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

Limits are for Λ_{LL}^{\pm} 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	$E_{cm} = 192\text{--}208$ GeV
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
>3.8	>5.6	95	ABBIENDI	00R OPAL	$E_{cm} = 189$ GeV
>4.4	>5.4	95	ABREU	00S DLPH	$E_{cm} = 183\text{--}189$ GeV
>4.3	>4.9	95	ACCIARRI	00P L3	$E_{cm} = 130\text{--}189$ GeV
>3.5	>3.2	95	BARATE	00I ALEP	$E_{cm} = 130\text{--}183$ GeV
>6.0	>7.7	95	² BOURILKOV 00	RVUE	$E_{cm} = 183\text{--}189$ GeV
>3.1	>3.8	95	ABBIENDI 99	OPAL	$E_{cm} = 130\text{--}136, 161\text{--}172, 183$ GeV
>2.2	>2.8	95	ABREU 99A	DLPH	$E_{cm} = 130\text{--}172$ GeV
>2.7	>2.4	95	ACCIARRI 98J	L3	$E_{cm} = 130\text{--}172$ GeV
>3.0	>2.5	95	ACKERSTAFF 98V	OPAL	$E_{cm} = 130\text{--}172$ GeV
>2.4	>2.2	95	ACKERSTAFF 97C	OPAL	$E_{cm} = 130\text{--}136, 161$ GeV
>1.7	>2.3	95	ARIMA 97	VNS	$E_{cm} = 57.77$ GeV
>1.6	>2.0	95	³ BUSKULIC 93Q	ALEP	$E_{cm} = 88.25\text{--}94.25$ GeV
>1.6		95	^{3,4} BUSKULIC 93Q	RVUE	
	>2.2	95	BUSKULIC 93Q	RVUE	
	>3.6	95	⁵ KROHA 92	RVUE	
>1.3		95	⁵ KROHA 92	RVUE	
>0.7	>2.8	95	BEHREND 91C	CELL	$E_{cm} = 35$ GeV
>1.3	>1.3	95	KIM 89	AMY	$E_{cm} = 50\text{--}57$ GeV
>1.4	>3.3	95	⁶ BRAUNSCH... 88	TASS	$E_{cm} = 12\text{--}46.8$ GeV
>1.0	>0.7	95	⁷ FERNANDEZ 87B	MAC	$E_{cm} = 29$ GeV
>1.1	>1.4	95	⁸ BARTEL 86C	JADE	$E_{cm} = 12\text{--}46.8$ GeV
>1.17	>0.87	95	⁹ DERRICK 86	HRS	$E_{cm} = 29$ GeV
>1.1	>0.76	95	¹⁰ BERGER 85B	PLUT	$E_{cm} = 34.7$ GeV

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

² A combined analysis of the data from ALEPH, L3, and OPAL.

³ 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.

⁴ This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data re-analyzed by KROHA 92.

⁵ 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 $\eta/\Lambda_{LL}^2 = +0.230 \pm 0.206$ TeV⁻².

⁶ BRAUNSCHWEIG 88 assumed $m_Z = 92$ GeV and $\sin^2\theta_W = 0.23$.

⁷ FERNANDEZ 87B assumed $\sin^2\theta_W = 0.22$.

⁸ BARTEL 86C assumed $m_Z = 93$ GeV and $\sin^2\theta_W = 0.217$.

⁹ DERRICK 86 assumed $m_Z = 93$ GeV and $g_V^2 = (-1/2 + 2\sin^2\theta_W)^2 = 0.004$.

¹⁰ 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 Λ_{LL}^{\pm} only. For other cases, see each reference.

Λ_{LL}^+ (TeV)	Λ_{LL}^- (TeV)	CL%	DOCUMENT ID	TECN	COMMENT
>6.6	> 6.3	95	ABREU	00S DLPH	$E_{cm} = 183-189$ GeV
> 8.5	>3.8	95	ACCIARRI	00P L3	$E_{cm} = 130-189$ GeV
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
>7.3	>4.6	95	ABBIENDI	00R OPAL	$E_{cm} = 189$ GeV
>4.0	>4.7	95	BARATE	00I ALEP	$E_{cm} = 130-183$ GeV
>4.5	>4.3	95	ABBIENDI	99 OPAL	$E_{cm} = 130-136, 161-172, 183$ GeV
>3.4	>2.7	95	ABREU	99A DLPH	$E_{cm} = 130-172$ GeV
>3.6	>2.4	95	ACCIARRI	98J L3	$E_{cm} = 130-172$ GeV
>2.9	>3.4	95	ACKERSTAFF	98V OPAL	$E_{cm} = 130-172$ GeV
>3.1	>2.0	95	MIURA	98 VNS	$E_{cm} = 57.77$ GeV
>2.4	>2.9	95	ACKERSTAFF	97C OPAL	$E_{cm} = 130-136, 161$ GeV
>1.7	>2.2	95	¹¹ VELISSARIS	94 AMY	$E_{cm} = 57.8$ GeV
>1.3	>1.5	95	¹¹ BUSKULIC	93Q ALEP	$E_{cm} = 88.25-94.25$ GeV
>2.6	>1.9	95	^{11,12} BUSKULIC	93Q RVUE	
>2.3	>2.0	95	HOWELL	92 TOPZ	$E_{cm} = 52-61.4$ GeV
	>1.7	95	¹³ KROHA	92 RVUE	
>2.5	>1.5	95	BEHREND	91C CELL	$E_{cm} = 35-43$ GeV
>1.6	>2.0	95	¹⁴ 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	¹⁵ BARTEL	86C JADE	$E_{cm} = 12-46.8$ GeV
>2.9	>0.86	95	¹⁶ BERGER	85 PLUT	$E_{cm} = 34.7$ GeV

¹¹ 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.

¹² This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data re-analyzed by KROHA 92.

¹³ KROHA 92 limit is from fit to BARTEL 86C, BEHREND 87C, BRAUNSCHWEIG 88D, BRAUNSCHWEIG 89C, ABE 90I, and BEHREND 91C. The fit gives $\eta/\Lambda_{LL}^2 = -0.155 \pm 0.095$ TeV⁻².

¹⁴ ABE 90I assumed $m_Z = 91.163$ GeV and $\sin^2\theta_W = 0.231$.

¹⁵ BARTEL 86C assumed $m_Z = 93$ GeV and $\sin^2\theta_W = 0.217$.

¹⁶ BERGER 85 assumed $m_Z = 93$ GeV and $\sin^2\theta_W = 0.217$.

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

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

Λ_{LL}^+ (TeV)	Λ_{LL}^- (TeV)	CL%	DOCUMENT ID	TECN	COMMENT
>3.9	> 6.5	95	ABBIENDI	00R OPAL	$E_{cm} = 189$ GeV
> 5.4	>4.7	95	ACCIARRI	00P L3	$E_{cm} = 130-189$ GeV
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
>5.2	>5.4	95	ABREU	00S DLPH	$E_{cm} = 183-189$ GeV
>3.9	>3.7	95	BARATE	00i ALEP	$E_{cm} = 130-183$ GeV
>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
>1.9	>3.0	95	ACKERSTAFF	97C OPAL	$E_{cm} = 130-136, 161$ GeV
>1.4	>2.0	95	¹⁷ VELISSARIS	94 AMY	$E_{cm} = 57.8$ GeV
>1.0	>1.5	95	¹⁷ BUSKULIC	93Q ALEP	$E_{cm} = 88.25-94.25$ GeV
>1.8	>2.3	95	^{17,18} BUSKULIC	93Q RVUE	
>1.9	>1.7	95	HOWELL	92 TOPZ	$E_{cm} = 52-61.4$ GeV
>1.9	>2.9	95	¹⁹ KROHA	92 RVUE	
>1.6	>2.3	95	BEHREND	91C CELL	$E_{cm} = 35-43$ GeV
>1.8	>1.3	95	²⁰ ABE	90i VNS	$E_{cm} = 50-60.8$ GeV
>2.2	>3.2	95	²¹ BARTEL	86 JADE	$E_{cm} = 12-46.8$ GeV

¹⁷BUSKULIC 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.

¹⁸This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data re-analyzed by KROHA 92.

¹⁹KROHA 92 limit is from fit to BARTEL 86C BEHREND 89B, BRAUNSCHWEIG 89C, ABE 90i, and BEHREND 91C. The fit gives $\eta/\Lambda_{LL}^2 = +0.095 \pm 0.120$ TeV⁻².

²⁰ABE 90i assumed $m_Z = 91.163$ GeV and $\sin^2\theta_W = 0.231$.

²¹BARTEL 86 assumed $m_Z = 93$ GeV and $\sin^2\theta_W = 0.217$.

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

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

Λ_{LL}^+ (TeV)	Λ_{LL}^- (TeV)	CL%	DOCUMENT ID	TECN	COMMENT
>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
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
>6.4	>7.2	95	ABBIENDI	00R OPAL	$E_{cm} = 189$ GeV
>5.3	>5.5	95	BARATE	00i ALEP	$E_{cm} = 130-183$ GeV
>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	²² ACCIARRI	98J L3	$E_{cm} = 130-172$ GeV
>3.4	>4.4	95	ACKERSTAFF	98V OPAL	$E_{cm} = 130-172$ GeV

>2.7	>3.8	95	ACKERSTAFF 97C	OPAL	$E_{cm} = 130\text{--}136, 161 \text{ GeV}$
>3.0	>2.3	95	22,23 BUSKULIC	93Q ALEP	$E_{cm} = 88.25\text{--}94.25 \text{ GeV}$
>3.5	>2.8	95	23,24 BUSKULIC	93Q RVUE	
>2.5	>2.2	95	25 HOWELL	92 TOPZ	$E_{cm} = 52\text{--}61.4 \text{ GeV}$
>3.4	>2.7	95	26 KROHA	92 RVUE	

²² From $e^+e^- \rightarrow e^+e^-, \mu^+\mu^-, \text{ and } \tau^+\tau^-$.

²³ 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.

²⁴ This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data re-analyzed by KROHA 92.

²⁵ HOWELL 92 limit is from $e^+e^- \rightarrow \mu^+\mu^- \text{ and } \tau^+\tau^-$.

²⁶ KROHA 92 limit is from fit to most PEP/PETRA/TRISTAN data. The fit gives $\eta/\Lambda_{LL}^2 = -0.0200 \pm 0.0666 \text{ TeV}^{-2}$.

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

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

Λ_{LL}^+ (TeV)	Λ_{LL}^- (TeV)	CL%	DOCUMENT ID	TECN	COMMENT
> 1.0 (CL = 95%) [$>23.3 \text{ TeV (CL = 95\%)} \text{ OUR 2002 BEST LIMIT}$]					
>23.3	>12.5	95	27 CHEUNG	01B RVUE	(<i>eeuu</i>)
>11.1	>26.4	95	27 CHEUNG	01B RVUE	(<i>eedd</i>)
> 5.6	>4.9	95	28 BARATE	00i ALEP	(<i>eebb</i>)
> 1.0	>2.1	95	29 ABREU	99A DLPH	(<i>eecc</i>)
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
> 2.7	>2.7	95	30 ACHARD	02J L3	(<i>eeetc</i>)
> 5.5	>3.1	95	31 ABBIENDI	00R OPAL	(<i>eeqq</i>)
> 4.9	>6.1	95	31 ABBIENDI	00R OPAL	(<i>eeuu</i>)
> 5.7	>4.5	95	31 ABBIENDI	00R OPAL	(<i>eedd</i>)
> 4.2	>2.8	95	32 ACCIARRI	00P L3	(<i>eeqq</i>)
> 2.4	>1.3	95	33 ADLOFF	00 H1	(<i>eeqq</i>)
> 5.4	>6.2	95	34 BARATE	00i ALEP	(<i>eeqq</i>)
			35 BREITWEG	00B ZEUS	
> 4.4	>2.8	95	36 ABBIENDI	99 OPAL	(<i>eeqq</i>)
> 4.0	>4.8	95	37 ABBIENDI	99 OPAL	(<i>eebb</i>)
> 3.3	>4.2	95	38 ABBOTT	99D D0	(<i>eeqq</i>)
> 2.4	>2.8	95	29 ABREU	99A DLPH	(<i>eeqq</i>) (<i>d or s quark</i>)
> 4.4	>3.9	95	29 ABREU	99A DLPH	(<i>eebb</i>)
> 1.0	>2.4	95	29 ABREU	99A DLPH	(<i>eeuu</i>)
> 4.0	>3.4	95	39 ZARNECKI	99 RVUE	(<i>eedd</i>)
> 4.3	>5.6	95	39 ZARNECKI	99 RVUE	(<i>eeuu</i>)
> 3.0	>2.1	95	40 ACCIARRI	98J L3	(<i>eeqq</i>)
> 3.4	>2.2	95	41 ACKERSTAFF	98V OPAL	(<i>eeqq</i>)
> 4.0	>2.8	95	42 ACKERSTAFF	98V OPAL	(<i>eebb</i>)
> 9.3	>12.0	95	43 BARGER	98E RVUE	(<i>eeuu</i>)
> 8.8	>11.9	95	43 BARGER	98E RVUE	(<i>eedd</i>)
> 2.5	>3.7	95	44 ABE	97T CDF	(<i>eeqq</i>) (<i>isosinglet</i>)
> 2.5	>2.1	95	45 ACKERSTAFF	97C OPAL	(<i>eeqq</i>)
> 3.1	>2.9	95	46 ACKERSTAFF	97C OPAL	(<i>eebb</i>)

> 7.4	>11.7	95	47	DEANDREA	97	RVUE	$eeuu$, atomic parity violation
> 2.3	>1.0	95	48	AID	95	H1	$(eeqq)$ (u, d quarks)
1.7	>2.2	95	49	ABE	91D	CDF	$(eeqq)$ (u, d quarks)
> 1.2		95	50	ADACHI	91	TOPZ	$(eeqq)$ (flavor-universal)
	>1.6	95	50	ADACHI	91	TOPZ	$(eeqq)$ (flavor-universal)
> 0.6	>1.7	95	51	BEHREND	91C	CELL	$(eecc)$
> 1.1	>1.0	95	51	BEHREND	91C	CELL	$(eebb)$
> 0.9		95	52	ABE	89L	VNS	$(eeqq)$ (flavor-universal)
	>1.7	95	52	ABE	89L	VNS	$(eeqq)$ (flavor-universal)
> 1.05	>1.61	95	53	HAGIWARA	89	RVUE	$(eecc)$
> 1.21	>0.53	95	54	HAGIWARA	89	RVUE	$(eebb)$

²⁷ CHEUNG 01B is an update of BARGER 98E.

²⁸ BARATE 00I limits are from R_b and jet-charge asymmetry at 130–183 GeV.

²⁹ ABREU 99A limits are from flavor-tagged $e^+e^- \rightarrow q\bar{q}$ cross section at 130–172 GeV.

³⁰ ACHARD 02J limit is from the bound on the $e^+e^- \rightarrow t\bar{c}$ cross section. $\Lambda_{LL} = \Lambda_{LR} = \Lambda_{RL} = \Lambda_{RR}$ and $m_t = 175$ GeV are assumed.

³¹ ABBIENDI 00R limits are from $e^+e^- \rightarrow q\bar{q}$ cross section at $\sqrt{s} = 130$ –189 GeV.

³² ACCIARRI 00P limit is from $e^+e^- \rightarrow qq$ cross section at $\sqrt{s} = 130$ –189 GeV.

³³ ADLOFF 00 limits are from the Q^2 spectrum measurement of $e^+p \rightarrow e^+X$.

³⁴ BARATE 00I limits are from $e^+e^- \rightarrow q\bar{q}$ cross section and jet-charge asymmetry at 130–183 GeV.

³⁵ BREITWEG 00B limits are from Q^2 spectrum measurement of e^+p collisions. See their Table 3 for the limits of various models.

³⁶ ABBIENDI 99 limits are from $e^+e^- \rightarrow q\bar{q}$ cross section at 130–136, 161–172, 183 GeV.

³⁷ ABBIENDI 99 limits are from R_b at 130–136, 161–172, 183 GeV.

³⁸ ABBOTT 99D limits are from e^+e^- mass distribution in $p\bar{p} \rightarrow e^+e^-X$ at $E_{cm} = 1.8$ TeV.

³⁹ ZARNECKI 99 use data from HERA, LEP, Tevatron, and various low-energy experiments.

⁴⁰ ACCIARRI 98J limits are from $e^+e^- \rightarrow q\bar{q}$ cross section at $E_{cm} = 130$ –172 GeV.

⁴¹ ACKERSTAFF 98V limits are from $e^+e^- \rightarrow q\bar{q}$ at $E_{cm} = 130$ –172 GeV.

⁴² ACKERSTAFF 98V limits are from R_b measurements at $E_{cm} = 130$ –172 GeV.

⁴³ BARGER 98E use data from HERA, LEP, Tevatron, and various low-energy experiments.

⁴⁴ ABE 97T limits are from e^+e^- mass distribution in $p\bar{p} \rightarrow e^+e^-X$ at $E_{cm} = 1.8$ TeV.

⁴⁵ ACKERSTAFF 97C limits are from $e^+e^- \rightarrow q\bar{q}$ cross section at $E_{cm} = 130$ –136 GeV and 161 GeV.

⁴⁶ ACKERSTAFF 97C limits are R_b measurements at $E_{cm} = 133$ GeV and 161 GeV.

⁴⁷ DEANDREA 97 limit is from atomic parity violation of cesium. The limit is eluded if the contact interactions are parity conserving.

⁴⁸ AID 95 limits are from the Q^2 spectrum measurement of $ep \rightarrow eX$.

⁴⁹ ABE 91D limits are from e^+e^- mass distribution in $p\bar{p} \rightarrow e^+e^-X$ at $E_{cm} = 1.8$ TeV.

⁵⁰ ADACHI 91 limits are from differential jet cross section. Universality of $\Lambda(eeqq)$ for five flavors is assumed.

⁵¹ BEHREND 91C is from data at $E_{cm} = 35$ –43 GeV.

⁵² ABE 89L limits are from jet charge asymmetry. Universality of $\Lambda(eeqq)$ for five flavors is assumed.

⁵³ The HAGIWARA 89 limit is derived from forward-backward asymmetry measurements of D/D^* mesons by ALTHOFF 83C, BARTEL 84E, and BARINGER 88.

⁵⁴ The HAGIWARA 89 limit is derived from forward-backward asymmetry measurement of b hadrons by BARTEL 84D.

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

Λ_{LL}^+ (TeV)	Λ_{LL}^- (TeV)	CL%	DOCUMENT ID	TECN	COMMENT
> 2.9	> 4.2	95	⁵⁵ 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)
⁵⁵ ABE 97T limits are from $\mu^+ \mu^-$ mass distribution in $\bar{p}p \rightarrow \mu^+ \mu^- X$ 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	⁵⁶ JODIDIO	86 SPEC	$\Lambda_{LR}^\pm(\nu_\mu\nu_e\mu e)$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
>3.8		⁵⁷ DIAZCRUZ	94 RVUE	$\Lambda_{LL}^+(\tau\nu_\tau e\nu_e)$
>8.1		⁵⁷ DIAZCRUZ	94 RVUE	$\Lambda_{LL}^-(\tau\nu_\tau e\nu_e)$
>4.1		⁵⁸ DIAZCRUZ	94 RVUE	$\Lambda_{LL}^+(\tau\nu_\tau \mu\nu_\mu)$
>6.5		⁵⁸ DIAZCRUZ	94 RVUE	$\Lambda_{LL}^-(\tau\nu_\tau \mu\nu_\mu)$

⁵⁶ JODIDIO 86 limit is from $\mu^+ \rightarrow \bar{\nu}_\mu e^+ \nu_e$. Chirality invariant interactions $L = (g^2/\Lambda^2) [\eta_{LL} (\bar{\nu}_\mu L \gamma^\alpha \mu_L) (\bar{e} L \gamma_\alpha \nu_e L) + \eta_{LR} (\bar{\nu}_\mu L \gamma^\alpha \nu_e L) (\bar{e} R \gamma_\alpha \mu_R)]$ with $g^2/4\pi = 1$ and $(\eta_{LL}, \eta_{LR}) = (0, \pm 1)$ are taken. No limits are given for Λ_{LL}^\pm with $(\eta_{LL}, \eta_{LR}) = (\pm 1, 0)$. For more general constraints with right-handed neutrinos and chirality nonconserving contact interactions, see their text.

⁵⁷ DIAZCRUZ 94 limits are from $\Gamma(\tau \rightarrow e\nu\nu)$ and assume flavor-dependent contact interactions with $\Lambda(\tau\nu_\tau e\nu_e) \ll \Lambda(\mu\nu_\mu e\nu_e)$.

⁵⁸ 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: $\Lambda(e\nu qq)$

VALUE (TeV)	CL%	DOCUMENT ID	TECN
>2.81	95	⁵⁹ AFFOLDER	01i CDF

⁵⁹ AFFOLDER 00i bound is for a scalar interaction $\bar{q}_R q_L \bar{\nu} e_L$.

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

Limits are for Λ_{LL}^{\pm} 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	60 ABBOTT	99C D0	$p\bar{p} \rightarrow$ dijet mass. Λ_{LL}^+
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
>2.0	95	61 ABBOTT	00E D0	H_T distribution; Λ_{LL}^+
>2.1	95	62 ABBOTT	98G D0	$p\bar{p} \rightarrow$ dijet angl. Λ_{LL}^+
		63 BERTRAM	98 RVUE	$p\bar{p} \rightarrow$ dijet mass
		64 ABE	96 CDF	$p\bar{p} \rightarrow$ jets inclusive
>1.6	95	65 ABE	96S CDF	$p\bar{p} \rightarrow$ dijet angl.; Λ_{LL}^+
>1.3	95	66 ABE	93G CDF	$p\bar{p} \rightarrow$ dijet mass
>1.4	95	67 ABE	92D CDF	$p\bar{p} \rightarrow$ jets inclusive
>1.0	99	68 ABE	92M CDF	$p\bar{p} \rightarrow$ dijet angl.
>0.825	95	69 ALITTI	91B UA2	$p\bar{p} \rightarrow$ jets inclusive
>0.700	95	67 ABE	89 CDF	$p\bar{p} \rightarrow$ jets inclusive
>0.330	95	70 ABE	89H CDF	$p\bar{p} \rightarrow$ dijet angl.
>0.400	95	71 ARNISON	86C UA1	$p\bar{p} \rightarrow$ jets inclusive
>0.415	95	72 ARNISON	86D UA1	$p\bar{p} \rightarrow$ dijet angl.
>0.370	95	73 APPEL	85 UA2	$p\bar{p} \rightarrow$ jets inclusive
>0.275	95	74 BAGNAIA	84C UA2	Repl. by APPEL 85

⁶⁰ The quoted limit is from inclusive dijet mass spectrum in $p\bar{p}$ collisions at $E_{cm}=1.8$ TeV.

ABBOTT 99C also obtain $\Lambda_{LL}^- > 2.4$ TeV. All quarks are assumed composite.

⁶¹ The quoted limit for ABBOTT 00E is from H_T distribution in $p\bar{p}$ collisions at $E_{cm}=1.8$

TeV. CTEQ4M PDF and $\mu=E_T^{\max}$ are assumed. For limits with different assumptions, see their Tables 2 and 3. All quarks are assumed composite.

⁶² ABBOTT 98G limit is from dijet angular distribution in $p\bar{p}$ collisions at $E_{cm}=1.8$ TeV.

All quarks are assumed composite.

⁶³ 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.

⁶⁴ ABE 96 finds that the inclusive jet cross section for $E_T > 200$ GeV is significantly higher than the $\mathcal{O}(\alpha_s^3)$ perturbative QCD prediction. This could be interpreted as the effect of a contact interaction with $\Lambda_{LL} \sim 1.6$ TeV. However, ABE 96 state that uncertainty in the parton distribution functions, higher-order QCD corrections, and the detector calibration may possibly account for the effect.

⁶⁵ ABE 96S limit is from dijet angular distribution in $p\bar{p}$ collisions at $E_{cm} = 1.8$ TeV. The

limit for Λ_{LL}^- is > 1.4 TeV. ABE 96S also obtain limits for flavor symmetric contact

interactions among all quark flavors: $\Lambda_{LL}^+ > 1.8$ TeV and $\Lambda_{LL}^- > 1.6$ TeV.

⁶⁶ ABE 93G limit is from dijet mass distribution in $p\bar{p}$ collisions at $E_{cm} = 1.8$ TeV. The limit is the weakest from several choices of structure functions and renormalization scale.

⁶⁷ Limit is from inclusive jet cross-section data in $p\bar{p}$ collisions at $E_{cm} = 1.8$ TeV. The limit takes into account uncertainties in choice of structure functions and in choice of process scale.

⁶⁸ ABE 92M limit is from dijet angular distribution for $m_{\text{dijet}} > 550$ GeV in $p\bar{p}$ collisions at $E_{cm}=1.8$ TeV.

- ⁶⁹ ALITTI 91B limit is from inclusive jet cross section in $p\bar{p}$ collisions at $E_{\text{cm}} = 630$ GeV. The limit takes into account uncertainties in choice of structure functions and in choice of process scale.
- ⁷⁰ ABE 89H limit is from dijet angular distribution for $m_{\text{dijet}} > 200$ GeV at the Fermilab Tevatron Collider with $E_{\text{cm}} = 1.8$ TeV. The QCD prediction is quite insensitive to choice of structure functions and choice of process scale.
- ⁷¹ ARNISON 86C limit is from the study of inclusive high- p_T jet distributions at the CERN $\bar{p}p$ collider ($E_{\text{cm}} = 546$ and 630 GeV). The QCD prediction renormalized to the low- p_T region gives a good fit to the data.
- ⁷² ARNISON 86D limit is from the study of dijet angular distribution in the range $240 < m(\text{dijet}) < 300$ GeV at the CERN $\bar{p}p$ collider ($E_{\text{cm}} = 630$ GeV). QCD prediction using EHLQ structure function (EICHTEN 84) with $\Lambda_{\text{QCD}} = 0.2$ GeV for the choice of $Q^2 = p_T^2$ gives the best fit to the data.
- ⁷³ APPEL 85 limit is from the study of inclusive high- p_T jet distributions at the CERN $\bar{p}p$ collider ($E_{\text{cm}} = 630$ GeV). The QCD prediction renormalized to the low- p_T region gives a good description of the data.
- ⁷⁴ BAGNAIA 84C limit is from the study of jet p_T and dijet mass distributions at the CERN $\bar{p}p$ collider ($E_{\text{cm}} = 540$ GeV). The limit suffers from the uncertainties in comparing the data with the QCD prediction.

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

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

Λ_{LL}^+ (TeV)	Λ_{LL}^- (TeV)	CL%	DOCUMENT ID	TECN	COMMENT
>5.0	>5.4	95	⁷⁵ MCFARLAND 98	CCFR	νN scattering

⁷⁵ 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**, 1 June, Part II (1992)).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>103.2 (CL = 95%)		[>100.0 GeV (CL = 95%) OUR 2002 BEST LIMIT]		
>103.2	95	⁷⁶ ABBIENDI	02G OPAL	$e^+e^- \rightarrow e^*e^*$ Homodoublet type

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

>100.0	95	77	ACCIARRI	01D L3	$e^+e^- \rightarrow e^*e^*$	Homodoublet type
> 91.3	95	78	ABBIENDI	00I OPAL	$e^+e^- \rightarrow e^*e^*$	Homodoublet type
> 94.2	95	79	ACCIARRI	00E L3	$e^+e^- \rightarrow e^*e^*$	Homodoublet type
> 90.7	95	80	ABREU	99O DLPH		Homodoublet type
> 85.0	95	81	ACKERSTAFF	98C OPAL	$e^+e^- \rightarrow e^*e^*$	Homodoublet type
		82	BARATE	98U ALEP	$Z \rightarrow e^*e^*$	
> 79.6	95	83,84	ABREU	97B DLPH	$e^+e^- \rightarrow e^*e^*$	Homodoublet type
> 77.9	95	83,85	ABREU	97B DLPH	$e^+e^- \rightarrow e^*e^*$	Sequential type
> 79.7	95	83	ACCIARRI	97G L3	$e^+e^- \rightarrow e^*e^*$	Sequential type
> 79.9	95	83,86	ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow e^*e^*$	Homodoublet type
> 62.5	95	87	ABREU	96K DLPH	$e^+e^- \rightarrow e^*e^*$	Homodoublet type
> 64.7	95	88	ACCIARRI	96D L3	$e^+e^- \rightarrow e^*e^*$	Sequential type
> 66.5	95	88	ALEXANDER	96Q OPAL	$e^+e^- \rightarrow e^*e^*$	Homodoublet type
> 65.2	95	88	BUSKULIC	96W ALEP	$e^+e^- \rightarrow e^*e^*$	Sequential type
> 45.6	95		ADRIANI	93M L3	$Z \rightarrow e^*e^*$	
> 45.6	95		ABREU	92C DLPH	$Z \rightarrow e^*e^*$	
> 29.8	95	89	BARDADIN-...	92 RVUE	$\Gamma(Z)$	
> 26.1	95	90	DECAMP	92 ALEP	$Z \rightarrow e^*e^*; \Gamma(Z)$	
> 46.1	95		DECAMP	92 ALEP	$Z \rightarrow e^*e^*$	
> 33	95	90	ABREU	91F DLPH	$Z \rightarrow e^*e^*; \Gamma(Z)$	
> 45.0	95	91	ADEVA	90F L3	$Z \rightarrow e^*e^*$	
> 44.9	95		AKRAWY	90I OPAL	$Z \rightarrow e^*e^*$	
> 44.6	95	92	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	93	ABE	88B VNS	$e^+e^- \rightarrow e^*e^*$	

⁷⁶ From e^+e^- collisions at $\sqrt{s} = 183\text{--}209$ GeV. $f = f'$ is assumed.

⁷⁷ From e^+e^- collisions at $\sqrt{s} = 192\text{--}202$ GeV. $f=f'$ is assumed. ACCIARRI 01D also obtain limit for $f=-f'$: $m_{e^*} > 93.4$ GeV.

⁷⁸ From e^+e^- collisions at $\sqrt{s}=161\text{--}183$ GeV. $f=f'$ is assumed. ABBIENDI 00I also obtain limit for $f=-f'$ ($e^* \rightarrow \nu W$): $m_{e^*} > 86.0$ GeV.

⁷⁹ 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.

⁸⁰ From e^+e^- collisions at $\sqrt{s}= 183$ GeV. $f=f'$ is assumed. ABREU 99O also obtain limit for $f=-f'$ ($e^* \rightarrow \nu W$): $m_{e^*} > 81.3$ GeV.

⁸¹ From e^+e^- collisions at $\sqrt{s}=170\text{--}172$ GeV. ACKERSTAFF 98C also obtain limit from $e^* \rightarrow \nu W$ decay mode: $m_{e^*} > 81.3$ GeV.

⁸² BARATE 98U obtain limits on the form factor. See their Fig. 14 for limits in mass-form factor plane.

⁸³ From e^+e^- collisions at $\sqrt{s}= 161$ GeV.

⁸⁴ ABREU 97B also obtain limit from charged current decay mode $e^* \rightarrow \nu W$, $m_{e^*} > 70.9$ GeV.

⁸⁵ ABREU 97B also obtain limit from charged current decay mode $e^* \rightarrow \nu W$, $m_{e^*} > 44.6$ GeV.

⁸⁶ ACKERSTAFF 97 also obtain limit from charged current decay mode $e^* \rightarrow \nu W$, $m_{\nu_e^*} > 77.1$ GeV.

⁸⁷ From e^+e^- collisions at $\sqrt{s}= 130\text{--}136$ GeV.

⁸⁸ From e^+e^- collisions at $\sqrt{s}=130\text{--}140$ GeV.

⁸⁹ BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on $\Delta\Gamma(Z)<36$ MeV.

⁹⁰ Limit is independent of e^* decay mode.

⁹¹ ADEVA 90F is superseded by ADRIANI 93M.

⁹² Superseded by DECAMP 92.

⁹³ ABE 88B limits assume $e^+e^- \rightarrow e^{*+}e^{*-}$ with one photon exchange only and $e^* \rightarrow e\gamma$ giving $e\epsilon\gamma\gamma$.

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 $\lambda\text{--}m_{e^*}$ 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
>255 (CL = 95%)		[>223 GeV (CL = 95%) OUR 2002 BEST LIMIT]		
>255	95	⁹⁴ ADLOFF	02B H1	$ep \rightarrow e^*X$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
>208	95	⁹⁵ ABBIENDI	02G OPAL	$e^+e^- \rightarrow ee^*$
>228	95	⁹⁶ CHEKANOV	02D ZEUS	$ep \rightarrow e^*X$
>202		⁹⁷ ACCIARRI	01D L3	$e^+e^- \rightarrow ee^*$
		⁹⁸ ABBIENDI	00I OPAL	$e^+e^- \rightarrow ee^*$
		⁹⁹ ACCIARRI	00E L3	$e^+e^- \rightarrow ee^*$
>223	95	¹⁰⁰ ADLOFF	00E H1	$ep \rightarrow e^*X$
		¹⁰¹ ABREU	99O DLPH	$e^+e^- \rightarrow ee^*$
none 20–170	95	¹⁰² ACCIARRI	98T L3	$e\gamma \rightarrow e^* \rightarrow e\gamma$
		¹⁰³ ACKERSTAFF	98C OPAL	$e^+e^- \rightarrow ee^*$
		¹⁰⁴ BARATE	98U ALEP	$e^+e^- \rightarrow ee^*$
		^{105,106} ABREU	97B DLPH	$e^+e^- \rightarrow ee^*$
		^{105,107} ACCIARRI	97G L3	$e^+e^- \rightarrow ee^*$
		¹⁰⁸ ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow ee^*$
		¹⁰⁹ ADLOFF	97 H1	Lepton-flavor violation
none 30–200	95	¹¹⁰ BREITWEG	97C ZEUS	$ep \rightarrow e^*X$
		¹¹¹ ABREU	96K DLPH	$e^+e^- \rightarrow ee^*$
		¹¹² ACCIARRI	96D L3	$e^+e^- \rightarrow ee^*$
		¹¹³ ALEXANDER	96Q OPAL	$e^+e^- \rightarrow ee^*$
		¹¹⁴ BUSKULIC	96W ALEP	$e^+e^- \rightarrow ee^*$
		¹¹⁵ DERRICK	95B ZEUS	$ep \rightarrow e^*X$
		¹¹⁶ ABT	93 H1	$ep \rightarrow e^*X$
> 86	95	ADRIANI	93M L3	$\lambda_\gamma > 0.04$
> 89	95	ADRIANI	93M L3	$Z \rightarrow ee^*$, $\lambda_Z > 0.5$
		¹¹⁷ DERRICK	93B ZEUS	Superseded by DERRICK 95B
> 88	95	ABREU	92C DLPH	$Z \rightarrow ee^*$, $\lambda_Z > 0.5$

> 86	95	ABREU	92C DLPH	$e^+e^- \rightarrow ee^*, \lambda_\gamma > 0.1$
> 91	95	DECAMP	92 ALEP	$Z \rightarrow ee^*, \lambda_Z > 1$
> 88	95	118 ADEVA	90F L3	$Z \rightarrow ee^*, \lambda_Z > 0.5$
> 86	95	118 ADEVA	90F L3	$Z \rightarrow ee^*, \lambda_Z > 0.04$
> 87	95	AKRAWY	90I OPAL	$Z \rightarrow ee^*, \lambda_Z > 0.5$
> 81	95	119 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	120 ABE	88B VNS	$e^+e^- \rightarrow ee^*, \lambda_\gamma > 0.04$
> 75	95	121 ANSARI	87D UA2	$W \rightarrow e^*\nu; \lambda_W > 0.7$
> 63	95	121 ANSARI	87D UA2	$W \rightarrow e^*\nu; \lambda_W > 0.2$
> 40	95	121 ANSARI	87D UA2	$W \rightarrow e^*\nu; \lambda_W > 0.09$

- 94 ADLOFF 02B search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma, eZ, \nu W$. $f = f' = \Lambda/m_{e^*}$ is assumed for the e^* coupling. See their Fig. 3 for the exclusion plot in the mass-coupling plane.
- 95 ABBIENDI 02G result is from e^+e^- collisions at $\sqrt{s} = 183\text{--}209$ GeV. $f = f' = \Lambda/m_{e^*}$ is assumed for e^* coupling. See their Fig. 4c for the exclusion limit in the mass-coupling plane.
- 96 CHEKANOV 02D search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma, eZ, \nu W$. $f = f' = \Lambda/m_{e^*}$ is assumed for the e^* coupling. See their Fig. 5a for the exclusion plot in the mass-coupling plane.
- 97 ACCIARRI 01D result is from e^+e^- collisions at $\sqrt{s} = 192\text{--}202$ GeV. $f=f'=\Lambda/m_{e^*}$ is assumed for the e^* coupling. See their Fig. 4 for limits in the mass-coupling plane.
- 98 ABBIENDI 00I result is from e^+e^- collisions at $\sqrt{s}=161\text{--}183$ 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 ADLOFF 00E search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma, eZ, \nu W$. $f=f'=\Lambda/m_{e^*}$ is assumed for the e^* coupling. See their Fig. 9 for the exclusion plot in the mass-coupling plane.
- 101 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.
- 102 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.
- 103 ACKERSTAFF 98C from e^+e^- collisions at $\sqrt{s}=170\text{--}172$ GeV. See their Fig. 11 for the exclusion limit in the mass-coupling plane.
- 104 BARATE 98U is from e^+e^- collision at $\sqrt{s}=M_Z$. See their Fig. 12 for limits in mass-coupling plane
- 105 From e^+e^- collisions at $\sqrt{s}=161$ GeV.
- 106 See Fig. 4a and Fig. 5a of ABREU 97B for the exclusion limit in the mass-coupling plane.
- 107 See Fig. 2 and Fig. 3 of ACCIARRI 97G for the exclusion limit in the mass-coupling plane.
- 108 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.
- 109 ADLOFF 97 search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma, eZ, \nu W$. 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.
- 110 BREITWEG 97C search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma, eZ, \nu W$. $f=f'=2\Lambda/m_{e^*}$ is assumed for the e^* coupling. See their Fig. 9 for the exclusion plot in the mass-coupling plane.

- 111 ABREU 96K result is from e^+e^- collisions at $\sqrt{s}=130\text{--}136$ GeV. See their Fig. 4 for the exclusion limit in the mass-coupling plane.
- 112 ACCIARRI 96D result is from e^+e^- collisions at $\sqrt{s}=130\text{--}140$ GeV. See their Fig. 2 for the exclusion limit in the mass-coupling plane.
- 113 ALEXANDER 96Q result is from e^+e^- collisions at $\sqrt{s}=130\text{--}140$ GeV. See their Fig. 3a for the exclusion limit in the mass-coupling plane.
- 114 BUSKULIC 96W result is from e^+e^- collisions at $\sqrt{s}=130\text{--}140$ GeV. See their Fig. 3 for the exclusion limit in the mass-coupling plane.
- 115 DERRICK 95B search for single e^* production via $e^*e\gamma$ coupling in ep collisions with the decays $e^* \rightarrow e\gamma, eZ, \nu W$. See their Fig. 13 for the exclusion plot in the $m_{e^*}-\lambda\gamma$ plane.
- 116 ABT 93 search for single e^* production via $e^*e\gamma$ coupling in ep collisions with the decays $e^* \rightarrow e\gamma, eZ, \nu W$. See their Fig. 4 for exclusion plot in the $m_{e^*}-\lambda\gamma$ plane.
- 117 DERRICK 93B search for single e^* production via $e^*e\gamma$ coupling in ep collisions with the decays $e^* \rightarrow e\gamma, eZ, \nu W$. See their Fig. 3 for exclusion plot in the $m_{e^*}-\lambda\gamma$ plane.
- 118 Superseded by ADRIANI 93M.
- 119 Superseded by DECAMP 92.
- 120 ABE 88B limits use $e^+e^- \rightarrow ee^*$ where t-channel photon exchange dominates giving $e\gamma(e)$ (quasi-real compton scattering).
- 121 ANSARI 87D is at $E_{cm} = 546\text{--}630$ 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 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**, 1 June, Part II (1992)).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>310	95	ACHARD	02D L3	$\sqrt{s}=192\text{--}209$ GeV
>311	95	ABREU	00A DLPH	$\sqrt{s}=189\text{--}202$ GeV
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
>283	95	¹²² ACCIARRI	00G L3	$\sqrt{s}=183\text{--}189$ GeV
>306	95	ABBIENDI	99P OPAL	$\sqrt{s}=189$ GeV
>231	95	ABREU	98J DLPH	$\sqrt{s}=130\text{--}183$ GeV
>194	95	ACKERSTAFF	98 OPAL	$\sqrt{s}=130\text{--}172$ GeV
>227	95	ACKER...,K...	98B OPAL	$\sqrt{s}=183$ GeV
>250	95	BARATE	98J ALEP	$\sqrt{s}=183$ GeV
>160	95	¹²³ BARATE	98U ALEP	
>210	95	¹²⁴ ACCIARRI	97W L3	$\sqrt{s}=161, 172$ GeV
>129	95	ACCIARRI	96L L3	$\sqrt{s}=133$ GeV
>147	95	ALEXANDER	96K OPAL	
>136	95	BUSKULIC	96Z ALEP	$\sqrt{s}=130, 136$ GeV
>146	95	ACCIARRI	95G L3	
		¹²⁵ BUSKULIC	93Q ALEP	
>127	95	¹²⁶ ADRIANI	92B L3	
>114	95	¹²⁷ BARDADIN-...	92 RVUE	

> 99	95	DECAMP	92	ALEP	
		128 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	129 ABE	89J	VNS	$\eta_L=1, \eta_R=0$
> 90.2	95	ADACHI	89B	TOPZ	
> 65	95	KIM	89	AMY	

- 122 ACCIARRI 00G also obtain a limit on e^* with chiral coupling, $m_{e^*} > 213$ GeV.
- 123 BARATE 98U is from e^+e^- collision at $\sqrt{s}=M_Z$. See their Fig. 5 for limits in mass-coupling plane
- 124 ACCIARRI 97W also obtain a limit on e^* with chiral coupling, $m_{e^*} > 157$ GeV (95%CL).
- 125 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^*} .
- 126 ADRIANI 92B superseded by ACCIARRI 95G.
- 127 BARDADIN-OTWINOWSKA 92 limit from fit to the combined data of DECAMP 92, ABREU 91E, ADEVA 90K, AKRAWY 91F.
- 128 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.
- 129 The ABE 89J limit assumes chiral coupling. This corresponds to $\lambda_\gamma = 0.7$ 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.

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

130	DORENBOS...	89	CHRM	$\bar{\nu}_\mu e \rightarrow \bar{\nu}_\mu e$ and $\nu_\mu e \rightarrow \nu_\mu e$
131	GRIFOLS	86	THEO	$\nu_\mu e \rightarrow \nu_\mu e$
132	RENARD	82	THEO	$g-2$ of electron

- 130 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 $\Lambda_{cut} = 1$ 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.
- 131 GRIFOLS 86 uses $\nu_\mu e \rightarrow \nu_\mu e$ and $\bar{\nu}_\mu e \rightarrow \bar{\nu}_\mu e$ data from CHARM Collaboration to derive mass limits which depend on the scale of compositeness.
- 132 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**, 1 June, Part II (1992)).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>103.2 (CL = 95%)		[>100.2 GeV (CL = 95%) OUR 2002 BEST LIMIT]		
>103.2	95	¹³³ ABBIENDI	02G OPAL	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
>100.2	95	¹³⁴ ACCIARRI	01D L3	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
> 91.3	95	¹³⁵ ABBIENDI	00I OPAL	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
> 94.2	95	¹³⁶ ACCIARRI	00E L3	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
> 90.7	95	¹³⁷ ABREU	99O DLPH	Homodoublet type
> 85.3	95	¹³⁸ ACKERSTAFF	98C OPAL	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
		¹³⁹ BARATE	98U ALEP	$Z \rightarrow \mu^*\mu^*$
> 79.6	95	^{140,141} ABREU	97B DLPH	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
> 78.4	95	^{140,142} ABREU	97B DLPH	$e^+e^- \rightarrow \mu^*\mu^*$ Sequential type
> 79.9	95	¹⁴⁰ ACCIARRI	97G L3	$e^+e^- \rightarrow \mu^*\mu^*$ Sequential type
> 80.0	95	^{140,143} ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
> 62.6	95	¹⁴⁴ ABREU	96K DLPH	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
> 64.9	95	¹⁴⁵ ACCIARRI	96D L3	$e^+e^- \rightarrow \mu^*\mu^*$ Sequential type
> 66.8	95	¹⁴⁵ ALEXANDER	96Q OPAL	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
> 65.4	95	¹⁴⁵ BUSKULIC	96W ALEP	$e^+e^- \rightarrow \mu^*\mu^*$ Sequential type
> 45.6	95	ADRIANI	93M L3	$Z \rightarrow \mu^*\mu^*$
> 45.6	95	ABREU	92C DLPH	$Z \rightarrow \mu^*\mu^*$
> 29.8	95	¹⁴⁶ BARDADIN-...	92 RVUE	$\Gamma(Z)$
> 26.1	95	¹⁴⁷ DECAMP	92 ALEP	$Z \rightarrow \mu^*\mu^*, \Gamma(Z)$
> 46.1	95	DECAMP	92 ALEP	$Z \rightarrow \mu^*\mu^*$
> 33	95	¹⁴⁷ ABREU	91F DLPH	$Z \rightarrow \mu^*\mu^*, \Gamma(Z)$
> 45.3	95	¹⁴⁸ ADEVA	90F L3	$Z \rightarrow \mu^*\mu^*$
> 44.9	95	AKRAWY	90I OPAL	$Z \rightarrow \mu^*\mu^*$
> 44.6	95	¹⁴⁹ 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	$e^+e^- \rightarrow \mu^*\mu^*$

¹³³ From e^+e^- collisions at $\sqrt{s} = 183\text{--}209$ GeV. $f = f'$ is assumed.

¹³⁴ From e^+e^- collisions at $\sqrt{s} = 192\text{--}202$ GeV. $f=f'$ is assumed. ACCIARRI 01D also obtain limit for $f=-f'$: $m_{\mu^*} > 93.4$ GeV.

¹³⁵ From e^+e^- collisions at $\sqrt{s}=161\text{--}183$ GeV. $f=f'$ is assumed. ABBIENDI 00I also obtain limit for $f=-f'$ ($\mu^* \rightarrow \nu W$): $m_{\mu^*} > 86.0$ GeV.

¹³⁶ From e^+e^- collisions at $\sqrt{s}=189$ GeV. $f=f'$ is assumed. ACCIARRI 00E also obtain limit for $f=-f'$ ($\mu^* \rightarrow \nu W$): $m_{\mu^*} > 92.6$ GeV.

- 137 From e^+e^- collisions at $\sqrt{s}=183$ GeV. $f=f'$ is assumed. ABREU 990 also obtain limit for $f=-f'$ ($\mu^* \rightarrow \nu W$): $m_{\mu^*} > 81.3$ GeV.
- 138 From e^+e^- collisions at $\sqrt{s}=170-172$ GeV. ACKERSTAFF 98C also obtain limit from $\mu^* \rightarrow \nu W$ decay mode: $m_{\mu^*} > 81.3$ GeV.
- 139 BARATE 98U obtain limits on the form factor. See their Fig. 14 for limits in mass-form factor plane.
- 140 From e^+e^- collisions at $\sqrt{s}=161$ GeV.
- 141 ABREU 97B also obtain limit from charged current decay mode $\mu^* \rightarrow \nu W$, $m_{\mu^*} > 70.9$ GeV.
- 142 ABREU 97B also obtain limit from charged current decay mode $\mu^* \rightarrow \nu W$, $m_{\mu^*} > 44.6$ GeV.
- 143 ACKERSTAFF 97 also obtain limit from charged current decay mode $\mu^* \rightarrow \nu W$, $m_{\nu_\mu} > 77.1$ GeV.
- 144 From e^+e^- collisions at $\sqrt{s}=130-136$ GeV.
- 145 From e^+e^- collisions at $\sqrt{s}=130-140$ GeV.
- 146 BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on $\Delta\Gamma(Z) < 36$ MeV.
- 147 Limit is independent of μ^* decay mode.
- 148 Superseded by ADRIANI 93M.
- 149 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
>190 (CL = 95%)		[>178 GeV (CL = 95%) OUR 2002 BEST LIMIT]		
>190	95	150 ABBIENDI	02G OPAL	$e^+e^- \rightarrow \mu\mu^*$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
>178	95	151 ACCIARRI	01D L3	$e^+e^- \rightarrow \mu\mu^*$
		152 ABBIENDI	00I OPAL	$e^+e^- \rightarrow \mu\mu^*$
		153 ACCIARRI	00E L3	$e^+e^- \rightarrow \mu\mu^*$
		154 ABREU	99O DLPH	$e^+e^- \rightarrow \mu\mu^*$
		155 ACKERSTAFF	98C OPAL	$e^+e^- \rightarrow \mu\mu^*$
		156 BARATE	98U ALEP	$Z \rightarrow \mu\mu^*$
		157,158 ABREU	97B DLPH	$e^+e^- \rightarrow \mu\mu^*$
		157,159 ACCIARRI	97G L3	$e^+e^- \rightarrow \mu\mu^*$
		160 ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow \mu\mu^*$
		161 ABREU	96K DLPH	$e^+e^- \rightarrow \mu\mu^*$
		162 ACCIARRI	96D L3	$e^+e^- \rightarrow \mu\mu^*$
		163 ALEXANDER	96Q OPAL	$e^+e^- \rightarrow \mu\mu^*$
		164 BUSKULIC	96W ALEP	$e^+e^- \rightarrow \mu\mu^*$

> 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	$Z \rightarrow \mu\mu^*, \lambda_Z > 1$
> 85	95	¹⁶⁵ ADEVA	90F L3	$Z \rightarrow \mu\mu^*, \lambda_Z > 1$
> 75	95	¹⁶⁵ ADEVA	90F L3	$Z \rightarrow \mu\mu^*, \lambda_Z > 0.1$
> 87	95	AKRAWY	90I OPAL	$Z \rightarrow \mu\mu^*, \lambda_Z > 1$
> 80	95	¹⁶⁶ DECAMP	90G ALEP	$e^+e^- \rightarrow \mu\mu^*, \lambda_Z=1$
> 50	95	ADACHI	89B TOPZ	$e^+e^- \rightarrow \mu\mu^*, \lambda_\gamma=0.7$
> 46	95	KIM	89 AMY	$e^+e^- \rightarrow \mu\mu^*, \lambda_\gamma=0.2$

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

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

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

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

154 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.

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

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

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

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

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

160 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.

161 ABREU 96K result is from e^+e^- collisions at $\sqrt{s}= 130\text{--}136$ GeV. See their Fig. 4 for the exclusion limit in the mass-coupling plane.

162 ACCIARRI 96D result is from e^+e^- collisions at $\sqrt{s}= 130\text{--}140$ GeV. See their Fig. 2 for the exclusion limit in the mass-coupling plane.

163 ALEXANDER 96Q result is from e^+e^- collisions at $\sqrt{s}= 130\text{--}140$ GeV. See their Fig. 3a for the exclusion limit in the mass-coupling plane.

164 BUSKULIC 96W result is from e^+e^- collisions at $\sqrt{s}= 130\text{--}140$ GeV. See their Fig. 3 for the exclusion limit in the mass-coupling plane.

¹⁶⁵ Superseded by ADRIANI 93M.

¹⁶⁶ 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.

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

¹⁶⁷ RENARD 82 THEO $g-2$ of muon

¹⁶⁷ 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**, 1 June, Part II (1992)).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>103.2 (CL = 95%)		[>99.8 GeV (CL = 95%) OUR 2002 BEST LIMIT]		
>103.2	95	168 ABBIENDI	02G OPAL	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
> 99.8	95	169 ACCIARRI	01D L3	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
> 91.2	95	170 ABBIENDI	00I OPAL	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
> 94.2	95	171 ACCIARRI	00E L3	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
> 89.7	95	172 ABREU	99O DLPH	Homodoublet type
> 84.6	95	173 ACKERSTAFF	98C OPAL	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
		174 BARATE	98U ALEP	$Z \rightarrow \tau^*\tau^*$
> 79.4	95	175,176 ABREU	97B DLPH	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
> 77.4	95	175,177 ABREU	97B DLPH	$e^+e^- \rightarrow \tau^*\tau^*$ Sequential type
> 79.3	95	175 ACCIARRI	97G L3	$e^+e^- \rightarrow \tau^*\tau^*$ Sequential type
> 79.1	95	175,178 ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
> 62.2	95	179 ABREU	96K DLPH	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
> 64.2	95	180 ACCIARRI	96D L3	$e^+e^- \rightarrow \tau^*\tau^*$ Sequential type
> 65.3	95	180 ALEXANDER	96Q OPAL	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
> 64.8	95	180 BUSKULIC	96W ALEP	$e^+e^- \rightarrow \tau^*\tau^*$ Sequential type
> 45.6	95	ADRIANI	93M L3	$Z \rightarrow \tau^*\tau^*$
> 45.3	95	ABREU	92C DLPH	$Z \rightarrow \tau^*\tau^*$
> 29.8	95	181 BARDADIN-...	92 RVUE	$\Gamma(Z)$
> 26.1	95	182 DECAMP	92 ALEP	$Z \rightarrow \tau^*\tau^*$; $\Gamma(Z)$
> 46.0	95	DECAMP	92 ALEP	$Z \rightarrow \tau^*\tau^*$
> 33	95	182 ABREU	91F DLPH	$Z \rightarrow \tau^*\tau^*$; $\Gamma(Z)$
> 45.5	95	183 ADEVA	90L L3	$Z \rightarrow \tau^*\tau^*$
> 44.9	95	AKRAWY	90I OPAL	$Z \rightarrow \tau^*\tau^*$
> 41.2	95	184 DECAMP	90G ALEP	$e^+e^- \rightarrow \tau^*\tau^*$
> 29.0	95	ADACHI	89B TOPZ	$e^+e^- \rightarrow \tau^*\tau^*$

168 From e^+e^- collisions at $\sqrt{s} = 183\text{--}209$ GeV. $f = f'$ is assumed.

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

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

171 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.

172 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.

- 173 From e^+e^- collisions at $\sqrt{s}=170\text{--}172$ GeV. ACKERSTAFF 98C also obtain limit from $\tau^* \rightarrow \nu W$ decay mode: $m_{\tau^*} > 81.3$ GeV.
- 174 BARATE 98U obtain limits on the form factor. See their Fig. 14 for limits in mass-form factor plane.
- 175 From e^+e^- collisions at $\sqrt{s}=161$ GeV.
- 176 ABREU 97B also obtain limit from charged current decay mode $\tau^* \rightarrow \nu W$, $m_{\tau^*} > 70.9$ GeV.
- 177 ABREU 97B also obtain limit from charged current decay mode $\tau^* \rightarrow \nu W$, $m_{\tau^*} > 44.6$ GeV.
- 178 ACKERSTAFF 97 also obtain limit from charged current decay mode $\tau^* \rightarrow \nu W$, $m_{\nu\tau^*} > 77.1$ GeV.
- 179 From e^+e^- collisions at $\sqrt{s}=130\text{--}136$ GeV.
- 180 From e^+e^- collisions at $\sqrt{s}=130\text{--}140$ GeV.
- 181 BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on $\Delta\Gamma(Z) < 36$ MeV.
- 182 Limit is independent of τ^* decay mode.
- 183 Superseded by ADRIANI 93M.
- 184 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 $\lambda\text{--}m_{\tau^*}$ plane. See the original papers.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>185	(CL = 95%)	[>173 GeV (CL = 95%) OUR 2002 BEST LIMIT]		
>185	95	185 ABBIENDI	02G OPAL	$e^+e^- \rightarrow \tau\tau^*$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
>173	95	186 ACCIARRI	01D L3	$e^+e^- \rightarrow \tau\tau^*$
		187 ABBIENDI	00I OPAL	$e^+e^- \rightarrow \tau\tau^*$
		188 ACCIARRI	00E L3	$e^+e^- \rightarrow \tau\tau^*$
		189 ABREU	99O DLPH	$e^+e^- \rightarrow \tau\tau^*$
		190 ACKERSTAFF	98C OPAL	$e^+e^- \rightarrow \tau\tau^*$
		191 BARATE	98U ALEP	$Z \rightarrow \tau\tau^*$
		192,193 ABREU	97B DLPH	$e^+e^- \rightarrow \tau\tau^*$
		192,194 ACCIARRI	97G L3	$e^+e^- \rightarrow \tau\tau^*$
		195 ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow \tau\tau^*$
		196 ABREU	96K DLPH	$e^+e^- \rightarrow \tau\tau^*$
		197 ACCIARRI	96D L3	$e^+e^- \rightarrow \tau\tau^*$
		198 ALEXANDER	96Q OPAL	$e^+e^- \rightarrow \tau\tau^*$
		199 BUSKULIC	96W ALEP	$e^+e^- \rightarrow \tau\tau^*$
> 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	$Z \rightarrow \tau\tau^*$, $\lambda_Z > 0.18$
> 88	95	200 ADEVA	90L L3	$Z \rightarrow \tau\tau^*$, $\lambda_Z > 1$
> 86.5	95	AKRAWY	90I OPAL	$Z \rightarrow \tau\tau^*$, $\lambda_Z > 1$
> 59	95	201 DECAMP	90G ALEP	$Z \rightarrow \tau\tau^*$, $\lambda_Z = 1$
> 40	95	202 BARTEL	86 JADE	$e^+e^- \rightarrow \tau\tau^*$, $\lambda_\gamma = 1$
> 41.4	95	203 BEHREND	86 CELL	$e^+e^- \rightarrow \tau\tau^*$, $\lambda_\gamma = 1$
> 40.8	95	203 BEHREND	86 CELL	$e^+e^- \rightarrow \tau\tau^*$, $\lambda_\gamma = 0.7$

- 185 ABBIENDI 02G result is from e^+e^- collisions at $\sqrt{s} = 183\text{--}209$ GeV. $f = f' = \Lambda/m_{\tau^*}$ is assumed for τ^* coupling. See their Fig. 4c for the exclusion limit in the mass-coupling plane.
- 186 ACCIARRI 01D result is from e^+e^- collisions at $\sqrt{s} = 192\text{--}202$ GeV. $f=f'=\Lambda/m_{\tau^*}$ is assumed for the τ^* coupling. See their Fig. 4 for limits in the mass-coupling plane.
- 187 ABBIENDI 00I result is from e^+e^- collisions at $\sqrt{s}=161\text{--}183$ GeV. See their Fig. 7 for limits in mass-coupling plane.
- 188 ACCIARRI 00E result is from e^+e^- collisions at $\sqrt{s}=189$ GeV. See their Fig. 3 for limits in mass-coupling plane.
- 189 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.
- 190 ACKERSTAFF 98C from e^+e^- collisions at $\sqrt{s}=170\text{--}172$ GeV. See their Fig. 11 for the exclusion limit in the mass-coupling plane.
- 191 BARATE 98U obtain limits on the $Z\tau\tau^*$ coupling. See their Fig. 12 for limits in mass-coupling plane
- 192 From e^+e^- collisions at $\sqrt{s}= 161$ GeV.
- 193 See Fig. 4a and Fig. 5a of ABREU 97B for the exclusion limit in the mass-coupling plane.
- 194 See Fig. 2 and Fig. 3 of ACCIARRI 97G for the exclusion limit in the mass-coupling plane.
- 195 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.
- 196 ABREU 96K result is from e^+e^- collisions at $\sqrt{s}= 130\text{--}136$ GeV. See their Fig. 4 for the exclusion limit in the mass-coupling plane.
- 197 ACCIARRI 96D result is from e^+e^- collisions at $\sqrt{s}= 130\text{--}140$ GeV. See their Fig. 2 for the exclusion limit in the mass-coupling plane.
- 198 ALEXANDER 96Q result is from e^+e^- collisions at $\sqrt{s}= 130\text{--}140$ GeV. See their Fig. 3a for the exclusion limit in the mass-coupling plane.
- 199 BUSKULIC 96W result is from e^+e^- collisions at $\sqrt{s}= 130\text{--}140$ GeV. See their Fig. 3 for the exclusion limit in the mass-coupling plane.
- 200 Superseded by ADRIANI 93M.
- 201 Superseded by DECAMP 92.
- 202 BARTEL 86 is at $E_{\text{cm}} = 30\text{--}46.78$ GeV.
- 203 BEHREND 86 limit is at $E_{\text{cm}} = 33\text{--}46.8$ GeV.

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
>99.4	95	204 ACCIARRI 01D	L3	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
>91.2	95	205 ABBIENDI 00I	OPAL	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type
		206 ABBIENDI,G 00D	OPAL	
>94.1	95	207 ACCIARRI 00E	L3	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type
		208 ABBIENDI 99F	OPAL	
>90.0	95	209 ABREU 99O	DLPH	Homodoublet type
>84.9	95	210 ACKERSTAFF 98C	OPAL	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type
		211 BARATE 98U	ALEP	$Z \rightarrow \nu^*\nu^*$
>77.6	95	212,213 ABREU 97B	DLPH	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type

>64.4	95 212,214	ABREU	97B DLPH	$e^+e^- \rightarrow \nu^*\nu^*$	Sequential type
>71.2	95 212,215	ACCIARRI	97G L3	$e^+e^- \rightarrow \nu^*\nu^*$	Sequential type
>77.8	95 212,216	ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow \nu^*\nu^*$	Homodoublet type
>61.4	95 217,218	ACCIARRI	96D L3	$e^+e^- \rightarrow \nu^*\nu^*$	Sequential type
>65.0	95 219,220	ALEXANDER	96Q OPAL	$e^+e^- \rightarrow \nu^*\nu^*$	Homodoublet type
>63.6	95 217	BUSKULIC	96W ALEP	$e^+e^- \rightarrow \nu^*\nu^*$	Sequential type
>43.7	95 221	BARDADIN-...	92 RVUE	$\Gamma(Z)$	
>47	95 222	DECAMP	92 ALEP		
>42.6	95 223	DECAMP	92 ALEP	$\Gamma(Z)$	
>35.4	95 224,225	DECAMP	90O ALEP	$\Gamma(Z)$	
>46	95 225,226	DECAMP	90O ALEP		

- 204 From e^+e^- collisions at $\sqrt{s} = 192\text{--}202$ 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.
- 205 From e^+e^- collisions at $\sqrt{s}=161\text{--}183$ 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.
- 206 From e^+e^- collisions at $\sqrt{s}=189$ GeV. ABBIENDI,G 00D obtain limit on $\sigma(e^+e^- \rightarrow \nu^*\nu^*)B(\nu^* \rightarrow \nu\gamma)^2$. See their Fig. 14. The limit ranges from 50 to 80 fb for $\sqrt{s}/2=95$ GeV $> m_{\nu_\mu^*} > 45$ GeV.
- 207 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.
- 208 From e^+e^- collisions at $\sqrt{s}=130\text{--}183$ GeV, ABBIENDI 99F obtain limit on $\sigma(e^+e^- \rightarrow \nu^*\nu^*) B(\nu^* \rightarrow \nu\gamma)^2$. See their Fig. 13. The limit ranges from 0.094 to 0.14 pb for $\sqrt{s}/2 > m_{\nu_\mu^*} > 45$ GeV.
- 209 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.
- 210 From e^+e^- collisions at $\sqrt{s}=170\text{--}172$ 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.
- 211 BARATE 98U obtain limits on the form factor. See their Fig. 14 for limits in mass-form factor plane.
- 212 From e^+e^- collisions at $\sqrt{s}=161$ GeV.
- 213 ABREU 97B also obtain limits from charged current decay modes, $m_{\nu_\mu^*} > 56.4$ GeV.
- 214 ABREU 97B also obtain limits from charged current decay modes, $m_{\nu_\mu^*} > 44.9$ GeV.
- 215 ACCIARRI 97G also obtain limits from charged current decay mode $\nu_e^* \rightarrow eW$, $m_{\nu_e^*} > 64.5$ GeV.
- 216 ACKERSTAFF 97 also obtain limits from charged current decay modes $m_{\nu_e^*} > 78.3$ GeV, $m_{\nu_\mu^*} > 78.9$ GeV, $m_{\nu_\tau^*} > 76.2$ GeV.
- 217 From e^+e^- collisions at $\sqrt{s}=130\text{--}140$ GeV.
- 218 ACCIARRI 96D also obtain limit from $\nu^* \rightarrow eW$ decay mode: $m_{\nu_\mu^*} > 57.3$ GeV.
- 219 From e^+e^- collisions at $\sqrt{s}=130\text{--}136$ GeV.
- 220 ALEXANDER 96Q also obtain limits from charged current decay modes: $m_{\nu_e^*} > 66.2$ GeV, $m_{\nu_\mu^*} > 66.5$ GeV, $m_{\nu_\tau^*} > 64.7$ GeV.

- 221 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^* .
- 222 Limit is based on $B(Z \rightarrow \nu^* \bar{\nu}^*) \times B(\nu^* \rightarrow \nu\gamma)^2 < 5 \times 10^{-5}$ (95%CL) assuming Dirac ν^* , $B(\nu^* \rightarrow \nu\gamma) = 1$.
- 223 Limit is for Dirac ν^* . The limit is 34.6 GeV for Majorana ν^* , 45.4 GeV for homodoublet ν^* .
- 224 DECAMP 900 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^* .
- 225 Superseded by DECAMP 92.
- 226 DECAMP 900 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 $e^+e^- \rightarrow \nu\nu^*$, $Z \rightarrow \nu\nu^*$, 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
>171	95	227 ACCIARRI	01D L3	$e^+e^- \rightarrow \nu\nu^*$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
none 50–150	95	228 ADLOFF	02 H1	$ep \rightarrow \nu^*X$
>158	95	229 CHEKANOV	02D ZEUS	$ep \rightarrow \nu^*X$
		230 ABBIENDI	00I OPAL	$e^+e^- \rightarrow \nu\nu^*$
		231 ABBIENDI,G	00D OPAL	
		232 ACCIARRI	00E L3	$e^+e^- \rightarrow \nu\nu^*$
>114	95	233 ADLOFF	00E H1	$ep \rightarrow \nu^*X$
		234 ABBIENDI	99F OPAL	
		235 ABREU	99O DLPH	$e^+e^- \rightarrow \nu\nu^*$
		236 ACKERSTAFF	98C OPAL	$e^+e^- \rightarrow \nu^*\nu^*$ Homodoublet type
		237 BARATE	98U ALEP	$Z \rightarrow \nu\nu^*$
		238,239 ABREU	97B DLPH	$e^+e^- \rightarrow \nu\nu^*$
		240 ABREU	97I DLPH	$\nu^* \rightarrow \ell W, \nu Z$
		241 ABREU	97J DLPH	$\nu^* \rightarrow \nu\gamma$
		238,242 ACCIARRI	97G L3	$e^+e^- \rightarrow \nu\nu^*$
		243 ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow \nu\nu^*$
		244 ADLOFF	97 H1	Lepton-flavor violation
none 40–96	95	245 BREITWEG	97C ZEUS	$ep \rightarrow \nu^*X$
		246 ACCIARRI	96D L3	$e^+e^- \rightarrow \nu\nu^*$
		247 ALEXANDER	96Q OPAL	$e^+e^- \rightarrow \nu\nu^*$
		248 BUSKULIC	96W ALEP	$e^+e^- \rightarrow \nu\nu^*$
		249 DERRICK	95B ZEUS	$ep \rightarrow \nu^*X$
		250 ABT	93 H1	$ep \rightarrow \nu^*X$
> 91	95	ADRIANI	93M L3	$\lambda_Z > 1, \nu^* \rightarrow \nu\gamma$
> 89	95	ADRIANI	93M L3	$\lambda_Z > 1, \nu_e^* \rightarrow eW$
> 87	95	ADRIANI	93M L3	$\lambda_Z > 0.1, \nu^* \rightarrow \nu\gamma$
> 74	95	ADRIANI	93M L3	$\lambda_Z > 0.1, \nu_e^* \rightarrow eW$
		251 BARDADIN-...	92 RVUE	
> 91	95	252 DECAMP	92 ALEP	$\lambda_Z > 1$

- | | | | | | | |
|--------|----|---------|--------|-----|------|--|
| > 74 | 95 | 252 | DECAMP | 92 | ALEP | $\lambda_Z > 0.034$ |
| > 91 | 95 | 253,254 | ADEVA | 900 | L3 | $\lambda_Z > 1$ |
| > 83 | 95 | 254 | ADEVA | 900 | L3 | $\lambda_Z > 0.1, \nu^* \rightarrow \nu\gamma$ |
| > 74 | 95 | 254 | ADEVA | 900 | L3 | $\lambda_Z > 0.1, \nu_e^* \rightarrow eW$ |
| > 90 | 95 | 255,256 | DECAMP | 900 | ALEP | $\lambda_Z > 1$ |
| > 74.7 | 95 | 255,256 | DECAMP | 900 | ALEP | $\lambda_Z > 0.06$ |
- 227 ACCIARRI 01D search for $\nu\nu^*$ production in e^+e^- collisions at $\sqrt{s} = 192\text{--}202$ 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.
- 228 ADLOFF 02 search for single ν^* production in ep collisions with the decays $\nu^* \rightarrow \nu\gamma, \nu Z, eW$. The quoted limit assumes $f = -f' = \Lambda/m_{\nu^*}$. See their Fig. 1 for the exclusion plots in the mass-coupling plane.
- 229 CHEKANOV 02D search for single ν^* production in ep collisions with the decays $\nu^* \rightarrow \nu\gamma, \nu Z, eW$. $f = -f' = \Lambda/m_{\nu^*}$ 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.
- 230 ABBIENDI 00i result is from e^+e^- collisions at $\sqrt{s}=161\text{--}183$ GeV. See their Fig. 7 for limits in mass-coupling plane.
- 231 From e^+e^- collisions at $\sqrt{s}=189$ GeV. ABBIENDI,G 00D obtain limit on $\sigma(e^+e^- \rightarrow \nu^*\nu^*)B(\nu^* \rightarrow \nu\gamma)^2$. See their Fig. 11.
- 232 ACCIARRI 00E result is from e^+e^- collisions at $\sqrt{s}=189$ GeV. See their Fig. 3 for limits in mass-coupling plane.
- 233 ADLOFF 00E search for single ν^* production in ep collisions with the decays $\nu^* \rightarrow \nu\gamma, \nu Z, eW$. The quoted limit assumes $f = -f' = \Lambda/m_{\nu^*}$. See their Fig. 10 for the exclusion plot in the mass-coupling plane.
- 234 From e^+e^- collisions at $\sqrt{s}=130\text{--}183$ GeV, ABBIENDI 99F obtain limit on $\sigma(e^+e^- \rightarrow \nu\nu^*) B(\nu^* \rightarrow \nu\gamma)$. See their Fig. 8.
- 235 ABREU 990 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.
- 236 ACKERSTAFF 98C from e^+e^- collisions at $\sqrt{s}=170\text{--}172$ GeV. See their Fig. 11 for the exclusion limit in the mass-coupling plane.
- 237 BARATE 98U obtain limits on the $Z\nu\nu^*$ coupling. See their Fig. 13 for limits in mass-coupling plane
- 238 From e^+e^- collisions at $\sqrt{s}=161$ GeV.
- 239 See Fig. 4b and Fig. 5b of ABREU 97B for the exclusion limit in the mass-coupling plane.
- 240 ABREU 97i limit is from $Z \rightarrow \nu\nu^*$. See their Fig. 12 for the exclusion limit in the mass-coupling plane.
- 241 ABREU 97J limit is from $Z \rightarrow \nu\nu^*$. See their Fig. 5 for the exclusion limit in the mass-coupling plane.
- 242 See Fig. 2 and Fig. 3 of ACCIARRI 97G for the exclusion limit in the mass-coupling plane.
- 243 ACKERSTAFF 97 result is from e^+e^- collisions at $\sqrt{s}=161$ GeV, for homodoublet ν^* . See their Fig. 3 for the exclusion limit in the mass-coupling plane.
- 244 ADLOFF 97 search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma, eZ, \nu W$. See their Fig. 4 for the rejection limits on the product of the production cross section and the branching ratio.
- 245 BREITWEG 97C search for single ν^* production in ep collisions with the decay $\nu^* \rightarrow \nu\gamma$. $f = -f' = 2\Lambda/m_{\nu^*}$ is assumed for the ν^* coupling. See their Fig. 10 for the exclusion plot in the mass-coupling plane.
- 246 ACCIARRI 96D result is from e^+e^- collisions at $\sqrt{s}=130\text{--}140$ GeV. See their Fig. 2 for the exclusion limit in the mass-coupling plane.

- 247 ALEXANDER 96Q result is from e^+e^- collisions at $\sqrt{s}=130\text{--}140$ GeV for homedoublet ν^* . See their Fig. 3b and Fig. 3c for the exclusion limit in the mass-coupling plane.
- 248 BUSKULIC 96W result is from e^+e^- collisions at $\sqrt{s}=130\text{--}140$ GeV. See their Fig. 4 for the exclusion limit in the mass-coupling plane.
- 249 DERRICK 95B search for single ν^* production via ν^*eW coupling in ep collisions with the decays $\nu^* \rightarrow \nu\gamma, \nu Z, eW$. See their Fig. 14 for the exclusion plot in the $m_{\nu^*}-\lambda\gamma$ plane.
- 250 ABT 93 search for single ν^* production via ν^*eW coupling in ep collisions with the decays $\nu^* \rightarrow \nu\gamma, \nu Z, eW$. See their Fig. 4 for exclusion plot in the $m_{\nu^*}-\lambda_W$ plane.
- 251 See Fig. 5 of BARDADIN-OTWINOWSKA 92 for combined limit of ADEVA 900, DECAMP 900, and DECAMP 92.
- 252 DECAMP 92 limit is based on $B(Z \rightarrow \nu^*\bar{\nu}) \times B(\nu^* \rightarrow \nu\gamma) < 2.7 \times 10^{-5}$ (95%CL) assuming Dirac ν^* , $B(\nu^* \rightarrow \nu\gamma) = 1$.
- 253 Limit is either for $\nu^* \rightarrow \nu\gamma$ or $\nu^* \rightarrow eW$.
- 254 Superseded by ADRIANI 93M.
- 255 DECAMP 900 limit based on $B(Z \rightarrow \nu\nu^*) \cdot B(\nu^* \rightarrow \nu\gamma) < 6 \times 10^{-5}$ (95%CL), assuming $B(\nu^* \rightarrow \nu\gamma) = 1$.
- 256 Superseded by DECAMP 92.

MASS LIMITS for Excited q (q^*)

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

These limits are obtained from $e^+e^- \rightarrow q^*\bar{q}^*$ 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	257 ADRIANI	93M L3	u or d type, $Z \rightarrow q^*q^*$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
		258 BARATE	98U ALEP	$Z \rightarrow q^*q^*$
		259 ADRIANI	92F L3	$Z \rightarrow q^*q^*$
>41.7	95	260 BARDADIN-...	92 RVUE	u -type, $\Gamma(Z)$
>44.7	95	260 BARDADIN-...	92 RVUE	d -type, $\Gamma(Z)$
>40.6	95	261 DECAMP	92 ALEP	u -type, $\Gamma(Z)$
>44.2	95	261 DECAMP	92 ALEP	d -type, $\Gamma(Z)$
>45	95	262 DECAMP	92 ALEP	u or d type, $Z \rightarrow q^*q^*$
>45	95	261 ABREU	91F DLPH	u -type, $\Gamma(Z)$
>45	95	261 ABREU	91F DLPH	d -type, $\Gamma(Z)$
>21.1	95	263 BEHREND	86C CELL	$e(q^*) = -1/3, q^* \rightarrow$ qg
>22.3	95	263 BEHREND	86C CELL	$e(q^*) = 2/3, q^* \rightarrow qg$
>22.5	95	263 BEHREND	86C CELL	$e(q^*) = -1/3, q^* \rightarrow$ $q\gamma$
>23.2	95	263 BEHREND	86C CELL	$e(q^*) = 2/3, q^* \rightarrow q\gamma$

- 257 ADRIANI 93M limit is valid for $B(q^* \rightarrow qg) > 0.25$ (0.17) for up (down) type.
- 258 BARATE 98U obtain limits on the form factor. See their Fig. 16 for limits in mass-form factor plane.
- 259 ADRIANI 92F search for $Z \rightarrow q^* \bar{q}^*$ followed with $q^* \rightarrow q\gamma$ decays and give the limit $\sigma_Z \cdot B(Z \rightarrow q^* \bar{q}^*) \cdot B^2(q^* \rightarrow q\gamma) < 2 \text{ pb}$ at 95%CL. Assuming five flavors of degenerate q^* of homodoublet type, $B(q^* \rightarrow q\gamma) < 4\%$ is obtained for $m_{q^*} < 45 \text{ GeV}$.
- 260 BARDADIN-OTWINOWSKA 92 limit based on $\Delta\Gamma(Z) < 36 \text{ MeV}$.
- 261 These limits are independent of decay modes.
- 262 Limit is for $B(q^* \rightarrow qg) + B(q^* \rightarrow q\gamma) = 1$.
- 263 BEHREND 86C search for $e^+ e^- \rightarrow q^* \bar{q}^*$ for $m_{q^*} > 5 \text{ GeV}$. But $m < 5 \text{ GeV}$ 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 $e^+ e^- \rightarrow q^* \bar{q}$ or $p\bar{p} \rightarrow q^* X$ 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
> 570, none 580-760 (CL = 95%) OUR EVALUATION				
>288 (CL = 90%) [$>88 \text{ GeV}$ (CL = 95%) OUR 1992 BEST LIMIT]				
none 200-520 and 580-760	95	264 ABE	97G CDF	$p\bar{p} \rightarrow q^* X, q^* \rightarrow 2$ jets
none 80-570	95	265 ABE	95N CDF	$p\bar{p} \rightarrow q^* X, q^* \rightarrow qg$ $q\gamma, qW$
>288	90	266 ALITTI	93 UA2	$p\bar{p} \rightarrow q^* X, q^* \rightarrow qg$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>205	95	267 CHEKANOV	02D ZEUS	$ep \rightarrow q^* X$
>188	95	268 ADLOFF	00E H1	$ep \rightarrow q^* X$
		269 ABREU	990 DLPH	$e^+ e^- \rightarrow qq^*$
		270 BARATE	98U ALEP	$Z \rightarrow qq^*$
		271 ADLOFF	97 H1	Lepton-flavor violation
none 40-169	95	272 BREITWEG	97C ZEUS	$ep \rightarrow q^* X$
		273 DERRICK	95B ZEUS	$ep \rightarrow q^* X$
none 80-540	95	274 ABE	94 CDF	$p\bar{p} \rightarrow q^* X, q^* \rightarrow q\gamma,$ qW
> 79	95	275 ADRIANI	93M L3	$\lambda_Z(L3) > 0.06$
		276 ABREU	92D DLPH	$Z \rightarrow qq^*$
		277 ADRIANI	92F L3	$Z \rightarrow qq^*$
> 75	95	275 DECAMP	92 ALEP	$Z \rightarrow qq^*, \lambda_Z > 1$
> 88	95	278 DECAMP	92 ALEP	$Z \rightarrow qq^*, \lambda_Z > 1$
> 86	95	278 AKRAWY	90J OPAL	$Z \rightarrow qq^*, \lambda_Z > 1.2$
		279 ALBAJAR	89 UA1	$p\bar{p} \rightarrow q^* X,$ $q^* \rightarrow qW$
> 39	95	280 BEHREND	86C CELL	$e^+ e^- \rightarrow q^* \bar{q} (q^* \rightarrow$ $qg, q\gamma), \lambda_\gamma = 1$

- 264 ABE 97G search for new particle decaying to dijets.
- 265 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.
- 266 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 $m_{d^*} \gg m_{u^*}$ ($m_{u^*} \gg m_{d^*}$).
- 267 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.
- 268 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.
- 269 ABREU 990 result is from e^+e^- collisions at $\sqrt{s}=183$ GeV. See their Fig. 6 for the exclusion limit in the mass-coupling plane.
- 270 BARATE 98U obtain limits on the $Zq q^*$ coupling. See their Fig. 16 for limits in mass-coupling plane
- 271 ADLOFF 97 search for single q^* production in ep collisions with the decay $q^* \rightarrow q\gamma$. See their Fig. 6 for the rejection limits on the product of the production cross section and the branching ratio.
- 272 BREITWEG 97C search for single q^* production in ep collisions with the decays $q^* \rightarrow q\gamma, qW$. $f_S=0$, and $f=-f'=2\Lambda/m_{q^*}$ is assumed for the q^* coupling. See their Fig. 11 for the exclusion plot in the mass-coupling plane.
- 273 DERRICK 95B search for single q^* production via $q^* q\gamma$ coupling in ep collisions with the decays $q^* \rightarrow qW, qZ, qg, q\gamma$. See their Fig. 15 for the exclusion plot in the $m_{q^*}-\lambda\gamma$ plane.
- 274 ABE 94 search for resonances in jet- γ and jet- W invariant mass in $p\bar{p}$ collisions at $E_{cm} = 1.8$ 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.
- 275 Assumes $B(q^* \rightarrow qg) = 1$.
- 276 ABREU 92D give $\sigma(e^+e^- \rightarrow Z \rightarrow q^*\bar{q} \text{ or } q\bar{q}^*) \times B(q^* \rightarrow q\gamma) < 15$ pb (95% CL) for $m_{q^*} < 80$ GeV.
- 277 ADRIANI 92F search for $Z \rightarrow qq^*$ with $q^* \rightarrow q\gamma$ and give the limit $\sigma_Z \cdot B(Z \rightarrow qq^*) \cdot B(q^* \rightarrow q\gamma) < (2-10)$ pb (95%CL) for $m_{q^*} = (46-82)$ GeV.
- 278 Assumes $B(q^* \rightarrow q\gamma) = 0.1$.
- 279 ALBAJAR 89 give $\sigma(q^* \rightarrow W + \text{jet})/\sigma(W) < 0.019$ (90% CL) for $m_{q^*} > 220$ GeV.
- 280 BEHREND 86C has $E_{cm} = 42.5-46.8$ GeV. See their Fig. 3 for excluded region in the $m_{q^*} - (\lambda_\gamma/m_{q^*})^2$ plane. The limit is for $\lambda_\gamma = 1$ with $\eta_L = \eta_R = 1$.

MASS LIMITS for Color Sextet Quarks (q_6)

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>84	95	281 ABE	89D CDF	$p\bar{p} \rightarrow q_6\bar{q}_6$

- 281 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	282 ABE	89D CDF	Stable ℓ_8 : $p\bar{p} \rightarrow \ell_8\bar{\ell}_8$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
none 3.0–30.3	95	283 ABT	93 H1	e_8 : $e p \rightarrow e_8 X$
none 3.5–30.3	95	284 KIM	90 AMY	e_8 : $e^+ e^- \rightarrow ee +$ jets
	95	284 KIM	90 AMY	μ_8 : $e^+ e^- \rightarrow \mu\mu +$ jets
	95	285 KIM	90 AMY	e_8 : $e^+ e^- \rightarrow gg$; R
>19.8	95	286 BARTEL	87B JADE	e_8, μ_8, τ_8 : $e^+ e^-$; R
none 5–23.2	95	286 BARTEL	87B JADE	μ_8 : $e^+ e^- \rightarrow \mu\mu +$ jets
		287 BARTEL	85K JADE	e_8 : $e^+ e^- \rightarrow gg$; R

282 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.

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

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

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

286 BARTEL 87B is at $E_{cm} = 46.3$ –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.

287 In BARTEL 85K, R can be affected by $e^+ e^- \rightarrow gg$ 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)

$$\lambda \equiv m_{\nu_8}/\Lambda$$

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>110	90	288 BARGER	89 RVUE	ν_8 : $p\bar{p} \rightarrow \nu_8\bar{\nu}_8$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
none 3.8–29.8	95	289 KIM	90 AMY	ν_8 : $e^+ e^- \rightarrow$ acoplanar jets
none 9–21.9	95	290 BARTEL	87B JADE	ν_8 : $e^+ e^- \rightarrow$ acoplanar jets

- 288 BARGER 89 used ABE 89B limit for events with large missing transverse momentum. Two-body decay $\nu_g \rightarrow \nu g$ is assumed.
- 289 KIM 90 is at $E_{\text{cm}} = 50\text{--}60.8$ GeV. The same assumptions as in BARTEL 87B are used.
- 290 BARTEL 87B is at $E_{\text{cm}} = 46.3\text{--}46.78$ GeV. The limit assumes the ν_g 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. • • •		
	291 ALBAJAR	89 UA1	$p\bar{p} \rightarrow W_8 X,$ $W_8 \rightarrow W g$
291	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

ABBIENDI	02G	PL B544 57	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ACHARD	02D	PL B531 28	P. Achard <i>et al.</i>	(L3 Collab.)
ACHARD	02J	PL B549 290	P. Achard <i>et al.</i>	(L3 Collab.)
ADLOFF	02	PL B525 9	C. Adloff <i>et al.</i>	(H1 Collab.)
ADLOFF	02B	PL B548 35	C. Adloff <i>et al.</i>	(H1 Collab.)
CHEKANOV	02D	PL B549 32	S. Chekanov <i>et al.</i>	(ZEUS Collab.)
ACCIARRI	01D	PL B502 37	M. Acciarri <i>et al.</i>	(L3 Collab.)
AFFOLDER	01I	PRL 87 231803	T. Affolder <i>et al.</i>	(CDF Collab.)
BOURILKOV	01	PR D64 071701	D. Bourilkov	
CHEUNG	01B	PL B517 167	K. Cheung	
ABBIENDI	00I	EPJ C14 73	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ABBIENDI	00R	EPJ C13 553	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ABBIENDI,G	00D	EPJ C18 253	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ABBOTT	00E	PR D62 031101	B. Abbott <i>et al.</i>	(D0 Collab.)
ABREU	00A	PL B491 67	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABREU	00S	PL B485 45	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ACCIARRI	00E	PL B473 177	M. Acciarri <i>et al.</i>	(L3 Collab.)
ACCIARRI	00G	PL B475 198	M. Acciarri <i>et al.</i>	(L3 Collab.)
ACCIARRI	00P	PL B489 81	M. Acciarri <i>et al.</i>	(L3 Collab.)
ADLOFF	00	PL B479 358	C. Adloff <i>et al.</i>	(H1 Collab.)
ADLOFF	00E	EPJ C17 567	C. Adloff <i>et al.</i>	(H1 Collab.)
AFFOLDER	00I	PR D62 012004	T. Affolder <i>et al.</i>	(CDF Collab.)
BARATE	00I	EPJ C12 183	R. Barate <i>et al.</i>	(ALEPH Collab.)
BOURILKOV	00	PR D62 076005	D. Bourilkov	
BREITWEG	00B	EPJ C14 239	J. Breitweg <i>et al.</i>	(ZEUS Collab.)
ABBIENDI	99	EPJ C6 1	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ABBIENDI	99F	EPJ C8 23	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ABBIENDI	99P	PL B465 303	G. Abbiendi <i>et al.</i>	(OPAL Collab.)
ABBOTT	99C	PRL 82 2457	B. Abbott <i>et al.</i>	(D0 Collab.)
ABBOTT	99D	PRL 82 4769	B. Abbott <i>et al.</i>	(D0 Collab.)
ABREU	99A	EPJ C11 383	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABREU	99O	EPJ C8 41	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ZARNECKI	99	EPJ C11 539	A.F. Zarnecki	
ABBOTT	98G	PRL 80 666	B. Abbott <i>et al.</i>	(D0 Collab.)
ABREU	98J	PL B433 429	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ACCIARRI	98J	PL B433 163	M. Acciarri <i>et al.</i>	(L3 Collab.)
ACCIARRI	98T	PL B439 183	M. Acciarri <i>et al.</i>	(L3 Collab.)
ACKERSTAFF	98	EPJ C1 21	K. Ackerstaff <i>et al.</i>	(OPAL Collab.)
ACKERSTAFF	98C	EPJ C1 45	K. Ackerstaff <i>et al.</i>	(OPAL Collab.)
ACKERSTAFF	98V	EPJ C2 441	K. Ackerstaff <i>et al.</i>	(OPAL Collab.)
ACKER...,K...	98B	PL B438 379	K. Ackerstaff <i>et al.</i>	(OPAL Collab.)
BARATE	98J	PL B429 201	R. Barate <i>et al.</i>	(ALEPH Collab.)
BARATE	98U	EPJ C4 571	R. Barate <i>et al.</i>	(ALEPH Collab.)
BARGER	98E	PR D57 391	V. Barger <i>et al.</i>	

BERTRAM	98	PL B443 347	I. Bertram, E.H. Simmons	
MCFARLAND	98	EPJ C1 509	K.S. McFarland <i>et al.</i>	(CCFR/NuTeV Collab.)
MIURA	98	PR D57 5345	M. Miura <i>et al.</i>	(VENUS Collab.)
ABE	97G	PR D55 R5263	F. Abe <i>et al.</i>	(CDF Collab.)
ABE	97T	PRL 79 2198	F. Abe <i>et al.</i>	(CDF Collab.)
ABREU	97B	PL B393 245	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABREU	97I	ZPHY C74 57	P. Abreu <i>et al.</i>	(DELPHI Collab.)
Also	97L	ZPHY C75 580	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABREU	97J	ZPHY C74 577	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ACCIARRI	97G	PL B401 139	M. Acciarri <i>et al.</i>	(L3 Collab.)
ACCIARRI	97W	PL B413 159	M. Acciarri <i>et al.</i>	(L3 Collab.)
ACKERSTAFF	97	PL B391 197	K. Ackerstaff <i>et al.</i>	(OPAL Collab.)
ACKERSTAFF	97C	PL B391 221	K. Ackerstaff <i>et al.</i>	(OPAL Collab.)
ADLOFF	97	NP B483 44	C. Adloff <i>et al.</i>	(H1 Collab.)
ARIMA	97	PR D55 19	T. Arima <i>et al.</i>	(VENUS Collab.)
BREITWEG	97C	ZPHY C76 631	J. Breitweg <i>et al.</i>	(ZEUS Collab.)
DEANDREA	97	PL B409 277	A. Deandrea	(MARS)
ABE	96	PRL 77 438	F. Abe <i>et al.</i>	(CDF Collab.)
ABE	96S	PRL 77 5336	F. Abe <i>et al.</i>	(CDF Collab.)
ABREU	96K	PL B380 480	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ACCIARRI	96D	PL B370 211	M. Acciarri <i>et al.</i>	(L3 Collab.)
ACCIARRI	96L	PL B384 323	M. Acciarri <i>et al.</i>	(L3 Collab.)
ALEXANDER	96K	PL B377 222	G. Alexander <i>et al.</i>	(OPAL Collab.)
ALEXANDER	96Q	PL B386 463	G. Alexander <i>et al.</i>	(OPAL Collab.)
BUSKULIC	96W	PL B385 445	D. Buskulic <i>et al.</i>	(ALEPH Collab.)
BUSKULIC	96Z	PL B384 333	D. Buskulic <i>et al.</i>	(ALEPH Collab.)
ABE	95N	PRL 74 3538	F. Abe <i>et al.</i>	(CDF Collab.)
ACCIARRI	95G	PL B353 136	M. Acciarri <i>et al.</i>	(L3 Collab.)
AID	95	PL B353 578	S. Aid <i>et al.</i>	(H1 Collab.)
DERRICK	95B	ZPHY C65 627	M. Derrick <i>et al.</i>	(ZEUS Collab.)
ABE	94	PRL 72 3004	F. Abe <i>et al.</i>	(CDF Collab.)
DIAZCRUZ	94	PR D49 R2149	J.L. Diaz Cruz, O.A. Sampayo	(CINV)
VELISSARIS	94	PL B331 227	C. Velissaris <i>et al.</i>	(AMY Collab.)
ABE	93G	PRL 71 2542	F. Abe <i>et al.</i>	(CDF Collab.)
ABT	93	NP B396 3	I. Abt <i>et al.</i>	(H1 Collab.)
ADRIANI	93M	PRPL 236 1	O. Adriani <i>et al.</i>	(L3 Collab.)
ALITTI	93	NP B400 3	J. Alitti <i>et al.</i>	(UA2 Collab.)
BUSKULIC	93Q	ZPHY C59 215	D. Buskulic <i>et al.</i>	(ALEPH Collab.)
DERRICK	93B	PL B316 207	M. Derrick <i>et al.</i>	(ZEUS Collab.)
ABE	92B	PRL 68 1463	F. Abe <i>et al.</i>	(CDF Collab.)
ABE	92D	PRL 68 1104	F. Abe <i>et al.</i>	(CDF Collab.)
ABE	92M	PRL 69 2896	F. Abe <i>et al.</i>	(CDF Collab.)
ABREU	92C	ZPHY C53 41	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABREU	92D	ZPHY C53 555	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ADRIANI	92B	PL B288 404	O. Adriani <i>et al.</i>	(L3 Collab.)
ADRIANI	92F	PL B292 472	O. Adriani <i>et al.</i>	(L3 Collab.)
BARBADIN-...	92	ZPHY C55 163	M. Bardadin-Otwinowska	(CLER)
DECAMP	92	PRPL 216 253	D. Decamp <i>et al.</i>	(ALEPH Collab.)
HOWELL	92	PL B291 206	B. Howell <i>et al.</i>	(TOPAZ Collab.)
KROHA	92	PR D46 58	H. Kroha	(ROCH)
PDG	92	PR D45, 1 June, Part II	K. Hikasa <i>et al.</i>	(KEK, LBL, BOST+)
SHIMOZAWA	92	PL B284 144	K. Shimosawa <i>et al.</i>	(TOPAZ Collab.)
ABE	91D	PRL 67 2418	F. Abe <i>et al.</i>	(CDF Collab.)
ABREU	91E	PL B268 296	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ABREU	91F	NP B367 511	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ADACHI	91	PL B255 613	I. Adachi <i>et al.</i>	(TOPAZ Collab.)
AKRAWY	91F	PL B257 531	M.Z. Akrawy <i>et al.</i>	(OPAL Collab.)
ALITTI	91B	PL B257 232	J. Alitti <i>et al.</i>	(UA2 Collab.)
BEHREND	91B	ZPHY C51 143	H.J. Behrend <i>et al.</i>	(CELLO Collab.)
BEHREND	91C	ZPHY C51 149	H.J. Behrend <i>et al.</i>	(CELLO Collab.)
Also	91B	ZPHY C51 143	H.J. Behrend <i>et al.</i>	(CELLO Collab.)
ABE	90I	ZPHY C48 13	K. Abe <i>et al.</i>	(VENUS Collab.)
ADEVA	90F	PL B247 177	B. Adeva <i>et al.</i>	(L3 Collab.)
ADEVA	90K	PL B250 199	B. Adeva <i>et al.</i>	(L3 Collab.)
ADEVA	90L	PL B250 205	B. Adeva <i>et al.</i>	(L3 Collab.)
ADEVA	90O	PL B252 525	B. Adeva <i>et al.</i>	(L3 Collab.)
AKRAWY	90F	PL B241 133	M.Z. Akrawy <i>et al.</i>	(OPAL Collab.)
AKRAWY	90I	PL B244 135	M.Z. Akrawy <i>et al.</i>	(OPAL Collab.)
AKRAWY	90J	PL B246 285	M.Z. Akrawy <i>et al.</i>	(OPAL Collab.)
DECAMP	90G	PL B236 501	D. Decamp <i>et al.</i>	(ALEPH Collab.)
DECAMP	90O	PL B250 172	D. Decamp <i>et al.</i>	(ALEPH Collab.)

KIM	90	PL B240 243	G.N. Kim <i>et al.</i>	(AMY Collab.)
ABE	89	PRL 62 613	F. Abe <i>et al.</i>	(CDF Collab.)
ABE	89B	PRL 62 1825	F. Abe <i>et al.</i>	(CDF Collab.)
ABE	89D	PRL 63 1447	F. Abe <i>et al.</i>	(CDF Collab.)
ABE	89H	PRL 62 3020	F. Abe <i>et al.</i>	(CDF Collab.)
ABE	89J	ZPHY C45 175	K. Abe <i>et al.</i>	(VENUS Collab.)
ABE	89L	PL B232 425	K. Abe <i>et al.</i>	(VENUS Collab.)
ADACHI	89B	PL B228 553	I. Adachi <i>et al.</i>	(TOPAZ Collab.)
ALBAJAR	89	ZPHY C44 15	C. Albajar <i>et al.</i>	(UA1 Collab.)
BARGER	89	PL B220 464	V. Barger <i>et al.</i>	(WISC, KEK)
BEHREND	89B	PL B222 163	H.J. Behrend <i>et al.</i>	(CELLO Collab.)
BRAUNSCH...	89C	ZPHY C43 549	W. Braunschweig <i>et al.</i>	(TASSO Collab.)
DORENBOS...	89	ZPHY C41 567	J. Dorenbosch <i>et al.</i>	(CHARM Collab.)
HAGIWARA	89	PL B219 369	K. Hagiwara, M. Sakuda, N. Terunuma	(KEK, DURH+)
KIM	89	PL B223 476	S.K. Kim <i>et al.</i>	(AMY Collab.)
ABE	88B	PL B213 400	K. Abe <i>et al.</i>	(VENUS Collab.)
BARINGER	88	PL B206 551	P. Baringer <i>et al.</i>	(HRS Collab.)
BRAUNSCH...	88	ZPHY C37 171	W. Braunschweig <i>et al.</i>	(TASSO Collab.)
BRAUNSCH...	88D	ZPHY C40 163	W. Braunschweig <i>et al.</i>	(TASSO Collab.)
ANSARI	87D	PL B195 613	R. Ansari <i>et al.</i>	(UA2 Collab.)
BARTEL	87B	ZPHY C36 15	W. Bartel <i>et al.</i>	(JADE Collab.)
BEHREND	87C	PL B191 209	H.J. Behrend <i>et al.</i>	(CELLO Collab.)
FERNANDEZ	87B	PR D35 10	E. Fernandez <i>et al.</i>	(MAC Collab.)
ARNISON	86C	PL B172 461	G.T.J. Arnison <i>et al.</i>	(UA1 Collab.)
ARNISON	86D	PL B177 244	G.T.J. Arnison <i>et al.</i>	(UA1 Collab.)
BARTEL	86	ZPHY C31 359	W. Bartel <i>et al.</i>	(JADE Collab.)
BARTEL	86C	ZPHY C30 371	W. Bartel <i>et al.</i>	(JADE Collab.)
BEHREND	86	PL 168B 420	H.J. Behrend <i>et al.</i>	(CELLO Collab.)
BEHREND	86C	PL B181 178	H.J. Behrend <i>et al.</i>	(CELLO Collab.)
DERRICK	86	PL 166B 463	M. Derrick <i>et al.</i>	(HRS Collab.)
Also	86B	PR D34 3286	M. Derrick <i>et al.</i>	(HRS Collab.)
DERRICK	86B	PR D34 3286	M. Derrick <i>et al.</i>	(HRS Collab.)
GRIFOLS	86	PL 168B 264	J.A. Grifols, S. Peris	(BARC)
JODIDIO	86	PR D34 1967	A. Jodidio <i>et al.</i>	(LBL, NWES, TRIU)
Also	88	PR D37 237 erratum	A. Jodidio <i>et al.</i>	(LBL, NWES, TRIU)
APPEL	85	PL 160B 349	J.A. Appel <i>et al.</i>	(UA2 Collab.)
BARTEL	85K	PL 160B 337	W. Bartel <i>et al.</i>	(JADE Collab.)
BERGER	85	ZPHY C28 1	C. Berger <i>et al.</i>	(PLUTO Collab.)
BERGER	85B	ZPHY C27 341	C. Berger <i>et al.</i>	(PLUTO Collab.)
BAGNAIA	84C	PL 138B 430	P. Bagnaia <i>et al.</i>	(UA2 Collab.)
BARTEL	84D	PL 146B 437	W. Bartel <i>et al.</i>	(JADE Collab.)
BARTEL	84E	PL 146B 121	W. Bartel <i>et al.</i>	(JADE Collab.)
EICHTEN	84	RMP 56 579	E. Eichten <i>et al.</i>	(FNAL, LBL, OSU)
ALTHOFF	83C	PL 126B 493	M. Althoff <i>et al.</i>	(TASSO Collab.)
RENARD	82	PL 116B 264	F.M. Renard	(CERN)