# Quark and Lepton Compositeness, Searches for

## SEARCHES FOR QUARK AND LEPTON COMPOSITENESS

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If quarks and leptons are made of constituents, then at the scale of constituent binding energies, there should appear new interactions among quarks and leptons. At energies much below the compositeness scale ( $\Lambda$ ), these interactions are suppressed by inverse powers of  $\Lambda$ . The dominant effect should come from the lowest dimensional interactions with four fermions (contact terms), whose most general chirally invariant form reads [1]

$$L = \frac{g^2}{2\Lambda^2} \left[ \eta_{LL} \,\overline{\psi}_L \,\gamma_\mu \,\psi_L \,\overline{\psi}_L \,\gamma^\mu \,\psi_L + \eta_{RR} \,\overline{\psi}_R \,\gamma_\mu \,\psi_R \,\overline{\psi}_R \,\gamma^\mu \,\psi_R \right] + 2\eta_{LR} \,\overline{\psi}_L \,\gamma_\mu \,\psi_L \,\overline{\psi}_R \,\gamma^\mu \,\psi_R \right] \,. \tag{1}$$

Chiral invariance provides a natural explanation why quark and lepton masses are much smaller than their inverse size  $\Lambda$ . We may determine the scale  $\Lambda$  unambiguously by using the above form of the effective interactions; the conventional method [1] is to fix its scale by setting  $g^2/4\pi = g^2(\Lambda)/4\pi = 1$  for the new strong interaction coupling and by setting the largest magnitude of the coefficients  $\eta_{\alpha\beta}$  to be unity. In the following, we denote

$$\begin{split} \Lambda &= \Lambda_{LL}^{\pm} \ \ \text{for} \ \ (\eta_{LL}, \ \eta_{RR}, \ \eta_{LR}) = (\pm 1, \ 0, \ 0) \ , \\ \Lambda &= \Lambda_{RR}^{\pm} \ \ \text{for} \ \ (\eta_{LL}, \ \eta_{RR}, \ \eta_{LR}) = (0, \ \pm 1, \ 0) \ , \\ \Lambda &= \Lambda_{VV}^{\pm} \ \ \text{for} \ \ (\eta_{LL}, \ \eta_{RR}, \ \eta_{LR}) = (\pm 1, \ \pm 1, \ \pm 1) \ , \\ \Lambda &= \Lambda_{AA}^{\pm} \ \ \text{for} \ \ (\eta_{LL}, \ \eta_{RR}, \ \eta_{LR}) = (\pm 1, \ \pm 1, \ \pm 1) \ , \end{split} \tag{2}$$
  
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as typical examples. Such interactions can arise by constituent interchange (when the fermions have common constituents, e.g., for  $ee \rightarrow ee$ ) and/or by exchange of the binding quanta (whenever binding quanta couple to constituents of both particles).

Another typical consequence of compositeness is the appearance of excited leptons and quarks ( $\ell^*$  and  $q^*$ ). Phenomenologically, an excited lepton is defined to be a heavy lepton which shares leptonic quantum number with one of the existing leptons (an excited quark is defined similarly). For example, an excited electron  $e^*$  is characterized by a nonzero transitionmagnetic coupling with electrons. Smallness of the lepton mass and the success of QED prediction for g-2 suggest chirality conservation, *i.e.*, an excited lepton should not couple to both left- and right-handed components of the corresponding lepton.

Excited leptons may be classified by  $SU(2) \times U(1)$  quantum numbers. Typical examples are:

1. Sequential type

$$egin{pmatrix} 
u^* \\ 
\ell^* \end{pmatrix}_L, \qquad [
u^*_R], \qquad \ell^*_R \ .$$

 $\nu_R^*$  is necessary unless  $\nu^*$  has a Majorana mass.

2. Mirror type

$$[
u_L^*] \ , \qquad \ell_L^* \ , \qquad \left( egin{array}{c} 
u^* \ \ell^* \end{array} 
ight)_R \ .$$

3. Homodoublet type

$$\begin{pmatrix} \nu^* \\ \ell^* \end{pmatrix}_L , \qquad \begin{pmatrix} \nu^* \\ \ell^* \end{pmatrix}_R$$

Similar classification can be made for excited quarks.

Excited fermions can be pair produced via their gauge couplings. The couplings of excited leptons with Z are listed

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	Sequential type	Mirror type	Homodoublet type
$V^{\ell^{*}} A^{\ell^{*}} A^{\ell^{*}} V^{ u^{*}_{D}} A^{ u^{*}_{D}} V^{ u^{*}_{M}} A^{ u^{*}_{M}}$	$-\frac{1}{2} + 2\sin^2\theta_W \\ -\frac{1}{2} \\ +\frac{1}{2} \\ +\frac{1}{2} \\ 0 \\ +1$	$ \begin{array}{r} -\frac{1}{2} + 2\sin^2\theta_W \\ +\frac{1}{2} \\ +\frac{1}{2} \\ -\frac{1}{2} \\ 0 \\ -1 \end{array} $	$\begin{array}{c} -1+2\sin^2\theta_W \\ 0 \\ +1 \\ 0 \\ \\ \end{array}$

Review of Particle Physics: C. Caso et al. (Particle Data Group), European Physical Journal C3, 1 (1998)

in the following table (for notation see Eq. (1) in "Standard Model of Electroweak Interactions"):

Here  $\nu_D^*$  ( $\nu_M^*$ ) stands for Dirac (Majorana) excited neutrino. The corresponding couplings of excited quarks can be easily obtained. Although form factor effects can be present for the gauge couplings at  $q^2 \neq 0$ , they are usually neglected.

In addition, transition magnetic type couplings with a gauge boson are expected. These couplings can be generally parametrized as follows:

$$\mathcal{L} = \frac{\lambda_{\gamma}^{(f^{*})} e}{2m_{f^{*}}} \overline{f}^{*} \sigma^{\mu\nu} (\eta_{L} \frac{1-\gamma_{5}}{2} + \eta_{R} \frac{1+\gamma_{5}}{2}) f F_{\mu\nu} + \frac{\lambda_{Z}^{(f^{*})} e}{2m_{f^{*}}} \overline{f}^{*} \sigma^{\mu\nu} (\eta_{L} \frac{1-\gamma_{5}}{2} + \eta_{R} \frac{1+\gamma_{5}}{2}) f Z_{\mu\nu} + \frac{\lambda_{W}^{(\ell^{*})} g}{2m_{\ell^{*}}} \overline{\ell}^{*} \sigma^{\mu\nu} \frac{1-\gamma_{5}}{2} \nu W_{\mu\nu} + \frac{\lambda_{W}^{(\nu^{*})} g}{2m_{\nu^{*}}} \overline{\nu}^{*} \sigma^{\mu\nu} (\eta_{L} \frac{1-\gamma_{5}}{2} + \eta_{R} \frac{1+\gamma_{5}}{2}) \ell W_{\mu\nu}^{\dagger} + \text{h.c.}, \qquad (3)$$

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where  $g = e/\sin\theta_W$ ,  $F_{\mu\nu} = \partial_{\mu}A_{\nu} - \partial_{\nu}A_{\mu}$  is the photon field strength,  $Z_{\mu\nu} = \partial_{\mu}Z_{\nu} - \partial_{\nu}Z_{\mu}$ , etc. The normalization of the coupling is chosen such that

$$\max(|\eta_L|, |\eta_R|) = 1$$
 .

Chirality conservation requires

$$\eta_L \eta_R = 0 . (4)$$

These couplings can arise from  $SU(2) \times U(1)$ -invariant higher-dimensional interactions. A well-studied model is the interaction of homodoublet type  $\ell^*$  with the Lagrangian [2,3]

$$\mathcal{L} = \frac{1}{2\Lambda} \overline{L}^* (g f \frac{\tau^a}{2} W^a_{\mu\nu} + g' f' Y B_{\mu\nu}) \frac{1 - \gamma_5}{2} L + \text{h.c.} , \qquad (5)$$

where L denotes the lepton doublet  $(\nu, \ell)$ ,  $\Lambda$  is the compositeness scale, g, g' are SU(2) and U(1)<sub>Y</sub> gauge couplings, and  $W^a_{\mu\nu}$ and  $B_{\mu\nu}$  are the field strengths for SU(2) and U(1)<sub>Y</sub> gauge fields. The same interaction occurs for mirror-type excited leptons. For sequential-type excited leptons, the  $\ell^*$  and  $\nu^*$ couplings become unrelated, and the couplings receive the extra suppression of (250 GeV)/ $\Lambda$  or  $m_{L^*}/\Lambda$ . In any case, these couplings satisfy the relation

$$\lambda_W = -\sqrt{2}\sin^2\theta_W(\lambda_Z \cot\theta_W + \lambda_\gamma) . \tag{6}$$

Additional coupling with gluons is possible for excited quarks:

$$\mathcal{L} = \frac{1}{2\Lambda} \overline{Q}^* \sigma^{\mu\nu} \left( g_s f_s \frac{\lambda^a}{2} G^a_{\mu\nu} + g f \frac{\tau^a}{2} W^a_{\mu\nu} + g' f' Y B_{\mu\nu} \right) \\ \times \frac{1 - \gamma_5}{2} Q + \text{h.c.} , \qquad (7)$$

where Q denotes a quark doublet,  $g_s$  is the QCD gauge coupling, and  $G^a_{\mu\nu}$  the gluon field strength.

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Some experimental analyses assume the relation  $\eta_L = \eta_R =$ 1, which violates chiral symmetry. We encode the results of such analyses if the crucial part of the cross section is proportional to the factor  $\eta_L^2 + \eta_R^2$  and the limits can be reinterpreted as those for chirality conserving cases  $(\eta_L, \eta_R) =$ (1, 0) or (0, 1) after rescaling  $\lambda$ .

Several different conventions are used by LEP experiments to express the transition magnetic couplings. To facilitate comparison, we reexpress these in terms of  $\lambda_Z$  and  $\lambda_{\gamma}$  using the following relations and taking  $\sin^2\theta_W = 0.23$ . We assume chiral couplings, *i.e.*, |c| = |d| in the notation of Ref. 2.

1. ALEPH (charged lepton and neutrino)

$$\lambda_Z^{\text{ALEPH}} = \frac{1}{2} \lambda_Z \quad (1990 \text{ papers}) \tag{8a}$$

$$\frac{2c}{\Lambda} = \frac{\lambda_Z}{m_{\ell^*} [\text{or } m_{\nu^*}]} \quad (\text{for } |c| = |d|)$$
(8b)

2. ALEPH (quark)

$$\lambda_u^{\text{ALEPH}} = \frac{\sin \theta_W \cos \theta_W}{\sqrt{\frac{1}{4} - \frac{2}{3} \sin^2 \theta_W + \frac{8}{9} \sin^4 \theta_W}} \lambda_Z = 1.11 \lambda_Z \quad (9)$$

3. L3 and DELPHI (charged lepton)

$$\lambda^{\text{L3}} = \lambda_Z^{\text{DELPHI}} = -\frac{\sqrt{2}}{\cot \theta_W - \tan \theta_W} \ \lambda_Z = -1.10\lambda_Z \ (10)$$

4. L3 (neutrino)

$$f_Z^{\rm L3} = \sqrt{2\lambda_Z} \tag{11}$$

5. OPAL (charged lepton)

$$\frac{f^{\text{OPAL}}}{\Lambda} = -\frac{2}{\cot \theta_W - \tan \theta_W} \frac{\lambda_Z}{m_{\ell^*}} = -1.56 \frac{\lambda_Z}{m_{\ell^*}} \qquad (12)$$

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6. OPAL (quark)

$$\frac{f^{\text{OPAL}}c}{\Lambda} = \frac{\lambda_Z}{2m_{q^*}} \quad (\text{for } |c| = |d|) \tag{13}$$

7. DELPHI (charged lepton)

$$\lambda_{\gamma}^{\text{DELPHI}} = -\frac{1}{\sqrt{2}} \lambda_{\gamma} \tag{14}$$

If leptons are made of color triplet and antitriplet constituents, we may expect their color-octet partners. Transitions between the octet leptons ( $\ell_8$ ) and the ordinary lepton ( $\ell$ ) may take place via the dimension-five interactions

$$\mathcal{L} = \frac{1}{2\Lambda} \sum_{\ell} \left\{ \overline{\ell}_8^{\alpha} g_S F^{\alpha}_{\mu\nu} \sigma^{\mu\nu} \left( \eta_L \ell_L + \eta_R \ell_R \right) + h.c. \right\}$$
(15)

where the summation is over charged leptons and neutrinos. The leptonic chiral invariance implies  $\eta_L \ \eta_R = 0$  as before.

## References

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- K. Hagiwara, S. Komamiya, and D. Zeppenfeld, Z. Phys. C29, 115 (1985).
- N. Cabibbo, L. Maiani, and Y. Srivastava, Phys. Lett. 139B, 459 (1984).

## SCALE LIMITS for Contact Interactions: A(eeee)

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

$\Lambda^+_{LL}$ (TeV)	$\Lambda^{-}_{LL}$ (TeV)	CL%	DOCUMENT ID	 TECN	COMMENT	_
> 2.4	/	95 95	ACKERSTAFF <sup>1</sup> KROHA		$E_{\rm cm} = 130 - 136$ , 161 GeV	

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

>1.7	>2.3	95	<sup>2</sup> ARIMA	97 VNS	E <sub>cm</sub> = 57.77 GeV
>1.6	>2.0	95	<sup>3</sup> BUSKULIC	93Q ALEP	$E_{\rm cm} = 88.25 - 94.25 {\rm GeV}$
>1.6		95	<sup>3,4</sup> BUSKULIC	93Q RVUE	
	>2.2	95	BUSKULIC	93Q RVUE	
>1.3		95	<sup>1</sup> KROHA	92 RVUE	
>0.7	>2.8	95	BEHREND	91C CELL	E <sub>cm</sub> =35 GeV
>1.3	>1.3	95	KIM	89 AMY	E <sub>cm</sub> =50–57 GeV
>1.4	>3.3	95	<sup>5</sup> BRAUNSCH		$E_{\rm cm} = 12 - 46.8  {\rm GeV}$
>1.0	>0.7	95	<sup>6</sup> FERNANDEZ	87b MAC	$E_{\rm cm}$ =29 GeV
>1.1	>1.4	95	<sup>7</sup> BARTEL	86c JADE	$E_{\rm cm} = 12 - 46.8  {\rm GeV}$
>1.17	>0.87	95	<sup>8</sup> DERRICK	86 HRS	$E_{\rm cm}$ =29 GeV
> 1.1	>0.76	95	<sup>9</sup> BERGER	85b PLUT	$E_{\rm cm}$ =34.7 GeV

<sup>1</sup> KROHA 92 limit is from fit to BERGER 85B, BARTEL 86C, DERRICK 86B, FERNAN-DEZ 87B, BRAUNSCHWEIG 88, BEHREND 91B, and BEHREND 91C. The fit gives  $\eta/\Lambda_{II}^2 = +0.230 \pm 0.206 \text{ TeV}^{-2}$ .

 ${}^{2}Z-Z'$  mixing is assumed to be zero.

<sup>3</sup> 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.

<sup>4</sup> This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.

<sup>5</sup> BRAUNSCHWEIG 88 assumed  $m_Z = 92$  GeV and  $\sin^2 \theta_W = 0.23$ .

<sup>6</sup>FERNANDEZ 87B assumed  $\sin^2 \theta_W = 0.22$ .

<sup>7</sup>BARTEL 86C assumed  $m_Z = 93$  GeV and  $\sin^2 \theta_W = 0.217$ .

<sup>8</sup> DERRICK 86 assumed  $m_Z^2 = 93$  GeV and  $g_V^2 = (-1/2 + 2\sin^2\theta_W)^2 = 0.004$ .

<sup>9</sup>BERGER 85B assumed  $m_Z = 93$  GeV and  $\sin^2 \theta_W = 0.217$ .

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

Limits are for  $\Lambda_{II}^{\pm}$  only. For other cases, see each reference.

$\Lambda^+_{LL}$ (TeV)	$\Lambda^{LL}({\rm TeV})$	CL%	DOCUMENT ID		TECN	COMMENT
>2.4	> 2.9	95		<b>97</b> C	OPAL	E <sub>cm</sub> = 130–136, 161 GeV
> 2.6	>1.9	<b>95 10</b> ,1	<sup>11</sup> BUSKULIC	93Q	RVUE	
• • • We	e do not use	the follow	ving data for aver	ages,	fits, lim	its, etc. ● ● ●
>1.7	>2.2		<sup>11</sup> VELISSARIS	94	AMY	E <sub>cm</sub> =57.8 GeV
>1.3	>1.5	95	<sup>11</sup> BUSKULIC	93Q	ALEP	E <sub>cm</sub> =88.25–94.25 GeV
>2.3	>2.0	95	HOWELL	92	TOPZ	E <sub>cm</sub> =52-61.4 GeV
	>1.7	95	<sup>12</sup> KROHA	92	RVUE	
>2.5	>1.5	95	BEHREND	<b>91</b> C	CELL	E <sub>cm</sub> =35–43 GeV
>1.6	>2.0	95	<sup>13</sup> ABE	901	VNS	$E_{\rm cm} = 50 - 60.8 {\rm GeV}$
>1.9	>1.0	95	KIM	89	AMY	$E_{\rm cm} = 50 - 57  \text{GeV}$
>2.3	>1.3	95	BRAUNSCH	88D	TASS	$E_{\rm cm} = 30 - 46.8  {\rm GeV}$
>4.4	>2.1	95	<sup>14</sup> BARTEL	<b>86</b> C	JADE	$E_{\rm cm} = 12 - 46.8 {\rm GeV}$
>2.9	>0.86	95	<sup>15</sup> BERGER			$E_{\rm cm}$ =34.7 GeV

<sup>10</sup> This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.

<sup>11</sup>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 KROHA 92 limit is from fit to BARTEL 86C, BEHREND 87C, BRAUNSCHWEIG 88D, BRAUNSCHWEIG 89C, ABE 90I, and BEHREND 91C. The fit gives  $\eta/\Lambda_{II}^2 = -0.155 \pm$ 0.095 TeV<sup>-2</sup>. <sup>13</sup> ABE 901 assumed  $m_Z$  =91.163 GeV and  $\sin^2\theta_W$  = 0.231.

<sup>14</sup> BARTEL 86C assumed  $m_Z = 93$  GeV and  $\sin^2 \theta_W = 0.217$ .

<sup>15</sup> 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  $\Lambda^{\pm}_{LL}$  only. For other cases, see each reference.

$\Lambda^+_{LL}$ (TeV)	$\Lambda^{LL}$ (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>1.9	>3.0	95	ACKERSTAFF	<b>9</b> 7C	OPAL	E <sub>cm</sub> = 130–136, 161 GeV
• • • We	do not use	the followi	ng data for aver	ages,	fits, lim	its, etc. ● ● ●
>1.4	>2.0	95 16	VELISSARIS	94	AMY	<i>E</i> <sub>cm</sub> =57.8 GeV
>1.0	>1.5		BUSKULIC	93Q	ALEP	<i>E</i> <sub>cm</sub> =88.25–94.25 GeV
>1.8	>2.3	95 16,17	BUSKULIC		RVUE	
>1.9	>1.7	95	HOWELL	92	TOPZ	E <sub>cm</sub> =52–61.4 GeV
>1.9	>2.9	95 18	<sup>3</sup> KROHA	92	RVUE	
>1.6	>2.3	95	BEHREND	<b>91</b> C	CELL	E <sub>cm</sub> =35–43 GeV
>1.8	>1.3		ABE	901	VNS	$E_{\rm cm} = 50 - 60.8 {\rm GeV}$
>2.2	>3.2	95 20	BARTEL	86	JADE	$E_{\rm cm} = 12 - 46.8  {\rm GeV}$

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

 $^{17}$  This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.

<sup>18</sup> KROHA 92 limit is from fit to BARTEL 86C BEHREND 89B, BRAUNSCHWEIG 89C, ABE 90I, and BEHREND 91C. The fit gives  $\eta/\Lambda_{LL}^2 = +0.095 \pm 0.120 \text{ TeV}^{-2}$ .

<sup>19</sup>ABE 901 assumed  $m_Z$  =91.163 GeV and  $\sin^2 \theta_W = 0.231$ .

<sup>20</sup> BARTEL 86 assumed  $m_Z = 93$  GeV and  $\sin^2 \theta_W = 0.217$ .

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

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

$\Lambda^+_{LL}$ (TeV)	$\Lambda^{-}_{LL}$ (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>2.7	> 3.8	95	ACKERSTAFF	<b>97</b> C	OPAL	E <sub>cm</sub> = 130–136, 161 GeV
> 3.5	>2.8	95	<sup>21,22</sup> BUSKULIC	93Q	RVUE	
• • • We	do not use	the f	following data for aver	ages,	fits, lim	iits, etc. • • •
>3.0	>2.3	95	<sup>22,23</sup> BUSKULIC	93Q	ALEP	E <sub>cm</sub> =88.25–94.25 GeV
>2.5	>2.2	95				$E_{\rm cm} = 52 - 61.4 {\rm GeV}$
>3.4	>2.7	95	<sup>25</sup> KROHA	92	RVUE	
21						

 $^{21}$  This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.

 $^{22}$  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.

<sup>23</sup> From  $e^+e^- \rightarrow e^+e^-$ ,  $\mu^+\mu^-$ , and  $\tau^+\tau^-$ .

<sup>24</sup> HOWELL 92 limit is from  $e^+e^- \rightarrow \mu^+\mu^-$  and  $\tau^+\tau^-$ .

 $^{25}$  KROHA 92 limit is from fit to most PEP/PETRA/TRISTAN data. The fit gives  $\eta/\Lambda_{11}^2$ 

 $= -0.0200 \pm 0.0666 \text{ TeV}^{-2}.$ 

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

Limits are for  $\Lambda_{II}^{\pm}$  only. For other cases, see each reference.

$\Lambda^+_{LL}$ (TeV)	$\Lambda^{-}_{LL}$ (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>2.5	>3.7	95	<sup>26</sup> ABE	97T	CDF	(eeqq) (isosinglet)
>3.1	>2.9	95	<sup>27</sup> ACKERSTAFF			
• • • We	do not use	the follo	owing data for avera	ages,	fits, lim	its, etc. ● ● ●
>2.5	>2.1	95	<sup>28</sup> ACKERSTAFF	<b>97</b> C	OPAL	(eeqq)
>7.4	>11.7	95	<sup>29</sup> DEANDREA			<i>eeuu</i> , atomic parity viola- tion
>2.3	>1.0	95	<sup>30</sup> AID	95	H1	(eeqq) ( <i>u</i> , <i>d</i> quarks)
1.7	>2.2	95	<sup>31</sup> ABE			(eeqq) $(u, d quarks)$
>1.2		95	<sup>32</sup> ADACHI	91	TOPZ	(eeqq) (flavor-universal)
	>1.6	95	<sup>32</sup> ADACHI	91	TOPZ	(e e q q) (flavor-universal)
>0.6	>1.7	95	<sup>33</sup> BEHREND	<b>91</b> C	CELL	(eecc)
> 1.1	>1.0	95	<sup>33</sup> BEHREND	<b>91</b> C	CELL	(eebb)
>0.9		95	<sup>34</sup> ABE	89L	VNS	(e e q q) (flavor-universal)
	>1.7	95	<sup>34</sup> ABE	89L	VNS	(e e q q) (flavor-universal)
>1.05	>1.61	95	<sup>35</sup> HAGIWARA	89	RVUE	(eecc)
>1.21	>0.53	95	<sup>36</sup> HAGIWARA	89	RVUE	(eebb)

<sup>26</sup> ABE 97T limits are from  $e^+e^-$  mass distribution in  $\overline{p}p \rightarrow e^+e^-$ X at  $E_{cm}$ =1.8 TeV. <sup>27</sup> ACKERSTAFF 97C limits are  $R_b$  measurements at  $E_{\rm cm} = 133$  GeV and 161 GeV.

<sup>28</sup> ACKERSTAFF 97C limits are from  $e^+e^- \rightarrow q\overline{q}$  cross section at  $E_{\rm cm} = 130-136$  GeV and 161 GeV. <sup>29</sup> DEANDREA 97 limit is from atomic parity violation of cesium. The limit is eluded if the

contact interactions are parity conserving.

<sup>30</sup> AID 95 limits are from the  $Q^2$  spectrum measurement of  $ep \rightarrow eX$ . <sup>31</sup> ABE 91D limits are from  $e^+e^-$  mass distribution in  $p\overline{p} \rightarrow e^+e^-X$  at  $E_{\rm cm} = 1.8$  TeV. <sup>32</sup> ADACHI 91 limits are from differential jet cross section. Universality of  $\Lambda(eeqq)$  for five flavors is assumed.

<sup>33</sup>BEHREND 91C is from data at  $E_{\rm cm} = 35-43$  GeV.

<sup>34</sup>ABE 89L limits are from jet charge asymmetry. Universality of  $\Lambda(eeqq)$  for five flavors is assumed. <sup>35</sup> The HAGIWARA 89 limit is derived from forward-backward asymmetry measurements of

 $D/D^*$  mesons by ALTHOFF 83C, BARTEL 84E, and BARINGER 88.

<sup>36</sup> The HAGIWARA 89 limit is derived from forward-backward asymmetry measurement of b hadrons by BARTEL 84D.

SCALE	LIMITS fo	or Contac	t Interactions	: <b>^(</b> µ	μ <b>μqq</b> )		
$\Lambda^+_{LL}$ (TeV)	$\Lambda^{LL}$ (TeV)	CL%	DOCUMENT ID		TECN	COMMENT	
>2.9	>4.2	95 3	<sup>7</sup> ABE	97T	CDF	$(\mu \mu q q)$ (isosinglet)	
• • • We	do not use	e the follow	ing data for ave	rages,	fits, lim	nits, etc. • • •	
>1.4	>1.6	95	ABE	<b>92</b> B	CDF	$(\mu \mu q q)$ (isosinglet)	
<sup>37</sup> ABE 9	97⊤ limits a	re from $\mu^+$	$\mu^-$ mass distrib	oution	in	$\rightarrow \mu^+ \mu^- X$ at $E_{\rm cm} = 1.8$ TeV.	I

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

VALUE (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>3.10	90	<sup>38</sup> JODIDIO	86	SPEC	$\Lambda^{\pm}_{LR}( u_{\mu} u_{e}\mu e)$
$\bullet \bullet \bullet$ We do not use the	ie followi	ng data for averages	s, fits	, limits,	etc. • • •
>3.8		<sup>39</sup> DIAZCRUZ	94	RVUE	$\Lambda^+_{LL}( au  u_ au  e   u_e)$
>8.1		<sup>39</sup> DIAZCRUZ	94	RVUE	$\Lambda_{II}^{-}(\tau \nu_{\tau} e \nu_{e})$
>4.1		<sup>40</sup> DIAZCRUZ	94	RVUE	$\Lambda_{LL}^{}(\tau \nu_{\tau} \mu \nu_{\mu})$
>6.5		<sup>40</sup> DIAZCRUZ	94	RVUE	$\Lambda_{LL}^{-}(\tau \nu_{\tau} \mu \nu_{\mu})$

<sup>38</sup> JODIDIO 86 limit is from  $\mu^+ \rightarrow \overline{\nu}_{\mu} e^+ \nu_e$ . Chirality invariant interactions  $L = (g^2/\Lambda^2)$  $\left[\eta_{LL} \left(\overline{\nu}_{\mu L} \gamma^{\alpha} \mu_{L}\right) \left(\overline{e}_{L} \gamma_{\alpha} \nu_{e L}\right) + \eta_{LR} \left(\overline{\nu}_{\mu L} \gamma^{\alpha} \nu_{e L} \left(\overline{e}_{R} \gamma_{\alpha} \mu_{R}\right)\right] \text{ with } g^{2}/4\pi = 1 \text{ and } g^{2}/4\pi = 1 \text{$  $(\eta_{LL},\eta_{LR}) = (0,\pm 1)$  are taken. No limits are given for  $\Lambda_{LL}^{\pm}$  with  $(\eta_{LL},\eta_{LR}) = (\pm 1,0)$ . For more general constraints with right-handed neutrinos and chirality nonconserving contact interactions, see their text.

 $^{39}$  DIAZCRUZ 94 limits are from  $\Gamma( au 
ightarrow e 
u 
u)$  and assume flavor-dependent contact interactions with  $\Lambda(\tau \nu_{\tau} e \nu_{e}) \ll \Lambda(\mu \nu_{\mu} e \nu_{e})$ .

 $^{40}$  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: $\Lambda(qqqq)$

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

VALUE (TeV)	<u>CL%</u>	DOCUMENT ID	TEG	CN COMMENT	
		<sup>41</sup> ABE	96 CD	$F  p\overline{p} \to \text{jets inclusive}$	_
>1.6	95	<sup>42</sup> ABE	96s CD	$F  p \overline{p} \to dijet angl.;  \Lambda^+_{LL}$	
• • • We do not use t	he follow	ing data for average	s, fits, lin	nits, etc. • • •	
>1.3	95	<sup>43</sup> ABE	93G CD	$F  p\overline{p} \to dijet \ mass$	
>1.4	95	<sup>44</sup> ABE	92d CD	F $p\overline{p} \rightarrow \text{jets inclusive}$	
>1.0	99	<sup>45</sup> ABE	92м CD	$F  p \overline{p} \to dijet  angl.$	
>0.825	95	<sup>46</sup> ALITTI	91b UA	2 $p\overline{p} \rightarrow \text{jets inclusive}$	
>0.700	95	<sup>44</sup> ABE	89 CD	$F  p \overline{p} \to jets \text{ inclusive}$	
>0.330	95	<sup>47</sup> ABE	89н CD	$F  p \overline{p} \to dijet  angl.$	
>0.400	95	<sup>48</sup> ARNISON	86C UA	1 $p\overline{p} \rightarrow \text{jets inclusive}$	
>0.415	95	<sup>49</sup> ARNISON	86d UA	$1 \qquad p \overline{p} \rightarrow \text{dijet angl.}$	
>0.370	95	<sup>50</sup> APPEL	85 UA	2 $p\overline{p} \rightarrow \text{jets inclusive}$	
>0.275	95	<sup>51</sup> BAGNAIA	84C UA	2 Repl. by APPEL 85	

- <sup>41</sup> 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.
- <sup>42</sup> ABE 96S limit is from dijet angular distribution in  $p\overline{p}$  collisions at  $E_{cm} = 1.8$  TeV. The limit for  $\Lambda_{LL}^-$  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.
- <sup>43</sup>ABE 93G limit is from dijet mass distribution in  $p\overline{p}$  collisions at  $E_{\rm cm} = 1.8$  TeV. The limit is the weakest from several choices of structure functions and renormalization scale.
- <sup>44</sup> Limit is from inclusive jet cross-section data in  $p\overline{p}$  collisions at  $E_{cm} = 1.8$  TeV. The limit takes into account uncertainties in choice of structure functions and in choice of process scale.
- <sup>45</sup>ABE 92M limit is from dijet angular distribution for  $m_{\text{dijet}} > 550$  GeV in  $p\overline{p}$  collisions at  $E_{\text{cm}} = 1.8$  TeV.
- <sup>46</sup> ALITTI 91B limit is from inclusive jet cross section in  $p\overline{p}$  collisions at  $E_{\rm cm} = 630$  GeV. The limit takes into account uncertainties in choice of structure functions and in choice of process scale.
- <sup>47</sup> 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.
- <sup>48</sup> ARNISON 86C limit is from the study of inclusive high- $p_T$  jet distributions at the CERN  $\overline{p}p$  collider ( $E_{cm} = 546$  and 630 GeV). The QCD prediction renormalized to the low- $p_T$  region gives a good fit to the data.

<sup>49</sup> ARNISON 86D limit is from the study of dijet angular distribution in the range 240 < m(dijet) < 300 GeV at the CERN  $\overline{p}p$  collider ( $E_{\rm cm} = 630$  GeV). QCD prediction using EHLQ structure function (EICHTEN 84) with  $\Lambda_{\rm QCD} = 0.2$  GeV for the choice of  $Q^2 = n^{-2}$  gives the best fit to the data

 $p_T^2$  gives the best fit to the data.

- <sup>50</sup> APPEL 85 limit is from the study of inclusive high- $p_T$  jet distributions at the CERN  $\overline{p}p$  collider ( $E_{\rm cm} = 630$  GeV). The QCD prediction renormalized to the low- $p_T$  region gives a good description of the data.
- <sup>51</sup> BAGNAIA 84C limit is from the study of jet  $p_T$  and dijet mass distributions at the CERN  $\overline{p}p$  collider ( $E_{cm} = 540$  GeV). The limit suffers from the uncertainties in comparing the data with the QCD prediction.

#### MASS LIMITS for Excited $e(e^*)$

Most  $e^+e^-$  experiments assume one-photon or Z exchange. The limits from some  $e^+e^-$  experiments which depend on  $\lambda$  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  $\lambda$  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

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of limits from Z decay, the  $e^*$  coupling is assumed to be of sequential type. Possible t channel contribution from transition magnetic coupling is neglected. All limits assume  $e^* \rightarrow e\gamma$  decay except the limits from  $\Gamma(Z)$ .

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

(200-))		DOCUMENT ID	TECN	COMMENT
VALUE (GeV)	<u>CL%</u>			
>85.0	95			$e^+e^-  ightarrow e^*e^*$ Homodoublet type
• • • We do	not u	ise the following data f	for averages	s, fits, limits, etc. ● ● ●
>79.6	95	<sup>53,54</sup> ABREU		$e^+e^-  ightarrow e^*e^*$ Homodoublet type
>77.9	95	<sup>53,55</sup> ABREU	97B DLPH	$e^+e^-  ightarrow e^*e^*$ Sequential type
>79.7	95	<sup>53</sup> ACCIARRI	97G L3	$e^+e^-  ightarrow \; e^*e^*$ Sequential type
>79.9	95	<sup>53,56</sup> ACKERSTAFF	97 OPAL	$e^+e^-  ightarrow e^*e^*$ Homodoublet type
>62.5	95	<sup>57</sup> ABREU	96K DLPH	$e^+e^-  ightarrow e^*e^*$ Homodoublet type
>64.7	95	<sup>58</sup> ACCIARRI	96d L3	$e^+e^-  ightarrow \; e^*e^*$ Sequential type
>66.5	95	<sup>58</sup> ALEXANDER	96Q OPAL	$e^+e^-  ightarrow e^*e^*$ Homodoublet type
>65.2	95	<sup>58</sup> BUSKULIC	96W ALEP	$e^+e^-  ightarrow e^*e^*$ Sequential type
>45.6	95	ADRIANI	93M L3	$Z \rightarrow e^* e^*$
>45.6	95	ABREU	92C DLPH	$I Z \rightarrow e^* e^*$
>29.8	95	<sup>59</sup> BARDADIN	92 RVUE	Ε Γ(Ζ)
>26.1	95	<sup>60</sup> DECAMP	92 ALEP	$Z \rightarrow e^* e^*; \Gamma(Z)$
>46.1	95	DECAMP	92 ALEP	$Z \rightarrow e^* e^*$
>33	95	<sup>60</sup> ABREU	91F DLPH	$I Z \rightarrow e^* e^*; \Gamma(Z)$
>45.0	95	<sup>61</sup> ADEVA	90F L3	$Z \rightarrow e^* e^*$
>44.9	95	AKRAWY	901 OPAL	$Z \rightarrow e^* e^*$
>44.6	95	<sup>62</sup> DECAMP	90G ALEP	$e^+e^- \rightarrow e^*e^*$
>30.2	95	ADACHI	89в тора	$2 e^+e^- \rightarrow e^*e^*$
>28.3	95	KIM	89 AMY	$e^+e^- \rightarrow e^*e^*$
>27.9	95	<sup>63</sup> ABE	88B VNS	$e^+e^- \rightarrow e^*e^*$
52 From at	o <sup></sup> c	ollisions at $\sqrt{c} = 170 - 17$	72 CAV AC	KERSTAFE 086 also obtain limit from

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

<sup>53</sup> From  $e^+e^-$  collisions at  $\sqrt{s}=$  161 GeV.

 $^{54}$  ABREU 97B also obtain limit from charged current decay mode  $e^* 
ightarrow 
u W$ ,  $m_{a^*} > 70.9$ GeV.

<sup>55</sup>ABREU 97B also obtain limit from charged current decay mode  $e^* \rightarrow \nu W$ ,  $m_{a^*} > 44.6$ GeV.

<sup>56</sup> ACKERSTAFF 97 also obtain limit from charged current decay mode  $e^* \rightarrow \nu W$ ,  $m_{\nu^*} >$ 77.1 GeV.

<sup>57</sup> From  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–136 GeV.

<sup>58</sup> From  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV.

- <sup>59</sup>BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on  $\Delta\Gamma(Z)$ <36 MeV.
- <sup>60</sup>Limit is independent of  $e^*$  decay mode.
- <sup>61</sup> ADEVA 90F is superseded by ADRIANI 93M.

<sup>62</sup> Superseded by DECAMP 92.

<sup>63</sup>ABE 88B limits assume  $e^+e^- \rightarrow e^{*+}e^{*-}$  with one photon exchange only and  $e^* \rightarrow$  $e\gamma$  giving  $ee\gamma\gamma$ .

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

These limits are from  $e^+e^- \rightarrow e^*e$ ,  $W \rightarrow e^*\nu$ , or  $ep \rightarrow e^*X$  and depend on transition magnetic coupling between e and  $e^*$ . All limits assume  $e^* \rightarrow e\gamma$  decay except as noted. Limits from LEP, UA2, and H1 are for chiral coupling, whereas all other limits are for nonchiral coupling,  $\eta_L=\eta_R=$  1. In most papers, the limit is papers.

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

(1992))	· ·				
VALUE (GeV)	CL%	DOCUI	MENT ID	TECN	COMMENT
none 30–200	95	<sup>64</sup> BREI <sup>-</sup>	TWEG 97c	ZEUS	$e p \rightarrow e^* X$
>89	95	ADRI	ANI 93M	L3	$Z  ightarrow ~ee^{st}$ , $\lambda_Z ~> 0.5$
>88	95	ABRE	U 92C	DLPH	$Z \rightarrow ee^*$ , $\lambda_Z^- > 0.5$
> <b>91</b>	95	DECA	MP 92	ALEP	$Z  ightarrow ee^*$ , $\lambda_Z^- > 1$
>87	95	AKRA	WY 901	OPAL	$Z  ightarrow$ ee*, $\lambda_Z$ $> 0.5$
$\bullet \bullet \bullet$ We do	not u	se the follow	ing data for av	verages, t	fits, limits, etc. • • •
	95	<sup>65</sup> ACKE	RSTAFF 98C	OPAL	$e^+e^- \rightarrow ee^*$
		66,67 ABRE	:U 97в	DLPH	$e^+e^- \rightarrow ee^*$
		66,68 ACCI/	ARRI 97G	-	$e^+e^- \rightarrow ee^*$
		<sup>69</sup> ACKE	RSTAFF 97	OPAL	$e^+e^- \rightarrow ee^*$
		<sup>70</sup> ADLC			Lepton-flavor violation
		<sup>71</sup> ABRE			
		<sup>72</sup> ACCI/	ARRI 96D		$e^+e^- \rightarrow ee^*$
				-	
		<sup>74</sup> BUSK			$e^+e^- \rightarrow ee^*$
		75 DERF		ZEUS	•
	05	<sup>76</sup> ABT	93		$e p \rightarrow e^* X$
>86	95	ADRI. 77			$\lambda_\gamma > 0.04$
	05	77 DERF			
>86	95	ABRE			$e^+e^-  ightarrow  e  e^*$ , $\lambda_\gamma \ > 0.1$
>88	95	<sup>78</sup> ADEV			$Z \rightarrow ee^*, \lambda_Z > 0.5$
>86	95	<sup>78</sup> ADEV			$Z \rightarrow ee^*, \lambda_Z > 0.04$
>81	95	<sup>79</sup> DECA			$Z \rightarrow ee^*, \lambda_Z > 1$
>50	95	ADAC			$e^+e^-  ightarrow ~ee^*$ , $\lambda_\gamma > 0.04$
>56	95	KIM	89	AMY	$e^+e^-  ightarrow~ee^*$ , $\lambda_\gamma >$ 0.03
none 23–54	95	<sup>80</sup> ABE	<b>88</b> B	VNS	$e^+e^-  ightarrow e e^* \lambda_\gamma > 0.04$
>75	95	<sup>81</sup> ANSA	<b>RI 87</b> D		$W \rightarrow e^* \nu; \lambda_W > 0.7$
>63	95	<sup>81</sup> ANSA	RI 87D		$W \rightarrow e^* \nu; \lambda_W > 0.2$
>40	95	<sup>81</sup> ANSA	RI 87D	UA2	$W \rightarrow e^* \nu; \lambda_W > 0.09$
C A					

 $^{64}$  BREITWEG 97C search for single  $e^*$  production in ep collisions with the decays  $e^* 
ightarrow$  $e\gamma$ , 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.

 $^{65}$  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.

<sup>66</sup> From  $e^+e^-$  collisions at  $\sqrt{s}=161$  GeV. <sup>67</sup> See Fig. 4a and Fig. 5a of ABREU 97B for the exclusion limit in the mass-coupling plane. <sup>68</sup>See Fig. 2 and Fig. 3 of ACCIARRI 97G for the exclusion limit in the mass-coupling plane.

- <sup>69</sup> 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.
- <sup>70</sup> 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.
- <sup>71</sup>ABREU 96K result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–136 GeV. See their Fig. 4 for the exclusion limit in the mass-coupling plane.
- <sup>72</sup> ACCIARRI 96D result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV. See their Fig. 2 for the exclusion limit in the mass-coupling plane.
- <sup>73</sup> ALEXANDER 96Q result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV. See their Fig. 3a for the exclusion limit in the mass-coupling plane.
- <sup>74</sup> BUSKULIC 96W result is from  $e^+e^-$  collisions at  $\sqrt{s}=$  130–140 GeV. See their Fig. 3 for the exclusion limit in the mass-coupling plane.
- <sup>75</sup> 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.
- <sup>76</sup>ABT 93 search for single  $e^*$  production via  $e^* e \gamma$  coupling in e p collisions with the decays  $e^* \rightarrow e \gamma$ , e Z,  $\nu W$ . See their Fig. 4 for exclusion plot in the  $m_{e^*} \lambda_{\gamma}$  plane.
- <sup>77</sup> 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  $m_{\rho^*} \lambda_{\gamma}$  plane.

<sup>78</sup> Superseded by ADRIANI 93M.

<sup>79</sup> Superseded by DECAMP 92.

- <sup>80</sup>ABE 88B limits use  $e^+e^- \rightarrow ee^*$  where t-channel photon exchange dominates giving  $e\gamma(e)$  (quasi-real compton scattering).
- $^{81}$  ANSARI 87D is at  $E_{\rm cm} = 546-630$  GeV.

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

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

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

VALUE (GeV)	CL%		DOCUMENT ID		TECN	COMMENT
>194	95		ACKERSTAFF	98	OPAL	$\sqrt{s}$ =130–172 GeV
$\bullet \bullet \bullet$ We do not use the	following	g da	ata for averages,	, fits,	, limits,	etc. • • •
>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	<b>95</b> G	L3	
				93Q	ALEP	
>127			ADRIANI	<b>9</b> 2B	-	
>114	95	84	BARDADIN	92	RVUE	
> 99	95		DECAMP	92	ALEP	
		85	SHIMOZAWA	92	TOPZ	
>100	95		ABREU	91e	DLPH	
>116	95		AKRAWY	91F	OPAL	
> 83	95		ADEVA	90ĸ	L3	
> 82	95		AKRAWY	90F	OPAL	
> 68	95	86	ABE	89J	VNS	$\eta_I = 1, \ \eta_R = 0$
> 90.2	95		ADACHI	<b>89</b> B	TOPZ	
> 65	95		KIM	89	AMY	

 $^{82}$  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  $m_{e^*}$ .

<sup>83</sup> ADRIANI 92B superseded by ACCIARRI 95G.

<sup>84</sup>BARDADIN-OTWINOWSKA 92 limit from fit to the combined data of DECAMP 92, ABREU 91E, ADEVA 90κ, AKRAWY 91F.

- <sup>85</sup> SHIMOZAWA 92 fit the data to the limiting form of the cross section with  $m_{e^*} \gg E_{\rm cm}$ 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.
- $^{86}$  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.

- $\begin{array}{c|c} \underline{VALUE (GeV)} & \underline{DOCUMENT ID} & \underline{TECN} & \underline{COMMENT} \\ \bullet \bullet \bullet & We \text{ do not use the following data for averages, fits, limits, etc. } \bullet \bullet \\ & & 87 \text{ DORENBOS... 89} & \text{CHRM } \overline{\nu}_{\mu} \begin{array}{c} e \rightarrow \overline{\nu}_{\mu} e \text{ and} \\ & \nu_{\mu} e \rightarrow \nu_{\mu} e \end{array} \\ & & & 88 \text{ GRIFOLS} & 86 & \text{THEO } \nu_{\mu} e \rightarrow \nu_{\mu} e \\ & & 89 \text{ RENARD} & 82 & \text{THEO } g-2 \text{ of electron} \end{array}$
- <sup>87</sup> DORENBOSCH 89 obtain the limit  $\lambda_{\gamma}^2 \Lambda_{\text{cut}}^2 / m_{e^*}^2 < 2.6$  (95% CL), where  $\Lambda_{\text{cut}}$  is the cutoff scale, based on the one-loop calculation by GRIFOLS 86. If one assumes that  $\Lambda_{\text{cut}} = 1$  TeV and  $\lambda_{\gamma} = 1$ , one obtains  $m_{e^*} > 620$  GeV. However, one generally expects  $\lambda_{\gamma} \approx m_{e^*} / \Lambda_{\text{cut}}$  in composite models.

<sup>88</sup> 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.

<sup>89</sup> RENARD 82 derived from g-2 data limits on mass and couplings of  $e^*$  and  $\mu^*$ . See figures 2 and 3 of the paper.

## MASS LIMITS for Excited $\mu$ ( $\mu^*$ )

#### Limits for Excited $\mu$ ( $\mu^*$ ) from Pair Production

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

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

VALUE (GeV) CL% DOCUMENT ID TECN COMMENT  $^{90}$  ACKERSTAFF 98C OPAL  $e^+e^- 
ightarrow \mu^*\mu^*$  Homodoublet type >85.3 95 • • • We do not use the following data for averages, fits, limits, etc. • • • <sup>91,92</sup> ABREU 97B DLPH  $e^+e^- \rightarrow \mu^*\mu^*$  Homodoublet type 95 >79.6 <sup>91,93</sup> ABREU 97B DLPH  $e^+e^- \rightarrow \mu^*\mu^*$  Sequential type >78.4 95 <sup>91</sup> ACCIARRI 97G L3  $e^+e^- \rightarrow \mu^*\mu^*$  Sequential type >79.9 95 <sup>91,94</sup> ACKERSTAFF 97 OPAL  $e^+e^- \rightarrow \mu^*\mu^*$  Homodoublet type 95 >80.0 <sup>95</sup> ABREU 95 96К DLPH  $e^+e^- \rightarrow \mu^*\mu^*$  Homodoublet type >62.6 <sup>96</sup> ACCIARRI 96D L3  $e^+e^- \rightarrow \mu^*\mu^*$  Sequential type 95 >64.9 HTTP://PDG.LBL.GOV Page 15 Created: 6/29/1998 12:37

>66.8	95	<sup>96</sup> ALEXANDER	96Q OPAL	$e^+e^-  ightarrow \mu^*\mu^*$ Homodoublet type
>65.4	95	<sup>96</sup> BUSKULIC	96W ALEP	$e^+e^- ightarrow\mu^*\mu^*$ Sequential type
>45.6	95	ADRIANI	93M L3	$Z  ightarrow \mu^* \mu^*$
>45.6	95	ABREU		$Z  ightarrow \ \mu^*  \mu^*$
>29.8	95	<sup>97</sup> BARDADIN	92 RVUE	$\Gamma(Z)$
>26.1	95	<sup>98</sup> DECAMP	92 ALEP	$Z  ightarrow \mu^* \mu^*; \ \Gamma(Z)$
>46.1	95	DECAMP	92 ALEP	$Z \rightarrow \mu^* \mu^*$
>33	95	<sup>98</sup> ABREU	91F DLPH	$Z  ightarrow \ \mu^{st}  \mu^{st};  F(Z)$
>45.3	95	<sup>99</sup> ADEVA	90F L3	$Z \rightarrow \mu^* \mu^*$
>44.9	95	AKRAWY	901 OPAL	$Z  ightarrow \mu^* \mu^*$
>44.6	95	<sup>100</sup> DECAMP	90g ALEP	$e^+e^-  ightarrow \mu^*\mu^*$
>29.9	95	ADACHI	89b TOPZ	$e^+e^-  ightarrow \mu^*\mu^*$
>28.3	95	KIM	89 AMY	$e^+e^-  ightarrow \ \mu^*\mu^*$

<sup>90</sup> 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.

 $^{91}\,{\rm From}\,\,e^+\,e^-$  collisions at  $\sqrt{s}{=}$  161 GeV.

<sup>92</sup> ABREU 97B also obtain limit from charged current decay mode  $\mu^* \rightarrow \nu W$ ,  $m_{\mu^*} > 70.9$ GeV

GeV. 93 ABREU 97B also obtain limit from charged current decay mode  $\mu^* \rightarrow \nu W$ ,  $m_{\mu^*} > 44.6$ , GeV.

<sup>94</sup> ACKERSTAFF 97 also obtain limit from charged current decay mode  $\mu^* \rightarrow \nu W$ ,  $m_{\nu_{\mu}^*} > 77.1 \text{ GeV}.$ 

- <sup>95</sup> From  $e^+e^-$  collisions at  $\sqrt{s}=$  130–136 GeV.
- <sup>96</sup> From  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV.
- $^{97}$  BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on  $\Delta\Gamma(Z){<}36$  MeV.

<sup>98</sup>Limit is independent of  $\mu^*$  decay mode.

<sup>99</sup> Superseded by ADRIANI 93M.

<sup>100</sup> Superseded by DECAMP 92.

## Limits for Excited $\mu$ ( $\mu^*$ ) from Single Production

These limits are from  $e^+e^- \rightarrow \mu^*\mu$  and depend on transition magnetic coupling between  $\mu$  and  $\mu^*$ . 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)	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT
>89	95	ADRIANI	93M L3	$\overline{Z  ightarrow \mu \mu^{st}}$ , $\lambda_{\overline{Z}} > 0.5$
>88	95	ABREU	92c DLPH	$Z  ightarrow \mu \mu^*$ , $\lambda_{\overline{Z}}^- > 0.5$
>91	95	DECAMP	92 ALEP	$Z \rightarrow \mu \mu^*$ , $\lambda_{\overline{Z}} > 1$
>87	95	AKRAWY	901 OPAL	$Z  ightarrow ~\mu \mu^{st}$ , $\lambda_{Z}^{-} > 1$

 $\bullet$   $\bullet$   $\bullet$  We do not use the following data for averages, fits, limits, etc.  $\bullet$   $\bullet$ 

	95 1	<sup>01</sup> ACKERSTAFF	98c OPAL	$e^+e^-  ightarrow \mu\mu^*$
	102,1		97b DLPH	$e^+e^- \rightarrow \mu\mu^*$
		<sup>04</sup> ACCIARRI	97G L3	$e^+e^- \rightarrow \mu\mu^*$
		<sup>05</sup> ACKERSTAFF	97 OPAL	$e^+e^-  ightarrow \mu\mu^*$
		<sup>06</sup> ABREU	96k DLPH	$e^+e^-  ightarrow \mu\mu^*$
		<sup>07</sup> ACCIARRI	96D L3	$e^+e^-  ightarrow \ \mu\mu^*$
		<sup>08</sup> ALEXANDER	96Q OPAL	$e^+e^-  ightarrow \mu\mu^*$
		<sup>09</sup> BUSKULIC	96W ALEP	$e^+e^-  ightarrow \ \mu\mu^*$
>85		<sup>10</sup> ADEVA	90F L3	$Z  ightarrow ~\mu \mu^{st}$ , $\lambda_{Z} > 1$
>75		<sup>10</sup> ADEVA	90F L3	$Z  ightarrow ~\mu \mu^{st}$ , $\lambda_Z ~>$ 0.1
>80	95 1	<sup>11</sup> DECAMP	90g ALEP	$e^+e^-  ightarrow ~\mu \mu^*$ , $\lambda_Z{=}1$
>50	95	ADACHI	89b TOPZ	$e^+e^-  ightarrow \mu\mu^*$ , $\lambda_\gamma^-=$ 0.7
>46	95	KIM		$e^+e^-  ightarrow \mu\mu^*$ , $\lambda_{\gamma}^{'}=$ 0.2

<sup>101</sup> 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.

<sup>102</sup> From  $e^+e^-$  collisions at  $\sqrt{s}=$  161 GeV.

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

<sup>104</sup> See Fig. 2 and Fig. 3 of ACCIARRI 97G for the exclusion limit in the mass-coupling plane.

<sup>105</sup> 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.

<sup>106</sup> ABREU 96K result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–136 GeV. See their Fig. 4 for the exclusion limit in the mass-coupling plane.

<sup>107</sup> ACCIARRI 96D result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV. See their Fig. 2 for the exclusion limit in the mass-coupling plane.

<sup>108</sup> ALEXANDER 96Q result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV. See their Fig. 3a for the exclusion limit in the mass-coupling plane.

<sup>109</sup> BUSKULIC 96W result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV. See their Fig. 3 for the exclusion limit in the mass-coupling plane.

<sup>110</sup> Superseded by ADRIANI 93M.

<sup>111</sup> Superseded by DECAMP 92.

## Indirect Limits for Excited $\mu$ ( $\mu^*$ )

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

VALUE (GeV)

/E (GeV)	DOCUMENTID	TECN	COMMENT	
			-	

 $\bullet \bullet \bullet$  We do not use the following data for averages, fits, limits, etc.  $\bullet \bullet \bullet$ 

<sup>112</sup> RENARD 82 THEO g-2 of muon

 $^{112}\,\rm RENARD$  82 derived from g-2 data limits on mass and couplings of  $e^*$  and  $\mu^*.$  See figures 2 and 3 of the paper.

## MASS LIMITS for Excited $\tau$ ( $\tau^*$ )

## Limits for Excited $\tau$ ( $\tau^*$ ) from Pair Production

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

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

(1991) <u>VALUE (GeV)</u>			DOCUMENT ID		TECN	COMMENT
<b>&gt;84.6</b>	95	113	ACKERSTAFF	<b>98</b> C	OPAL	$e^+e^-  ightarrow \  au^* au^*$ Homodoublet type
$\bullet \bullet \bullet$ We do	not use	the	following data f	or av	verages,	fits, limits, etc. • • •
>79.4			ABREU	<b>97</b> B	DLPH	$e^+e^-  ightarrow \  au^* au^*$ Homodoublet type
>77.4			ABREU	<b>97</b> B	DLPH	$e^+e^-  ightarrow ~ au^*  au^*$ Sequential type
>79.3	95	114	ACCIARRI	<b>97</b> G		$e^+e^-  ightarrow ~ au^*  au^*$ Sequential type
>79.1	95 <sup>114</sup>	,117	ACKERSTAFF			
>62.2	95	118	ABREU	<b>96</b> K	DLPH	$e^+e^-  ightarrow ~ au^* au^*$ Homodoublet type
>64.2	95	119	ACCIARRI	<b>96</b> D	L3	$e^+e^-  ightarrow ~ au^*  au^*$ Sequential type
>65.3	95	119	ALEXANDER	96Q	OPAL	51
>64.8	95	119	BUSKULIC	96W	ALEP	$e^+e^-  ightarrow ~ au^*  au^*$ Sequential type
>45.6	95		ADRIANI	<b>9</b> 3M		$Z \rightarrow \tau^* \tau^*$
>45.3	95		ABREU			$Z \rightarrow \tau^* \tau^*$
>29.8	95	120	BARDADIN	92	RVUE	$\Gamma(Z)$
>26.1	95	121	DECAMP			$Z  ightarrow  au^*  au^*; \ \Gamma(Z)$
>46.0	95		DECAMP			$Z \rightarrow \tau^* \tau^*$
>33	95		ABREU			$Z \rightarrow \tau^* \tau^*; \Gamma(Z)$
>45.5	95	122	ADEVA			$Z \rightarrow \tau^* \tau^*$
>44.9	95		AKRAWY			$Z \rightarrow \tau^* \tau^*$
>41.2	95	123	DECAMP			$e^+e^- \rightarrow \tau^*\tau^*$
>29.0	95		ADACHI	<b>89</b> B	TOPZ	$e^+e^- \rightarrow \tau^*\tau^*$
$^{113}$ From $e^+$	e <sup>—</sup> colli	sion	s at $\sqrt{s}{=}170{-}17$	72 Ge	eV. ACK	ERSTAFF 98C also obtain limit from
$\tau^* \rightarrow \nu V$	<i>V</i> decay	/ mo	de: $m_{ au^*}^{} > 81.3$	3 Ge\	/.	
$^{114}$ From $e^+$	e <sup>—</sup> colli	sion	s at $\sqrt{s}=161~{ m G}$	ieV.		
					current	decay mode $ au^*  ightarrow ~ u$ W, $m^{}_{ au^*} >$ 70.9
GeV.						,
GeV.	I B also	obta	in limit from cha	argeo	current	decay mode $ au^*  ightarrow ~  u$ W, $m_{ au^*}^{} >$ 44.6
<sup>117</sup> ACKERS1	TAFF 9	7 als	so obtain limit	from	charge	d current decay mode $ au^*  o  u W$ ,
$m_{\nu_{-}^{*}}^{*} > 77$	7.1 GeV			nom	charge	a cancile accay mode (
7			s at $\sqrt{s}=$ 130–1	36 C	<u>م</u> \/	
			s at $\sqrt{s}$ = 130 1 s at $\sqrt{s}$ = 130–1			
						ndent of decay modes. Based on
$\Delta\Gamma(Z) < 3$	6 MeV.	VIIV		111 15	muepe	indent of decay modes. Dased off
			of $ au^*$ decay mod	de.		
<sup>122</sup> Supersede	d by Al	DRIA	NI 93M.	-		
122 -		21(1)				

<sup>123</sup>Superseded by DECAMP 92.

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## Limits for Excited $\tau$ ( $\tau^*$ ) from Single Production

These limits are from  $e^+e^- \rightarrow \tau^*\tau$  and depend on transition magnetic coupling between  $\tau$  and  $\tau^*$ . 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)	<u>CL%</u>	DOCUMENT ID	TEC	CN	COMMENT
>88	95	ADRIANI	93M L3		$Z  ightarrow ~ au  au^*$ , $\lambda_{\mathcal{T}} > 0.5$
>87	95	ABREU	92C DLI	PH	$Z \rightarrow \tau \tau^*$ , $\lambda_Z^- > 0.5$
>90	95	DECAMP	92 AL	EP	$Z  ightarrow  au  au^*$ , $\lambda_Z^- > 0.18$
>86.5	95	AKRAWY	901 OP/	AL	$Z  ightarrow ~ au  au^*$ , $\lambda_Z > 1$
$\bullet$ $\bullet$ $\bullet$ We do	not use	the following data f	or average	ges, f	ïts, limits, etc. ● ● ●
	95	<sup>124</sup> ACKERSTAFF	98C OP	AL	$e^+e^- \rightarrow \tau \tau^*$
		<sup>,126</sup> ABREU	978 DLI	PH	$e^+e^- \rightarrow \tau \tau^*$
	125				$e^+e^- \rightarrow \tau \tau^*$
		<sup>128</sup> ACKERSTAFF			
					$e^+e^- \rightarrow \tau \tau^*$
					$e^+e^- \rightarrow \tau \tau^*$
		<sup>131</sup> ALEXANDER			
					$e^+e^- \rightarrow \tau \tau^*$
>88	95	<sup>133</sup> ADEVA	90L L3		$Z  ightarrow ~ au  au^*$ , $\lambda_Z > 1$
>59	95	<sup>134</sup> DECAMP			$Z  ightarrow  au  au^*$ , $\lambda_Z \!=\! 1$
>40	95	<sup>135</sup> BARTEL	86 JAE	DE	$e^+e^-  ightarrow  au  au^*$ , $\lambda_\gamma{=}1$
>41.4	95	<sup>136</sup> BEHREND	86 CEI	LL	$e^+e^-  ightarrow  au  au^*$ , $\lambda_\gamma^{}=\!1$
>40.8	95	<sup>136</sup> BEHREND			$e^+e^-  ightarrow  au  au^*$ , $\lambda_{\gamma}^{'}=$ 0.7
					7

<sup>124</sup> 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.

<sup>125</sup> From  $e^+e^-$  collisions at  $\sqrt{s}=$  161 GeV.

 $^{126}$  See Fig. 4a and Fig. 5a of ABREU 97B for the exclusion limit in the mass-coupling plane.

<sup>127</sup> See Fig. 2 and Fig. 3 of ACCIARRI 97G for the exclusion limit in the mass-coupling plane. <sup>128</sup> 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.

- <sup>129</sup>ABREU 96K result is from  $e^+e^-$  collisions at  $\sqrt{s}=$  130–136 GeV. See their Fig. 4 for the exclusion limit in the mass-coupling plane.
- <sup>130</sup> ACCIARRI 96D result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV. See their Fig. 2 for the exclusion limit in the mass-coupling plane.
- <sup>131</sup> ALEXANDER 96Q result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV. See their Fig. 3a for the exclusion limit in the mass-coupling plane.
- <sup>132</sup> BUSKULIC 96W result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV. See their Fig. 3 for the exclusion limit in the mass-coupling plane.
- <sup>133</sup> Superseded by ADRIANI 93M.
- <sup>134</sup> Superseded by DECAMP 92.
- <sup>135</sup> BARTEL 86 is at  $E_{\rm cm} = 30-46.78$  GeV.

 $^{136}$  BEHREND 86 limit is at  $E_{\rm cm}=$  33–46.8 GeV.

#### MASS LIMITS for Excited Neutrino ( $\nu^*$ )

#### Limits for Excited $\nu$ ( $\nu^*$ ) from Pair Production

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

				·····
VALUE (GeV	) <u>CL%</u> <u>DOC</u>	UMENT ID	TECN	COMMENT
<b>&gt;84.9</b>	95 <sup>137</sup> ACK	ERSTAFF 98C	OPAL	$e^+e^-  ightarrow  u^* u^*$ Homodoublet type
• • • We	do not use the follow	wing data for av	/erages,	fits, limits, etc. • • •
>77.6	95 <sup>138,139</sup> ABR		DLPH	$e^+e^-  ightarrow  u^* u^*$ Homodoublet type
>64.4	95 <sup>138,140</sup> ABR		DLPH	$e^+e^-  ightarrow \  u^* u^*$ Sequential type
>71.2	95 <sup>138,141</sup> ACC			$e^+e^-  ightarrow \  u^* u^*$ Sequential type
>77.8	95 <sup>138,142</sup> ACK	ERSTAFF 97	OPAL	$e^+e^- \rightarrow \  u^* u^*$ Homodoublet type
>61.4	95 <sup>143,144</sup> ACC		L3	$e^+e^-  ightarrow \  u^* u^*$ Sequential type
>65.0	95 <sup>145,146</sup> ALE		OPAL	$e^+e^- \rightarrow \ \nu^* \nu^*$ Homodoublet type
>63.6	95 <sup>143</sup> BUS		/ ALEP	$e^+e^-  ightarrow \  u^* u^*$ Sequential type
>43.7	95 <sup>147</sup> BAR	2 NDADIN 92	RVUE	$\Gamma(Z)$
>47	95 <sup>148</sup> DEC		ALEP	
>42.6	95 <sup>149</sup> DEC	AMP 92	ALEP	$\Gamma(Z)$
>35.4	95 <sup>150,151</sup> DEC	AMP 900	ALEP	$\Gamma(Z)$
>46	95 <sup>151,152</sup> DEC	AMP 900	ALEP	
137 –	+	- 170 170 C		

<sup>137</sup> 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,  $m_{\nu_u^*}$  > 83.9 GeV, and  $m_{\nu_\tau^*}$  > 79.4 GeV.

<sup>138</sup> From  $e^+e^-$  collisions at  $\sqrt{s}=$  161 GeV.

 $^{139}$ ABREU 97B also obtain limits from charged current decay modes,  $m_{\nu^*} > 56.4$  GeV.

<sup>140</sup>ABREU 97B also obtain limits from charged current decay modes,  $m_{\chi^*} > 44.9$  GeV.

 $^{141}\,{\rm ACCIARRI}$  97G also obtain limits from charged current decay mode  $\nu_e^* \rightarrow ~e\,W$  ,  $m_{\nu^*}^{} >$ 

 $^{64.5}$  GeV.  $^{142}\rm ACKERSTAFF$  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.

<sup>143</sup> From  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV.

<sup>144</sup> ACCIARRI 96D also obtain limit from  $\nu^* \rightarrow eW$  decay mode:  $m_{\nu^*} > 57.3$  GeV.

<sup>145</sup> From  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–136 GeV.

 $^{146}$  ALEXANDER 96Q also obtain limits from charged current decay modes:  $m_{\mu^*}^{} > 66.2$ GeV,  $m_{\nu_{\mu}^{*}}^{} > 66.5$  GeV,  $m_{\nu_{-}^{*}}^{} > 64.7$  GeV.

<sup>147</sup> BARDADIN-OTWINOWSKA 92 limit is for Dirac  $\nu^*$ . Based on  $\Delta\Gamma(Z)$ <36 MeV. The

limit is 36.4 GeV for Majorana  $\nu^*$ , 45.4 GeV for homodoublet  $\nu^*$ . <sup>148</sup>Limit is based on B( $Z \rightarrow \nu^* \overline{\nu}^*$ )×B( $\nu^* \rightarrow \nu \gamma$ )<sup>2</sup> < 5 × 10<sup>-5</sup> (95%CL) assuming Dirac  $\nu^*$ , B( $\nu^* \rightarrow \nu \gamma$ ) = 1.

<sup>149</sup>Limit is for Dirac  $\nu^*$ . The limit is 34.6 GeV for Majorana  $\nu^*$ , 45.4 GeV for homodoublet  $\nu^*$ 

<sup>150</sup> DECAMP 900 limit is from excess  $\Delta\Gamma(Z) < 89$  MeV. The above value is for Dirac  $\nu^*$ ; 26.6 GeV for Majorana  $u^*$ ; 44.8 GeV for homodoublet  $u^*$ .

<sup>151</sup>Superseded by DECAMP 92.

<sup>152</sup>DECAMP 900 limit based on B( $Z \rightarrow \nu^* \nu^*$ )·B( $\nu^* \rightarrow \nu \gamma$ )<sup>2</sup> < 7 × 10<sup>-5</sup> (95%CL), assuming Dirac  $\nu^*$ , B( $\nu^* \rightarrow \nu \gamma$ ) = 1.

#### Limits for Excited $\nu$ ( $\nu^*$ ) from Single Production

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

VALUE (GeV)	CL%		DOCUMENT ID		TECN	COMMENT
none 40–96	95	153	BREITWEG	97C	ZEUS	$ep \rightarrow \nu^* X$
>91	95		ADRIANI			$\lambda_{7} > 1, \nu^{*} \rightarrow \nu \gamma$
>89	95		ADRIANI	<b>9</b> 3M	L3	$\lambda_Z > 1, \nu_e^* \rightarrow eW$
>91	95	154	DECAMP			$\lambda_{7} > 1$
• • We do not use the	e followi	ng d	ata for averages			
	95	155	ACKERSTAFF	98C	OPAL	$e p \rightarrow \nu^* \nu^*$
	156	6,157	ABREU			$e^+e^- \rightarrow \nu \nu^*$
		158	ABREU	97ı	DLPH	$\nu^* \rightarrow \ell W, \nu Z$
		159	ABREU	97J	DLPH	$\nu^* \rightarrow \nu \gamma$
	156	6,160	ACCIARRI	<b>97</b> G	L3	$e^+e^- \rightarrow \nu \nu^*$
		161	ACKERSTAFF	97	OPAL	$e^+e^- \rightarrow \nu \nu^*$
		162	ADLOFF			Lepton-flavor violation
		163	ACCIARRI	<b>96</b> D	L3	$e^+e^- \rightarrow \nu \nu^*$
		164	ALEXANDER			$e^+e^- \rightarrow \nu \nu^*$
		165	BUSKULIC	96W	ALEP	$e^+e^- \rightarrow \nu \nu^*$
		166	DERRICK	<b>95</b> B	ZEUS	$ep \rightarrow \nu^* X$
		167	ABT	93	H1	$ep \rightarrow \nu^* X$
>87	95		ADRIANI	<b>9</b> 3M	L3	$\lambda_Z >$ 0.1, $\nu^* \rightarrow \nu \gamma$
>74	95		ADRIANI	<b>9</b> 3M	L3	$\lambda_Z > 0.1, \ \nu_e^* \rightarrow e W$
		168	BARDADIN	92	RVUE	_ 0
>74	95	154	DECAMP	92	ALEP	$\lambda_Z > 0.034$
>91	95 <sup>169</sup>		ADEVA	<b>90</b> 0	L3	$\lambda_Z^- > 1$
>83	95	170	ADEVA	<b>90</b> 0	L3	$\lambda_{Z}$ > 0.1, $ u^{*}  ightarrow  u \gamma$
>74	95		ADEVA	<b>90</b> 0	L3	$\lambda_Z^- > 0.1, \nu_e^* \rightarrow eW$
>90	95 171	,172	DECAMP			$\lambda_{Z} > 1$
>74.7	95 171	.,172	DECAMP			$\lambda_Z > 0.06$
53						

<sup>153</sup> BREITWEG 97C search for single  $\nu^*$  production in *ep* collisions with the decay  $\nu^* \rightarrow \nu\gamma$ .  $f=-f'=2\Lambda/m_{\nu^*}$  is assumed for the  $\nu^*$  coupling. See their Fig. 10 for the exclusion plot in the mass-coupling plane.

<sup>154</sup> DECAMP 92 limit is based on B( $Z \rightarrow \nu^* \overline{\nu}$ )×B( $\nu^* \rightarrow \nu \gamma$ ) < 2.7 × 10<sup>-5</sup> (95%CL) assuming Dirac  $\nu^*$ , B( $\nu^* \rightarrow \nu \gamma$ ) = 1.

<sup>155</sup> 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.

<sup>156</sup> From  $e^+e^-$  collisions at  $\sqrt{s}=$  161 GeV.

<sup>157</sup> See Fig. 4b and Fig. 5b of ABREU 97B for the exclusion limit in the mass-coupling plane.

<sup>158</sup>ABREU 971 limit is from  $Z \rightarrow \nu \nu^*$ . See their Fig. 12 for the exclusion limit in the mass-coupling plane.

<sup>159</sup>ABREU 97J limit is from  $Z \rightarrow \nu \nu^*$ . See their Fig. 5 for the exclusion limit in the mass-coupling plane.

 $^{160}$  See Fig. 2 and Fig. 3 of ACCIARRI 97G for the exclusion limit in the mass-coupling plane.

<sup>161</sup> ACKERSTAFF 97 result is from  $e^+e^-$  collisions at  $\sqrt{s}=$  161 GeV, for homodoublet  $\nu^*$ . See their Fig. 3 for the exclusion limit in the mass-coupling plane.

<sup>162</sup> 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.

- <sup>163</sup> ACCIARRI 96D result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV. See their Fig. 2 for the exclusion limit in the mass-coupling plane.
- <sup>164</sup> ALEXANDER 96Q result is from  $e^+e^-$  collisions at  $\sqrt{s}=$  130–140 GeV for homedoublet  $\nu^*$ . See their Fig. 3b and Fig. 3c for the exclusion limit in the mass-coupling plane.
- <sup>165</sup> BUSKULIC 96W result is from  $e^+e^-$  collisions at  $\sqrt{s}$ = 130–140 GeV. See their Fig. 4 for the exclusion limit in the mass-coupling plane.
- <sup>166</sup> DERRICK 95B search for single  $\nu^*$  production via  $\nu^* e W$  coupling in ep collisions with the decays  $\nu^* \rightarrow \nu \gamma$ ,  $\nu Z$ , e W. See their Fig. 14 for the exclusion plot in the  $m_{\nu^*} \lambda \gamma$  plane.
- <sup>167</sup> ABT 93 search for single  $\nu^*$  production via  $\nu^* eW$  coupling in ep collisions with the decays  $\nu^* \rightarrow \nu\gamma$ ,  $\nuZ$ , eW. See their Fig. 4 for exclusion plot in the  $m_{\nu^*} \lambda_W$  plane.
- <sup>168</sup>See Fig. 5 of BARDADIN-OTWINOWSKA 92 for combined limit of ADEVA 900, DE-CAMP 900, and DECAMP 92.
- <sup>169</sup>Limit is either for  $\nu^* \rightarrow \nu \gamma$  or  $\nu^* \rightarrow eW$ .
- <sup>170</sup> Superseded by ADRIANI 93M.
- <sup>171</sup>DECAMP 900 limit based on B( $Z \rightarrow \nu \nu^*$ )·B( $\nu^* \rightarrow \nu \gamma$ ) < 6 × 10<sup>-5</sup> (95%CL),
- assuming  $B(\nu^* \rightarrow \nu \gamma) = 1$ .
- <sup>172</sup> Superseded by DECAMP 92.

#### MASS LIMITS for Excited $q(q^*)$

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

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

VALUE (GeV)	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT
>45.6	95	<sup>173</sup> ADRIANI	<b>9</b> 3M	L3	$u \text{ or } d$ type, $Z  ightarrow q^* q^*$
$\bullet \bullet \bullet$ We do not use the	followi	ng data for averages	, fits,	limits,	etc. • • •
		<sup>174</sup> ADRIANI	92F	L3	$Z \rightarrow q^* q^*$
>41.7	95	<sup>175</sup> BARDADIN	92	RVUE	$u$ -type, $\Gamma(Z)$
>44.7	95	<sup>175</sup> BARDADIN	92	RVUE	$d$ -type, $\Gamma(Z)$
>40.6	95	<sup>176</sup> DECAMP	92	ALEP	u-type, $\Gamma(Z)$
>44.2	95	<sup>176</sup> DECAMP	92	ALEP	d-type, $\Gamma(Z)$
>45	95	<sup>177</sup> DECAMP	92	ALEP	<i>u</i> or <i>d</i> type,
					$Z \rightarrow q^* q^*$
>45	95	<sup>176</sup> ABREU	91F	DLPH	<i>u</i> -type, $\Gamma(Z)$
>45	95	<sup>176</sup> ABREU	91F	DLPH	d-type, $\Gamma(Z)$
>21.1	95	<sup>178</sup> BEHREND	<b>86</b> C	CELL	$e(q^*) = -1/3, \ q^* \rightarrow$
		170			qg
>22.3	95	178 BEHREND	86C	CELL	$e(q^*)=2/3, q^*  ightarrow qg$
>22.5	95	<sup>178</sup> BEHREND	86C	CELL	$e(q^*)=-1/3,~q^* ightarrow$
>23.2	95	<sup>178</sup> BEHREND			$e(q^*)=2/3, q^*  ightarrow q\gamma$
173 ADDIANILO2M (1	a stallad a	(		0 17) f.	

<sup>173</sup> ADRIANI 93M limit is valid for B( $q^* \rightarrow qg$ )> 0.25 (0.17) for up (down) type.

<sup>174</sup> ADRIANI 92F search for Z → q\* q̄\* followed with q\* → qγ decays and give the limit σ<sub>Z</sub> · B(Z → q\* q̄\*) · B<sup>2</sup>(q\* → qγ) <2 pb at 95%CL. Assuming five flavors of degenerate q\* of homodoublet type, B(q\* → qγ) <4% is obtained for m<sub>q\*</sub> <45 GeV.</li>
<sup>175</sup> BARDADIN-OTWINOWSKA 92 limit based on ΔΓ(Z)<36 MeV.</li>
<sup>176</sup> These limits are independent of decay modes.

<sup>177</sup>Limit is for  $B(q^* \rightarrow qg) + B(q^* \rightarrow q\gamma) = 1$ .

<sup>178</sup> BEHREND 86C search for  $e^+e^- \rightarrow q^* \overline{q}^*$  for  $m_{q^*} > 5$  GeV. But m < 5 GeV excluded by total hadronic cross section. The limits are for point-like photon couplings of excited quarks.

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

These limits are from  $e^+e^- \rightarrow q^*\overline{q}$  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

in the foothotes ar									
VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT				
>570 (CL = 95%) OUR EVALUATION									
none 200–520 and 580–760	95	<sup>179</sup> ABE	<b>97</b> G	CDF	$p \overline{p} \rightarrow q^* X, q^* \rightarrow 2$ jets				
none 40–169	95	<sup>180</sup> BREITWEG	<b>97</b> C	ZEUS	$e p \rightarrow q^* X$				
none 80–570	95	<sup>181</sup> ABE	95N	CDF	$p \overline{p}  ightarrow q^* X, q^*  ightarrow qg$ $q \gamma, qW$				
>288	90	<sup>182</sup> ALITTI	93	UA2	$p\overline{p} \rightarrow q^* X, q^* \rightarrow qg$				
> 88	95	<sup>183</sup> DECAMP	92	ALEP	$Z  ightarrow ~qq^{st}$ , $\lambda_{Z}$ $> 1$				
> 86	95	<sup>183</sup> AKRAWY	90J	OPAL	$Z  ightarrow ~qq^{st}$ , $\lambda_{Z} ~> 1.2$				
$\bullet \bullet \bullet$ We do not use the	followi	ng data for averages	, fits,	limits,	etc. • • •				
		<sup>184</sup> ADLOFF	97	H1	Lepton-flavor violation				
		<sup>185</sup> DERRICK	<b>95</b> B	ZEUS	$ep \rightarrow q^*X$				
none 80–540	95	<sup>186</sup> ABE	94	CDF	$p \overline{p}  o q^* X, \ q^*  o q \gamma, \ q W$				
> 79	95	<sup>187</sup> ADRIANI	<b>9</b> 3M	L3	$\lambda_{Z}(L3) > 0.06$				
		<sup>188</sup> ABREU	<b>92</b> D	DLPH	$Z \rightarrow q q^*$				
		<sup>189</sup> ADRIANI			$Z \rightarrow q q^*$				
> 75	95	<sup>187</sup> DECAMP	92	ALEP	$Z  ightarrow ~q  q^*$ , $\lambda_Z > 1$				
		<sup>190</sup> ALBAJAR	89	UA1	$p\overline{p}  ightarrow q^* X$ ,				
> 39	95	<sup>191</sup> BEHREND	86C	CELL	$egin{aligned} q^{*} & ightarrow qW \ e^{+}e^{-} & ightarrow q^{*}\overline{q}  (q^{*}  ightarrow qg, q\gamma),  \lambda_{\gamma} = 1 \end{aligned}$				

<sup>179</sup>ABE 97G search for new particle decaying to dijets.

 $^{13}$  ABE 97G search for new particle decaying to dijets.  $^{180}$  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.

- <sup>181</sup>ABE 95N assume a degenerate  $u^*$  and  $d^*$  with  $f_s = f = f' = \Lambda/m_{a^*}$ . See their Fig. 4 for the excluded region in  $m_{a^*} - f$  plane.
- $^{182}$  ALITTI 93 search for resonances in the two-jet invariant mass. The limit is for  $f_{\rm s}=f$  $f' = \Lambda/m_{q^*}$ .  $u^*$  and  $d^*$  are assumed to be degenerate. If not, the limit for  $u^*(d^*)$ is 277 (247) GeV if  $m_{d^*} \gg m_{\mu^*} (m_{\mu^*} \gg m_{d^*})$ .

<sup>183</sup>Assumes B( $q^* \rightarrow q\gamma$ ) = 0.1.

<sup>184</sup> 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.

<sup>185</sup> 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  $m_{a^*}^{-\lambda\gamma}$  plane.

<sup>186</sup> ABE 94 search for resonances in jet- $\gamma$  and jet-W invariant mass in  $p\overline{p}$  collisions at  $E_{\rm cm}$ = 1.8 TeV. The limit is for  $f_s = f = f' = \Lambda/m_{q^*}$  and  $u^*$  and  $d^*$  are assumed to be degenerate. See their Fig. 4 for the excluded region in  $m_{q^*}$ -f plane. <sup>187</sup> Assumes B( $q^* \rightarrow qg$ ) = 1.

188 ABREU 92D give  $\sigma(e^+e^- \rightarrow Z \rightarrow q^*\overline{q} \text{ or } q\overline{q}^*) \times B(q^* \rightarrow q\gamma) < 15 \text{ pb } (95\% \text{ CL})$ for  $m_{q^*} < 80 \text{ GeV}$ . 189 ADRIANI 92F search for  $Z \rightarrow qq^*$  with  $q^* \rightarrow q\gamma$  and give the limit  $\sigma_Z \cdot B(Z \rightarrow qq^*) \cdot B(q^* \rightarrow q\gamma) < (2-10) \text{ pb } (95\% \text{ CL})$  for  $m_{q^*} = (46-82) \text{ GeV}$ . 190 ALBAJAR 89 give  $\sigma(q^* \rightarrow W + \text{jet})/\sigma(W) < 0.019 (90\% \text{ CL})$  for  $m_{q^*} > 220 \text{ GeV}$ . 191 DELIDEND, 266 here  $\overline{z} = -425 \cdot 46.9 \text{ CeV}$ . See their  $\overline{z}$  is a related matrix in the

<sup>191</sup> BEHREND 86C has  $E_{\rm cm} = 42.5$ –46.8 GeV. See their Fig. 3 for excluded region in the  $m_{q^*} - (\lambda_\gamma/m_{q^*})^2$  plane. The limit is for  $\lambda_\gamma = 1$  with  $\eta_L = \eta_R = 1$ .

## MASS LIMITS for Color Sextet Quarks $(q_6)$

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>84	95	<sup>192</sup> ABE	89D CDF	$p\overline{p} \rightarrow q_6 \overline{q}_6$

<sup>192</sup> 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 ( $\ell_8$ )

 $\lambda \equiv m_{\ell_0}/\Lambda$ 

$\ell = \ell_8 / \ell_8$							
VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT		
>86	95	<sup>193</sup> ABE	<b>89</b> D	CDF	Stable $\ell_8: \ p \overline{p} \rightarrow \ \ell_8 \overline{\ell}_8$		
• • • We do not use the following data for averages, fits, limits, etc. • •							
		<sup>194</sup> АВТ	93	H1	$e_8: e_p \rightarrow e_8 X$		
none 3.0-30.3	95	<sup>195</sup> KIM	90	AMY	$e_8: e^+e^- \rightarrow ee^+$		
none 3.5–30.3	95	<sup>195</sup> KIM	90	AMY	jets $\mu_8: e^+e^- \rightarrow \mu\mu +$ jets		
		<sup>196</sup> KIM	90	AMY	$e_8: e^+e^- \rightarrow gg; R$		
>19.8	95	<sup>197</sup> BARTEL	<b>87</b> B	JADE	e <sub>8</sub> , μ <sub>8</sub> , τ <sub>8</sub> : e <sup>+</sup> e <sup>-</sup> ; R		
none 5–23.2	95	<sup>197</sup> BARTEL	<b>87</b> B	JADE	$\mu_8: e^+e^- \rightarrow \mu\mu +$		
		<sup>198</sup> BARTEL			jets $e_8: e^+e^- \rightarrow gg; R$		

<sup>193</sup> 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.

<sup>194</sup> 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.

<sup>195</sup> KIM 90 is at  $E_{\rm cm} = 50$ –60.8 GeV. The same assumptions as in BARTEL 87B are used. <sup>196</sup> 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.

<sup>197</sup> BARTEL 87B is at  $E_{\rm cm} = 46.3$ –46.78 GeV. The limits assume  $\ell_8$  pair production cross sections to be eight times larger than those of the corresponding heavy lepton pair production.

<sup>198</sup> 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 ( $\nu_8$ )

$\lambda \equiv m_{\ell_8}/\Lambda$							
VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT		
>110	90	<sup>199</sup> BARGER	89	RVUE	$\nu_8: p\overline{p} \rightarrow$	$\nu_8 \overline{\nu}_8$	
• • • We do not use the following data for averages, fits, limits, etc. • • •							
none 3.8–29.8	95	<sup>200</sup> KIM	90	AMY	$\nu_8: e^+e^-$	$\rightarrow$ acoplanar	
none 9–21.9	95	<sup>201</sup> BARTEL	<b>87</b> B	JADE	$\nu_8: e^+e^-$ jets	$\rightarrow$ acoplanar	

 $^{199}\,{\rm BARGER}$  89 used ABE 89B limit for events with large missing transverse momentum. Two-body decay  $\nu_8 \rightarrow \ \nu g$  is assumed.

<sup>200</sup> KIM 90 is at  $E_{\rm cm} = 50-60.8$  GeV. The same assumptions as in BARTEL 87B are used. <sup>201</sup> BARTEL 87B is at  $E_{\rm cm} = 46.3-46.78$  GeV. The limit assumes the  $\nu_8$  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)<sub>1</sub> × U(1)<sub>Y</sub> quantum numbers.

### MASS LIMITS for W<sub>8</sub> (Color Octet W Boson)

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
$\bullet \bullet \bullet$ We do not use the follow	ing data for averages, fits	s, limits,	etc. • • •
	<sup>202</sup> ALBAJAR 89	UA1	$p\overline{p} \xrightarrow{\longrightarrow} W_8 X, W_8 \xrightarrow{\longrightarrow} Wg$
$^{202}$ ALBAJAR 89 give $\sigma(W_8  ightarrow$	$W+ ext{jet})/\sigma(W) < 0.01$	.9 (90%	CL) for $m_{W_8}$ > 220 GeV.

#### Limits on $ZZ\gamma$ Coupling

Limits are for the electric dipole transition form factor for  $Z \rightarrow \gamma Z^*$  parametrized as  $f(s') = \beta(s'/m_Z^2 - 1)$ , where s' is the virtual Z mass. In the Standard Model  $\beta \sim 10^{-5}$ . <u>VALUE</u> <u>CL%</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • • • <0.80 95 ADRIANI 92J L3  $Z \rightarrow \gamma \nu \overline{\nu}$ 

## REFERENCES FOR Searches for Quark and Lepton Compositeness

ACKERSTAFF         90C         EPJ C1 21         K. Ackerstäft+         (OPAL Collab.)           ACKERSTAFF         90C         PIZ 145         K. Ackerstäft+         (OPC Collab.)           ABE         97T         PRL 79 2198         +Akimoto, Akopian, Albrow, Amendola+         (CDF Collab.)           ABREU         97B         PL 8393 245         +Adam, Adye, Ajinenko, Alekseev+         (DELPHI Collab.)           ABREU         971         ZPHY C74 57         PAtam. Adye, Ajinenko, Alekseev+         (DELPHI Collab.)           ABREU         971         ZPHY C74 577         P. Abreu+         (DELPHI Collab.)           ACKERSTAFF         97         PL 8391 127         +Alexander, Allison, Altekamp, Ametewee+         (OPAL Collab.)           ACKERSTAFF         97         PL 8391 1221         +Alexander, Allison, Altekamp, Ametewee+         (OPAL Collab.)           ACKERSTAFF         97         PL 8309 277         (CPF Collab.)         CEVEY V76 6 631         +Adian, Aguian-Benitze, Allenn         (IEC Collab.)           ABRE         96         PRL 77 438         +Akimoto, Akopian, Albrow, Amendolai+         (CDF Collab.)           ABRE         960         PL 77 438         +Adam, Adriani, Aguian-Benitze, Allenn +         (IS Collab.)           ACKARRA         90D         PL B383 433						
ACKERSTAFF         98C         EPJ C1 45         K. Ackerstaff+         (CDF Collab.)           ABRE         977         PR D55 R5263         +Akimoto, Akopian, Albrow, Amendolia+         (CDF Collab.)           ABREU         971         ZPHY C75 550         +Adam, Adye, Ajinenko, Alekseev+         (DELPHI Collab.)           ABREU         971         ZPHY C75 550         +Adam, Adye, Ajinenko, Alekseev+         (DELPHI Collab.)           ARECLU         971         ZPHY C75 550         +Adam, Adye, Ajinenko, Hekseev+         (DELPHI Collab.)           ACKLART         976         PL B391         197         +Abraunder, Allison, Altekamp, Ametewee+         (OPAL Collab.)           ACKERSTAFF         97         PL B391         191         +Abraunder, Allison, Altekamp, Ametewee+         (OPAL Collab.)           ADLOFF         97         NP B483         4         +Ada, Adgewa, Shirai, Tsuboyama+         (VENUS Collab.)           ARIMA         97         PR D53         91         +Odaka, Ogawa, Shirai, Tsuboyama+         (VENUS Collab.)           ABE         965         PRI. 77         438         +Akimoto, Akopian, Albrow, Amendola+         (DELPHI Collab.)           ABE         965         PRI. 77         438         +Akimoto, Akopian, Albrow, Amendola+         (DELPHI Collab.)	ACKERSTAFF	98	EPJ C1 21	K. Ackerstaff+	(OPAL	Collab.)
ABE         97C         PR D55         R5283         +Akimoto, Akopian, Albrow, Amendolia, +         (CDF Collab.)           ABREU         97D         PL B393         245         +Adam, Adye, Ajinenko, Alekseev+         (DELPHI Collab.)           ABREU         971         ZPHY C74         57         PAtreu+         (DELPHI Collab.)           ABREU         971         ZPHY C74         577         P. Abreu+         (DELPHI Collab.)           ABREU         972         ZPHY C74         577         P. Abreu+         (DELPHI Collab.)           ACKARRI         970         PL B401         139         +Adriani, Aguilar-Benitez, Ahlen, Alpat+         (VELDEL Collab.)           ACKERSTAFF         97C         PL B301         221         +Alexander, Allison, Attekamp, Ametewee+         (OPAL Collab.)           ARIMA         97         NP B483         4+         -Adramo, Akopian, Albrow-         (VENUS Collab.)           RETI'WEG         972         PLP V76         631         +Adramoto, Akopian, Albrow-         (VENUS Collab.)           ABRE         96         PRL 77         336         +Akimoto, Akopian, Albrow-         (DELPHI Collab.)           ACLARRI         960         PL B330         237         +Adam, Adriani, Aguilar-Benitez, Ahlen.         (CDF Collab					<u>}</u> .	
ABEE         97T         PRL 79 2198         +Akim. Akepian, Albrow, Amendolia+         (CDF Collab.)           ABREU         97B         PL B393 245         +Adam, Adye, Ajinenko, Alekseev+         (DELPHI Collab.)           ABREU         971         ZPHY C75 580         Frankam, Adye, Ajinenko, Alekseev+         (DELPHI Collab.)           ARE         971         ZPHY C75 580         Frankam, Adye, Ajinenko, Alekseev+         (DELPHI Collab.)           ACKLERSTAFF         97         PL B391 197         +Akexander, Allison, Altekamp, Ametewee+         (OPAL Collab.)           ACKERSTAFF         97         PL B391 197         +Akexander, Allison, Altekamp, Ametewee+         (OPAL Collab.)           ARIMA         97         PR D5 19         +Odaka, Ogawa, Shirai, Tsuboyama+         (VENUS Collab.)           ARIMA         97         PL B409 277         CPHY C76 631         +Akimoto, Akopian, Albrow, Amendolia+         (CDF Collab.)           ABE         965         PRL 77         438         +Akimoto, Akopian, Albrow, Amendolia+         (DELPHI Collab.)           ACCIARRI         90D         PL B330 201         +Adam, Adriani, Aguila-Benitze, Alhen+         (IS Collab.)           ACCIARRI         90D         PL B353 136         +Alam, Adriani, Aguila-Benitze, Alhen+         (IS Collab.)           ACCIARRI					·	
ABREU         971         PH B 303 245         +Adam, Adye, Ajinenko, Alekseev+         (DELPHI Collab.)           ABREU         971         ZPHY C74 57         P. Abreu-         (DELPHI Collab.)           ABREU         971         ZPHY C75 580         erratum Abreu, Adam, Adye, Ajinenko, Alekseev+         (DELPHI Collab.)           AGCIARRI         970         P. B301 197         P. Abreu-t         (DELPHI Collab.)           ACKERSTAFF         977         P. B391 1291         +Alexander, Allison, Alrekamp, Ametswee+         (OPAL Collab.)           ACKERSTAFF         977         P. B391 1291         +Alexander, Allison, Alrekamp, Ametswee+         (OPAL Collab.)           ARIMA         97         P. D5 19         +Odraka, Ogawa, Shirai, Tsuboyama+         (WENUS Collab.)           DEANDREA         97         P. B409 277         +Akimoto, Akopian, Albrow+         (CDF Collab.)           ABE         96         PRL 77 438         +Akimoto, Akopian, Albrow, Amedolia+ (DF Collab.)           ACCIARRI         960         P. B380 430         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ACCIARRI         960         P. B385 445         +De Bonis, Decamp, Chez, Goy, Leest +         (ALEPH Collab.)           ACCIARRI         960         P. B335 578         +Adam, Adriani, Aguilar-Benitez						
ABREU         97L         ZPHY C74 57         +Adam, Adye, Ajinenko, Alekseev-+         (DELPHI Collab)           ABREU         97L         ZPHY C75 580         PAbreu+         (DELPHI Collab)           ACCLARRI         976         PL B391 197         +Alexander, Allison, Altekamp, Ametewee+         (OPAL Collab)           ACKERSTAFF         97         PL B391 127         +Alexander, Allison, Altekamp, Ametewee+         (OPAL Collab)           ACKERSTAFF         97         PL B483 44         +Aid, Anderson, Andrex, Andrieu, Andt+         (H1 Collab)           ACKERSTAFF         97         PL B493 277         +Alexander, Allison, Altekamp, Ametewee+         (OPAL Collab)           BREITWEG         97         PL B409 277         (MARS)         (DEC Collab)           ABBE         96         PL T7 5336         +Akimoto, Akopian, Albrow+         (DE CD Collab)           ABREU         90K         PL B370 221         +Adam, Adriani, Aguilar-Benitez, Alhen+         (L3 Collab)           ACCLARRI         90L         PL B34 323         +Adam, Adriani, Aguilar-Benitez, Alhen+         (DPA Collab)           ACCLARRI         90C         PL B385 435         +De Bonis, Decamp, Ghez, Goy, Lese+         (ALEPH Collab)           ALEXANDER         96K         PL B333 356         +Adam, Adriani, Aguilar-Benitez,	ABE	97T	PRL 79 2198	+Akimoto, Akopian, Albrow, Amendolia+	(CDF	Collab.)
ABREU         97L         ZPHY C74 57         +Adam, Adye, Ajinenko, Alekseev-+         (DELPHI Collab)           ABREU         97L         ZPHY C75 580         PAbreu+         (DELPHI Collab)           ACCLARRI         976         PL B391 197         +Alexander, Allison, Altekamp, Ametewee+         (OPAL Collab)           ACKERSTAFF         97         PL B391 127         +Alexander, Allison, Altekamp, Ametewee+         (OPAL Collab)           ACKERSTAFF         97         PL B483 44         +Aid, Anderson, Andrex, Andrieu, Andt+         (H1 Collab)           ACKERSTAFF         97         PL B493 277         +Alexander, Allison, Altekamp, Ametewee+         (OPAL Collab)           BREITWEG         97         PL B409 277         (MARS)         (DEC Collab)           ABBE         96         PL T7 5336         +Akimoto, Akopian, Albrow+         (DE CD Collab)           ABREU         90K         PL B370 221         +Adam, Adriani, Aguilar-Benitez, Alhen+         (L3 Collab)           ACCLARRI         90L         PL B34 323         +Adam, Adriani, Aguilar-Benitez, Alhen+         (DPA Collab)           ACCLARRI         90C         PL B385 435         +De Bonis, Decamp, Ghez, Goy, Lese+         (ALEPH Collab)           ALEXANDER         96K         PL B333 356         +Adam, Adriani, Aguilar-Benitez,	ABREU	97B	PL B393 245	+Adam, Adve, Aiinenko, Alekseev+	(DELPHI	Collab.)
Also         97L         ZPHY C75 850         eratum         Adrain, Aguiar-Benitez, Ahlen, Alpat+         (DELPHI Collab.)           ACKLRSTAFF         97C         PL B301 197         +Adrain, Aguiar-Benitez, Ahlen, Alpext+         (J S Collab.)           ACKERSTAFF         97C         PL B301 121         +Alexander, Allison, Attekamp, Ametewee+         (OPAL Collab.)           ACKERSTAFF         97C         PL B391 121         +Alexander, Allison, Attekamp, Ametewee+         (VENUS Collab.)           ARIMA         97         PL B409 277         +Odaka, Ogawa, Shirai, Tsuboyam+         (VENUS Collab.)           DEANDREA         97         PL B409 277         +Akimoto, Akopian, Albrow, Amendolia+         (CDF Collab.)           ABE         96         PRL 77 433         +Akimoto, Akopian, Albrow, Amendolia-         (CDF Collab.)           ABERU         96K         PL B370 211         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ACCIARRI         96K         PL B385 445         +DE Bonis, Decamp, Ghez, Goy, Lees+         (ALEPH Collab.)           ALEXANDER         96K         PL B385 445         +De Bonis, Decamp, Ghez, Goy, Lees+         (ALEPH Collab.)           DUSKULC         96Z         PL B385 445         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L12 Collab.)           DESKUL					2	
ABREU         970         PL P401         237         PL Abreu+         (DELPHI Collab)           ACCLARRI         970         PL B301         197         +Adriani, Aguilar-Benitez, Ahlen, Apat+         (U3 Collab)           ACKERSTAFF         97         PL B301         221         +Adriani, Aguilar-Benitez, Ahlen, Ametewee+         (OPAL Collab)           ACKERSTAFF         97         PP B483         +Aid, Anderson, Antekamp, Ametewee+         (OPAL Collab)           ARIMA         97         PP B483         +Aid, Anderson, Antekamp, Ametewee+         (OPAL Collab)           ARIMA         97         PP B483         +Aidmot, Aguilar-Benitez, Ahlen, Ametewee+         (DEVIS Collab)           BRETIVEG         970         PP H209         277         +Akimoto, Akopian, Albrow+         (CDF Collab)           ABE         965         PRL 77         336         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (DE Collab)           ACCLARRI         906         PL B370         221         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (DE Collab)           ALEXANDER         960         PL B386         433         +Alamo, Adriani, Aguilar-Benitez, Ahlen+         (DE Collab)           AUSUNULC         960         PL B384         338         +Allrow, Amedola, Amide, Antes+         (DE Col					2	
ACCLARRI         970         PL E401 139         +Adriani, Águila-Benitez, Ahlen, Alpat+         (13 Collab)           ACKERSTAFF         970         PL B391 121         +Alexander, Allison, Altrekamp, Ametewee+         (OPAL Collab)           ARIMA         97         PR D55 19         +Odtaka, Ogawa, Shirai, Tsuboyama+         (VENUS Collab)           BREITWEG         970         CZHY C76 631         +Odtaka, Ogawa, Shirai, Tsuboyama+         (VENUS Collab)           DEANDRA         97         PL B30 211         +Akimoto, Akopian, Albrow+         (DDF Collab)           ABE         960         PRL 77 5336         +Akimoto, Akopian, Albrow, Amendolia+         (DDF Collab)           ABE         965         PRL 77 5336         +Akimoto, Akopian, Albrow, Amendolia+         (DDF Collab)           ACCLARRI         960         PL B384 323         +Adam, Adriani, Aguila-Benitez, Ahlen+         (L3 Collab)           ACCLARRI         966         PL B386 445         +De Bonis, Decamp, Ghez, Goy, Lees+         (ALEPH Collab)           BUSKULIC         9607         PL B333 336         +De Bonis, Decamp, Ghez+         (ALEPH Collab)           ACCLARRI         961         PL B333 336         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab)           ADSKULIC         9607         PL B333 336 <t< td=""><td></td><td></td><td></td><td></td><td>2</td><td></td></t<>					2	
ACKERSTAFF97PLB391+Alexander, Allison, Altekamp, Ametewee+(OPAL Collab.)ACKERSTAFF97NPB48344+Aid, Anderson, Andrew, Andrieu, Andrit-(H1Collab.)ARIMA97PRD5519+Derrick, Krakauer, Magill+(ZEUS Collab.)BREITWEG9727HYC76631+Derrick, Krakauer, Magill+(ZEUS Collab.)DEANDREA97PLB409277+Akimoto, Akopian, Albrow+(CDFCollab.)ABE96PRI. 77438+Akimoto, Akopian, Albrow+, Manedolia+(DFCollab.)ABE965PRI. 775336+Adiam, Adriani, Aguilar-Benitez, Ahlen+(L3Collab.)ACCLARRI960PLB38422+(OPALCollab.)ACCLARRI960PLB38442+DeBonis, Decamp, Chez.+(ALEPHCollab.)ALEXANDER960PLB383438+DeBonis, Decamp, Chez.+(ALEPHCollab.)AUSKULIC960PLB35318+Adam, Adriani, Aguilar-Benitez, Ahlen+(L3Collab.)ADCLARRI956PLB35318+Adamo, Amidia, Anway-Wiese, Apollinari+(CDFCollab.)ADRIANI956PLB35318+Adamo, Admidia, Anway-Wiese, Apollinari+(CDFCollab.)ADRIANI956PLB35318+Adamo, Admidia, Anway-Wiese, Apollinari+(CDFCollab.)ADRIANI958PLPL230	ABREU	97 J	ZPHY C74 577	P. Abreu+	(DELPHI	Collab.)
ACKERSTAFF97PLB391+Alexander, Allison, Altekamp, Ametewee+(OPAL Collab.)ACKERSTAFF97NPB48344+Aid, Anderson, Andrew, Andrieu, Andrit-(H1Collab.)ARIMA97PRD5519+Derrick, Krakauer, Magill+(ZEUS Collab.)BREITWEG9727HYC76631+Derrick, Krakauer, Magill+(ZEUS Collab.)DEANDREA97PLB409277+Akimoto, Akopian, Albrow+(CDFCollab.)ABE96PRI. 77438+Akimoto, Akopian, Albrow+, Manedolia+(DFCollab.)ABE965PRI. 775336+Adiam, Adriani, Aguilar-Benitez, Ahlen+(L3Collab.)ACCLARRI960PLB38422+(OPALCollab.)ACCLARRI960PLB38442+DeBonis, Decamp, Chez.+(ALEPHCollab.)ALEXANDER960PLB383438+DeBonis, Decamp, Chez.+(ALEPHCollab.)AUSKULIC960PLB35318+Adam, Adriani, Aguilar-Benitez, Ahlen+(L3Collab.)ADCLARRI956PLB35318+Adamo, Amidia, Anway-Wiese, Apollinari+(CDFCollab.)ADRIANI956PLB35318+Adamo, Admidia, Anway-Wiese, Apollinari+(CDFCollab.)ADRIANI956PLB35318+Adamo, Admidia, Anway-Wiese, Apollinari+(CDFCollab.)ADRIANI958PLPL230	ACCIARRI	97G	PL B401 139	+Adriani, Aguilar-Benitez, Ahlen, Alpat+	) (L3	Collab.)
ACKERSTAFF97PD 8483 44+Aid, Anderson, Antekamp, Ameteweet, (OPAL Collab.)ADLOFF97NP B483 44+Aid, Anderson, Anterew, Andrieu, Amdt+(HI Collab.)BREITWEG97PL B409 277+Darick, Krakauer, Magill+(ZEUS Collab.)ABE96PRL 77 438+Akimoto, Akopian, Albrow+(CDF Collab.)ABE965PRL 77 536+Akimoto, Akopian, Albrow, Amendolia+(CDF Collab.)ABREU966PRL 77 536+Akimoto, Akopian, Albrow, Amendolia+(CDF Collab.)ACCIARRI961PL B370 221+Adam, Adriani, Aguilar-Benitez, Ahlen+(LI Collab.)ACCIARRI966PL B384 323+Adam, Adriani, Aguilar-Benitez, Ahlen+(LI Collab.)ALEXANDER960PL B385 435+De Bonis, Decarmo, Chez, Goy, Les+(ALEPH Collab.)BUSKULIC960PL B385 436+Albrow, Amendolia, Antos+(CDF Collab.)ABE950PRL 74 3538+Aldrew, Adriani, Aguilar-Benitez, Ahlen+(LI Collab.)ADD95PL B353 578+Adam, Adriani, Aguilar-Benitez, Ahlen+(LI Collab.)ADI 25PL B353 578+Andrew, Andrieu, Appuhn, Arpagaus+(CDF Collab.)ABE94PRL 72 3004+Albrow, Amidei, Anway-Wiese, Apollinari, (CDF Collab.)ABE93PRL 72 3004+Abrow, Amidei, Anway-Wiese, Apollinari, Atas'ABE94PRL 72 525+Andrew, Andrieu, Appuhn, Arpagaus+(CDF Collab.)ABE93PRL 236 1+Adam, Adami, Aday, Akoes, Aloraor+(LEPH Collab.)ABE94 </td <td></td> <td></td> <td></td> <td>· · · · · · · · · · · · · · · · · · ·</td> <td></td> <td></td>				· · · · · · · · · · · · · · · · · · ·		
ADLOFF         97         NP B483 44         +Aid, Anderson, Andreev, Andrieu, Amdt+         (H1 Collab.)           BREITWEG         97C         ZPHY C76 631         +Derrick, Krakauer, Magill+         (ZEUS Collab.)           BRE         96         PR. 77 438         +Akimoto, Akopian, Albrow+         (CDF Collab.)           ABE         96         PR. 77 438         +Akimoto, Akopian, Albrow, Amendolia+         (CDF Collab.)           ABRE         966         PR. 77 438         +Akimoto, Akopian, Albrow, Amendolia+         (CDF Collab.)           ACIARRI         960         PL B380 430         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ACCIARRI         960         PL B384 323         +Adam, Adriani, Aguilar-Benitez, Hore+         (OPAL Collab.)           ALEXANDER         960         PL B386 433         +De Bonis, Decamp, Ghez, Goy, Lees+         (ALEPH Collab.)           BUSKULIC         960         PL B335 376         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ALEXANDER         951         PR 174 3338         +Albrow, Ameidolia, Antos+         (CDF Collab.)           ACIARRI         952         PL B335 376         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ADI         959         PL B335 376         +Adam, A					2	
ARIMA         97         PR D55 19         + Odaka, Ogawa, Shirai, Tsuboyama+         (ZENZ Collab.)           BREITWEG         97         PL B409 277         -         (ZEVS Collab.)           ABE         96         PRI. 77 438         + Akimoto, Akopian, Albrow+         (CDF Collab.)           ABE         965         PRI. 77 533         + Akimoto, Akopian, Albrow, Amendolia+         (CDF Collab.)           ACCLARRI         960         PL B370 211         + Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ACCLARRI         960         PL B370 221         +         (DPA Collab.)           ALEXANDER         960         PL B384 333         + De Bonis, Decamp, Ghez, Goy, Lees+         (ALEPH Collab.)           ALEXANDER         960         PL B383 136         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           BUSKULIC         960         PL B353 378         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ADI         95         PL B353 378         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ADR         94         PL 331 227         +trakauer, Magill, Musgrave, Repond+         (ZEUS Collab.)           ADRAN         95         PL B331 257         +trakauer, Magill, Anway-Wiese, Apolinari+         (CDF				+Alexander, Allison, Altekamp, Ametewee-		- /
BREITWEG         97         ZUPY C76 631         +Derrick, Krakauer, Magill+         (ZEUS Collab.)           ABE         96         PRL 77 438         +Akimoto, Akopian, Albrow,+         (CDF Collab.)           ABRE         965         PRL 77 5336         +Akimoto, Akopian, Albrow,-         (DELPHI Collab.)           ABREU         966         PL B380 480         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (LD Collab.)           ACCIARRI         960         PL B384 323         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ALEXANDER         960         PL B386 445         +De Bonis, Decamp, Ghez,         (OPAL Collab.)           ALEXANDER         95N         PRL 74 3538         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           BUSKULIC         960         PL B385 3578         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L2 Collab.)           ACCIARRI         95         PL B353 578         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L2 Collab.)           ACIARRI         957         PL 353 578         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L2 Collab.)           ACIARRI         958         ZPHY C56 627         +Krakauer, Magil, Musgrave, Repond+         (CDF Collab.)           ACIARRI         93         NP B409 82149         +Lan	ADLOFF	97	NP B483 44	+Aid, Anderson, Andreev, Andrieu, Arndt-	+ (H1	Collab.)
BREITWEG         97         ZUPY C76 631         +Derrick, Krakauer, Magill+         (ZEUS Collab.)           ABE         96         PRL 77 438         +Akimoto, Akopian, Albrow,+         (CDF Collab.)           ABRE         965         PRL 77 5336         +Akimoto, Akopian, Albrow,-         (DELPHI Collab.)           ABREU         966         PL B380 480         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (LD Collab.)           ACCIARRI         960         PL B384 323         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ALEXANDER         960         PL B386 445         +De Bonis, Decamp, Ghez,         (OPAL Collab.)           ALEXANDER         95N         PRL 74 3538         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           BUSKULIC         960         PL B385 3578         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L2 Collab.)           ACCIARRI         95         PL B353 578         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L2 Collab.)           ACIARRI         957         PL 353 578         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L2 Collab.)           ACIARRI         958         ZPHY C56 627         +Krakauer, Magil, Musgrave, Repond+         (CDF Collab.)           ACIARRI         93         NP B409 82149         +Lan	ARIMA	97	PR D55 19	+Odaka Ogawa Shirai Tsuboyama $+$	(VENUS	Collab)
DEANDREA         97         PL B409 277         (MARS)           ABE         96         PRL 77 438         +Akimoto, Akopian, Albrow+         (CDF Collab.)           ABREU         96K         PL B300 480         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (DELPHI Collab.)           ACCIARRI         96L         PL B370 211         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (DAL Collab.)           ACCIARRI         96L         PL B383 432         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (DAL Collab.)           ALEXANDER         96K         PL B385 445         +De Bonis, Decamp, Ghez, Goy, Lees+         (ALEPH Collab.)           BUSKULIC         96Z         PL B353 136         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (LS Collab.)           ACCIARRI         95G         PL B353 136         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (LS Collab.)           ADB         95         PL B353 136         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (LS Collab.)           ADRAN         95G         PL B353 136         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (LS Collab.)           ADRAN         95G         PL B353 136         +Adarew, Andrieu, Appuhn, Arpagus+         (HI Collab.)           ADRAN         95G         PL 77 2004         +Abrow, Amidei, Anway-Wiese, Apolinari+						
ABE         96         PRL 77 438         +Akimoto, Akopian, Albrow, Amendolia+         (CDF Collab.)           ABREU         96K         PL B380 480         +Akimoto, Akopian, Albrow, Amendolia+         (CDF Collab.)           ABREU         96K         PL B380 1211         +Adam, Adriani, Aguian-Benitez, Ahlen+         (DELPHI Collab.)           ACCIARRI         96L         PL B372 222         +         (OPAL Collab.)           ALEXANDER         96K         PL B384 432         +Adam, Adriani, Aguian-Benitez, Ahlen+         (I3 Collab.)           BUSKULIC         96W         PL B385 445         +De Bonis, Decamp, Ghez+         (OPAL Collab.)           BUSKULIC         96W         PL B335 378         +Adam, Adriani, Aguian-Benitez, Ahlen+         (13 Collab.)           ACIARRI         95         PL B333 378         +Adam, Adriani, Aguian-Benitez, Ahlen+         (12 COF Collab.)           ABE         94         PR 17 23004         +Abrow, Amidei, Anway-Wiese, Apollinari+         (CDF Collab.)           DIAZCRUZ         94         PR 1236 1         +Aguian-Benitez, Ahlen+         (2EUS Collab.)           ABE         93         PRL 71 2542         +Abrow, Amidei, Anway-Wiese, Apollinari+         (CDF Collab.)           ABE         93         PRPL 236 1         +Aguian-Benitez, Ahlen, Akraz, Alosio				Denick, Makader, Magin	· ·	
ABE         965         PRL 77 5336         +Akimoto, Akopian, Albrow, Amendolia+         (CDF Collab.)           ABREU         96K         PL B380 480         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ACCIARRI         96D         PL B370 211         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ALEXANDER         96K         PL B383 432         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (CPAL Collab.)           ALEXANDER         96K         PL B385 445         +De Bonis, Decamp, Ghez, Goy, Lees+         (ALEPH Collab.)           BUSKULIC         96Z         PL B353 136         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ACCIARRI         95G         PL B353 578         +Andreev, Andrieu, Appuhn, Arpagaus+         (H1 Collab.)           ADERNCY 95B         PLHY C56 627         +Krakauer, Magil, Musgrave, Repond+         (ZEU S Collab.)           ABE         94         PRL 72 3004         +Albrow, Amidei, Anway-Wiese, Apollinari+         (CDF Collab.)           ABE         93         PR 2361         +Aguilar-Benitez, Ahlen, Alcaraz, Alosio+         (CDF Collab.)           ABT         93         PR 2361         +Aguilar-Benitez, Ahlen, Alcaraz, Alosio+         (L3 Collab.)           ADRIANI         93M         PRL 631 160						
ABREU         96K         PL         B370         211         +Adam, Adrani, Aguilar-Benitez, Ahlen,+         (DELPHI Collab.)           ACCIARRI         96L         PL         B384         323         +Adam, Adriani, Aguilar-Benitez, Ahlen,+         (DAL         Collab.)           ALEXANDER         96K         PL         B384         433         +De         Bons, Decamp, Ghez, Goy, Less+         (OPAL         Collab.)           BUSKULIC         96W         PL         B384         433         +De         Bons, Decamp, Ghez, Goy, Less+         (ALEPH Collab.)           BUSKULIC         96Z         PL         B383         136         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3         Collab.)           ACCIARRI         95R         PRL 74         553         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3         Collab.)           ACCIARRI         95B         PHY C56         627         +Krakauer, Magill, Musgrave, Repond+         (ZEUS Collab.)           DAZCRUZ         94         PR D49         P212         +Lusin, Chung, Park, Cho, Bodek, Kim+         (CDF         Collab.)           VELSSRIS         94         PR D4331         227         +Lusin, Chung, Park, Cho, Bodek, Kim+         (LDF         Collab.)           ABE         <	ABE	96	PRL 77 438	+Akimoto, Akopian, Albrow+	(CDF	Collab.)
ABREU         96K         PL         B370         211         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (DELPHI Collab.)           ACCIARRI         96L         PL         B370         211         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3         Collab.)           ALEXANDER         96K         PL         B384         433         +De         Bons, Decamp, Ghez, Goy, Less+         (OPAL Collab.)           BUSKULIC         96W         PL         B384         433         +De         Bons, Decamp, Ghez, Goy, Less+         (ALEPH Collab.)           ABE         95N         PRL 74         3538         +Albrow, Amendolia, Amidei, Antos+         (CDF Collab.)           ACCIARRI         95G         PL         B333         356         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3         Collab.)           ACCIARRI         95G         PL         B333         126         Horow, Amidei, Anway-Wiese, Apollinari+         (CDF Collab.)           DERRICK         95B         ZPHY C56         627         +Krakauer, Magill, Musgrave, Repond+         (ZEUS Collab.)           DAZCRUZ         94         PR D49         PL         224         +Albrow, Ahimoto, Animoto, Animota, Anway-Wiese+         (CDF Collab.)           ABE         93G         PR D4	ABE	96S	PRL 77 5336	+Akimoto, Akopian, Albrow, Amendolia+	(CDF	Collab.)
ACCIARRI         96D         PL B370 211         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ACCIARRI         96L         PL B384 323         +Adam, Adriani, Aguilar-Benitez, Helen+         (DPAL Collab.)           ALEXANDER         96Q         PL B385 463         +Allison, Altekamp, Ametewee+         (OPAL Collab.)           ALEXANDER         96Q         PL B385 445         +De Bonis, Decamp, Ghez, Goy, Lees+         (ALEPH Collab.)           BUSKULC         96Z         PL B353 136         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ACCIARRI         95G         PL B353 378         +Andreev, Andrieu, Appuhn, Arpagaus+         (HI Collab.)           ACCIARRI         95G         PL B353 126         +Ahdreev, Andrieu, Appuhn, Arpagaus+         (L1 Collab.)           DERRICK         95B         PRL 72 3004         +Abrow, Amidei, Anway-Wiese, Apollinari+         (CDF Collab.)           DIAZCRUZ         94         PRL 72 3004         +Abrow, Akimoto, Amidei, Anway-Wiese+         (CDF Collab.)           ABE         93         PR D49 82149         Diaz Cruz, Sampayo         (CINV)           VELISSARIS         94         PRL 72 301         +Aguilar-Benitez, Ahlen, Alcaraz, Aloisic+         (L2 Collab.)           ADRIANI         93         NP B400 3	ABRELL					
$ \begin{array}{llllllllllllllllllllllllllllllllllll$					· .	
ALEXANDER         96K         PL         B377         222         +         (OPAL Collab.)           ALEXANDER         960         PL         B385         445         +De         Bonis, Decamp, Ghez, Goy, Lees+         (ALEPH Collab.)           BUSKULIC         96V         PL         B385         445         +De         Bonis, Decamp, Ghez, Goy, Lees+         (ALEPH Collab.)           ABE         95N         PRI         74         353         +Adbrow, Amedolia, Amidei, Antos+         (CDF Collab.)           ADD         95         PL         B353         578         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3 Collab.)           ABE         94         PRI         72         3004         +Albrow, Amidei, Anway-Wiese, Apolliari+         (CDF Collab.)           ABE         93G         PRI         72         3004         +Audreev, Andrieu, Appuhn, Arpagaus+         (H1 Collab.)           ABE         93G         PRI         72         303         +Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+         (L3 Collab.)           ABT         93         NP         B400         3         +Amirosin, Anarcia, Autrino, Bareyre+         (UA2 Collab.)           ADRIANI         93M         PRE 292         215         +Decamp, Goy, Lees, Minard, Mo						
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	ACCIARRI	96L	PL B384 323	+Adam, Adriani, Aguilar-Benitez+	(L3	Collab.)
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	ALEXANDER	96K	PL B377 222	+	(OPAL	Collab.)
BUSKULIC96WPL B385 445+De Bonis, Decamp, Ghez, Goy, Lees,+(ALEPH Collab.)BUSKULIC96ZPL B383 136+De Bonis, Decamp, Ghez,+(ALEPH Collab.)ABE95NPRL 74 3538+Albrow, Amendolia, Antoiei, Antos,+(CDF Collab.)AID95PL B353 578+Andreev, Anguilar-Benitez, Ahlen,+(L3 Collab.)ABE94PRL 72 3004+Krakauer, Magill, Musgrave, Repond,+(ZEUS Collab.)ABE94PR D49 R2149Diaz Cruz, Sampayo(CINV)VELISSARIS94PL B331 227+Lusin, Chung, Park, Cho, Bodek, Kim+(AMY Collab.)ABE93GPRL 71 2542+Albrow, Amidei, Anway-Wiese, Apollinari,+(CDF Collab.)ABT93NP B396 3+Andreev, Andrieu, Appuhn, Arpagaus+(H1 Collab.)ABT93NP B400 3+Amitosin, Ansari, Autiero, Bareyre+(UA2 Collab.)ALITTI93NP B400 3+Amidei, Anoy-Wiese, Apollinari, Atac, Auchincloss+(CDF Collab.)ABE92DPRL 68 1104+Amidei, Apollinari, Atac, Auchincloss+(CDF Collab.)ABE92DPRL 68 1104+Amidei, Apollinari, Atac, Auchincloss+(CDF Collab.)ABE92DPRL 68 2896+Amidei, Anay-Wiese, Apollinari, Atac, Auchincloss+(CDF Collab.)ABE92DPRL 69 2896+Amidei, Apollinari, Atac, Auchincloss+(CDF Collab.)ABE92DPRL 68 1603+Amidei, Apollinari, Atac, Auchincloss+(CDF Collab.)ABE92DPRL 68 286+Adam, Adami, Adye, Akesson+(DELPH						
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ABE95NPRL 74 3538+Albrow, Amendola, Amidei, Antos+(CDF Collab.)ACCIARRI95GPL B353 136+Adram, Adriani, Aguilar-Benitez, Ahlen+(L3 Collab.)AID95PL B353 578+Andrew, Andrieu, Appuhn, Arpagaus+(H1 Collab.)DERRICK95BZPHY C65 627+Krakauer, Magill, Musgrave, Repond+(ZEUS Collab.)ABE94PRL 72 3004+Albrow, Amidei, Anway-Wiese, Apollinari+(CDF Collab.)DIAZCRUZ94PR D49 R2149Diaz Cruz, Sampayo(CINV)VELISSARIS94PL B331 227+Lusin, Chung, Park, Cho, Bodek, Kim+(AMY Collab.)ABE936PRL 71 2542+Albrow, Akimoto, Amidei, Anway-Wiese+(CDF Collab.)ADRIANI93MPRPL 236 1+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+(L3 Collab.)AULTTI93NP B400+Amdrein, Appuhn, Arpagaus+(H1 Collab.)BUSKULIC93QZPHY C59 215+Decamp, Goy, Lees, Minard, Mours+(ALEPH Collab.)DERRICK93BPL B316 207+Krakauer, Magill, Musgrave, Repond+(ZEUS Collab.)ABE92DPRL 68 1104+Amidei, Apollinari, Atac, Auchincloss+(CDF Collab.)ABE92DPRL 68 1104+Amidei, Apollinari, Atac, Auchincloss+(CDF Collab.)ABREU92CZPHY C53 455+Adam, Adami, Adye, Akesson, Alekseev+(DELPHI Collab.)ADRIANI92BPL B282 472+Aguilar-Benitez, Ahlen, Akbari, Alcarez+(L3 Collab.)ADRIANI92BPL B292 4769+Aguilar-Benitez, Ahlen, Akbari, Alcarez					2	
ACCIARRI         95G         PL         B353         136         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3         Collab.)           AID         95         PL         B353         578         +Andreev, Andrieu, Appuhn, Arpagaus+         (H1         Collab.)           ABE         94         PRL 72         3004         +Albrow, Amidei, Anway-Wiese, Apollinari+         (CDF         Collab.)           DIAZCRUZ         94         PR         D49         R2149         Diaz         Cuz, Sampayo         (CINV)           VELISSARIS         94         PR         T1         2542         +Albrow, Akimoto, Amidei, Anway-Wiese, Apollinari, +         (CDF         Collab.)           ABE         936         PRL 71         2542         +Albrow, Akimoto, Amidei, Anway-Wiese, H         (CDF         Collab.)           ABT         93         NP B396         +Andreev, Andrieu, Appuhn, Arpagaus+         (L3         Collab.)           ADRIANI         93M         PRPL 261         215         +Decamp, Goy, Lees, Minard, Mours+         (ALEPH Collab.)           BUSKULIC         930         PRL 68         1607         +Krakauer, Magill, Musgrave, Repond+         (ZEUS         Collab.)           ABE         92D         PRL 68         1604         +A	BUSKULIC	96Z	PL B384 333	+De Bonis, Decamp, Ghez+	(ALEPH	Collab.)
ACCIARRI         95G         PL         B353         136         +Adam, Adriani, Aguilar-Benitez, Ahlen+         (L3         Collab.)           AID         95         PL         B353         578         +Andreev, Andrieu, Appuhn, Arpagaus+         (H1         Collab.)           ABE         94         PRL 72         3004         +Albrow, Amidei, Anway-Wiese, Apollinari+         (CDF         Collab.)           DIAZCRUZ         94         PR         D49         R2149         Diaz         Cuz, Sampayo         (CINV)           VELISSARIS         94         PR         T1         2542         +Albrow, Akimoto, Amidei, Anway-Wiese, Apollinari, +         (CDF         Collab.)           ABE         936         PRL 71         2542         +Albrow, Akimoto, Amidei, Anway-Wiese, H         (CDF         Collab.)           ABT         93         NP B396         +Andreev, Andrieu, Appuhn, Arpagaus+         (L3         Collab.)           ADRIANI         93M         PRPL 261         215         +Decamp, Goy, Lees, Minard, Mours+         (ALEPH Collab.)           BUSKULIC         930         PRL 68         1607         +Krakauer, Magill, Musgrave, Repond+         (ZEUS         Collab.)           ABE         92D         PRL 68         1604         +A	ABE	95N	PRL 74 3538	+Albrow, Amendolia, Amidei, Antos+	(CDF	Collab.)
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DERRICK95BZPHY C65 627+Krakauer, Magill, Musgrave, Repond+(ZEUS Collab.)ABE94PR D49 R2149Diaz Cruz, Sampayo(CINV)VELISSARIS94PL B331 227+Lusin, Chung, Park, Cho, Bodek, Kim+(AMY Collab.)ABE93GPR L71 2542+Albrow, Akimoto, Amidei, Anway-Wiese, Apollinari, H1 Collab.)ABTABT93PRPL 236 1+Andreev, Andrieu, Appuhn, Arpagaus+(LI Collab.)ADRIANI93MPRPL 236 1+Audreev, Andrieu, Appuhn, Arpagaus+(LI Collab.)ALITTI93PB 400 3+Ambrosini, Ansari, Autiero, Bareyre+(UA2 Collab.)BUSKULIC93QZPHY C59 215+Decamp, Goy, Lees, Minard, Mours+(ALEPH Collab.)DERRICK93BPL B316 207+Krakauer, Magill, Musgrave, Repond+(ZEUS Collab.)ABE92DPRL 68 1104+Amidei, Apollinari, Atac, Auchincloss+(CDF Collab.)ABE92DPRL 68 104+Amidei, Apollinari, Atac, Auchincloss+(CDF Collab.)ABREU92CZPHY C53 555+Adam, Adami, Adye, Akesson, Alekseev+(DELPHI Collab.)ADRIANI92BPL 8288 404+Aguilar-Benitez, Ahlen, Akbari, Alcarez+(L3 Collab.)ADRIANI92FPL B292 472+Aguilar-Benitez, Ahlen, Akbari, Alcarez+(L3 Collab.)ADRIANI92FPL B292 472+Aguilar-Benitez, Ahlen, Akbari, Alcarez+(L3 Collab.)ADRIANI92FPL B292 472+Aguilar-Benitez, Ahlen, Akbari, Alcarez+(L3 Collab.)ADRIANI92FPL B292 472+Aguilar-Ben					A	
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BARDADIN92ZPHY C55 163Bardadin-Otwinowska(CLER)DECAMP92PRPL 216 253+Deschizeaux, Goy, Lees, Minard+(ALEPH Collab.)HOWELL92PL B291 206+Koltick, Tauchi, Miyamoto, Kichimi+(TOPAZ Collab.)KROHA92PR D46 58(ROCH)PDG92PR D45, 1 June, Part II Hikasa, Barnett, Stone+(KEK, LBL, BOST+)SHIMOZAWA92PL B284 144+Fujimoto, Abe, Adachi, Doser+(TOPAZ Collab.)ABE91DPRL 67 2418+Adam, Adami, Adye, Akesson+(DELPHI Collab.)ABREU91FNP B367 511+Adam, Adami, Adye, Akesson+(DELPHI Collab.)ADACHI91PL B255 613+Anazawa, Doser, Enomoto+(TOPAZ Collab.)AKRAWY91FPL B257 232+Ansari, Autiero, Bareyre, Blaylock+(UA2 Collab.)ALITTI91BZPHY C51 143+Criegee, Field, Franke, Jung+(CELLO Collab.)BEHREND91CZPHY C51 149+Criegee, Field, Franke, Jung+(CELLO Collab.)ABE901ZPHY C51 143+Arnako, Arai, Asano, Chiba+(VENUS Collab.)ADEVA90FPL B247 177+Adriani, Aguilar-Benitez, Akbari, Alcaraz+(L3 Collab.)ADEVA90KPL B250 199+Adriani, Aguilar-Benitez, Akbari, Alcaraz+(L3 Collab.)					<u>`````````````````````````````````````</u>	
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DECAMP92PRPL 216 253+Deschizeaux, Goy, Lees, Minard+(ALEPH Collab.)HOWELL92PL B291 206+Koltick, Tauchi, Miyamoto, Kichimi+(TOPAZ Collab.)KROHA92PR D46 58(ROCH)PDG92PR D45, 1 June, Part II Hikasa, Barnett, Stone+(KEK, LBL, BOST+)SHIMOZAWA92PL B284 144+Fujimoto, Abe, Adachi, Doser+(TOPAZ Collab.)ABE91DPRL 67 2418+Adam, Adami, Adye, Akesson+(DELPHI Collab.)ABREU91FNP B367 511+Adam, Adami, Adye, Akesson+(DELPHI Collab.)ADACHI91PL B255 613+Anzawa, Doser, Enomoto+(TOPAZ Collab.)AKRAWY91FPL B257 232+Ansari, Autiero, Bareyre, Blaylock+(UA2 Collab.)ALITTI91BZPHY C51 143+Criegee, Field, Franke, Jung+(CELLO Collab.)BEHREND91CZPHY C51 149+Criegee, Field, Franke, Jung+(CELLO Collab.)ABE901ZPHY C51 143+Adriani, Aguilar-Benitez, Akbari, Alcaraz+(L3 Collab.)ADEVA90FPL B247 177+Adriani, Aguilar-Benitez, Akbari, Alcaraz+(L3 Collab.)ADEVA90KPL B250 199+Adriani, Aguilar-Benitez, Akbari, Alcaraz+(L3 Collab.)	BARDADIN	92	ZPHY C55 163	Bardadin-Otwinowska		(CLER)
HOWELL92PLB291206+Koltick, Tauchi, Miyamoto, Kichimi+(TOPAZ Collab.)KROHA92PRD4558(ROCH)PDG92PRD45, 1June, PartIIHikasa, Barnett, Stone+(KEK, LBL, BOST+)SHIMOZAWA92PLB284144+Fujimoto, Abe, Adachi, Doser+(TOPAZ Collab.)ABE91DPRL 672418+Amidei, Apollinari, Atac, Auchincloss+(CDF Collab.)ABREU91EPLB268296+Adam, Adami, Adye, Akesson+(DELPHI Collab.)ABREU91FNPB367511+Adam, Adami, Adye, Akesson+(DELPHI Collab.)ADACHI91PLB255613+Anazawa, Doser, Enomoto+(TOPAZ Collab.)AKRAWY91FPLB257321+Alexander, Allison, Allport, Anderson+(OPAL Collab.)ALITTI91BPLB257143+Criegee, Field, Franke, Jung+(CELLO Collab.)BEHREND91CZPHY C51143+Criegee, Field, Franke, Jung+(CELLO Collab.)ABE901ZPHY C51143+Arako, Arai, Asano, Chiba+(VENUS Collab.)ADEVA90FPLB247177+Adriani, Aguilar-Benitez, Akbari, Alcaraz+(L3 Collab.)ADEVA90KPLB250199+Adriani, Aguilar-Benitez, Akbari, Alcaraz+(L3 Collab.)	DECAMP	92	PRPI 216 253	+Deschizeaux Gov Lees Minard+	(ALEPH	
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BEHREND91BZPHY C51143+Criegee, Field, Franke, Jung+(CÈLLO Collab.)BEHREND91CZPHY C51149+Criegee, Field, Franke, Jung, Meyer+(CELLO Collab.)Also91BZPHY C51143Behrend, Criegee, Field, Franke, Jung+(CELLO Collab.)ABE90IZPHY C4813+Amako, Arai, Asano, Chiba+(VENUS Collab.)ADEVA90FPLB247177+Adriani, Aguilar-Benitez, Akbari, Alcaraz+(L3 Collab.)ADEVA90KPLB250199+Adriani, Aguilar-Benitez, Akbari, Alcaraz+(L3 Collab.)						
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ADEVA90FPLB247177+Adriani, Aguilar-Benitez, Akbari, Alcaraz+(L3 Collab.)ADEVA90KPLB250199+Adriani, Aguilar-Benitez, Akbari, Alcaraz+(L3 Collab.)						
ADEVA 90K PL B250 199 +Adriani, Aguilar-Benitez, Akbari, Alcarez+ (L3 Collab.)					· ·	
ADEVA 90K PL B250 199 +Adriani, Aguilar-Benitez, Akbari, Alcarez+ (L3 Collab.)	ADEVA	90F	PL B247 177	+Adriani, Aguilar-Benitez, Akbari, Alcaraz-	+ (L3	Collab.)
	ADEVA	90K	PL B250 199	+Adriani, Aguilar-Benitez, Akbari, Alcarez-	+ (Ľ3	Collab.)
					. (20	

ADEVA	90O	PL B252 525	+Adriani, Aguilar-Benitez, Akbari, Alc	araz+ (L3 Collab.)
AKRAWY	90F	PL B241 133	+Alexander, Allison, Allport+	(OPAL Collab.)
AKRAWY	901	PL B244 135	+Alexander, Allison, Allport, Andersor	+ (OPAL Collab.)
AKRAWY	90J	PL B246 285	+Alexander, Allison, Allport, Andersor	+ (OPAL Collab.)
DECAMP	90G	PL B236 501	+Deschizeaux, Lees, Minard+	(ÀLEPH Collab.)
DECAMP	90O	PL B250 172	+Deschizeaux, Goy, Lees+	(ALEPH Collab.)
KIM	90	PL B240 243	+Breedon, Ko, Lander, Maeshima, Ma	
ABE	89	PRL 62 613	+Amidei, Apollinari, Ascori, Atac+	(CDF Collab.)
ABE	89B	PRL 62 1825	+Amidei, Apollinari, Ascoli, Atac+	(CDF Collab.)
ABE	89D	PRL 63 1447	+Amidei, Apollinari, Ascoli, Atac+	(CDF Collab.)
ABE	89H	PRL 62 3020	+Amidei, Apollinari, Ascoli, Atac+	(CDF Collab.)
ABE	89J	ZPHY C45 175	+Amako, Arai, Fukawa+	(VENUS Collab.)
ABE	89L	PL B232 425	+Amako, Arai, Asano, Chiba+	(VENUS Collab.)
ADACHI	89B	PL B228 553	+Aihara, Doser, Enomoto, Fujii+	(TOPAZ Collab.)
ALBAJAR	89	ZPHY C44 15	+Albrow, Allkofer, Arnison, Astbury+	(UA1 Collab.)
BARGER	89	PL B220 464	+Hagiwara, Han, Zeppenfeld	(WISC, KEK)
BEHREND	89B	PL B222 163	+Criegee, Dainton, Field, Franke+	(CELLO Collab.)
BRAUNSCH	89C	ZPHY C43 549	Braunschweig, Gerhards, Kirschfink+	· · · · · · /
DORENBOS	89	ZPHY C41 567	Dorenbosch, Udo, Allaby, Amaldi+	(CHARM Collab.)
HAGIWARA	89	PL B219 369	+Sakuda, Terunuma	(KEK, DURH, HIRO)
KIM	89	PL B223 476	+Kim, Kang, Lee, Myung, Bacala	(AMY Collab.)
ABE	88B	PL B213 400	+Amako, Arai, Asano, Chiba, Chiba+	. `
BARINGER	88	PL B206 551	+Bylsma, De Bonte, Koltick, Low+	(HRS Collab.)
BRAUNSCH	88	ZPHY C37 171	Braunschweig, Gerhards+	(TASSO Collab.)
BRAUNSCH	88D	ZPHY C40 163	Braunschweig, Gerhards, Kirschfink+	
ANSARI	87D	PL B195 613	+Bagnaia, Banner+	(UA2 Collab.)
BARTEL	87B	ZPHY C36 15	+Becker, Felst+	(JADE Collab.)
BEHREND	87C	PL B191 209	+Buerger, Criegee, Dainton+	(CELLO Collab.)
FERNANDEZ	87B	PR D35 10	+Ford, Qi, Read, Smith, Camporesi+	(MAC Collab.)
ARNISON	86C	PL B172 461	+Albrow, Allkofer+	(UA1 Collab.)
ARNISON	86D	PL B177 244	+Albajar, Albrow+	(UA1 Collab.)
BARTEL	86	ZPHY C31 359	+Becker, Felst, Haidt+	(JADE Collab.)
BARTEL	86C	ZPHY C30 371	+Becker, Cords, Felst, Haidt+	(JADE Collab.)
BEHREND	86	PL 168B 420	+Buerger, Criegee, Fenner+	(CELLO Collab.)
BEHREND	86C	PL B181 178	+Buerger, Criegee, Dainton+	(CELLO Collab.)
DERRICK	86	PL 166B 463	+Gan, Kooijman, Loos+	(HRS Collab.)
Also	86B	PR D34 3286	Derrick, Gan, Kooijman, Loos, Muse	· · · · · · · · · · · · · · · · · · ·
DERRICK	86B	PR D34 3286	+Gan, Kooijman, Loos, Musgrave+	(HRS Collab.)
GRIFOLS	86	PL 168B 264	+Peris	(BARC)
JODIDIO	86	PR D34 1967	+Balke, Carr, Gidal, Shinsky+	(LBL, NWES, TRIU)
Also	88	PR D37 237 erratum	Jodidio, Balke, Carr+	(LBL, NWES, TRIU)
APPEL	85	PL 160B 349	+Bagnaia, Banner+	(UA2 Collab.)
BARTEL	85K	PL 160B 337	+Baghala, Banner+ +Becker, Cords, Eichler+	(JADE Collab.)
BERGER	85	ZPHY C28 1	+Genzel, Lackas, Pielorz+	(PLUTO Collab.)
BERGER	85B	ZPHY C27 341	+Deuter, Genzel, Lackas, Pielorz+	(PLUTO Collab.)
BAGNAIA	оэд 84С	PL 138B 430	+Deuter, Genzel, Lackas, Pielorz+ +Banner, Battiston+	(
BAGNAIA	84C 84D	PL 138B 430 PL 146B 437		(UA2 Collab.)
BARTEL	84D 84E	PL 146B 437 PL 146B 121	+Becker, Bowdery, Cords+	(JADE Collab.)
EICHTEN	04⊏ 84	RMP 56 579	+Becker, Bowdery, Cords, Felst+	(JADE Collab.)
-	84 83C	PL 126B 493	+Hinchliffe, Lane, Quigg	(FNAL, LBL, OSU)
	83C 82		+Fischer, Burkhardt+	(TASSO Collab.)
RENARD	ŏΖ	PL 116B 264		(CERN)