assumed that a fourth generation $L^{\pm}$ decayed to a fourth generation ν_L (or L^0) where ν_L was stable. New data show that stable ν_L have $m_{\nu_L} > 42.7$ GeV so that the above assumption is not valid for any mass limit ≤ 42.7 GeV. One can instead assume that $L^{\pm}$ decays via mixing to ν_e, ν_μ and/or ν_τ, and in that context the limits below are meaningful.

VALUE (GeV)	*CL%*		*DOCUMENT ID*		*TECN*	*COMMENT*
< 48 or > 61	95	[1]	ACCIARRI	96G	L3	
>64.5	95		ALEXANDER	96P	OPAL	$m_L - m_{L^0} > 10$ GeV
>63.9	95		ALEXANDER	96P	OPAL	Decay to massless ν's
>63.5	95		BUSKULIC	96S	ALEP	$m_L - m_{L^0} > 7$ GeV
>65	95		BUSKULIC	96S	ALEP	Decay to massless ν's
>42.8	95		ADEVA	90S	L3	Dirac
>44.3	95		AKRAWY	90G	OPAL	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
none 10–225		[2]	AHMED	94	CNTR	H1 Collab. at HERA
none 12.6–29.6	95		KIM	91B	AMY	Massless ν assumed
>42.7	95		DECAMP	90F	ALEP	
none 0.5–10	95	[3]	RILES	90	MRK2	For $(m_{L^-} - m_{L^0}) >$ 0.25–0.4 GeV
> 8		[4]	STOKER	89	MRK2	For $(m_{L^+} - m_{L^0}) = 0.4$ GeV
>12		[4]	STOKER	89	MRK2	For m_{L^0}=0.9 GeV
none 18.4–27.6	95	[5]	ABE	88	VNS	
>25.5	95	[6]	ADACHI	88B	TOPZ	
none 1.5–22.0	95		BEHREND	88C	CELL	
>41	90	[7]	ALBAJAR	87B	UA1	
>22.5	95	[8]	ADEVA	85	MRKJ	
>18.0	95	[9]	BARTEL	83	JADE	
none 4–14.5	95	[10]	BERGER	81B	PLUT	
>15.5	95	[11]	BRANDELIK	81	TASS	
>13.		[12]	AZIMOV	80		
>16.	95	[13]	BARBER	80B	CNTR	
> 0.490		[14]	ROTHE	69	RVUE	

[1] ACCIARRI 96G assumes LEP result that the associated neutral heavy lepton mass > 40 GeV.

[2] The AHMED 94 limits are from a search for neutral and charged sequential heavy leptons at HERA via the decay channels $L^- \to e\gamma$, $L^- \to \nu W^-$, $L^- \to eZ$; and $L^0 \to \nu\gamma$, $L^0 \to e^- W^+$, $L^- \to \nu Z$, where the W decays to $\ell\nu_\ell$, or to jets, and Z decays to $\ell^+\ell^-$ or jets.

[3] RILES 90 limits were the result of a special analysis of the data in the case where the mass difference $m_{L^-} - m_{L^0}$ was allowed to be quite small, where L^0 denotes the neutrino into which the sequential charged lepton decays. With a slightly reduced $m_{L^\pm}$ range, the mass difference extends to about 4 GeV.

[4] STOKER 89 (Mark II at PEP) gives bounds on charged heavy lepton (L^+) mass for the generalized case in which the corresponding neutral heavy lepton (L^0) in the SU(2) doublet is not of negligible mass.

[5] ABE 88 search for L^+ and $L^- \rightarrow$ hadrons looking for acoplanar jets. The bound is valid for $m_\nu < 10$ GeV.

[6] ADACHI 88B search for hadronic decays giving acoplanar events with large missing energy. $E_{cm}{}^{ee} = 52$ GeV.

[7] Assumes associated neutrino is approximately massless.

[8] ADEVA 85 analyze one-isolated-muon data and sensitive to τ <10 nanosec. Assume B(lepton) = 0.30. $E_{cm} = 40$–47 GeV.

[9] BARTEL 83 limit is from PETRA $e^+ e^-$ experiment with average $E_{cm} = 34.2$ GeV.

[10] BERGER 81B is DESY DORIS and PETRA experiment. Looking for $e^+ e^- \rightarrow L^+ L^-$.

[11] BRANDELIK 81 is DESY-PETRA experiment. Looking for $e^+ e^- \rightarrow L^+ L^-$.

[12] AZIMOV 80 estimated probabilities for $M + N$ type events in $e^+ e^- \rightarrow L^+ L^-$ deducing semi-hadronic decay multiplicities of L from $e^+ e^-$ annihilation data at $E_{cm} = (2/3)m_L$. Obtained above limit comparing these with $e^+ e^-$ data (BRANDELIK 80).

[13] BARBER 80B looked for $e^+ e^- \rightarrow L^+ L^-$, $L \rightarrow \nu_L^+$ X with MARK-J at DESY-PETRA.

[14] ROTHE 69 examines previous data on μ pair production and π and K decays.

Stable Charged Heavy Lepton ($L^\pm$) MASS LIMITS

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*
>42.8 (CL = 95%) OUR LIMIT				
>28.2	95	[15] ADACHI	90C	TOPZ
none 18.5–42.8	95	AKRAWY	90O	OPAL
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>26.5	95	DECAMP	90F	ALEP
none m_μ–36.3	95	SODERSTROM	90	MRK2

[15] ADACHI 90C put lower limits on the mass of stable charged particles with electric charge Q satisying $2/3 < Q/e < 4/3$ and with spin 0 or 1/2. We list here the special case for a stable charged heavy lepton.

Charged Long-Lived Heavy Lepton MASS LIMITS

VALUE (GeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>0.1	0	[16] ANSORGE	73B	HBC	–	Long-lived
none 0.55–4.5		[17] BUSHNIN	73	CNTR	–	Long-lived
none 0.2–0.92		[18] BARNA	68	CNTR	–	Long-lived
none 0.97–1.03		[18] BARNA	68	CNTR	–	Long-lived

[16] ANSORGE 73B looks for electron pair production and electron-like Bremsstrahlung.

[17] BUSHNIN 73 is SERPUKOV 70 GeV p experiment. Masses assume mean life above 7×10^{-10} and 3×10^{-8} respectively. Calculated from cross section (see "Charged Quasi-Stable Lepton Production Differential Cross Section" below) and 30 GeV muon pair production data.

[18] BARNA 68 is SLAC photoproduction experiment.

Doubly-Charged Heavy Lepton MASS LIMITS

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*CHG*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
none 1–9 GeV	90	[19] CLARK	81	SPEC	++

[19] CLARK 81 is FNAL experiment with 209 GeV muons. Bounds apply to μ_P which couples with full weak strength to muon. See also section on "Doubly-Charged Lepton Produciton Cross Section."

Doubly-Charged Lepton Production Cross Section (μN Scattering)

VALUE (cm^2)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<6. \times 10^{-38}$	0	[20] CLARK	81	SPEC	++

[20] CLARK 81 is FNAL experiment with 209 GeV muon. Looked for μ^+ nucleon $\rightarrow \overline{\mu}^0_P$ X, $\overline{\mu}^0_P \rightarrow \mu^+ \mu^- \overline{\nu}_\mu$ 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.

REFERENCES FOR Heavy Charged Lepton Searches

ACCIARRI	96G	PL B377 304	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)
ALEXANDER	96P	PL B385 433	+Allison, Altekamp, Ametewee+	(OPAL Collab.)
BUSKULIC	96S	PL B384 439	+De Bonis, Decamp, Ghez+	(ALEPH Collab.)
AHMED	94	PL B340 205	+	(H1 Collab.)
KIM	91B	IJMP A6 2583	+Smith, Breedon, Ko+	(AMY 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	90O	PL B252 290	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
DECAMP	90F	PL B236 511	+Deschizeaux, Lees, Minard+	(ALEPH Collab.)
RILES	90	PR D42 1	+Perl, Barklow+	(Mark II Collab.)
SODERSTROM	90	PRL 64 2980	+McKenna, Abrams, Adolphsen, Averill+	(Mark II 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.)
BEHREND	88C	ZPHY C41 7	+Buerger, Criegee, Dainton+	(CELLO Collab.)
ALBAJAR	87B	PL B185 241	+Albrow, Allkofer, Arnison+	(UA1 Collab.)
ADEVA	85	PL 152B 439	+Becker, Becker-Szendy+	(Mark-J Collab.)
Also	84C	PRPL 109 131	Adeva, Barber, Becker+	(Mark-J Collab.)
BARTEL	83	PL 123B 353	+Cords, Dietrich, Eichler+	(JADE 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.)
ANSORGE	73B	PR D7 26	+Baker, Krzesinski, Neale, Rushbrooke+	(CAVE)
BUSHNIN	73	NP B58 476	+Dunaitzev, Golovkin, Kubarovsky+	(SERP)
Also	72	PL 42B 136	Golovkin, Grachev, Shodyrev+	(SERP)
ROTHE	69	NP B10 241	+Wolsky	(PENN)
BARNA	68	PR 173 1391	+Cox, Martin, Perl, Tan, Toner, Zipf+	(SLAC, STAN)

OTHER RELATED PAPERS

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