Searches for Quark and Lepton Compositeness

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SCALE LIMITS for Contact Interactions: $\Lambda(eeee)$

Limits are for $\Lambda^{\pm}_{LL}$ only. For other cases, see each reference.

Λ^{+}_{LL}(TeV)	Λ^{-}_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>1.6		95	[1,2] BUSKULIC	93Q	RVUE	
	>3.6	95	[3] KROHA	92	RVUE	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>1.6	>2.0	95	[2] BUSKULIC	93Q	ALEP	E_{cm}=88.25–94.25 GeV
	>2.2	95	BUSKULIC	93Q	RVUE	
>1.3		95	[3] KROHA	92	RVUE	
>0.7	>2.8	95	BEHREND	91C	CELL	E_{cm}=35 GeV
>1.3	>1.3	95	KIM	89	AMY	E_{cm}=50–57 GeV
>1.4	>3.3	95	[4] BRAUNSCH...	88	TASS	E_{cm}=12–46.8 GeV
>1.0	>0.7	95	[5] FERNANDEZ	87B	MAC	E_{cm}=29 GeV
>1.1	>1.4	95	[6] BARTEL	86C	JADE	E_{cm}=12–46.8 GeV
>1.17	>0.87	95	[7] DERRICK	86	HRS	E_{cm}=29 GeV
>1.1	>0.76	95	[8] BERGER	85B	PLUT	E_{cm}=34.7 GeV

[1] This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data re-analyzed by KROHA 92.

[2] BUSKULIC 93Q uses the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted for the limit.

[3] KROHA 92 limit is from fit to BERGER 85B, BARTEL 86C, DERRICK 86B, FERNANDEZ 87B, BRAUNSCHWEIG 88, BEHREND 91B, and BEHREND 91C. The fit gives $\eta/\Lambda^2_{LL} = +0.230 \pm 0.206$ TeV^{-2}.

[4] BRAUNSCHWEIG 88 assumed $m_Z = 92$ GeV and $\sin^2\theta_W = 0.23$.

[5] FERNANDEZ 87B assumed $\sin^2\theta_W = 0.22$.

[6] BARTEL 86C assumed $m_Z = 93$ GeV and $\sin^2\theta_W = 0.217$.

[7] DERRICK 86 assumed $m_Z = 93$ GeV and $g^2_V = (-1/2+2\sin^2\theta_W)^2 = 0.004$.

[8] BERGER 85B assumed $m_Z = 93$ GeV and $\sin^2\theta_W = 0.217$.

SCALE LIMITS for Contact Interactions: $\Lambda(ee\mu\mu)$

Limits are for $\Lambda^{\pm}_{LL}$ only. For other cases, see each reference.

Λ^{+}_{LL}(TeV)	Λ^{-}_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>2.6	**>1.9**	95	[9,10] BUSKULIC	93Q	RVUE	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>1.7	>2.2	95	[10] VELISSARIS	94	AMY	E_{cm}=57.8 GeV
>1.3	>1.5	95	[10] BUSKULIC	93Q	ALEP	E_{cm}=88.25–94.25 GeV
>2.3	>2.0	95	HOWELL	92	TOPZ	E_{cm}=52–61.4 GeV
	>1.7	95	[11] KROHA	92	RVUE	
>2.5	>1.5	95	BEHREND	91C	CELL	E_{cm}=35–43 GeV
>1.6	>2.0	95	[12] ABE	90I	VNS	E_{cm}=50–60.8 GeV
>1.9	>1.0	95	KIM	89	AMY	E_{cm}=50–57 GeV
>2.3	>1.3	95	BRAUNSCH...	88D	TASS	E_{cm}=30–46.8 GeV
>4.4	>2.1	95	[13] BARTEL	86C	JADE	E_{cm}=12–46.8 GeV
>2.9	>0.86	95	[14] BERGER	85	PLUT	E_{cm}=34.7 GeV

[9] This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data re-analyzed by KROHA 92.

[10] BUSKULIC 93Q and VELISSARIS 94 use the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted for the limit.

[11] KROHA 92 limit is from fit to BARTEL 86C, BEHREND 87C, BRAUNSCHWEIG 88D, BRAUNSCHWEIG 89C, ABE 90I, and BEHREND 91C. The fit gives $\eta/\Lambda^2_{LL} = -0.155 \pm 0.095$ TeV^{-2}.

[12] ABE 90I assumed m_Z =91.163 GeV and $\sin^2\theta_W = 0.231$.

[13] BARTEL 86C assumed $m_Z = 93$ GeV and $\sin^2\theta_W = 0.217$.

[14] BERGER 85 assumed $m_Z = 93$ GeV and $\sin^2\theta_W = 0.217$.

*CITATION: L. Montanet et al., Physical Review D50, 1173 (1994) and 1995 off-year partial update for the 1996 edition (URL: http://pdg.lbl.gov/)

SCALE LIMITS for Contact Interactions: $\Lambda(ee\tau\tau)$

Limits are for $\Lambda^{\pm}_{LL}$ only. For other cases, see each reference.

Λ^{+}_{LL}(TeV)	Λ^{-}_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>1.9	**>2.9**	95	[15] KROHA	92	RVUE	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>1.4	>2.0	95	[16] VELISSARIS	94	AMY	E_{cm}=57.8 GeV
>1.0	>1.5	95	[16] BUSKULIC	93Q	ALEP	E_{cm}=88.25–94.25 GeV
>1.8	>2.3	95	[16,17] BUSKULIC	93Q	RVUE	
>1.9	>1.7	95	HOWELL	92	TOPZ	E_{cm}=52–61.4 GeV
>1.6	>2.3	95	BEHREND	91C	CELL	E_{cm}=35–43 GeV
>1.8	>1.3	95	[18] ABE	90I	VNS	E_{cm}=50–60.8 GeV
>2.2	>3.2	95	[19] BARTEL	86	JADE	E_{cm}=12–46.8 GeV

[15] KROHA 92 limit is from fit to BARTEL 86C BEHREND 89B, BRAUNSCHWEIG 89C, ABE 90I, and BEHREND 91C. The fit gives η/Λ^2_{LL} = +0.095 ± 0.120 TeV^{-2}.

[16] BUSKULIC 93Q and VELISSARIS 94 use the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted for the limit.

[17] This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data re-analyzed by KROHA 92.

[18] ABE 90I assumed m_Z =91.163 GeV and $\sin^2\theta_W$ = 0.231.

[19] BARTEL 86 assumed m_Z = 93 GeV and $\sin^2\theta_W$ = 0.217.

SCALE LIMITS for Contact Interactions: $\Lambda(\ell\ell\ell\ell)$

Lepton universality assumed. Limits are for $\Lambda^{\pm}_{LL}$ only. For other cases, see each reference.

Λ^{+}_{LL}(TeV)	Λ^{-}_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>3.5	**>2.8**	95	[20,21] BUSKULIC	93Q	RVUE	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>3.0	>2.3	95	[21,22] BUSKULIC	93Q	ALEP	E_{cm}=88.25–94.25 GeV
>2.5	>2.2	95	[23] HOWELL	92	TOPZ	E_{cm}=52–61.4 GeV
>3.4	>2.7	95	[24] KROHA	92	RVUE	

[20] This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data re-analyzed by KROHA 92.

[21] BUSKULIC 93Q uses the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted for the limit.

[22] From $e^+e^- \rightarrow e^+e^-$, $\mu^+\mu^-$, and $\tau^+\tau^-$.

[23] HOWELL 92 limit is from $e^+e^- \rightarrow \mu^+\mu^-$ and $\tau^+\tau^-$.

[24] KROHA 92 limit is from fit to most PEP/PETRA/TRISTAN data. The fit gives η/Λ^2_{LL} = −0.0200 ± 0.0666 TeV^{-2}.

SCALE LIMITS for Contact Interactions: $\Lambda(eeqq)$

Limits are for $\Lambda^{\pm}_{LL}$ only. For other cases, see each reference.

Λ^{+}_{LL}(TeV)	Λ^{-}_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>1.7	**>2.2**	95	[25] ABE	91D	CDF	$(eeqq)$ (isosinglet)
>1.2		95	[26] ADACHI	91	TOPZ	$(eeqq)$ (flavor-universal)
	>1.7	95	[27] ABE	89L	VNS	$(eeqq)$ (flavor-universal)
• • • We do not use the following data for averages, fits, limits, etc. • • •						
	>1.6	95	[26] ADACHI	91	TOPZ	$(eeqq)$ (flavor-universal)
>0.6	>1.7	95	[28] BEHREND	91C	CELL	$(eecc)$
>1.1	>1.0	95	[28] BEHREND	91C	CELL	$(eebb)$
>0.9		95	[27] ABE	89L	VNS	$(eeqq)$ (flavor-universal)
>1.05	>1.61	95	[29] HAGIWARA	89	RVUE	$(eecc)$
>1.21	>0.53	95	[30] HAGIWARA	89	RVUE	$(eebb)$

[25] ABE 91D limits are from e^+e^- mass distribution in $p\overline{p} \rightarrow e^+e^- X$ at E_{cm} = 1.8 TeV.

[26] ADACHI 91 limits are from differential jet cross section. Universality of $\Lambda(eeqq)$ for five flavors is assumed.

[27] ABE 89L limits are from jet charge asymmetry. Universality of $\Lambda(eeqq)$ for five flavors is assumed.

[28] BEHREND 91C is from data at E_{cm} = 35–43 GeV.

[29] The HAGIWARA 89 limit is derived from forward-backward asymmetry measurements of D/D^* mesons by ALTHOFF 83C, BARTEL 84E, and BARINGER 88.

[30] The HAGIWARA 89 limit is derived from forward-backward asymmetry measurement of b hadrons by BARTEL 84D.

SCALE LIMITS for Contact Interactions: $\Lambda(\mu\mu q q)$

Λ^+_{LL}(TeV)	Λ^-_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>1.4	**>1.6**	95	ABE	92B	CDF	$(\mu\mu q q)$ (isosinglet)

SCALE LIMITS for Contact Interactions: $\Lambda(\ell\nu\ell\nu)$

VALUE (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>3.10	90	[31] JODIDIO	86	SPEC	$\Lambda^{\pm}_{LR}(\nu_\mu \nu_e \mu e)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>3.8		[32] DIAZCRUZ	94	RVUE	$\Lambda^+_{LL}(\tau\nu_\tau e\nu_e)$
>8.1		[32] DIAZCRUZ	94	RVUE	$\Lambda^-_{LL}(\tau\nu_\tau e\nu_e)$
>4.1		[33] DIAZCRUZ	94	RVUE	$\Lambda^+_{LL}(\tau\nu_\tau \mu\nu_\mu)$
>6.5		[33] DIAZCRUZ	94	RVUE	$\Lambda^-_{LL}(\tau\nu_\tau \mu\nu_\mu)$

[31] JODIDIO 86 limit is from $\mu^+ \rightarrow \overline{\nu}_\mu e^+ \nu_e$. Chirality invariant interactions $L = (g^2/\Lambda^2)$ $[\eta_{LL}\ (\overline{\nu}_{\mu L}\gamma^\alpha \mu_L)\ (\overline{e}_L\gamma_\alpha \nu_{eL}) + \eta_{LR}\ (\overline{\nu}_{\mu L}\gamma^\alpha \nu_{eL}\ (\overline{e}_R\gamma_\alpha \mu_R)]$ with $g^2/4\pi = 1$ and $(\eta_{LL},\eta_{LR}) = (0,\pm1)$ are taken. No limits are given for $\Lambda^{\pm}_{LL}$ with $(\eta_{LL},\eta_{LR}) = (\pm1,0)$. For more general constraints with right-handed neutrinos and chirality nonconserving contact interactions, see their text.

[32] DIAZCRUZ 94 limits are from $\Gamma(\tau \rightarrow e\nu\nu)$ and assume flavor-dependent contact interactions with $\Lambda(\tau\nu_\tau e\nu_e) \ll \Lambda(\mu\nu_\mu e\nu_e)$.

[33] DIAZCRUZ 94 limits are from $\Gamma(\tau \rightarrow \mu\nu\nu)$ and assume flavor-dependent contact interactions with $\Lambda(\tau\nu_\tau \mu\nu_\mu) \ll \Lambda(\mu\nu_\mu e\nu_e)$.

SCALE LIMITS for Contact Interactions: $\Lambda(q q q q)$

Limits are for $\Lambda^{\pm}_{LL}$ with color-singlet isoscalar exchanges among u_L's and d_L's only. See EICHTEN 84 for details.

VALUE (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>1.4	95	[34] ABE	92D	CDF	$p\overline{p} \rightarrow$ jets inclusive
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>1.3	95	[35] ABE	93G	CDF	$p\overline{p} \rightarrow$ dijet mass
>1.0	99	[36] ABE	92M	CDF	$p\overline{p} \rightarrow$ dijet angl.
>0.825	95	[37] ALITTI	91B	UA2	$p\overline{p} \rightarrow$ jets inclusive
>0.700	95	[34] ABE	89	CDF	$p\overline{p} \rightarrow$ jets inclusive
>0.330	95	[38] ABE	89H	CDF	$p\overline{p} \rightarrow$ dijet angl.
>0.400	95	[39] ARNISON	86C	UA1	$p\overline{p} \rightarrow$ jets inclusive
>0.415	95	[40] ARNISON	86D	UA1	$p\overline{p} \rightarrow$ dijet angl.
>0.370	95	[41] APPEL	85	UA2	$p\overline{p} \rightarrow$ jets inclusive
>0.275	95	[42] BAGNAIA	84C	UA2	Repl. by APPEL 85

[34] Limit is from inclusive jet cross-section data in $p\overline{p}$ collisions at E_{cm} = 1.8 TeV. The limit takes into account uncertainties in choice of structure functions and in choice of process scale.

[35] ABE 93G limit is from dijet mass distribution in $p\overline{p}$ collisions at E_{cm} = 1.8 TeV. The limit is the weakest from several choices of structure functions and renormalization scale.

[36] ABE 92M limit is from dijet angular distribution for m_{dijet} >550 GeV in $p\overline{p}$ collisions at E_{cm}=1.8 TeV.

[37] ALITTI 91B limit is from inclusive jet cross section in $p\overline{p}$ collisions at E_{cm} = 630 GeV. The limit takes into account uncertainties in choice of structure functions and in choice of process scale.

[38] ABE 89H limit is from dijet angular distribution for m_{dijet} > 200 GeV at the Fermilab Tevatron Collider with E_{cm} = 1.8 TeV. The QCD prediction is quite insensitive to choice of structure functions and choice of process scale.

[39] ARNISON 86C limit is from the study of inclusive high-p_T jet distributions at the CERN $\overline{p}p$ collider (E_{cm} = 546 and 630 GeV). The QCD prediction renormalized to the low-p_T region gives a good fit to the data.

[40] ARNISON 86D limit is from the study of dijet angular distribution in the range 240 < m(dijet) < 300 GeV at the CERN $\overline{p}p$ collider (E_{cm} = 630 GeV). QCD prediction using EHLQ structure function (EICHTEN 84) with Λ_{QCD} = 0.2 GeV for the choice of $Q^2 = {p_T}^2$ gives the best fit to the data.

[41] APPEL 85 limit is from the study of inclusive high-p_T jet distributions at the CERN $\overline{p}p$ collider (E_{cm} = 630 GeV). The QCD prediction renormalized to the low-p_T region gives a good description of the data.

[42] BAGNAIA 84C limit is from the study of jet p_T and dijet mass distributions at the CERN $\overline{p}p$ collider (E_{cm} = 540 GeV). The limit suffers from the uncertainties in comparing the data with the QCD prediction.

MASS LIMITS for Excited e (e^*)

Most e^+e^- experiments assume one-photon or Z exchange. The limits from some e^+e^- experiments which depend on λ have assumed transition couplings which are chirality violating ($\eta_L = \eta_R$). However they can be interpreted as limits for chirality-conserving interactions after multiplying the coupling value λ by $\sqrt{2}$; see Note.

Excited leptons have the same quantum numbers as other ortholeptons. See also the searches for ortholeptons in the "Searches for Heavy Leptons" section.

Limits for Excited e (e^*) from Pair Production

These limits are obtained from $e^+e^- \rightarrow e^{*+}e^{*-}$ and thus rely only on the (electroweak) charge of e^*. Form factor effects are ignored unless noted. For the case of limits from Z decay, the e^* coupling is assumed to be of sequential type. Possible t channel contribution from transition magnetic coupling is neglected. All limits assume $e^* \rightarrow e\gamma$ decay except the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review **D45,** 1 June, Part II (1992)).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>45.6	95	ADRIANI	93M	L3	$Z \rightarrow e^*e^*$
>45.6	95	ABREU	92C	DLPH	$Z \rightarrow e^*e^*$
>46.1	95	DECAMP	92	ALEP	$Z \rightarrow e^*e^*$
>44.9	95	AKRAWY	90I	OPAL	$Z \rightarrow e^*e^*$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>29.8	95	[43] BARDADIN-...	92	RVUE	$\Gamma(Z)$
>26.1	95	[44] DECAMP	92	ALEP	$Z \rightarrow e^*e^*$; $\Gamma(Z)$
>33	95	[44] ABREU	91F	DLPH	$Z \rightarrow e^*e^*$; $\Gamma(Z)$
>45.0	95	[45] ADEVA	90F	L3	$Z \rightarrow e^*e^*$
>44.6	95	[46] DECAMP	90G	ALEP	$e^+e^- \rightarrow e^*e^*$
>30.2	95	ADACHI	89B	TOPZ	$e^+e^- \rightarrow e^*e^*$
>28.3	95	KIM	89	AMY	$e^+e^- \rightarrow e^*e^*$
>27.9	95	[47] ABE	88B	VNS	$e^+e^- \rightarrow e^*e^*$

[43] BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on $\Delta\Gamma(Z)$<36 MeV.

[44] Limit is independent of e^* decay mode.

[45] ADEVA 90F is superseded by ADRIANI 93M.

[46] Superseded by DECAMP 92.

[47] ABE 88B limits assume $e^+e^- \rightarrow e^{*+}e^{*-}$ with one photon exchange only and $e^* \rightarrow e\gamma$ giving $ee\gamma\gamma$.

Limits for Excited e (e^*) from Single Production

These limits are from $e^+e^- \rightarrow e^*e$, $W \rightarrow e^*\nu$, or $ep \rightarrow e^*X$ and depend on transition magnetic coupling between e and e^*. All limits assume $e^* \rightarrow e\gamma$ decay except as noted. Limits from LEP, UA2, and H1 are for chiral coupling, whereas all other limits are for nonchiral coupling, $\eta_L = \eta_R = 1$. In most papers, the limit is expressed in the form of an excluded region in the $\lambda - m_{e^*}$ plane. See the original papers.

For limits prior to 1987, see our 1992 edition (Physical Review **D45,** 1 June, Part II (1992)).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>89	95	ADRIANI	93M	L3	$Z \rightarrow ee^*$, $\lambda_Z > 0.5$
>88	95	ABREU	92C	DLPH	$Z \rightarrow ee^*$, $\lambda_Z > 0.5$
>91	95	DECAMP	92	ALEP	$Z \rightarrow ee^*$, λ_Z >1
>87	95	AKRAWY	90I	OPAL	$Z \rightarrow ee^*$, $\lambda_Z > 0.5$

• • • We do not use the following data for averages, fits, limits, etc. • • •

		[48] ABT	93	H1	$ep \rightarrow e^* X$
>86	95	ADRIANI	93M	L3	$\lambda_\gamma > 0.04$
		[49] DERRICK	93B	ZEUS	$ep \rightarrow e^* X$
>86	95	ABREU	92C	DLPH	$e^+e^- \rightarrow ee^*$, $\lambda_\gamma > 0.1$
>88	95	[50] ADEVA	90F	L3	$Z \rightarrow ee^*$, $\lambda_Z > 0.5$
>86	95	[50] ADEVA	90F	L3	$Z \rightarrow ee^*$, $\lambda_Z > 0.04$
>81	95	[51] DECAMP	90G	ALEP	$Z \rightarrow ee^*$, $\lambda_Z > 1$
>50	95	ADACHI	89B	TOPZ	$e^+e^- \rightarrow ee^*$, $\lambda_\gamma > 0.04$
>56	95	KIM	89	AMY	$e^+e^- \rightarrow ee^*$, $\lambda_\gamma > 0.03$
none 23–54	95	[52] ABE	88B	VNS	$e^+e^- \rightarrow ee^*$ $\lambda_\gamma > 0.04$
>75	95	[53] ANSARI	87D	UA2	$W \rightarrow e^*\nu$; $\lambda_W > 0.7$
>63	95	[53] ANSARI	87D	UA2	$W \rightarrow e^*\nu$; $\lambda_W > 0.2$
>40	95	[53] ANSARI	87D	UA2	$W \rightarrow e^*\nu$; $\lambda_W > 0.09$

[48] ABT 93 search for single e^* production via $e^* e\gamma$ coupling in ep collisions with the decays $e^* \rightarrow e\gamma$, eZ, νW. See their Fig. 4 for exclusion plot in the m_{e^*}–λ_γ plane.

[49] DERRICK 93B search for single e^* production via $e^* e\gamma$ coupling in ep collisions with the decays $e^* \rightarrow e\gamma$, eZ, νW. See their Fig. 3 for exclusion plot in the m_{e^*}–λ_γ plane.

[50] Superseded by ADRIANI 93M.

[51] Superseded by DECAMP 92.

[52] ABE 88B limits use $e^+e^- \rightarrow ee^*$ where t-channel photon exchange dominates giving $e\gamma(e)$ (quasi-real compton scattering).

[53] ANSARI 87D is at E_{cm} = 546–630 GeV.

Limits for Excited e (e^*) from $e^+e^- \rightarrow \gamma\gamma$

These limits are derived from indirect effects due to e^* exchange in the t channel and depend on transition magnetic coupling between e and e^*. All limits are for $\lambda_\gamma = 1$. All limits except ABE 89J are for nonchiral coupling with $\eta_L = \eta_R = 1$.

For limits prior to 1987, see our 1992 edition (Physical Review **D45,** 1 June, Part II (1992)).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>127	95	ADRIANI	92B	L3	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[54] BUSKULIC	93Q	ALEP	
>114	95	[55] BARDADIN-...	92	RVUE	
> 99	95	DECAMP	92	ALEP	
		[56] SHIMOZAWA	92	TOPZ	
>100	95	ABREU	91E	DLPH	
>116	95	AKRAWY	91F	OPAL	
> 83	95	ADEVA	90K	L3	
> 82	95	AKRAWY	90F	OPAL	
> 68	95	[57] ABE	89J	VNS	η_L=1, η_R=0
> 90.2	95	ADACHI	89B	TOPZ	
> 65	95	KIM	89	AMY	

[54] BUSKULIC 93Q obtain $\Lambda^+ >$121 GeV (95%CL) from ALEPH experiment and $\Lambda^+ >$135 GeV from combined TRISTAN and ALEPH data. These limits roughly correspond to limits on m_{e^*}.

[55] BARDADIN-OTWINOWSKA 92 limit from fit to the combined data of DECAMP 92, ABREU 91E, ADEVA 90K, AKRAWY 91F.

[56] SHIMOZAWA 92 fit the data to the limiting form of the cross section with $m_{e^*} \gg E_{cm}$ and obtain $m_{e^*} >$168 GeV at 95%CL. Use of the full form would reduce this limit by a few GeV. The statistically unexpected large value is due to fluctuation in the data.

[57] The ABE 89J limit assumes chiral coupling. This corresponds to λ_γ = 0.7 for nonchiral coupling.

Indirect Limits for Excited e (e^*)

These limits make use of loop effects involving e^* and are therefore subject to theoretical uncertainty.

VALUE (GeV)	*DOCUMENT ID*	*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •			

[58] DORENBOS...	89	CHRM	$\overline{\nu}_\mu e \rightarrow \overline{\nu}_\mu e$ and $\nu_\mu e \rightarrow \nu_\mu e$
[59] GRIFOLS	86	THEO	$\nu_\mu e \rightarrow \nu_\mu e$
[60] RENARD	82	THEO	$g-2$ of electron

[58] DORENBOSCH 89 obtain the limit $\lambda_\gamma^2 \Lambda_{cut}^2 / m_{e^*}^2 < 2.6$ (95% CL), where Λ_{cut} is the cutoff scale, based on the one-loop calculation by GRIFOLS 86. If one assumes that Λ_{cut} = 1 TeV and $\lambda_\gamma = 1$, one obtains $m_{e^*} > 620$ GeV. However, one generally expects $\lambda_\gamma \approx m_{e^*}/\Lambda_{cut}$ in composite models.

[59] GRIFOLS 86 uses $\nu_\mu e \rightarrow \nu_\mu e$ and $\overline{\nu}_\mu e \rightarrow \overline{\nu}_\mu e$ data from CHARM Collaboration to derive mass limits which depend on the scale of compositeness.

[60] RENARD 82 derived from $g-2$ data limits on mass and couplings of e^* and μ^*. See figures 2 and 3 of the paper.

MASS LIMITS for Excited μ (μ^*)

Limits for Excited μ (μ^*) from Pair Production

These limits are obtained from $e^+ e^- \rightarrow \mu^{*+} \mu^{*-}$ and thus rely only on the (electroweak) charge of μ^*. Form factor effects are ignored unless noted. For the case of limits from Z decay, the μ^* coupling is assumed to be of sequential type. All limits assume $\mu^* \rightarrow \mu\gamma$ decay except for the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review **D45,** 1 June, Part II (1992)).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>45.6	95	ADRIANI	93M	L3	$Z \rightarrow \mu^* \mu^*$
>45.6	95	ABREU	92C	DLPH	$Z \rightarrow \mu^* \mu^*$
>46.1	95	DECAMP	92	ALEP	$Z \rightarrow \mu^* \mu^*$
>44.9	95	AKRAWY	90I	OPAL	$Z \rightarrow \mu^* \mu^*$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>29.8	95	[61] BARDADIN-...	92	RVUE	$\Gamma(Z)$
>26.1	95	[62] DECAMP	92	ALEP	$Z \rightarrow \mu^* \mu^*$; $\Gamma(Z)$
>33	95	[62] ABREU	91F	DLPH	$Z \rightarrow \mu^* \mu^*$; $\Gamma(Z)$
>45.3	95	[63] ADEVA	90F	L3	$Z \rightarrow \mu^* \mu^*$
>44.6	95	[64] DECAMP	90G	ALEP	$e^+ e^- \rightarrow \mu^* \mu^*$
>29.9	95	ADACHI	89B	TOPZ	$e^+ e^- \rightarrow \mu^* \mu^*$
>28.3	95	KIM	89	AMY	$e^+ e^- \rightarrow \mu^* \mu^*$

[61] BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on $\Delta\Gamma(Z)$<36 MeV.

[62] Limit is independent of μ^* decay mode.

[63] Superseded by ADRIANI 93M.

[64] Superseded by DECAMP 92.

Limits for Excited μ (μ^*) from Single Production

These limits are from $e^+ e^- \rightarrow \mu^* \mu$ and depend on transition magnetic coupling between μ and μ^*. All limits assume $\mu^* \rightarrow \mu\gamma$ decay. Limits from LEP are for chiral coupling, whereas all other limits are for nonchiral coupling, $\eta_L = \eta_R = 1$. In most papers, the limit is expressed in the form of an excluded region in the $\lambda - m_{\mu^*}$ plane. See the original papers.

For limits prior to 1987, see our 1992 edition (Physical Review **D45,** 1 June, Part II (1992)).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>89	95	ADRIANI	93M	L3	$Z \rightarrow \mu\mu^*$, $\lambda_Z > 0.5$
>88	95	ABREU	92C	DLPH	$Z \rightarrow \mu\mu^*$, $\lambda_Z > 0.5$
>91	95	DECAMP	92	ALEP	$Z \rightarrow \mu\mu^*$, λ_Z >1
>87	95	AKRAWY	90I	OPAL	$Z \rightarrow \mu\mu^*$, λ_Z >1
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>85	95	[65] ADEVA	90F	L3	$Z \rightarrow \mu\mu^*$, $\lambda_Z > 1$
>75	95	[65] ADEVA	90F	L3	$Z \rightarrow \mu\mu^*$, $\lambda_Z > 0.1$
>80	95	[66] DECAMP	90G	ALEP	$e^+ e^- \rightarrow \mu\mu^*$, λ_Z=1
>50	95	ADACHI	89B	TOPZ	$e^+ e^- \rightarrow \mu\mu^*$, λ_γ=0.7
>46	95	KIM	89	AMY	$e^+ e^- \rightarrow \mu\mu^*$, λ_γ=0.2

[65] Superseded by ADRIANI 93M.

[66] Superseded by DECAMP 92.

Indirect Limits for Excited μ (μ^*)

These limits make use of loop effects involving μ^* and are therefore subject to theoretical uncertainty.

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[67] RENARD	82	THEO	$g-2$ of muon

[67] RENARD 82 derived from $g-2$ data limits on mass and couplings of e^* and μ^*. See figures 2 and 3 of the paper.

MASS LIMITS for Excited τ (τ^*)

Limits for Excited τ (τ^*) from Pair Production

These limits are obtained from $e^+e^- \rightarrow \tau^{*+}\tau^{*-}$ and thus rely only on the (electroweak) charge of τ^*. Form factor effects are ignored unless noted. For the case of limits from Z decay, the τ^* coupling is assumed to be of sequential type. All limits assume $\tau^* \rightarrow \tau\gamma$ decay except for the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review **D45,** 1 June, Part II (1992)).

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>45.6	95	ADRIANI	93M	L3	$Z \rightarrow \tau^*\tau^*$
>45.3	95	ABREU	92C	DLPH	$Z \rightarrow \tau^*\tau^*$
>46.0	95	DECAMP	92	ALEP	$Z \rightarrow \tau^*\tau^*$
>44.9	95	AKRAWY	90I	OPAL	$Z \rightarrow \tau^*\tau^*$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>29.8	95	[68] BARDADIN-...	92	RVUE	$\Gamma(Z)$
>26.1	95	[69] DECAMP	92	ALEP	$Z \rightarrow \tau^*\tau^*$; $\Gamma(Z)$
>33	95	[69] ABREU	91F	DLPH	$Z \rightarrow \tau^*\tau^*$; $\Gamma(Z)$
>45.5	95	[70] ADEVA	90L	L3	$Z \rightarrow \tau^*\tau^*$
>41.2	95	[71] DECAMP	90G	ALEP	$e^+e^- \rightarrow \tau^*\tau^*$
>29.0	95	ADACHI	89B	TOPZ	$e^+e^- \rightarrow \tau^*\tau^*$

[68] BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on $\Delta\Gamma(Z)<36$ MeV.
[69] Limit is independent of τ^* decay mode.
[70] Superseded by ADRIANI 93M.
[71] Superseded by DECAMP 92.

Limits for Excited τ (τ^*) from Single Production

These limits are from $e^+e^- \rightarrow \tau^*\tau$ and depend on transition magnetic coupling between τ and τ^*. All limits assume $\tau^* \rightarrow \tau\gamma$ decay. Limits from LEP are for chiral coupling, whereas all other limits are for nonchiral coupling, $\eta_L = \eta_R = 1$. In most papers, the limit is expressed in the form of an excluded region in the $\lambda - m_{\tau^*}$ plane. See the original papers.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>88	95	ADRIANI	93M	L3	$Z \rightarrow \tau\tau^*$, $\lambda_Z > 0.5$
>87	95	ABREU	92C	DLPH	$Z \rightarrow \tau\tau^*$, $\lambda_Z > 0.5$
>90	95	DECAMP	92	ALEP	$Z \rightarrow \tau\tau^*$, $\lambda_Z > 0.18$
>86.5	95	AKRAWY	90I	OPAL	$Z \rightarrow \tau\tau^*$, $\lambda_Z > 1$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>88	95	[72] ADEVA	90L	L3	$Z \rightarrow \tau\tau^*$, $\lambda_Z > 1$
>59	95	[73] DECAMP	90G	ALEP	$Z \rightarrow \tau\tau^*$, $\lambda_Z = 1$
>40	95	[74] BARTEL	86	JADE	$e^+e^- \rightarrow \tau\tau^*$, $\lambda_\gamma = 1$
>41.4	95	[75] BEHREND	86	CELL	$e^+e^- \rightarrow \tau\tau^*$, $\lambda_\gamma = 1$
>40.8	95	[75] BEHREND	86	CELL	$e^+e^- \rightarrow \tau\tau^*$, $\lambda_\gamma = 0.7$

[72] Superseded by ADRIANI 93M.
[73] Superseded by DECAMP 92.
[74] BARTEL 86 is at E_{cm} = 30–46.78 GeV.
[75] BEHREND 86 limit is at E_{cm} = 33–46.8 GeV.

MASS LIMITS for Excited Neutrino (ν^*)

Limits for Excited ν (ν^*) from Pair Production

These limits are obtained from $Z \rightarrow \nu^* \nu^*$ decay and thus rely only on the (electroweak) charge of ν^*. Form factor effects are ignored unless noted. The ν^* coupling is assumed to be of sequential type. Limits assume $\nu^* \rightarrow \nu\gamma$ decay except for the $\Gamma(Z)$ measurement which makes no assumption about decay mode.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>47	95	[76] DECAMP	92	ALEP	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>43.7	95	[77] BARDADIN-...	92	RVUE	$\Gamma(Z)$
>42.6	95	[78] DECAMP	92	ALEP	$\Gamma(Z)$
>35.4	95	[79,80] DECAMP	90O	ALEP	$\Gamma(Z)$
>46	95	[80,81] DECAMP	90O	ALEP	

[76] Limit is based on $B(Z \rightarrow \nu^* \overline{\nu}^*) \times B(\nu^* \rightarrow \nu\gamma)^2 < 5 \times 10^{-5}$ (95%CL) assuming Dirac ν^*, $B(\nu^* \rightarrow \nu\gamma) = 1$.

[77] BARDADIN-OTWINOWSKA 92 limit is for Dirac ν^*. Based on $\Delta\Gamma(Z) < 36$ MeV. The limit is 36.4 GeV for Majorana ν^*, 45.4 GeV for homodoublet ν^*.

[78] Limit is for Dirac ν^*. The limit is 34.6 GeV for Majorana ν^*, 45.4 GeV for homodoublet ν^*.

[79] DECAMP 90O limit is from excess $\Delta\Gamma(Z) < 89$ MeV. The above value is for Dirac ν^*; 26.6 GeV for Majorana ν^*; 44.8 GeV for homodoublet ν^*.

[80] Superseded by DECAMP 92.

[81] DECAMP 90O limit based on $B(Z \rightarrow \nu^* \nu^*) \cdot B(\nu^* \rightarrow \nu\gamma)^2 < 7 \times 10^{-5}$ (95%CL), assuming Dirac ν^*, $B(\nu^* \rightarrow \nu\gamma) = 1$.

Limits for Excited ν (ν^*) from Single Production

These limits are from $Z \rightarrow \nu\nu^*$ or $ep \rightarrow \nu^* X$ and depend on transition magnetic coupling between ν/e and ν^*. Assumptions about ν^* decay mode are given in footnotes.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>91	95	ADRIANI	93M	L3	$\lambda_Z > 1$, $\nu^* \rightarrow \nu\gamma$
>89	95	ADRIANI	93M	L3	$\lambda_Z > 1$, $\nu_e^* \rightarrow eW$
>91	95	[82] DECAMP	92	ALEP	$\lambda_Z > 1$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[83] ABT	93	H1	$ep \rightarrow \nu^* X$
>87	95	ADRIANI	93M	L3	$\lambda_Z > 0.1$, $\nu^* \rightarrow \nu\gamma$
>74	95	ADRIANI	93M	L3	$\lambda_Z > 0.1$, $\nu_e^* \rightarrow eW$
		[84] BARDADIN-...	92	RVUE	
>74	95	[82] DECAMP	92	ALEP	$\lambda_Z > 0.034$
>91	95	[85,86] ADEVA	90O	L3	$\lambda_Z > 1$
>83	95	[86] ADEVA	90O	L3	$\lambda_Z > 0.1$, $\nu^* \rightarrow \nu\gamma$
>74	95	[86] ADEVA	90O	L3	$\lambda_Z > 0.1$, $\nu_e^* \rightarrow eW$
>90	95	[87,88] DECAMP	90O	ALEP	$\lambda_Z > 1$
>74.7	95	[87,88] DECAMP	90O	ALEP	$\lambda_Z > 0.06$

[82] DECAMP 92 limit is based on $B(Z \rightarrow \nu^* \overline{\nu}) \times B(\nu^* \rightarrow \nu\gamma) < 2.7 \times 10^{-5}$ (95%CL) assuming Dirac ν^*, $B(\nu^* \rightarrow \nu\gamma) = 1$.

[83] ABT 93 search for single ν^* production via $\nu^* eW$ coupling in ep collisions with the decays $\nu^* \rightarrow \nu\gamma$, νZ, eW. See their Fig. 4 for exclusion plot in the m_{ν^*}–λ_W plane.

[84] See Fig. 5 of BARDADIN-OTWINOWSKA 92 for combined limit of ADEVA 90O, DECAMP 90O, and DECAMP 92.

[85] Limit is either for $\nu^* \rightarrow \nu\gamma$ or $\nu^* \rightarrow eW$.

[86] Superseded by ADRIANI 93M.

[87] DECAMP 90O limit based on $B(Z \rightarrow \nu\nu^*) \cdot B(\nu^* \rightarrow \nu\gamma) < 6 \times 10^{-5}$ (95%CL), assuming $B(\nu^* \rightarrow \nu\gamma) = 1$.

[88] Superseded by DECAMP 92.

MASS LIMITS for Excited q (q^*)

Limits for Excited q (q^*) from Pair Production

These limits are obtained from $e^+ e^- \rightarrow q^* \overline{q}^*$ and thus rely only on the (electroweak) charge of the q^*. Form factor effects are ignored unless noted. Assumptions about the q^* decay are given in the comments and footnotes.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>45.6	95	[89] ADRIANI	93M	L3	u or d type, $Z \rightarrow q^* q^*$
>45	95	[90] DECAMP	92	ALEP	u or d type, $Z \rightarrow q^* q^*$

• • • We do not use the following data for averages, fits, limits, etc. • • •

		[91] ADRIANI	92F	L3	$Z \to q^* q^*$
>41.7	95	[92] BARDADIN-...	92	RVUE	u-type, $\Gamma(Z)$
>44.7	95	[92] BARDADIN-...	92	RVUE	d-type, $\Gamma(Z)$
>40.6	95	[93] DECAMP	92	ALEP	u-type, $\Gamma(Z)$
>44.2	95	[93] DECAMP	92	ALEP	d-type, $\Gamma(Z)$
>45	95	[93] ABREU	91F	DLPH	u-type, $\Gamma(Z)$
>45	95	[93] ABREU	91F	DLPH	d-type, $\Gamma(Z)$
>21.1	95	[94] BEHREND	86C	CELL	$e(q^*) = -1/3$, $q^* \to qg$
>22.3	95	[94] BEHREND	86C	CELL	$e(q^*) = 2/3$, $q^* \to qg$
>22.5	95	[94] BEHREND	86C	CELL	$e(q^*) = -1/3$, $q^* \to q\gamma$
>23.2	95	[94] BEHREND	86C	CELL	$e(q^*) = 2/3$, $q^* \to q\gamma$

[89] ADRIANI 93M limit is valid for B($q^* \to qg$)> 0.25 (0.17) for up (down) type.

[90] Limit is for B($q^* \to qg$)+B($q^* \to q\gamma$)=1.

[91] ADRIANI 92F search for $Z \to q^* \overline{q}^*$ followed with $q^* \to q\gamma$ decays and give the limit $\sigma_Z \cdot$ B($Z \to q^* \overline{q}^*$) $\cdot$ B^2($q^* \to q\gamma$) <2 pb at 95%CL. Assuming five flavors of degenerate q^* of homodoublet type, B($q^* \to q\gamma$) <4% is obtained for m_{q^*} <45 GeV.

[92] BARDADIN-OTWINOWSKA 92 limit based on $\Delta\Gamma(Z)$<36 MeV.

[93] These limits are independent of decay modes.

[94] BEHREND 86C search for $e^+ e^- \to q^* \overline{q}^*$ for m_{q^*} >5 GeV. But m < 5 GeV excluded by total hadronic cross section. The limits are for point-like photon couplings of excited quarks.

Limits for Excited q (q^*) from Single Production

These limits are from $e^+ e^- \to q^* \overline{q}$ or $p\overline{p} \to q^* X$ and depend on transition magnetic couplings between q and q^*. Assumptions about q^* decay mode are given in the footnotes and comments.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>540 (CL = 95%) OUR EVALUATION					
none 80–540	95	[95] ABE	94	CDF	$p\overline{p} \to q^* X$, $q^* \to q\gamma$, qW
>288	90	[96] ALITTI	93	UA2	$p\overline{p} \to q^* X$, $q^* \to qg$
> 88	95	[97] DECAMP	92	ALEP	$Z \to qq^*$, λ_Z >1
> 86	95	[97] AKRAWY	90J	OPAL	$Z \to qq^*$, λ_Z > 1.2
• • • We do not use the following data for averages, fits, limits, etc. • • •					
> 79	95	[98] ADRIANI	93M	L3	λ_Z(L3)> 0.06
		[99] ABREU	92D	DLPH	$Z \to qq^*$
		[100] ADRIANI	92F	L3	$Z \to qq^*$
> 75	95	[98] DECAMP	92	ALEP	$Z \to qq^*$, λ_Z >1
		[101] ALBAJAR	89	UA1	$p\overline{p} \to q^* X$, $q^* \to qW$
> 39	95	[102] BEHREND	86C	CELL	$e^+ e^- \to q^* \overline{q}$ ($q^* \to qg, q\gamma$), λ_γ=1

[95] ABE 94 search for resonances in jet-γ and jet-W invariant mass in $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.8 TeV. The limit is for $f_s = f = f' = \Lambda/m_{q^*}$ and u^* and d^* are assumed to be degenerate. See their Fig. 4 for the excluded region in m_{q^*}-f plane.

[96] ALITTI 93 search for resonances in the two-jet invariant mass. The limit is for $f_s = f = f' = \Lambda/m_{q^*}$. u^* and d^* are assumed to be degenerate. If not, the limit for u^* (d^*) is 277 (247) GeV if $m_{d^*} \gg m_{u^*}$ ($m_{u^*} \gg m_{d^*}$).

[97] Assumes B($q^* \to q\gamma$) = 0.1.

[98] Assumes B($q^* \to qg$) = 1.

[99] ABREU 92D give σ($e^+ e^- \to Z \to q^* \overline{q}$ or $q\overline{q}^*$)×B($q^* \to q\gamma$) <15 pb (95% CL) for m_{q^*} <80 GeV.

[100] ADRIANI 92F search for $Z \to qq^*$ with $q^* \to q\gamma$ and give the limit $\sigma_Z \cdot$ B($Z \to qq^*$) $\cdot$ B($q^* \to q\gamma$) <(2–10) pb (95%CL) for m_{q^*} = (46–82) GeV.

[101] ALBAJAR 89 give σ($q^* \to W +$ jet)/$\sigma(W)$ < 0.019 (90% CL) for m_{q^*} > 220 GeV.

[102] BEHREND 86C has $E_{\rm cm}$ = 42.5–46.8 GeV. See their Fig. 3 for excluded region in the m_{q^*}–$(\lambda_\gamma/m_{q^*})^2$ plane. The limit is for λ_γ = 1 with $\eta_L = \eta_R$ = 1.

MASS LIMITS for Color Sextet Quarks (q_6)

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>84	95	[103] ABE	89D	CDF	$p\overline{p} \to q_6 \overline{q}_6$

[103] ABE 89D look for pair production of unit-charged particles which leave the detector before decaying. In the above limit the color sextet quark is assumed to fragment into a unit-charged or neutral hadron with equal probability and to have long enough lifetime not to decay within the detector. A limit of 121 GeV is obtained for a color decuplet.

MASS LIMITS for Color Octet Charged Leptons (ℓ_8)

$\lambda \equiv m_{\ell_8}/\Lambda$

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>86	95	[104] ABE	89D	CDF	Stable ℓ_8: $p\overline{p} \to \ell_8 \overline{\ell}_8$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[105] ABT	93	H1	e_8: $ep \to e_8 X$
none 3.0–30.3	95	[106] KIM	90	AMY	e_8: $e^+e^- \to ee +$ jets
none 3.5–30.3	95	[106] KIM	90	AMY	μ_8: $e^+e^- \to \mu\mu +$ jets
		[107] KIM	90	AMY	e_8: $e^+e^- \to gg$; R
>19.8	95	[108] BARTEL	87B	JADE	e_8, μ_8, τ_8: e^+e^-; R
none 5–23.2	95	[108] BARTEL	87B	JADE	μ_8: $e^+e^- \to \mu\mu +$ jets
		[109] BARTEL	85K	JADE	e_8: $e^+e^- \to gg$; R

[104] ABE 89D look for pair production of unit-charged particles which leave the detector before decaying. In the above limit the color octet lepton is assumed to fragment into a unit-charged or neutral hadron with equal probability and to have long enough lifetime not to decay within the detector. The limit improves to 99 GeV if it always fragments into a unit-charged hadron.

[105] ABT 93 search for e_8 production via e-gluon fusion in ep collisions with $e_8 \to eg$. See their Fig. 3 for exclusion plot in the m_{e_8}–Λ plane for m_{e_8} = 35–220 GeV.

[106] KIM 90 is at $E_{\rm cm}$ = 50–60.8 GeV. The same assumptions as in BARTEL 87B are used.

[107] KIM 90 result $(m_{e_8}\Lambda_M)^{1/2} >$ 178.4 GeV (95%CL, α_s = 0.16 used) is subject to the same restriction as for BARTEL 85K.

[108] BARTEL 87B is at $E_{\rm cm}$ = 46.3–46.78 GeV. The limits assume ℓ_8 pair production cross sections to be eight times larger than those of the corresponding heavy lepton pair production.

[109] In BARTEL 85K, R can be affected by $e^+e^- \to gg$ via e_q exchange. Their limit m_{e_8} >173 GeV (CL=95%) at $\lambda = m_{e_8}/\Lambda_M = 1$ ($\eta_L = \eta_R = 1$) is not listed above because the cross section is sensitive to the product $\eta_L \eta_R$, which should be absent in ordinary theory with electronic chiral invariance.

MASS LIMITS for Color Octet Neutrinos (ν_8)

$\lambda \equiv m_{\ell_8}/\Lambda$

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>110	90	[110] BARGER	89	RVUE	ν_8: $p\overline{p} \to \nu_8 \overline{\nu}_8$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
none 3.8–29.8	95	[111] KIM	90	AMY	ν_8: $e^+e^- \to$ acoplanar jets
none 9–21.9	95	[112] BARTEL	87B	JADE	ν_8: $e^+e^- \to$ acoplanar jets

[110] BARGER 89 used ABE 89B limit for events with large missing transverse momentum. Two-body decay $\nu_8 \to \nu g$ is assumed.

[111] KIM 90 is at $E_{\rm cm}$ = 50–60.8 GeV. The same assumptions as in BARTEL 87B are used.

[112] BARTEL 87B is at $E_{\rm cm}$ = 46.3–46.78 GeV. The limit assumes the ν_8 pair production cross section to be eight times larger than that of the corresponding heavy neutrino pair production. This assumption is not valid in general for the weak couplings, and the limit can be sensitive to its $SU(2)_L \times U(1)_Y$ quantum numbers.

MASS LIMITS for W_8 (Color Octet W Boson)

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[113] ALBAJAR	89	UA1	$p\overline{p} \to W_8 X$, $W_8 \to Wg$

[113] ALBAJAR 89 give $\sigma(W_8 \to W+{\rm jet})/\sigma(W) < 0.019$ (90% CL) for $m_{W_8} >$ 220 GeV.

Limits on $ZZ\gamma$ Coupling

Limits are for the electric dipole transition form factor for $Z \rightarrow \gamma Z^*$ parametrized as $f(s') = \beta(s'/m_Z^2 - 1)$, where s' is the virtual Z mass. In the Standard Model $\beta \sim 10^{-5}$.

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.80	95	ADRIANI	92J	L3	$Z \rightarrow \gamma \nu \overline{\nu}$

REFERENCES FOR Searches for Quark and Lepton Compositeness

ABE	94	PRL 72 3004	+Albrow, Amidei, Anway-Wiese, Apollinari+	(CDF Collab.)
DIAZCRUZ	94	PR D49 R2149	Diaz Cruz, Sampayo	(CINV)
VELISSARIS	94	PL B331 227	+Lusin, Chung, Park, Cho, Bodek, Kim+	(AMY Collab.)
ABE	93G	PRL 71 2542	+Albrow, Akimoto, Amidei, Anway-Wiese+	(CDF Collab.)
ABT	93	NP B396 3	+Andreev, Andrieu, Appuhn, Arpagaus+	(H1 Collab.)
ADRIANI	93M	PRPL 236 1	+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+	(L3 Collab.)
ALITTI	93	NP B400 3	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
BUSKULIC	93Q	ZPHY C59 215	+Decamp, Goy, Lees, Minard, Mours+	(ALEPH Collab.)
DERRICK	93B	PL B316 207	+Krakauer, Magill, Musgrave, Repond+	(ZEUS Collab.)
ABE	92B	PRL 68 1463	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ABE	92D	PRL 68 1104	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ABE	92M	PRL 69 2896	+Amidei, Anway-Wiese, Apollinari, Atac+	(CDF Collab.)
ABREU	92C	ZPHY C53 41	+Adam, Adami, Adye, Akesson+	(DELPHI Collab.)
ABREU	92D	ZPHY C53 555	+Adam, Adami, Adye, Akesson, Alekseev+	(DELPHI Collab.)
ADRIANI	92B	PL B288 404	+Aguilar-Benitez, Ahlen, Akbari, Alcaraz+	(L3 Collab.)
ADRIANI	92F	PL B292 472	+Aguilar-Benitez, Ahlen, Akbari, Alcarez+	(L3 Collab.)
ADRIANI	92J	PL B297 469	+Aguilar-Benitez, Ahlen, Alcarez, Aloisio+	(L3 Collab.)
BARDADIN-...	92	ZPHY C55 163	Bardadin-Otwinowska	(CLER)
DECAMP	92	PRPL 216 253	+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
HOWELL	92	PL B291 206	+Koltick, Tauchi, Miyamoto, Kichimi+	(TOPAZ Collab.)
KROHA	92	PR D46 58		(ROCH)
PDG	92	PR D45, 1 June, Part II	Hikasa, Barnett, Stone+	(KEK, LBL, BOST+)
SHIMOZAWA	92	PL B284 144	+Fujimoto, Abe, Adachi, Doser+	(TOPAZ Collab.)
ABE	91D	PRL 67 2418	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ABREU	91E	PL B268 296	+Adam, Adami, Adye, Akesson+	(DELPHI Collab.)
ABREU	91F	NP B367 511	+Adam, Adami, Adye, Akesson+	(DELPHI Collab.)
ADACHI	91	PL B255 613	+Anazawa, Doser, Enomoto+	(TOPAZ Collab.)
AKRAWY	91F	PL B257 531	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
ALITTI	91B	PL B257 232	+Ansari, Autiero, Bareyre, Blaylock+	(UA2 Collab.)
BEHREND	91B	ZPHY C51 143	+Criegee, Field, Franke, Jung+	(CELLO Collab.)
BEHREND	91C	ZPHY C51 149	+Criegee, Field, Franke, Jung, Meyer+	(CELLO Collab.)
Also	91B	ZPHY C51 143	Behrend, Criegee, Field, Franke, Jung+	(CELLO Collab.)
ABE	90I	ZPHY C48 13	+Amako, Arai, Asano, Chiba+	(VENUS Collab.)
ADEVA	90F	PL B247 177	+Adriani, Aguilar-Benitez, Akbari, Alcaraz+	(L3 Collab.)
ADEVA	90K	PL B250 199	+Adriani, Aguilar-Benitez, Akbari, Alcarez+	(L3 Collab.)
ADEVA	90L	PL B250 205	+Adriani, Aguilar-Benitez, Akbari, Alcaraz+	(L3 Collab.)
ADEVA	90O	PL B252 525	+Adriani, Aguilar-Benitez, Akbari, Alcaraz+	(L3 Collab.)
AKRAWY	90F	PL B241 133	+Alexander, Allison, Allport+	(OPAL Collab.)
AKRAWY	90I	PL B244 135	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
AKRAWY	90J	PL B246 285	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
DECAMP	90G	PL B236 501	+Deschizeaux, Lees, Minard+	(ALEPH Collab.)
DECAMP	90O	PL B250 172	+Deschizeaux, Goy, Lees+	(ALEPH Collab.)
KIM	90	PL B240 243	+Breedon, Ko, Lander, Maeshima, Malchow+	(AMY Collab.)
ABE	89	PRL 62 613	+Amidei, Apollinari, Ascori, Atac+	(CDF Collab.)
ABE	89B	PRL 62 1825	+Amidei, Apollinari, Ascoli, Atac+	(CDF Collab.)
ABE	89D	PRL 63 1447	+Amidei, Apollinari, Ascoli, Atac+	(CDF Collab.)
ABE	89H	PRL 62 3020	+Amidei, Apollinari, Ascoli, Atac+	(CDF Collab.)
ABE	89J	ZPHY C45 175	+Amako, Arai, Fukawa+	(VENUS Collab.)
ABE	89L	PL B232 425	+Amako, Arai, Asano, Chiba+	(VENUS Collab.)
ADACHI	89B	PL B228 553	+Aihara, Doser, Enomoto, Fujii+	(TOPAZ Collab.)
ALBAJAR	89	ZPHY C44 15	+Albrow, Allkofer, Arnison, Astbury+	(UA1 Collab.)
BARGER	89	PL B220 464	+Hagiwara, Han, Zeppenfeld	(WISC, KEK)
BEHREND	89B	PL B222 163	+Criegee, Dainton, Field, Franke+	(CELLO Collab.)
BRAUNSCH...	89C	ZPHY C43 549	Braunschweig, Gerhards, Kirschfink+	(TASSO Collab.)
DORENBOS...	89	ZPHY C41 567	Dorenbosch, Udo, Allaby, Amaldi+	(CHARM Collab.)
HAGIWARA	89	PL B219 369	+Sakuda, Terunuma	(KEK, DURH, HIRO)
KIM	89	PL B223 476	+Kim, Kang, Lee, Myung, Bacala	(AMY Collab.)
ABE	88B	PL B213 400	+Amako, Arai, Asano, Chiba, Chiba+	(VENUS Collab.)
BARINGER	88	PL B206 551	+Bylsma, De Bonte, Koltick, Low+	(HRS Collab.)
BRAUNSCH...	88	ZPHY C37 171	Braunschweig, Gerhards+	(TASSO Collab.)
BRAUNSCH...	88D	ZPHY C40 163	Braunschweig, Gerhards, Kirschfink+	(TASSO Collab.)
ANSARI	87D	PL B195 613	+Bagnaia, Banner+	(UA2 Collab.)
BARTEL	87B	ZPHY C36 15	+Becker, Felst+	(JADE Collab.)
BEHREND	87C	PL B191 209	+Buerger, Criegee, Dainton+	(CELLO Collab.)
FERNANDEZ	87B	PR D35 10	+Ford, Qi, Read, Smith, Camporesi+	(MAC Collab.)
ARNISON	86C	PL B172 461	+Albrow, Allkofer+	(UA1 Collab.)
ARNISON	86D	PL B177 244	+Albajar, Albrow+	(UA1 Collab.)
BARTEL	86	ZPHY C31 359	+Becker, Felst, Haidt+	(JADE Collab.)
BARTEL	86C	ZPHY C30 371	+Becker, Cords, Felst, Haidt+	(JADE Collab.)
BEHREND	86	PL 168B 420	+Buerger, Criegee, Fenner+	(CELLO Collab.)
BEHREND	86C	PL B181 178	+Buerger, Criegee, Dainton+	(CELLO Collab.)
DERRICK	86	PL 166B 463	+Gan, Kooijman, Loos+	(HRS Collab.)
Also	86B	PR D34 3286	Derrick, Gan, Kooijman, Loos, Musgrave+	(HRS Collab.)
DERRICK	86B	PR D34 3286	+Gan, Kooijman, Loos, Musgrave+	(HRS Collab.)
GRIFOLS	86	PL 168B 264	+Peris	(BARC)
JODIDIO	86	PR D34 1967	+Balke, Carr, Gidal, Shinsky+	(LBL, NWES, TRIU)
Also	88	PR D37 237 erratum	Jodidio, Balke, Carr+	(LBL, NWES, TRIU)

APPEL	85	PL 160B 349	+Bagnaia, Banner+	(UA2 Collab.)
BARTEL	85K	PL 160B 337	+Becker, Cords, Eichler+	(JADE Collab.)
BERGER	85	ZPHY C28 1	+Genzel, Lackas, Pielorz+	(PLUTO Collab.)
BERGER	85B	ZPHY C27 341	+Deuter, Genzel, Lackas, Pielorz+	(PLUTO Collab.)
BAGNAIA	84C	PL 138B 430	+Banner, Battiston+	(UA2 Collab.)
BARTEL	84D	PL 146B 437	+Becker, Bowdery, Cords+	(JADE Collab.)
BARTEL	84E	PL 146B 121	+Becker, Bowdery, Cords, Felst+	(JADE Collab.)
EICHTEN	84	RMP 56 579	+Hinchliffe, Lane, Quigg	(FNAL, LBL, OSU)
ALTHOFF	83C	PL 126B 493	+Fischer, Burkhardt+	(TASSO Collab.)
RENARD	82	PL 116B 264		(CERN)