Quark and Lepton Compositeness, Searches for

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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
>8.3	**>10.3**	95	[1] BOURILKOV	01	RVUE	$E_{\rm cm}$= 192–208 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>4.5	>7.0	95	[2] SCHAEL	07A	ALEP	$E_{\rm cm}$= 189–209 GeV
>5.3	>6.8	95	ABDALLAH	06C	DLPH	$E_{\rm cm}$= 130–207 GeV
>4.7	>6.1	95	[3] ABBIENDI	04G	OPAL	$E_{\rm cm}$= 130–207 GeV
>3.8	>5.6	95	ABBIENDI	00R	OPAL	$E_{\rm cm}$= 189 GeV
>4.4	>5.4	95	ABREU	00S	DLPH	$E_{\rm cm}$= 183–189 GeV
>4.3	>4.9	95	ACCIARRI	00P	L3	$E_{\rm cm}$= 130–189 GeV
>3.5	>3.2	95	BARATE	00I	ALEP	Superseded by SCHAEL 07A
>6.0	>7.7	95	[4] BOURILKOV	00	RVUE	$E_{\rm cm}$= 183–189 GeV
>3.1	>3.8	95	ABBIENDI	99	OPAL	$E_{\rm cm}$= 130–136, 161–172, 183 GeV
>2.2	>2.8	95	ABREU	99A	DLPH	$E_{\rm cm}$= 130–172 GeV
>2.7	>2.4	95	ACCIARRI	98J	L3	$E_{\rm cm}$= 130–172 GeV
>3.0	>2.5	95	ACKERSTAFF	98V	OPAL	$E_{\rm cm}$= 130–172 GeV

[1] A combined analysis of the data from ALEPH, DELPHI, L3, and OPAL.

[2] SCHAEL 07A limits are from R_c, Q^{depl}_{FB}, and hadronic cross section measurements.

[3] ABBIENDI 04G limits are from $e^+e^- \to e^+e^-$ cross section at $\sqrt{s}$ = 130–207 GeV.

[4] A combined analysis of the data from ALEPH, L3, and OPAL.

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
>6.6	**>9.5**	95	[5] SCHAEL	07A	ALEP	$E_{\rm cm}$= 189–209 GeV
> 8.5	>3.8	95	ACCIARRI	00P	L3	$E_{\rm cm}$= 130–189 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>7.3	>7.6	95	ABDALLAH	06C	DLPH	$E_{\rm cm}$= 130–207 GeV
>8.1	>7.3	95	[6] ABBIENDI	04G	OPAL	$E_{\rm cm}$= 130–207 GeV
>7.3	>4.6	95	ABBIENDI	00R	OPAL	$E_{\rm cm}$= 189 GeV
>6.6	>6.3	95	ABREU	00S	DLPH	$E_{\rm cm}$= 183–189 GeV
>4.0	>4.7	95	BARATE	00I	ALEP	Superseded by SCHAEL 07A
>4.5	>4.3	95	ABBIENDI	99	OPAL	$E_{\rm cm}$= 130–136, 161–172, 183 GeV
>3.4	>2.7	95	ABREU	99A	DLPH	$E_{\rm cm}$= 130–172 GeV
>3.6	>2.4	95	ACCIARRI	98J	L3	$E_{\rm cm}$= 130–172 GeV
>2.9	>3.4	95	ACKERSTAFF	98V	OPAL	$E_{\rm cm}$= 130–172 GeV
>3.1	>2.0	95	MIURA	98	VNS	$E_{\rm cm}$= 57.77 GeV

[5] SCHAEL 07A limits are from R_c, Q_{FB}^{depl}, and hadronic cross section measurements.

[6] ABBIENDI 04G limits are from $e^+e^- \rightarrow \mu\mu$ cross section at $\sqrt{s}$ = 130–207 GeV.

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
>7.9	>5.8	95	[7] SCHAEL	07A	ALEP	E_{cm}= 189–209 GeV
>7.9	>4.6	95	ABDALLAH	06C	DLPH	E_{cm}= 130–207 GeV
>4.9	**>7.2**	95	[8] ABBIENDI	04G	OPAL	E_{cm}= 130–207 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>3.9	>6.5	95	ABBIENDI	00R	OPAL	E_{cm}= 189 GeV
>5.2	>5.4	95	ABREU	00S	DLPH	E_{cm}= 183–189 GeV
>5.4	>4.7	95	ACCIARRI	00P	L3	E_{cm}= 130–189 GeV
>3.9	>3.7	95	BARATE	00I	ALEP	Superseded by SCHAEL 07A
>3.8	>4.0	95	ABBIENDI	99	OPAL	E_{cm}= 130–136, 161–172, 183 GeV
>2.8	>2.6	95	ABREU	99A	DLPH	E_{cm}= 130–172 GeV
>2.4	>2.8	95	ACCIARRI	98J	L3	E_{cm}= 130–172 GeV
>2.3	>3.7	95	ACKERSTAFF	98V	OPAL	E_{cm}= 130–172 GeV

[7] SCHAEL 07A limits are from R_c, Q_{FB}^{depl}, and hadronic cross section measurements.

[8] ABBIENDI 04G limits are from $e^+e^- \rightarrow \tau\tau$ cross section at $\sqrt{s}$ = 130–207 GeV.

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
>7.9	**> 10.3**	95	[9] SCHAEL	07A	ALEP	E_{cm}= 189–209 GeV
>9.1	>8.2	95	ABDALLAH	06C	DLPH	E_{cm}= 130–207 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>7.7	>9.5	95	[10] ABBIENDI	04G	OPAL	E_{cm}= 130–207 GeV
			[11] BABICH	03	RVUE	
>6.4	>7.2	95	ABBIENDI	00R	OPAL	E_{cm}= 189 GeV
>7.3	>7.8	95	ABREU	00S	DLPH	E_{cm}= 183–189 GeV
>9.0	>5.2	95	ACCIARRI	00P	L3	E_{cm}= 130–189 GeV
>5.3	>5.5	95	BARATE	00I	ALEP	Superseded by SCHAEL 07A
>5.2	>5.3	95	ABBIENDI	99	OPAL	E_{cm}= 130–136, 161–172, 183 GeV
>4.4	>4.2	95	ABREU	99A	DLPH	E_{cm}= 130–172 GeV
>4.0	>3.1	95	[12] ACCIARRI	98J	L3	E_{cm}= 130–172 GeV
>3.4	>4.4	95	ACKERSTAFF	98V	OPAL	E_{cm}= 130–172 GeV

[9] SCHAEL 07A limits are from R_c, Q^{depl}_{FB}, and hadronic cross section measurements.

[10] ABBIENDI 04G limits are from $e^+ e^- \rightarrow \ell^+ \ell^-$ cross section at $\sqrt{s}$ = 130–207 GeV.

[11] BABICH 03 obtain a bound -0.175 TeV^{-2} $<1/\Lambda^2_{LL} <$ 0.095 TeV^{-2} (95%CL) in a model independent analysis allowing all of Λ_{LL}, Λ_{LR}, Λ_{RL}, Λ_{RR} to coexist.

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

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
> 9.4	**>5.6**	95	[13] SCHAEL	07A	ALEP	$(eecc)$
> 9.4	**>4.9**	95	[14] SCHAEL	07A	ALEP	$(eebb)$
>23.3	**>12.5**	95	[15] CHEUNG	01B	RVUE	$(eeuu)$
>11.1	**>26.4**	95	[15] CHEUNG	01B	RVUE	$(eedd)$

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

Λ^+_{LL}(TeV)	Λ^-_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>12.9	>7.2	95	[16] SCHAEL	07A	ALEP	$(eeqq)$
> 3.7	>5.9	95	[17] ABULENCIA	06L	CDF	$(eeqq)$
> 8.2	>3.7	95	[18] ABBIENDI	04G	OPAL	$(eeqq)$
> 5.9	>9.1	95	[18] ABBIENDI	04G	OPAL	$(eeuu)$
> 8.6	>5.5	95	[18] ABBIENDI	04G	OPAL	$(eedd)$
> 2.7	>1.7	95	CHEKANOV	04B	ZEUS	$(eeqq)$
> 2.8	>1.6	95	[19] ADLOFF	03	H1	$(eeqq)$
> 2.7	>2.7	95	[20] ACHARD	02J	L3	$(eetc)$
> 5.5	>3.1	95	[21] ABBIENDI	00R	OPAL	$(eeqq)$
> 4.9	>6.1	95	[21] ABBIENDI	00R	OPAL	$(eeuu)$
> 5.7	>4.5	95	[21] ABBIENDI	00R	OPAL	$(eedd)$
> 4.2	>2.8	95	[22] ACCIARRI	00P	L3	$(eeqq)$
> 2.4	>1.3	95	[23] ADLOFF	00	H1	$(eeqq)$
> 5.4	>6.2	95	[24] BARATE	00I	ALEP	Superseded by SCHAEL 07A
> 5.6	>4.9	95	[25] BARATE	00I	ALEP	Superseded by SCHAEL 07A
			[26] BREITWEG	00B	ZEUS	
> 4.4	>2.8	95	[27] ABBIENDI	99	OPAL	$(eeqq)$
> 4.0	>4.8	95	[28] ABBIENDI	99	OPAL	$(eebb)$
> 3.3	>4.2	95	[29] ABBOTT	99D	D0	$(eeqq)$
> 2.4	>2.8	95	[30] ABREU	99A	DLPH	$(eeqq)$ (d or s quark)
> 4.4	>3.9	95	[30] ABREU	99A	DLPH	$(eebb)$
> 1.0	>2.4	95	[30] ABREU	99A	DLPH	$(eeuu)$
> 1.0	>2.1	95	[30] ABREU	99A	DLPH	$(eecc)$
> 4.0	>3.4	95	[31] ZARNECKI	99	RVUE	$(eedd)$
> 4.3	>5.6	95	[31] ZARNECKI	99	RVUE	$(eeuu)$
> 3.0	>2.1	95	[32] ACCIARRI	98J	L3	$(eeqq)$
> 3.4	>2.2	95	[33] ACKERSTAFF	98V	OPAL	$(eeqq)$
> 4.0	>2.8	95	[34] ACKERSTAFF	98V	OPAL	$(eebb)$
> 9.3	>12.0	95	[35] BARGER	98E	RVUE	$(eeuu)$
> 8.8	>11.9	95	[35] BARGER	98E	RVUE	$(eedd)$

[13] SCHAEL 07A limits are from R_c, Q_{FB}^{depl}, and hadronic cross section measurements.

[14] SCHAEL 07A limits are from R_b, A_{FB}^{b}.

[15] CHEUNG 01B is an update of BARGER 98E.

[16] SCHAEL 07A limit assumes quark flavor universality of the contact interactions.

[17] ABULENCIA 06L limits are from $p\overline{p}$ collisions at $\sqrt{s} = 1.96$ TeV.

[18] ABBIENDI 04G limits are from $e^+ e^- \rightarrow q\overline{q}$ cross section at $\sqrt{s} = 130$–207 GeV.

[19] ADLOFF 03 limits are from the $d\sigma/dQ^2$ measurement of $e^{\pm} p \rightarrow e^{\pm} X$.

[20] ACHARD 02J limit is from the bound on the $e^+ e^- \rightarrow t\overline{c}$ cross section. $\Lambda_{LL} = \Lambda_{LR} = \Lambda_{RL} = \Lambda_{RR}$ and $m_t = 175$ GeV are assumed.

[21] ABBIENDI 00R limits are from $e^+ e^- \rightarrow q\overline{q}$ cross section at $\sqrt{s}= 130$–189 GeV.

[22] ACCIARRI 00P limit is from $e^+ e^- \rightarrow qq$ cross section at $\sqrt{s}=130$–189 GeV.

[23] ADLOFF 00 limits are from the Q^2 spectrum measurement of $e^+ p \rightarrow e^+ X$.

[24] BARATE 00I limits are from $e^+ e^- \rightarrow q\overline{q}$ cross section and jet-charge asymmetry at 130–183 GeV.

[25] BARATE 00I limits are from R_b and jet-charge asymmetry at 130–183 GeV.

[26] BREITWEG 00B limits are from Q^2 spectrum measurement of $e^+ p$ collisions. See their Table 3 for the limits of various models.

[27] ABBIENDI 99 limits are from $e^+ e^- \rightarrow q\overline{q}$ cross section at 130–136, 161–172, 183 GeV.

[28] ABBIENDI 99 limits are from R_b at 130–136, 161–172, 183 GeV.

[29] ABBOTT 99D limits are from $e^+ e^-$ mass distribution in $p\overline{p} \rightarrow e^+ e^- X$ at $E_{cm}=$ 1.8 TeV.

[30] ABREU 99A limits are from flavor-tagged $e^+ e^- \rightarrow q\overline{q}$ cross section at 130–172 GeV.

[31] ZARNECKI 99 use data from HERA, LEP, Tevatron, and various low-energy experiments.

[32] ACCIARRI 98J limits are from $e^+ e^- \rightarrow q\overline{q}$ cross section at $E_{cm}= 130$–172 GeV.

[33] ACKERSTAFF 98V limits are from $e^+ e^- \rightarrow q\overline{q}$ at $E_{cm}= 130$–172 GeV.

[34] ACKERSTAFF 98V limits are from R_b measurements at $E_{cm}= 130$–172 GeV.

[35] BARGER 98E use data from HERA, LEP, Tevatron, and various low-energy experiments.

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

Λ^+_{LL}(TeV)	Λ^-_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
> 2.9	**> 4.2**	95	[36] ABE	97T	CDF	$(\mu\mu qq)$ (isosinglet)
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>1.4	>1.6	95	ABE	92B	CDF	$(\mu\mu qq)$ (isosinglet)

[36] ABE 97T limits are from $\mu^+ \mu^-$ mass distribution in $\overline{p}p \rightarrow \mu^+ \mu^- X$ at E_{cm}=1.8 TeV.

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

VALUE (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>3.10	90	[37] 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		[38] DIAZCRUZ	94	RVUE	$\Lambda^{+}_{LL}(\tau\nu_\tau e\nu_e)$
>8.1		[38] DIAZCRUZ	94	RVUE	$\Lambda^{-}_{LL}(\tau\nu_\tau e\nu_e)$
>4.1		[39] DIAZCRUZ	94	RVUE	$\Lambda^{+}_{LL}(\tau\nu_\tau \mu\nu_\mu)$
>6.5		[39] DIAZCRUZ	94	RVUE	$\Lambda^{-}_{LL}(\tau\nu_\tau \mu\nu_\mu)$

[37] JODIDIO 86 limit is from $\mu^+ \to \overline{\nu}_\mu e^+ \nu_e$. 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.

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

[39] DIAZCRUZ 94 limits are from $\Gamma(\tau \to \mu\nu\nu)$ 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: $\Lambda(e\nu qq)$

VALUE (TeV)	*CL%*	*DOCUMENT ID*		*TECN*
>2.81	95	[40] AFFOLDER	01I	CDF

[40] AFFOLDER 00I bound is for a scalar interaction $\overline{q}_R q_L \overline{\nu} e_L$.

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

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

VALUE (TeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>2.7	95	[41] ABBOTT	99C	D0	$p\overline{p} \to$ dijet mass. Λ^+_{LL}
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>2.0	95	[42] ABBOTT	00E	D0	H_T distribution; Λ^+_{LL}
>2.1	95	[43] ABBOTT	98G	D0	$p\overline{p} \to$ dijet angl. Λ^+_{LL}
		[44] BERTRAM	98	RVUE	$p\overline{p} \to$ dijet mass

[41] The quoted limit is from inclusive dijet mass spectrum in $p\overline{p}$ collisions at E_{cm}=1.8 TeV. ABBOTT 99C also obtain $\Lambda^-_{LL} > 2.4$ TeV. All quarks are assumed composite.

[42] The quoted limit for ABBOTT 00E is from H_T distribution in $p\overline{p}$ collisions at E_{cm}=1.8 TeV. CTEQ4M PDF and μ=E_T^{max} are assumed. For limits with different assumptions, see their Tables 2 and 3. All quarks are assumed composite.

[43] ABBOTT 98G limit is from dijet angular distribution in $p\overline{p}$ collisions at E_{cm}= 1.8 TeV. All quarks are assumed composite.

[44] BERTRAM 98 obtain limit on the scale of color-octet axial-vector flavor-universal contact interactions: $\Lambda_{A8} > 2.1$ TeV. They also obtain a limit $\Lambda_{V8} > 2.4$ TeV on a color-octet flavor-universal vectorial contact interaction.

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

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

Λ^+_{LL}(TeV)	Λ^-_{LL}(TeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>5.0	**>5.4**	95	[45] MCFARLAND	98	CCFR	νN scattering

[45] MCFARLAND 98 assumed a flavor universal interaction. Neutrinos were mostly of muon type.

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 a dominant $e^* \rightarrow e\gamma$ decay except the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>103.2	95	[46] ABBIENDI	02G	OPAL	$e^+ e^- \rightarrow e^* e^*$ Homodoublet type
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>102.8	95	[47] ACHARD	03B	L3	$e^+ e^- \rightarrow e^* e^*$ Homodoublet type
>100.0	95	[48] ACCIARRI	01D	L3	$e^+ e^- \rightarrow e^* e^*$ Homodoublet type
> 91.3	95	[49] ABBIENDI	00I	OPAL	$e^+ e^- \rightarrow e^* e^*$ Homodoublet type
> 94.2	95	[50] ACCIARRI	00E	L3	$e^+ e^- \rightarrow e^* e^*$ Homodoublet type
> 90.7	95	[51] ABREU	99O	DLPH	Homodoublet type
> 85.0	95	[52] ACKERSTAFF	98C	OPAL	$e^+ e^- \rightarrow e^* e^*$ Homodoublet type
		[53] BARATE	98U	ALEP	$Z \rightarrow e^* e^*$
> 79.6	95	[54,55] ABREU	97B	DLPH	$e^+ e^- \rightarrow e^* e^*$ Homodoublet type
> 77.9	95	[54,56] ABREU	97B	DLPH	$e^+ e^- \rightarrow e^* e^*$ Sequential type
> 79.7	95	[54] ACCIARRI	97G	L3	$e^+ e^- \rightarrow e^* e^*$ Sequential type

[46] From $e^+ e^-$ collisions at $\sqrt{s} = 183$–209 GeV. $f = f'$ is assumed.

[47] From $e^+ e^-$ collisions at $\sqrt{s} = 189$–209 GeV. $f = f'$ is assumed. ACHARD 03B also obtain limit for $f = -f'$: $m_{e^*} > 96.6$ GeV.

[48] From $e^+ e^-$ collisions at $\sqrt{s} = 192$–202 GeV. $f=f'$ is assumed. ACCIARRI 01D also obtain limit for $f=-f'$: $m_{e^*} > 93.4$ GeV.

[49] From $e^+ e^-$ collisions at $\sqrt{s}=161$–183 GeV. $f=f'$ is assumed. ABBIENDI 00I also obtain limit for $f=-f'$ ($e^* \rightarrow \nu W$): $m_{e^*} > 86.0$ GeV.

[50] From $e^+ e^-$ collisions at $\sqrt{s}=189$ GeV. $f=f'$ is assumed. ACCIARRI 00E also obtain limit for $f=-f'$ ($e^* \rightarrow \nu W$): $m_{e^*} > 92.6$ GeV.

[51] From $e^+ e^-$ collisions at $\sqrt{s}$= 183 GeV. f=f' is assumed. ABREU 99O also obtain limit for f=$-f'$ ($e^* \to \nu W$): $m_{e^*} > 81.3$ GeV.

[52] From $e^+ e^-$ collisions at $\sqrt{s}$=170–172 GeV. ACKERSTAFF 98C also obtain limit from $e^* \to \nu W$ decay mode: $m_{e^*} > 81.3$ GeV.

[53] BARATE 98U obtain limits on the form factor. See their Fig. 14 for limits in mass-form factor plane.

[54] From $e^+ e^-$ collisions at $\sqrt{s}$= 161 GeV.

[55] ABREU 97B also obtain limit from charged current decay mode $e^* \to \nu W$, $m_{e^*} > 70.9$ GeV.

[56] ABREU 97B also obtain limit from charged current decay mode $e^* \to \nu W$, $m_{e^*} > 44.6$ GeV.

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

These limits are from $e^+ e^- \to e^* e$, $W \to e^* \nu$, or $e p \to e^* X$ and depend on transition magnetic coupling between e and e^*. All limits assume $e^* \to e \gamma$ 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** S1 (1992)).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>255	95	[57] ADLOFF	02B	H1	$e p \to e^* X$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>209	95	[58] ACOSTA	05B	CDF	$p \overline{p} \to e^* X$
>206	95	[59] ACHARD	03B	L3	$e^+ e^- \to e e^*$
>208	95	[60] ABBIENDI	02G	OPAL	$e^+ e^- \to e e^*$
>228	95	[61] CHEKANOV	02D	ZEUS	$e p \to e^* X$
>202		[62] ACCIARRI	01D	L3	$e^+ e^- \to e e^*$
		[63] ABBIENDI	00I	OPAL	$e^+ e^- \to e e^*$
		[64] ACCIARRI	00E	L3	$e^+ e^- \to e e^*$
>223	95	[65] ADLOFF	00E	H1	$e p \to e^* X$
		[66] ABREU	99O	DLPH	$e^+ e^- \to e e^*$
none 20–170	95	[67] ACCIARRI	98T	L3	$e \gamma \to e^* \to e \gamma$
		[68] ACKERSTAFF	98C	OPAL	$e^+ e^- \to e e^*$
		[69] BARATE	98U	ALEP	$e^+ e^- \to e e^*$
		[70,71] ABREU	97B	DLPH	$e^+ e^- \to e e^*$
		[70,72] ACCIARRI	97G	L3	$e^+ e^- \to e e^*$
		[73] ACKERSTAFF	97	OPAL	$e^+ e^- \to e e^*$
		[74] ADLOFF	97	H1	Lepton-flavor violation
none 30–200	95	[75] BREITWEG	97C	ZEUS	$e p \to e^* X$

[57] ADLOFF 02B search for single e^* production in $e p$ collisions with the decays $e^* \to e \gamma$, $e Z$, νW. $f = f' = \Lambda / m_{e^*}$ is assumed for the e^* coupling. See their Fig. 3 for the exclusion plot in the mass-coupling plane.

[58] ACOSTA 05B search for single e^* production in $p \overline{p}$ collisions with the decays $e^* \to e \gamma$. $f = f' = \Lambda / m_{e^*}$ is assumed for the e^* coupling. See their Fig.3 for the exclusion limit in the mass-coupling plane.

[59] ACHARD 03B result is from $e^+ e^-$ collisions at $\sqrt{s}$ = 189–209 GeV. See their Fig. 4 for the exclusion plot in the mass-coupling plane.

[60] ABBIENDI 02G result is from $e^+ e^-$ collisions at $\sqrt{s}$ = 183–209 GeV. $f = f' = \Lambda/m_{e^*}$ is assumed for e^* coupling. See their Fig. 4c for the exclusion limit in the mass-coupling plane.

[61] CHEKANOV 02D search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma$, eZ, νW. $f = f' = \Lambda/m_{e^*}$ is assumed for the e^* coupling. See their Fig. 5a for the exclusion plot in the mass-coupling plane.

[62] ACCIARRI 01D result is from $e^+ e^-$ collisions at $\sqrt{s}$ = 192–202 GeV. $f{=}f'{=}\Lambda/m_{e^*}$ is assumed for the e^* coupling. See their Fig. 4 for limits in the mass-coupling plane.

[63] ABBIENDI 00I result is from $e^+ e^-$ collisions at $\sqrt{s}$=161–183 GeV. See their Fig. 7 for limits in mass-coupling plane.

[64] ACCIARRI 00E result is from $e^+ e^-$ collisions at $\sqrt{s}$=189 GeV. See their Fig. 3 for limits in mass-coupling plane.

[65] ADLOFF 00E search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma$, eZ, νW. $f{=}f'{=}\Lambda/m_{e^*}$ is assumed for the e^* coupling. See their Fig. 9 for the exclusion plot in the mass-coupling plane.

[66] ABREU 99O result is from $e^+ e^-$ collisions at $\sqrt{s}$= 183 GeV. See their Figs. 4 and 5 for the exclusion limit in the mass-coupling plane.

[67] ACCIARRI 98T search for single e^* production in quasi-real Compton scattering. The limit is for $|\lambda| > 1.0 \times 10^{-1}$ and non-chiral coupling of e^*. See their Fig. 7 for the exclusion plot in the mass-coupling plane.

[68] ACKERSTAFF 98C from $e^+ e^-$ collisions at $\sqrt{s}$=170–172 GeV. See their Fig. 11 for the exclusion limit in the mass-coupling plane.

[69] BARATE 98U is from $e^+ e^-$ collision at $\sqrt{s}{=}M_Z$. See their Fig. 12 for limits in mass-coupling plane

[70] From $e^+ e^-$ collisions at $\sqrt{s}$= 161 GeV.

[71] See Fig. 4a and Fig. 5a of ABREU 97B for the exclusion limit in the mass-coupling plane.

[72] See Fig. 2 and Fig. 3 of ACCIARRI 97G for the exclusion limit in the mass-coupling plane.

[73] ACKERSTAFF 97 result is from $e^+ e^-$ collisions at $\sqrt{s}$= 161 GeV. See their Fig. 3 for the exclusion limit in the mass-coupling plane.

[74] ADLOFF 97 search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma$, eZ, νW. See their Fig. 4 for the rejection limits on the product of the production cross section and the branching ratio into a specific decay channel.

[75] BREITWEG 97C search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma$, eZ, νW. $f{=}f'{=}2\Lambda/m_{e^*}$ is assumed for the e^* coupling. See their Fig. 9 for the exclusion plot in the mass-coupling plane.

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 and ACHARD 02D are for nonchiral coupling with $\eta_L = \eta_R$ = 1. We choose the chiral coupling limit as the best limit and list it in the Summary Table.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>310	95	ACHARD	02D	L3	$\sqrt{s}$= 192–209 GeV

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

>356	95	[76] ABDALLAH	04N	DLPH	$\sqrt{s}$= 161–208 GeV
>311	95	ABREU	00A	DLPH	$\sqrt{s}$= 189–202 GeV
>283	95	[77] ACCIARRI	00G	L3	$\sqrt{s}$= 183–189 GeV
>306	95	ABBIENDI	99P	OPAL	$\sqrt{s}$= 189 GeV
>231	95	ABREU	98J	DLPH	$\sqrt{s}$= 130–183 GeV
>194	95	ACKERSTAFF	98	OPAL	$\sqrt{s}$= 130–172 GeV
>227	95	ACKER..,K...	98B	OPAL	$\sqrt{s}$= 183 GeV
>250	95	BARATE	98J	ALEP	$\sqrt{s}$= 183 GeV
>160	95	[78] BARATE	98U	ALEP	

[76] ABDALLAH 04N also obtain a limit on the excited electron mass with $e e^*$ chiral coupling, $m_{e^*} > 295$ GeV at 95% CL.

[77] ACCIARRI 00G also obtain a limit on e^* with chiral coupling, $m_{e^*} > 213$ GeV.

[78] BARATE 98U is from $e^+ e^-$ collision at $\sqrt{s}=M_Z$. See their Fig. 5 for limits in mass-coupling plane

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

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

[80] 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.

[81] 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 a dominant $\mu^* \rightarrow \mu\gamma$ decay except the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>103.2	95	[82] ABBIENDI	02G	OPAL	$e^+ e^- \rightarrow \mu^* \mu^*$ Homodoublet type

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

>102.8	95	[83] ACHARD	03B	L3	$e^+e^- \to \mu^*\mu^*$ Homodoublet type
>100.2	95	[84] ACCIARRI	01D	L3	$e^+e^- \to \mu^*\mu^*$ Homodoublet type
>91.3	95	[85] ABBIENDI	00I	OPAL	$e^+e^- \to \mu^*\mu^*$ Homodoublet type
>94.2	95	[86] ACCIARRI	00E	L3	$e^+e^- \to \mu^*\mu^*$ Homodoublet type
>90.7	95	[87] ABREU	99O	DLPH	Homodoublet type
>85.3	95	[88] ACKERSTAFF	98C	OPAL	$e^+e^- \to \mu^*\mu^*$ Homodoublet type
		[89] BARATE	98U	ALEP	$Z \to \mu^*\mu^*$
>79.6	95	[90,91] ABREU	97B	DLPH	$e^+e^- \to \mu^*\mu^*$ Homodoublet type
>78.4	95	[90,92] ABREU	97B	DLPH	$e^+e^- \to \mu^*\mu^*$ Sequential type
>79.9	95	[90] ACCIARRI	97G	L3	$e^+e^- \to \mu^*\mu^*$ Sequential type

[82] From e^+e^- collisions at $\sqrt{s}$ = 183–209 GeV. $f = f'$ is assumed.

[83] From e^+e^- collisions at $\sqrt{s}$ = 189–209 GeV. $f = f'$ is assumed. ACHARD 03B also obtain limit for $f = -f'$: $m_{\mu^*} > 96.6$ GeV.

[84] From e^+e^- collisions at $\sqrt{s}$ = 192–202 GeV. f=f' is assumed. ACCIARRI 01D also obtain limit for f=$-f'$: $m_{\mu^*} > 93.4$ GeV.

[85] From e^+e^- collisions at $\sqrt{s}$=161–183 GeV. f=f' is assumed. ABBIENDI 00I also obtain limit for f=$-f'$ ($\mu^* \to \nu W$): $m_{\mu^*} > 86.0$ GeV.

[86] From e^+e^- collisions at $\sqrt{s}$=189 GeV. f=f' is assumed. ACCIARRI 00E also obtain limit for f=$-f'$ ($\mu^* \to \nu W$): $m_{\mu^*} > 92.6$ GeV.

[87] From e^+e^- collisions at $\sqrt{s}$= 183 GeV. f=f' is assumed. ABREU 99O also obtain limit for f=$-f'$ ($\mu^* \to \nu W$): $m_{\mu^*} > 81.3$ GeV.

[88] From e^+e^- collisions at $\sqrt{s}$=170–172 GeV. ACKERSTAFF 98C also obtain limit from $\mu^* \to \nu W$ decay mode: $m_{\mu^*} > 81.3$ GeV.

[89] BARATE 98U obtain limits on the form factor. See their Fig. 14 for limits in mass-form factor plane.

[90] From e^+e^- collisions at $\sqrt{s}$= 161 GeV.

[91] ABREU 97B also obtain limit from charged current decay mode $\mu^* \to \nu W$, $m_{\mu^*} > 70.9$ GeV.

[92] ABREU 97B also obtain limit from charged current decay mode $\mu^* \to \nu W$, $m_{\mu^*} > 44.6$ GeV.

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

These limits are from $e^+e^- \to \mu^*\mu$ and depend on transition magnetic coupling between μ and μ^*. All limits assume $\mu^* \to \mu\gamma$ 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** S1 (1992)).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>221	95	[93] ABULENCIA,A	06B	CDF	$p\overline{p} \to \mu\mu^*$, $\mu^* \to \mu\gamma$

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

	95	[94] ABAZOV 06E	D0	$p\overline{p} \to \mu\mu^*$
>180	95	[95] ACHARD 03B	L3	$e^+e^- \to \mu\mu^*$
>190	95	[96] ABBIENDI 02G	OPAL	$e^+e^- \to \mu\mu^*$
>178	95	[97] ACCIARRI 01D	L3	$e^+e^- \to \mu\mu^*$
		[98] ABBIENDI 00I	OPAL	$e^+e^- \to \mu\mu^*$
		[99] ACCIARRI 00E	L3	$e^+e^- \to \mu\mu^*$
		[100] ABREU 99O	DLPH	$e^+e^- \to \mu\mu^*$
		[101] ACKERSTAFF 98C	OPAL	$e^+e^- \to \mu\mu^*$
		[102] BARATE 98U	ALEP	$Z \to \mu\mu^*$

[93] $f = f' = \Lambda/m_{\mu^*}$ is assumed for the μ^* coupling. See their Fig.4 for the exclusion limit in the mass-coupling plane. ABULENCIA,A 06B also obtain m_{μ^*} limit in the contact interaction model with $\Lambda = m_{\mu^*}$, $m_{\mu^*} > 696$ GeV.

[94] ABAZOV 06E assume $\mu\mu^*$ production via four-fermion contact interaction $(4\pi/\Lambda^2)(\overline{q}_L\gamma^\mu q_L)(\overline{\mu}^*_L\gamma_\mu\mu)$. The obtained limit is $m_{\mu^*} > 618$ GeV ($m_{\mu^*} > 688$ GeV) for $\Lambda = 1$ TeV ($\Lambda = m_{\mu^*}$).

[95] ACHARD 03B result is from e^+e^- collisions at $\sqrt{s} = 189$–209 GeV. $f = f' = \Lambda/m_{\mu^*}$ is assumed. See their Fig. 4 for the exclusion plot in the mass-coupling plane.

[96] ABBIENDI 02G result is from e^+e^- collisions at $\sqrt{s} = 183$–209 GeV. $f = f' = \Lambda/m_{\mu^*}$ is assumed for μ^* coupling. See their Fig. 4c for the exclusion limit in the mass-coupling plane.

[97] ACCIARRI 01D result is from e^+e^- collisions at $\sqrt{s} = 192$–202 GeV. $f=f'=\Lambda/m_{\mu^*}$ is assumed for the μ^* coupling. See their Fig. 4 for limits in the mass-coupling plane.

[98] ABBIENDI 00I result is from e^+e^- collisions at $\sqrt{s}$=161–183 GeV. See their Fig. 7 for limits in mass-coupling plane.

[99] ACCIARRI 00E result is from e^+e^- collisions at $\sqrt{s}$=189 GeV. See their Fig. 3 for limits in mass-coupling plane.

[100] ABREU 99O result is from e^+e^- collisions at $\sqrt{s}$= 183 GeV. See their Figs. 4 and 5 for the exclusion limit in the mass-coupling plane.

[101] ACKERSTAFF 98C from e^+e^- collisions at $\sqrt{s}$=170–172 GeV. See their Fig. 11 for the exclusion limit in the mass-coupling plane.

[102] BARATE 98U obtain limits on the $Z\mu\mu^*$ coupling. See their Fig. 12 for limits in mass-coupling plane

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. • • •			
	[103] RENARD 82	THEO	$g-2$ of muon

[103] 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 a dominant $\tau^* \rightarrow \tau\gamma$ decay except the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>103.2	95	[104] ABBIENDI	02G	OPAL	$e^+ e^- \rightarrow \tau^* \tau^*$ Homodoublet type
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$>$102.8	95	[105] ACHARD	03B	L3	$e^+ e^- \rightarrow \tau^* \tau^*$ Homodoublet type
$>$ 99.8	95	[106] ACCIARRI	01D	L3	$e^+ e^- \rightarrow \tau^* \tau^*$ Homodoublet type
$>$ 91.2	95	[107] ABBIENDI	00I	OPAL	$e^+ e^- \rightarrow \tau^* \tau^*$ Homodoublet type
$>$ 94.2	95	[108] ACCIARRI	00E	L3	$e^+ e^- \rightarrow \tau^* \tau^*$ Homodoublet type
$>$ 89.7	95	[109] ABREU	99O	DLPH	Homodoublet type
$>$ 84.6	95	[110] ACKERSTAFF	98C	OPAL	$e^+ e^- \rightarrow \tau^* \tau^*$ Homodoublet type
		[111] BARATE	98U	ALEP	$Z \rightarrow \tau^* \tau^*$
$>$ 79.4	95	[112,113] ABREU	97B	DLPH	$e^+ e^- \rightarrow \tau^* \tau^*$ Homodoublet type
$>$ 77.4	95	[112,114] ABREU	97B	DLPH	$e^+ e^- \rightarrow \tau^* \tau^*$ Sequential type
$>$ 79.3	95	[112] ACCIARRI	97G	L3	$e^+ e^- \rightarrow \tau^* \tau^*$ Sequential type

[104] From $e^+ e^-$ collisions at $\sqrt{s}$ = 183–209 GeV. $f = f'$ is assumed.

[105] From $e^+ e^-$ collisions at $\sqrt{s}$ = 189–209 GeV. $f = f'$ is assumed. ACHARD 03B also obtain limit for $f = -f'$: $m_{\tau^*} > 96.6$ GeV.

[106] From $e^+ e^-$ collisions at $\sqrt{s}$ = 192–202 GeV. $f=f'$ is assumed. ACCIARRI 01D also obtain limit for $f=-f'$: $m_{\tau^*} > 93.4$ GeV.

[107] From $e^+ e^-$ collisions at $\sqrt{s}$=161–183 GeV. $f=f'$ is assumed. ABBIENDI 00I also obtain limit for $f=-f'$ ($\tau^* \rightarrow \nu W$): $m_{\tau^*} > 86.0$ GeV.

[108] From $e^+ e^-$ collisions at $\sqrt{s}$=189 GeV. $f=f'$ is assumed. ACCIARRI 00E also obtain limit for $f=-f'$ ($\tau^* \rightarrow \nu W$): $m_{\tau^*} > 92.6$ GeV.

[109] From $e^+ e^-$ collisions at $\sqrt{s}$= 183 GeV. $f=f'$ is assumed. ABREU 99O also obtain limit for $f=-f'$ ($\tau^* \rightarrow \nu W$): $m_{\tau^*} > 81.3$ GeV.

[110] From $e^+ e^-$ collisions at $\sqrt{s}$=170–172 GeV. ACKERSTAFF 98C also obtain limit from $\tau^* \rightarrow \nu W$ decay mode: $m_{\tau^*} > 81.3$ GeV.

[111] BARATE 98U obtain limits on the form factor. See their Fig. 14 for limits in mass-form factor plane.

[112] From $e^+ e^-$ collisions at $\sqrt{s}$= 161 GeV.

[113] ABREU 97B also obtain limit from charged current decay mode $\tau^* \rightarrow \nu W$, $m_{\tau^*} > 70.9$ GeV.

[114] ABREU 97B also obtain limit from charged current decay mode $\tau^* \rightarrow \nu W$, $m_{\tau^*} > 44.6$ GeV.

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*
>185	95	[115] ABBIENDI	02G	OPAL	$e^+ e^- \rightarrow \tau\tau^*$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>180	95	[116] ACHARD	03B	L3	$e^+ e^- \rightarrow \tau\tau^*$
>173	95	[117] ACCIARRI	01D	L3	$e^+ e^- \rightarrow \tau\tau^*$
		[118] ABBIENDI	00I	OPAL	$e^+ e^- \rightarrow \tau\tau^*$
		[119] ACCIARRI	00E	L3	$e^+ e^- \rightarrow \tau\tau^*$
		[120] ABREU	99O	DLPH	$e^+ e^- \rightarrow \tau\tau^*$
		[121] ACKERSTAFF	98C	OPAL	$e^+ e^- \rightarrow \tau\tau^*$
		[122] BARATE	98U	ALEP	$Z \rightarrow \tau\tau^*$

[115] ABBIENDI 02G result is from $e^+ e^-$ collisions at $\sqrt{s}$ = 183–209 GeV. $f = f' = \Lambda/m_{\tau^*}$ is assumed for τ^* coupling. See their Fig. 4c for the exclusion limit in the mass-coupling plane.

[116] ACHARD 03B result is from $e^+ e^-$ collisions at $\sqrt{s}$ = 189–209 GeV. $f = f' = \Lambda/m_{\tau^*}$ is assumed. See their Fig. 4 for the exclusion plot in the mass-coupling plane.

[117] ACCIARRI 01D result is from $e^+ e^-$ collisions at $\sqrt{s}$ = 192–202 GeV. $f=f'=\Lambda/m_{\tau^*}$ is assumed for the τ^* coupling. See their Fig. 4 for limits in the mass-coupling plane.

[118] ABBIENDI 00I result is from $e^+ e^-$ collisions at $\sqrt{s}$=161–183 GeV. See their Fig. 7 for limits in mass-coupling plane.

[119] ACCIARRI 00E result is from $e^+ e^-$ collisions at $\sqrt{s}$=189 GeV. See their Fig. 3 for limits in mass-coupling plane.

[120] ABREU 99O result is from $e^+ e^-$ collisions at $\sqrt{s}$= 183 GeV. See their Figs. 4 and 5 for the exclusion limit in the mass-coupling plane.

[121] ACKERSTAFF 98C from $e^+ e^-$ collisions at $\sqrt{s}$=170–172 GeV. See their Fig. 11 for the exclusion limit in the mass-coupling plane.

[122] BARATE 98U obtain limits on the $Z\tau\tau^*$ coupling. See their Fig. 12 for limits in mass-coupling plane

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MASS LIMITS for Excited Neutrino (ν^*)

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

These limits are obtained from $e^+ e^- \rightarrow \nu^* \nu^*$ 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 unless otherwise noted. All limits assume a dominant $\nu^* \rightarrow \nu\gamma$ decay except the limits from $\Gamma(Z)$.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>102.6	95	[123] ACHARD	03B	L3	$e^+ e^- \rightarrow \nu^* \nu^*$ Homodoublet type

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

		[124] ABBIENDI	04N	OPAL	
$>$ 99.4	95	[125] ACCIARRI	01D	L3	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type
$>$ 91.2	95	[126] ABBIENDI	00I	OPAL	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type
		[127] ABBIENDI,G	00D	OPAL	
$>$ 94.1	95	[128] ACCIARRI	00E	L3	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type
		[129] ABBIENDI	99F	OPAL	
$>$ 90.0	95	[130] ABREU	99O	DLPH	Homodoublet type
$>$ 84.9	95	[131] ACKERSTAFF	98C	OPAL	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type
		[132] BARATE	98U	ALEP	$Z \rightarrow \nu^*\nu^*$
$>$ 77.6	95	[133,134] ABREU	97B	DLPH	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type
$>$ 64.4	95	[133,135] ABREU	97B	DLPH	$e^+e^- \rightarrow \nu^*\nu^*$ Sequential type
$>$ 71.2	95	[133,136] ACCIARRI	97G	L3	$e^+e^- \rightarrow \nu^*\nu^*$ Sequential type

[123] From e^+e^- collisions at $\sqrt{s}$ = 189–209 GeV. $f = -f'$ is assumed. ACHARD 03B also obtain limit for $f = f'$: $m_{\nu_e^*} > 101.7$ GeV, $m_{\nu_\mu^*} > 101.8$ GeV, and $m_{\nu_\tau^*} > 92.9$ GeV. See their Fig. 4 for the exclusion plot in the mass-coupling plane.

[124] From e^+e^- collisions at $\sqrt{s}$ = 192–209 GeV, ABBIENDI 04N obtain limit on $\sigma(e^+e^- \rightarrow \nu^*\nu^*)$ $B^2(\nu^* \rightarrow \nu\gamma)$. See their Fig.2. The limit ranges from 20 to 45fb for $m_{\nu^*} > 45$ GeV.

[125] From e^+e^- collisions at $\sqrt{s}$ = 192–202 GeV. f=f' is assumed. ACCIARRI 01D also obtain limit for f=$-f'$: $m_{\nu_e^*} > 99.1$ GeV, $m_{\nu_\mu^*} > 99.3$ GeV, $m_{\nu_\tau^*} > 90.5$ GeV.

[126] From e^+e^- collisions at $\sqrt{s}$=161–183 GeV. f=$-f'$ (photonic decay) is assumed. ABBIENDI 00I also obtain limit for f=f' ($\nu^* \rightarrow \ell W$): $m_{\nu_e^*} > 91.1$ GeV, $m_{\nu_\mu^*} > 91.1$ GeV, $m_{\nu_\tau^*} > 83.1$ GeV.

[127] From e^+e^- collisions at $\sqrt{s}$= 189 GeV. ABBIENDI,G 00D obtain limit on $\sigma(e^+e^- \rightarrow \nu^*\nu^*)\mathrm{B}(\nu^* \rightarrow \nu\gamma)^2$. See their Fig. 14. The limit ranges from 50 to 80 fb for $\sqrt{s}/2$= 95 GeV$>m_{\nu^*}>$45 GeV.

[128] From e^+e^- collisions at $\sqrt{s}$=189 GeV. f=$-f'$ (photonic decay) is assumed. ACCIARRI 00E also obtain limit for f=f' ($\nu^* \rightarrow \ell W$): $m_{\nu_e^*} > 93.9$ GeV, $m_{\nu_\mu^*} > 94.0$ GeV, $m_{\nu_\tau^*} > 91.5$ GeV.

[129] From e^+e^- collisions at $\sqrt{s}$= 130–183 GeV, ABBIENDI 99F obtain limit on $\sigma(e^+e^- \rightarrow \nu^*\nu^*)$ $\mathrm{B}(\nu^* \rightarrow \nu\gamma)^2$. See their Fig. 13. The limit ranges from 0.094 to 0.14 pb for $\sqrt{s}/2>m_{\nu^*} > 45$ GeV.

[130] From e^+e^- collisions at $\sqrt{s}$= 183 GeV. f=$-f'$ is assumed. ABREU 99O also obtain limit for f=f': $m_{\nu_{e^*}} > 87.3$ GeV, $m_{\nu_{\mu^*}} > 88.0$ GeV, $m_{\nu_{\tau^*}} > 81.0$ GeV.

[131] From e^+e^- collisions at $\sqrt{s}$=170–172 GeV. ACKERSTAFF 98C also obtain limit from charged decay modes: $m_{\nu_e^*} > 84.1$ GeV, $m_{\nu_\mu^*} > 83.9$ GeV, and $m_{\nu_\tau^*} > 79.4$ GeV.

[132] BARATE 98U obtain limits on the form factor. See their Fig. 14 for limits in mass-form factor plane.

[133] From e^+e^- collisions at $\sqrt{s}$= 161 GeV.

[134] ABREU 97B also obtain limits from charged current decay modes, $m_{\nu^*} > 56.4$ GeV.

[135] ABREU 97B also obtain limits from charged current decay modes, $m_{\nu^*} > 44.9$ GeV.

[136] ACCIARRI 97G also obtain limits from charged current decay mode $\nu^*_e \rightarrow eW$, $m_{\nu^*} >$ 64.5 GeV.

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

These limits are from $e^+e^- \rightarrow \nu\nu^*$, $Z \rightarrow \nu\nu^*$, 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*
>190	95	[137] ACHARD	03B	L3	$e^+e^- \rightarrow \nu\nu^*$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
none 50–150	95	[138] ADLOFF	02	H1	$ep \rightarrow \nu^* X$
>158	95	[139] CHEKANOV	02D	ZEUS	$ep \rightarrow \nu^* X$
>171	95	[140] ACCIARRI	01D	L3	$e^+e^- \rightarrow \nu\nu^*$
		[141] ABBIENDI	00I	OPAL	$e^+e^- \rightarrow \nu\nu^*$
		[142] ABBIENDI,G	00D	OPAL	
		[143] ACCIARRI	00E	L3	$e^+e^- \rightarrow \nu\nu^*$
>114	95	[144] ADLOFF	00E	H1	$ep \rightarrow \nu^* X$
		[145] ABBIENDI	99F	OPAL	
		[146] ABREU	99O	DLPH	$e^+e^- \rightarrow \nu\nu^*$
		[147] ACKERSTAFF	98C	OPAL	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type
		[148] BARATE	98U	ALEP	$Z \rightarrow \nu\nu^*$

[137] ACHARD 03B result is from e^+e^- collisions at $\sqrt{s} = 189$–209 GeV. The quoted limit is for ν^*_e. $f = -f' = \Lambda/m_{\nu^*}$ is assumed. See their Fig. 4 for the exclusion plot in the mass-coupling plane.

[138] ADLOFF 02 search for single ν^* production in ep collisions with the decays $\nu^* \rightarrow \nu\gamma$, νZ, eW. The quoted limit assumes $f = -f' = \Lambda/m_{\nu^*}$. See their Fig. 1 for the exclusion plots in the mass-coupling plane.

[139] CHEKANOV 02D search for single ν^* production in ep collisions with the decays $\nu^* \rightarrow \nu\gamma$, νZ, eW. $f = -f' = \Lambda/m_{\nu^*}$ is assumed for the e^* coupling. CHEKANOV 02D also obtain limit for $f = f' = \Lambda/m_{\nu^*}$: $m_{\nu^*} >135$ GeV. See their Fig. 5c and Fig. 5d for the exclusion plot in the mass-coupling plane.

[140] ACCIARRI 01D search for $\nu\nu^*$ production in e^+e^- collisions at $\sqrt{s} = 192$–202 GeV with decays $\nu^* \rightarrow \nu\gamma$, $\nu^* \rightarrow eW$. $f=-f'=\Lambda/m_{\nu^*}$ is assumed for the ν^* coupling. See their Fig. 4 for limits in the mass-coupling plane.

[141] ABBIENDI 00I result is from e^+e^- collisions at $\sqrt{s}$=161–183 GeV. See their Fig. 7 for limits in mass-coupling plane.

[142] From e^+e^- collisions at $\sqrt{s}$= 189 GeV. ABBIENDI,G 00D obtain limit on $\sigma(e^+e^- \rightarrow \nu^*\nu^*)\mathrm{B}(\nu^* \rightarrow \nu\gamma)^2$. See their Fig. 11.

[143] ACCIARRI 00E result is from e^+e^- collisions at $\sqrt{s}$=189 GeV. See their Fig. 3 for limits in mass-coupling plane.

[144] ADLOFF 00E search for single ν^* production in ep collisions with the decays $\nu^* \rightarrow \nu\gamma$, νZ, eW. The quoted limit assumes $f=-f'=\Lambda/m_{\nu^*}$. See their Fig. 10 for the exclusion plot in the mass-coupling plane.

[145] From e^+e^- collisions at $\sqrt{s}$= 130–183 GeV, ABBIENDI 99F obtain limit on $\sigma(e^+e^- \rightarrow \nu\nu^*)$ $\mathrm{B}(\nu^* \rightarrow \nu\gamma)$. See their Fig. 8.

[146] ABREU 99O result is from e^+e^- collisions at $\sqrt{s}$= 183 GeV. See their Figs. 4 and 5 for the exclusion limit in the mass-coupling plane.

[147] ACKERSTAFF 98C from e^+e^- collisions at $\sqrt{s}$=170–172 GeV. See their Fig. 11 for the exclusion limit in the mass-coupling plane.

[148] BARATE 98U obtain limits on the $Z\nu\nu^*$ coupling. See their Fig. 13 for limits in mass-coupling plane

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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	[149] ADRIANI	93M	L3	*u* or *d* type, $Z \rightarrow q^*q^*$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[150] BARATE	98U	ALEP	$Z \rightarrow q^*q^*$
		[151] ADRIANI	92F	L3	$Z \rightarrow q^*q^*$
>41.7	95	[152] BARDADIN-...	92	RVUE	*u*-type, $\Gamma(Z)$
>44.7	95	[152] BARDADIN-...	92	RVUE	*d*-type, $\Gamma(Z)$
>40.6	95	[153] DECAMP	92	ALEP	*u*-type, $\Gamma(Z)$
>44.2	95	[153] DECAMP	92	ALEP	*d*-type, $\Gamma(Z)$
>45	95	[154] DECAMP	92	ALEP	*u* or *d* type, $Z \rightarrow q^*q^*$
>45	95	[153] ABREU	91F	DLPH	*u*-type, $\Gamma(Z)$
>45	95	[153] ABREU	91F	DLPH	*d*-type, $\Gamma(Z)$

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

[150] BARATE 98U obtain limits on the form factor. See their Fig. 16 for limits in mass-form factor plane.

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

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

[153] These limits are independent of decay modes.

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

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

These limits are from $e^+e^- \rightarrow q^*\overline{q}$ or $p\overline{p} \rightarrow q^*X$ 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*
>775	95	[155] ABAZOV	04C	D0	$p\overline{p} \rightarrow q^*X$, $q^* \rightarrow qg$
none 200–520 and 580–760	95	[156] ABE	97G	CDF	$p\overline{p} \rightarrow q^*X$, $q^* \rightarrow$ 2 jets
none 80–570	95	[157] ABE	95N	CDF	$p\overline{p} \rightarrow q^*X$, $q^* \rightarrow qg$ $q\gamma$, qW
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>510	95	[158] ABAZOV	06F	D0	$p\overline{p} \rightarrow q^*X$, $q^* \rightarrow qZ$
>205	95	[159] CHEKANOV	02D	ZEUS	$ep \rightarrow q^*X$
>188	95	[160] ADLOFF	00E	H1	$ep \rightarrow q^*X$
		[161] ABREU	99O	DLPH	$e^+e^- \rightarrow qq^*$
		[162] BARATE	98U	ALEP	$Z \rightarrow qq^*$

[155] ABAZOV 04C assume $f_s = f = f' = \Lambda/m_{q^*}$.

[156] ABE 97G search for new particle decaying to dijets.

[157] ABE 95N assume a degenerate u^* and d^* with $f_s{=}f{=}f'{=}\Lambda/m_{q^*}$. See their Fig. 4 for the excluded region in $m_{q^*} - f$ plane.

[158] ABAZOV 06F assume q^* production via qg fusion and via contact interactions. The quoted limit is for $\Lambda = m_{q^*}$.

[159] CHEKANOV 02D search for single q^* production in ep collisions with the decays $q^* \rightarrow q\gamma$, qZ, qW. $f_s = 0$ and $f = f' = \Lambda/m_{q^*}$ is assumed for the q^* coupling. See their Fig. 5b for the exclusion plot in the mass-coupling plane.

[160] ADLOFF 00E search for single q^* production in ep collisions with the decays $q^* \rightarrow q\gamma$, qZ, qW. $f_s{=}0$ and $f{=}f'{=}\Lambda/m_{q^*}$ is assumed for the q^* coupling. See their Fig. 11 for the exclusion plot in the mass-coupling plane.

[161] ABREU 99O result is from e^+e^- collisions at $\sqrt{s}$= 183 GeV. See their Fig. 6 for the exclusion limit in the mass-coupling plane.

[162] BARATE 98U obtain limits on the Zqq^* coupling. See their Fig. 16 for limits in mass-coupling plane

MASS LIMITS for Color Sextet Quarks (q_6)

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>84	95	[163] ABE	89D	CDF	$p\overline{p} \rightarrow q_6\overline{q}_6$

[163] 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	[164] ABE	89D	CDF	Stable ℓ_8: $p\overline{p} \rightarrow \ell_8\overline{\ell}_8$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[165] ABT	93	H1	e_8: $ep \rightarrow e_8X$
none 3.0–30.3	95	[166] KIM	90	AMY	e_8: $e^+e^- \rightarrow ee$ + jets
none 3.5–30.3	95	[166] KIM	90	AMY	μ_8: $e^+e^- \rightarrow \mu\mu$ + jets
		[167] KIM	90	AMY	e_8: $e^+e^- \rightarrow gg$; R

[164] 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.

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

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

[167] 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.

MASS LIMITS for Color Octet Neutrinos (ν_8)

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

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>110	90	[168] BARGER	89	RVUE	ν_8: $p\overline{p} \rightarrow \nu_8 \overline{\nu}_8$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
none 3.8–29.8	95	[169] KIM	90	AMY	ν_8: $e^+e^- \rightarrow$ acoplanar jets
none 9–21.9	95	[170] BARTEL	87B	JADE	ν_8: $e^+e^- \rightarrow$ acoplanar jets

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

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

[170] BARTEL 87B is at E_{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. • • •				
	[171] ALBAJAR	89	UA1	$p\overline{p} \rightarrow W_8 X$, $W_8 \rightarrow W g$

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

REFERENCES FOR Searches for Quark and Lepton Compositeness

SCHAEL	07A	EPJ C49 411	S. Schael *et al.*	(ALEPH Collab.)
ABAZOV	06E	PR D73 111102R	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	06F	PR D74 011104R	V.M. Abazov *et al.*	(D0 Collab.)
ABDALLAH	06C	EPJ C45 589	J. Abdallah *et al.*	(DELPHI Collab.)
ABULENCIA	06L	PRL 96 211801	A. Abulencia *et al.*	(CDF Collab.)
ABULENCIA,A	06B	PRL 97 191802	A. Abulencia *et al.*	(CDF Collab.)
ACOSTA	05B	PRL 94 101802	D. Acosta *et al.*	(CDF Collab.)
ABAZOV	04C	PR D69 111101R	V.M. Abazov *et al.*	(D0 Collab.)
ABBIENDI	04G	EPJ C33 173	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	04N	PL B602 167	G. Abbiendi *et al.*	(OPAL Collab.)
ABDALLAH	04N	EPJ C37 405	J. Abdallah *et al.*	(DELPHI Collab.)
CHEKANOV	04B	PL B591 23	S. Chekanov *et al.*	(ZEUS Collab.)
ACHARD	03B	PL B568 23	P. Achard *et al.*	(L3 Collab.)
ADLOFF	03	PL B568 35	C. Adloff *et al.*	(H1 Collab.)
BABICH	03	EPJ C29 103	A.A. Babich *et al.*	
ABBIENDI	02G	PL B544 57	G. Abbiendi *et al.*	(OPAL Collab.)
ACHARD	02D	PL B531 28	P. Achard *et al.*	(L3 Collab.)
ACHARD	02J	PL B549 290	P. Achard *et al.*	(L3 Collab.)
ADLOFF	02	PL B525 9	C. Adloff *et al.*	(H1 Collab.)
ADLOFF	02B	PL B548 35	C. Adloff *et al.*	(H1 Collab.)
CHEKANOV	02D	PL B549 32	S. Chekanov *et al.*	(ZEUS Collab.)
ACCIARRI	01D	PL B502 37	M. Acciarri *et al.*	(L3 Collab.)
AFFOLDER	01I	PRL 87 231803	T. Affolder *et al.*	(CDF Collab.)
BOURILKOV	01	PR D64 071701	D. Bourilkov	
CHEUNG	01B	PL B517 167	K. Cheung	
ABBIENDI	00I	EPJ C14 73	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	00R	EPJ C13 553	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI,G	00D	EPJ C18 253	G. Abbiendi *et al.*	(OPAL Collab.)
ABBOTT	00E	PR D62 031101	B. Abbott *et al.*	(D0 Collab.)
ABREU	00A	PL B491 67	P. Abreu *et al.*	(DELPHI Collab.)

ABREU	00S	PL B485 45	P. Abreu *et al.*	(DELPHI Collab.)
ACCIARRI	00E	PL B473 177	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	00G	PL B475 198	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	00P	PL B489 81	M. Acciarri *et al.*	(L3 Collab.)
ADLOFF	00	PL B479 358	C. Adloff *et al.*	(H1 Collab.)
ADLOFF	00E	EPJ C17 567	C. Adloff *et al.*	(H1 Collab.)
AFFOLDER	00I	PR D62 012004	T. Affolder *et al.*	(CDF Collab.)
BARATE	00I	EPJ C12 183	R. Barate *et al.*	(ALEPH Collab.)
BOURILKOV	00	PR D62 076005	D. Bourilkov	
BREITWEG	00B	EPJ C14 239	J. Breitweg *et al.*	(ZEUS Collab.)
ABBIENDI	99	EPJ C6 1	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	99F	EPJ C8 23	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	99P	PL B465 303	G. Abbiendi *et al.*	(OPAL Collab.)
ABBOTT	99C	PRL 82 2457	B. Abbott *et al.*	(D0 Collab.)
ABBOTT	99D	PRL 82 4769	B. Abbott *et al.*	(D0 Collab.)
ABREU	99A	EPJ C11 383	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	99O	EPJ C8 41	P. Abreu *et al.*	(DELPHI Collab.)
ZARNECKI	99	EPJ C11 539	A.F. Zarnecki	
ABBOTT	98G	PRL 80 666	B. Abbott *et al.*	(D0 Collab.)
ABREU	98J	PL B433 429	P. Abreu *et al.*	(DELPHI Collab.)
ACCIARRI	98J	PL B433 163	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	98T	PL B439 183	M. Acciarri *et al.*	(L3 Collab.)
ACKERSTAFF	98	EPJ C1 21	K. Ackerstaff *et al.*	(OPAL Collab.)
ACKERSTAFF	98C	EPJ C1 45	K. Ackerstaff *et al.*	(OPAL Collab.)
ACKERSTAFF	98V	EPJ C2 441	K. Ackerstaff *et al.*	(OPAL Collab.)
ACKER..,K...	98B	PL B438 379	K. Ackerstaff *et al.*	(OPAL Collab.)
BARATE	98J	PL B429 201	R. Barate *et al.*	(ALEPH Collab.)
BARATE	98U	EPJ C4 571	R. Barate *et al.*	(ALEPH Collab.)
BARGER	98E	PR D57 391	V. Barger *et al.*	
BERTRAM	98	PL B443 347	I. Bertram, E.H. Simmons	
MCFARLAND	98	EPJ C1 509	K.S. McFarland *et al.*	(CCFR/NuTeV Collab.)
MIURA	98	PR D57 5345	M. Miura *et al.*	(VENUS Collab.)
ABE	97G	PR D55 R5263	F. Abe *et al.*	(CDF Collab.)
ABE	97T	PRL 79 2198	F. Abe *et al.*	(CDF Collab.)
ABREU	97B	PL B393 245	P. Abreu *et al.*	(DELPHI Collab.)
ACCIARRI	97G	PL B401 139	M. Acciarri *et al.*	(L3 Collab.)
ACKERSTAFF	97	PL B391 197	K. Ackerstaff *et al.*	(OPAL Collab.)
ADLOFF	97	NP B483 44	C. Adloff *et al.*	(H1 Collab.)
BREITWEG	97C	ZPHY C76 631	J. Breitweg *et al.*	(ZEUS Collab.)
ABE	95N	PRL 74 3538	F. Abe *et al.*	(CDF Collab.)
DIAZCRUZ	94	PR D49 R2149	J.L. Diaz Cruz, O.A. Sampayo	(CINV)
ABT	93	NP B396 3	I. Abt *et al.*	(H1 Collab.)
ADRIANI	93M	PRPL 236 1	O. Adriani *et al.*	(L3 Collab.)
ABE	92B	PRL 68 1463	F. Abe *et al.*	(CDF Collab.)
ADRIANI	92F	PL B292 472	O. Adriani *et al.*	(L3 Collab.)
BARDADIN-...	92	ZPHY C55 163	M. Bardadin-Otwinowska	(CLER)
DECAMP	92	PRPL 216 253	D. Decamp *et al.*	(ALEPH Collab.)
PDG	92	PR D45 S1	K. Hikasa *et al.*	(KEK, LBL, BOST+)
ABREU	91F	NP B367 511	P. Abreu *et al.*	(DELPHI Collab.)
KIM	90	PL B240 243	G.N. Kim *et al.*	(AMY Collab.)
ABE	89B	PRL 62 1825	F. Abe *et al.*	(CDF Collab.)
ABE	89D	PRL 63 1447	F. Abe *et al.*	(CDF Collab.)
ABE	89J	ZPHY C45 175	K. Abe *et al.*	(VENUS Collab.)
ALBAJAR	89	ZPHY C44 15	C. Albajar *et al.*	(UA1 Collab.)
BARGER	89	PL B220 464	V. Barger *et al.*	(WISC, KEK)
DORENBOS...	89	ZPHY C41 567	J. Dorenbosch *et al.*	(CHARM Collab.)
BARTEL	87B	ZPHY C36 15	W. Bartel *et al.*	(JADE Collab.)
GRIFOLS	86	PL 168B 264	J.A. Grifols, S. Peris	(BARC)
JODIDIO	86	PR D34 1967	A. Jodidio *et al.*	(LBL, NWES, TRIU)
Also		PR D37 237 (erratum)	A. Jodidio *et al.*	(LBL, NWES, TRIU)
BARTEL	85K	PL 160B 337	W. Bartel *et al.*	(JADE Collab.)
EICHTEN	84	RMP 56 579	E. Eichten *et al.*	(FNAL, LBL, OSU)
RENARD	82	PL 116B 264	F.M. Renard	(CERN)