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*
>100.8	95	ACHARD	01B	L3	Decay to νW
>101.9	95	ACHARD	01B	L3	$m_L - m_{L^0} > 15$ GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
> 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 $L^\pm \rightarrow \nu W$
< 48 or > 61	95	[1] ACCIARRI	96G	L3	
> 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
none 10–225		[2] AHMED	94	CNTR	H1 Collab. at HERA
none 12.6–29.6	95	KIM	91B	AMY	Massless ν assumed
> 44.3	95	AKRAWY	90G	OPAL	
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
>102.6	95	ACHARD	01B	L3
• • • We do not use the following data for averages, fits, limits, etc. • • •				
> 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 satisfying $2/3 < Q/e < 4/3$ 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)	CL%	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>574	95	CHATRCHYAN	13AB	CMS		Leptons singlet model
>102.0	95	ABBIENDI	03L	OPAL		pair produced in $e^+ e^-$
> 0.1		[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 SERPUKHOV 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 Production 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 $\rightarrow$ $\overline{\mu}_P^0$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.

REFERENCES FOR Heavy Charged Lepton Searches

CHATRCHYAN	13AB	JHEP 1307 122	S. Chatrchyan et al.	(CMS Collab.)
ABBIENDI	03L	PL B572 8	G. Abbiendi et al.	(OPAL Collab.)
ACHARD	01B	PL B517 75	P. Achard et al.	(L3 Collab.)
ACKERSTAFF	98C	EPJ C1 45	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.)
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		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		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		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 Physics in Collision Conference.	M.L. Perl	(SLAC)