

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 $(m_{L^0} - m_{L^0}) > 0.25$ – 0.4 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 $L^- \rightarrow e\gamma$, $L^- \rightarrow \nu W^-$, $L^- \rightarrow eZ$; 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.

- ⁴STOKER 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.
- ⁵ABE 88 search for L^+ and $L^- \rightarrow$ hadrons looking for acoplanar jets. The bound is valid for $m_{\nu} < 10$ GeV.
- ⁶ADACHI 88B search for hadronic decays giving acoplanar events with large missing energy. $E_{\text{cm}}^{ee} = 52$ GeV.
- ⁷Assumes associated neutrino is approximately massless.
- ⁸ADEVA 85 analyze one-isolated-muon data and sensitive to $\tau < 10$ nanosec. Assume $B(\text{lepton}) = 0.30$. $E_{\text{cm}} = 40\text{--}47$ GeV.
- ⁹BARTEL 83 limit is from PETRA e^+e^- experiment with average $E_{\text{cm}} = 34.2$ GeV.
- ¹⁰BERGER 81B is DESY DORIS and PETRA experiment. Looking for $e^+e^- \rightarrow L^+L^-$.
- ¹¹BRANDELIK 81 is DESY-PETRA experiment. Looking for $e^+e^- \rightarrow L^+L^-$.
- ¹²AZIMOV 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 $E_{\text{cm}} = (2/3)m_L$. Obtained above limit comparing these with e^+e^- data (BRANDELIK 80).
- ¹³BARBER 80B looked for $e^+e^- \rightarrow L^+L^-$, $L \rightarrow \nu_L^+ X$ with MARK-J at DESY-PETRA.
- ¹⁴ROTHER 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	SODERSTROM90	MRK2

- ¹⁵ADACHI 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

- ¹⁶ANSORGE 73B looks for electron pair production and electron-like Bremsstrahlung.
- ¹⁷BUSHNIN 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.
- ¹⁸BARNA 68 is SLAC photoproduction experiment.

Doubly-Charged Heavy Lepton MASS LIMITS

<u>VALUE (GeV)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
--------------------	------------	--------------------	-------------	------------

● ● ● 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)**

<u>VALUE (cm²)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
-------------------------------	-------------	--------------------	-------------	------------

● ● ● 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 $\rightarrow \bar{\pi}_P^0 X$, $\bar{\mu}_P^0 \rightarrow \mu^+ \mu^- \bar{\nu}_\mu$ 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 <i>et al.</i>	(CMS Collab.)
Also		JHEP 2211 149 (errat.)	S. Chatrchyan <i>et al.</i>	(CMS Collab.)
ABBIENDI	03L	PL B572 8	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ACHARD	01B	PL B517 75	P. Achard <i>et al.</i>	(L3 Collab.)
ACKERSTAFF	98C	EPJ C1 45	K. Ackerstaff <i>et al.</i>	(OPAL Collab.)
ACCIARRI	96G	PL B377 304	M. Acciarri <i>et al.</i>	(L3 Collab.)
ALEXANDER	96P	PL B385 433	G. Alexander <i>et al.</i>	(OPAL Collab.)
BUSKULIC	96S	PL B384 439	D. Buskulic <i>et al.</i>	(ALEPH Collab.)
AHMED	94	PL B340 205	T. Ahmed <i>et al.</i>	(H1 Collab.)
KIM	91B	IJMP A6 2583	G.N. Kim <i>et al.</i>	(AMY Collab.)
ADACHI	90C	PL B244 352	I. Adachi <i>et al.</i>	(TOPAZ Collab.)
AKRAWY	90G	PL B240 250	M.Z. Akrawy <i>et al.</i>	(OPAL Collab.)
AKRAWY	90O	PL B252 290	M.Z. Akrawy <i>et al.</i>	(OPAL Collab.)
DECAMP	90F	PL B236 511	D. Decamp <i>et al.</i>	(ALEPH Collab.)
RILES	90	PR D42 1	K. Riles <i>et al.</i>	(Mark II Collab.)
SODERSTROM	90	PRL 64 2980	E. Soderstrom <i>et al.</i>	(Mark II Collab.)
STOKER	89	PR D39 1811	D.P. Stoker <i>et al.</i>	(Mark II Collab.)
ABE	88	PRL 61 915	K. Abe <i>et al.</i>	(VENUS Collab.)
ADACHI	88B	PR D37 1339	I. Adachi <i>et al.</i>	(TOPAZ Collab.)
BEHREND	88C	ZPHY C41 7	H.J. Behrend <i>et al.</i>	(CELLO Collab.)
ALBAJAR	87B	PL B185 241	C. Albajar <i>et al.</i>	(UA1 Collab.)
ADEVA	85	PL 152B 439	B. Adeva <i>et al.</i>	(Mark-J Collab.)
Also		PRPL 109 131	B. Adeva <i>et al.</i>	(Mark-J Collab.)
BARTEL	83	PL 123B 353	W. Bartel <i>et al.</i>	(JADE Collab.)
BERGER	81B	PL 99B 489	C. Berger <i>et al.</i>	(PLUTO Collab.)
BRANDELIK	81	PL 99B 163	R. Brandelik <i>et al.</i>	(TASSO Collab.)
CLARK	81	PRL 46 299	A.R. Clark <i>et al.</i>	(UCB, LBL, FNAL+)
Also		PR D25 2762	W.H. Smith <i>et al.</i>	(LBL, FNAL, PRIN)
AZIMOV	80	JETPL 32 664	Y.I. Azimov, V.A. Khoze	(PNPI)
		Translated from ZETFP 32 677.		
BARBER	80B	PRL 45 1904	D.P. Barber <i>et al.</i>	(Mark-J Collab.)
BRANDELIK	80	PL 92B 199	R. Brandelik <i>et al.</i>	(TASSO Collab.)
ANSORGE	73B	PR D7 26	R.E. Ansorge <i>et al.</i>	(CAVE)
BUSHNIN	73	NP B58 476	Y.B. Bushnin <i>et al.</i>	(SERP)
Also		PL 42B 136	S.V. Golovkin <i>et al.</i>	(SERP)
ROTHE	69	NP B10 241	K.W. Rothe, A.M. Wolsky	(PENN)
BARNA	68	PR 173 1391	A. Barna <i>et al.</i>	(SLAC, STAN)

OTHER RELATED PAPERS

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