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, or that $L^{\pm}$ decays to a light ν_ℓ via mixing.

See the "Quark and Lepton Compositeness, Searches for" Listings for limits on radiatively decaying excited leptons, *i.e.* $\ell^* \rightarrow \ell\gamma$. See the "WIMPs and other Particle Searches" section for heavy charged particle search limits in which the charged particle could be a lepton.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>93.9	95	ACCIARRI	99L	L3	$m_{L^{\pm}} - m_{L^0} > 10$ GeV
>92.4	95	ACCIARRI	99L	L3	Decay to massless ν's
>81.5	95	ACKERSTAFF	98C	OPAL	Assumed $m_{L^{\pm}} - m_{L^0} > 8.4$ GeV
>80.2	95	ACKERSTAFF	98C	OPAL	$m_{L^0} > m_{L^{\pm}}$ and $L^{\pm} \rightarrow \nu W$
>72	95	ACCIARRI	97P	L3	Assumed $m_{L^{\pm}} - m_{\nu_L} > 10$ GeV
>81	95	ACCIARRI	97P	L3	Assumed $m_{L^{\pm}} - m_{\nu_L} > 20$ GeV
>78.7	95	ACCIARRI	97P	L3	Light ν, $\sqrt{s}$=161, 172 GeV
< 48 or > 61	95	[1] ACCIARRI	96G	L3	
>64.5	95	ALEXANDER	96P	OPAL	$m_L - m_{L^0} > 10$ GeV
>63.5	95	BUSKULIC	96S	ALEP	$m_L - m_{L^0} > 7$ GeV
>42.8	95	ADEVA	90S	L3	Decay to Dirac ν_L
>44.3	95	AKRAWY	90G	OPAL	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>73.5	95	ACKERSTAFF	97D	OPAL	Assumed $m_{L^{\pm}} - m_{\nu_L} > 13$ GeV
>76.7	95	ACKERSTAFF	97D	OPAL	$m_{\nu_L} > m_{L^{\pm}}$ and $L^{\pm} \rightarrow \nu W^*$
>63.9	95	ALEXANDER	96P	OPAL	Decay to massless ν's
>65	95	BUSKULIC	96S	ALEP	Decay to massless ν's
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^0}-m_{L^0})> 0.25–0.4GeV
> 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 $L^- \rightarrow e\gamma$, $L^- \rightarrow \nu W^-$, $L^- \rightarrow eZ$; and $L^0 \rightarrow \nu\gamma$, $L^0 \rightarrow e^- W^+$, $L^- \rightarrow \nu Z$, 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
>93.5	95	ACCIARRI	99L	L3
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>84.2	95	ACCIARRI	97P	L3
>28.2	95	[15] ADACHI	90C	TOPZ
none 18.5–42.8	95	AKRAWY	90O	OPAL
>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	99L	PL B462 354	M. Acciarri *et al.*	(L3 Collab.)
ACKERSTAFF	98C	EPJ C1 45	K. Ackerstaff *et al.*	(OPAL Collab.)
ACCIARRI	97P	PL B412 189	M. Acciarri *et al.*	(L3 Collab.)
ACKERSTAFF	97D	PL B393 217	K. Ackerstaff *et al.*	(OPAL Collab.)
ACCIARRI	96G	PL B377 304	M. Acciarri *et al.*	(L3 Collab.)
ALEXANDER	96P	PL B385 433	G. Alexander *et al.*	(OPAL Collab.)
BUSKULIC	96S	PL B384 439	D. Buskulic *et al.*	(ALEPH Collab.)
AHMED	94	PL B340 205	T. Ahmed *et al.*	(H1 Collab.)
KIM	91B	IJMP A6 2583	G.N. Kim *et al.*	(AMY Collab.)
ADACHI	90C	PL B244 352	I. Adachi *et al.*	(TOPAZ Collab.)
ADEVA	90S	PL B251 321	B. Adeva *et al.*	(L3 Collab.)
AKRAWY	90G	PL B240 250	M.Z. Akrawy *et al.*	(OPAL Collab.)
AKRAWY	90O	PL B252 290	M.Z. Akrawy *et al.*	(OPAL Collab.)
DECAMP	90F	PL B236 511	D. Decamp *et al.*	(ALEPH Collab.)
RILES	90	PR D42 1	K. Riles *et al.*	(Mark II Collab.)
SODERSTROM	90	PRL 64 2980	E. Soderstrom *et al.*	(Mark II Collab.)
STOKER	89	PR D39 1811	D.P. Stoker *et al.*	(Mark II Collab.)
ABE	88	PRL 61 915	K. Abe *et al.*	(VENUS Collab.)
ADACHI	88B	PR D37 1339	I. Adachi *et al.*	(TOPAZ Collab.)
BEHREND	88C	ZPHY C41 7	H.J. Behrend *et al.*	(CELLO Collab.)
ALBAJAR	87B	PL B185 241	C. Albajar *et al.*	(UA1 Collab.)
ADEVA	85	PL 152B 439	B. Adeva *et al.*	(Mark-J Collab.)
Also	84C	PRPL 109 131	B. Adeva *et al.*	(Mark-J Collab.)
BARTEL	83	PL 123B 353	W. Bartel *et al.*	(JADE Collab.)
BERGER	81B	PL 99B 489	C. Berger *et al.*	(PLUTO Collab.)
BRANDELIK	81	PL 99B 163	R. Brandelik *et al.*	(TASSO Collab.)
CLARK	81	PRL 46 299	A.R. Clark *et al.*	(UCB, LBL, FNAL+)
Also	82	PR D25 2762	W.H. Smith *et al.*	(LBL, FNAL, PRIN)
AZIMOV	80	JETPL 32 664 Translated from ZETFP 32 677.	Y.I. Azimov, V.A. Khoze	(PNPI)

BARBER 80B PRL 45 1904 D.P. Barber *et al.* (Mark-J Collab.)
BRANDELIK 80 PL 92B 199 R. Brandelik *et al.* (TASSO Collab.)
ANSORGE 73B PR D7 26 R.E. Ansorge *et al.* (CAVE)
BUSHNIN 73 NP B58 476 Y.B. Bushnin *et al.* (SERP)
Also 72 PL 42B 136 S.V. Golovkin *et al.* (SERP)
ROTHE 69 NP B10 241 K.W. Rothe, A.M. Wolsky (PENN)
BARNA 68 PR 173 1391 A. Barna *et al.* (SLAC, STAN)

OTHER RELATED PAPERS

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