Quark and Lepton Compositeness, Searches for

NODE=S054
NODE=S054

The latest unpublished results are described in the "Quark and Lepton Compositeness" review.

See the related review(s):

Searches for Quark and Lepton Compositeness

CONTENTS:

NODE=S054CNT
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SCALE LIMITS for Contact Interactions: $\Lambda(e e e e)$

NODE=S054CTE

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

NODE=S054CTE
NODE=S054CTE

Λ^+_{LL}(TeV)	Λ^-_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>8.3	**>10.3**	95	[1] BOURILKOV	01	RVUE	E_{cm}= 192–208 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>4.5	>7.0	95	[2] SCHAEL	07A	ALEP	E_{cm}= 189–209 GeV
>5.3	>6.8	95	ABDALLAH	06C	DLPH	E_{cm}= 130–207 GeV
>4.7	>6.1	95	[3] ABBIENDI	04G	OPAL	E_{cm}= 130–207 GeV
>4.3	>4.9	95	ACCIARRI	00P	L3	E_{cm}= 130–189 GeV

[1] A combined analysis of the data from ALEPH, DELPHI, L3, and OPAL. NODE=S054CTE;LINKAGE=BT

[2] SCHAEL 07A limits are from R_c, Q^{depl}_{FB}, and hadronic cross section measurements. NODE=S054CTE;LINKAGE=SE

[3] ABBIENDI 04G limits are from $e^+ e^- \rightarrow e^+ e^-$ cross section at $\sqrt{s}$ = 130–207 GeV. NODE=S054CTE;LINKAGE=AB

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

NODE=S054CTM

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

NODE=S054CTM
NODE=S054CTM

Λ^+_{LL}(TeV)	Λ^-_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>6.6	**>9.5**	95	[1] SCHAEL	07A	ALEP	E_{cm}= 189–209 GeV
> 8.5	>3.8	95	ACCIARRI	00P	L3	E_{cm}= 130–189 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>7.3	>7.6	95	ABDALLAH	06C	DLPH	E_{cm}= 130–207 GeV
>8.1	>7.3	95	[2] ABBIENDI	04G	OPAL	E_{cm}= 130–207 GeV

[1] SCHAEL 07A limits are from R_c, Q_{FB}^{depl}, and hadronic cross section measurements. NODE=S054CTM;LINKAGE=SE

[2] ABBIENDI 04G limits are from $e^+ e^- \to \mu\mu$ cross section at $\sqrt{s}$ = 130–207 GeV. NODE=S054CTM;LINKAGE=AB

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

NODE=S054CTT

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

NODE=S054CTT
NODE=S054CTT

Λ^{+}_{LL}(TeV)	Λ^{-}_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>7.9	>5.8	95	[1] SCHAEL	07A	ALEP	E_{cm}= 189–209 GeV
>7.9	>4.6	95	ABDALLAH	06C	DLPH	E_{cm}= 130–207 GeV
>4.9	**>7.2**	95	[2] ABBIENDI	04G	OPAL	E_{cm}= 130–207 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>5.4	>4.7	95	ACCIARRI	00P	L3	E_{cm}= 130–189 GeV

[1] SCHAEL 07A limits are from R_c, Q_{FB}^{depl}, and hadronic cross section measurements. NODE=S054CTT;LINKAGE=SE

[2] ABBIENDI 04G limits are from $e^+ e^- \to \tau\tau$ cross section at $\sqrt{s}$ = 130–207 GeV. NODE=S054CTT;LINKAGE=AB

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

NODE=S054CTL

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

NODE=S054CTL
NODE=S054CTL

Λ^{+}_{LL}(TeV)	Λ^{-}_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>7.9	**> 10.3**	95	[1] SCHAEL	07A	ALEP	E_{cm}= 189–209 GeV
>9.1	>8.2	95	ABDALLAH	06C	DLPH	E_{cm}= 130–207 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>7.7	>9.5	95	[2] ABBIENDI	04G	OPAL	E_{cm}= 130–207 GeV
			[3] BABICH	03	RVUE	
>9.0	>5.2	95	ACCIARRI	00P	L3	E_{cm}= 130–189 GeV

[1] SCHAEL 07A limits are from R_c, Q_{FB}^{depl}, and hadronic cross section measurements. NODE=S054CTL;LINKAGE=SE

[2] ABBIENDI 04G limits are from $e^+ e^- \to \ell^+ \ell^-$ cross section at $\sqrt{s}$ = 130–207 GeV. NODE=S054CTL;LINKAGE=AB

[3] BABICH 03 obtain a bound -0.175 TeV^{-2} $<1/\Lambda^2_{LL} <$ 0.095 TeV^{-2} (95%CL) in a model independent analysis allowing all of Λ_{LL}, Λ_{LR}, Λ_{RL}, Λ_{RR} to coexist. NODE=S054CTL;LINKAGE=HB

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

NODE=S054CTH

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

NODE=S054CTH
NODE=S054CTH;CHECK LIMITS

Λ^{+}_{LL}(TeV)	Λ^{-}_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT	
>24	**>37**	95	[1] AABOUD	17AT	ATLS	($eeqq$)	OCCUR=2
> 8.4	**>10.2**	95	[2] ABDALLAH	09	DLPH	($eebb$)	
> 9.4	**>5.6**	95	[3] SCHAEL	07A	ALEP	($eecc$)	
> 9.4	>4.9	95	[2] SCHAEL	07A	ALEP	($eebb$)	OCCUR=2
>23.3	**>12.5**	95	[4] CHEUNG	01B	RVUE	($eeuu$)	
>11.1	**>26.4**	95	[4] CHEUNG	01B	RVUE	($eedd$)	OCCUR=2
• • • We do not use the following data for averages, fits, limits, etc. • • •							
> 7.1	>7.1	95	[5] AAD	21AU	ATLS	($eebs$)	
>23.5	>26.1	95	[6] AAD	21Q	ATLS	($eeqq$)	
>19.5	>24.0	95	[7] SIRUNYAN	21N	CMS	($eeqq$)	
>23.5	>26.1	95	[8] AAD	20AP	ATLS	($eeqq$)	
> 4.5	>12.8	95	[9] ABRAMOWICZ	19	ZEUS	($eeqq$)	
>16.8	>23.9	95	[10] SIRUNYAN	19AC	CMS	($eeqq$)	
>15.5	>19.5	95	[11] AABOUD	16U	ATLS	($eeqq$)	
>13.5	>18.3	95	[12] KHACHATRY...	15AE	CMS	($eeqq$)	
>16.4	>20.7	95	[13] AAD	14BE	ATLS	($eeqq$)	
> 9.5	>12.1	95	[14] AAD	13E	ATLS	($eeqq$)	
>10.1	>9.4	95	[15] AAD	12AB	ATLS	($eeqq$)	
> 4.2	>4.0	95	[16] AARON	11C	H1	($eeqq$)	
> 3.8	>3.8	95	[17] ABDALLAH	11	DLPH	($eetc$)	
>12.9	>7.2	95	[18] SCHAEL	07A	ALEP	($eeqq$)	OCCUR=3
> 3.7	>5.9	95	[19] ABULENCIA	06L	CDF	($eeqq$)	

[1] AABOUD 17AT limits are from pp collisions at $\sqrt{s} = 13$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$. NODE=S054CTH;LINKAGE=N

[2] ABDALLAH 09 and SCHAEL 07A limits are from R_b, A^b_{FB}. NODE=S054CTH;LINKAGE=AL

[3] SCHAEL 07A limits are from R_c, Q^{depl}_{FB}, and hadronic cross section measurements. NODE=S054CTH;LINKAGE=SE

[4] CHEUNG 01B is an update of BARGER 98E. NODE=S054CTH;LINKAGE=BC

[5] AAD 21AU search for new phenomena in final states with $e^+ e^-$ and one or no b-tagged jets in pp collisions at $\sqrt{s} = 13$ TeV. The quoted limits assume $g^2_* = 4\,\pi$. NODE=S054CTH;LINKAGE=T

[6] AAD 21Q limits are from pp collisions at $\sqrt{s} = 13$ TeV. A frequentist statistical framework is used to remove the prior dependence. NODE=S054CTH;LINKAGE=R

[7] SIRUNYAN 21N limits are from $e^+ e^-$ mass distribution in pp collisions at $\sqrt{s} = 13$ TeV. NODE=S054CTH;LINKAGE=S

[8] AAD 20AP limits are from $e^+ e^-$ mass distribution in pp collisions at $\sqrt{s} = 13$ TeV. NODE=S054CTH;LINKAGE=Q

[9] ABRAMOWICZ 19 limits are from Q^2 spectrum measurements of $e^\pm p \to e^\pm X$. NODE=S054CTH;LINKAGE=O

[10] SIRUNYAN 19AC limits are from $e^+ e^-$ mass distribution in pp collisions at $\sqrt{s} = 13$ TeV. NODE=S054CTH;LINKAGE=P

[11] AABOUD 16U limits are from pp collisions at $\sqrt{s} = 13$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$. NODE=S054CTH;LINKAGE=L

[12] KHACHATRYAN 15AE limit is from $e^+ e^-$ mass distribution in pp collisions at $E_{\rm cm} = 8$ TeV. NODE=S054CTH;LINKAGE=K

[13] AAD 14BE limits are from pp collisions at $\sqrt{s} = 8$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$. NODE=S054CTH;LINKAGE=J

[14] AAD 13E limis are from $e^+ e^-$ mass distribution in pp collisions at $E_{\rm cm} = 7$ TeV. NODE=S054CTH;LINKAGE=I

[15] AAD 12AB limis are from $e^+ e^-$ mass distribution in pp collisions at $E_{\rm cm} = 7$ TeV. NODE=S054CTH;LINKAGE=G

[16] AARON 11C limits are from Q^2 spectrum measurements of $e^\pm p \to e^\pm X$. NODE=S054CTH;LINKAGE=RO

[17] ABDALLAH 11 limit is from $e^+ e^- \to t\bar{c}$ cross section. $\Lambda_{LL} = \Lambda_{LR} = \Lambda_{RL} = \Lambda_{RR}$ is assumed. NODE=S054CTH;LINKAGE=AA

[18] SCHAEL 07A limit assumes quark flavor universality of the contact interactions. NODE=S054CTH;LINKAGE=CE

[19] ABULENCIA 06L limits are from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. NODE=S054CTH;LINKAGE=AI

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

NODE=S054CTS
NODE=S054CTS

Λ^+_{LL}(TeV)	Λ^-_{LL}(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>23.3	**>40.0**	95	[1] SIRUNYAN	21N	CMS	$(\mu\mu qq)$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
> 8.5	>8.5	95	[2] AAD	21AU	ATLS	$(\mu\mu bs)$
>22.3	>32.7	95	[3] AAD	21Q	ATLS	$(\mu\mu qq)$
>22.3	>32.7	95	[4] AAD	20AP	ATLS	$(\mu\mu qq)$
>20.4	>30.4	95	[5] SIRUNYAN	19AC	CMS	$(\mu\mu qq)$
>20	>30	95	[6] AABOUD	17AT	ATLS	$(\mu\mu qq)$
>15.8	>21.8	95	[7] AABOUD	16U	ATLS	$(\mu\mu qq)$
>12.0	>15.2	95	[8] KHACHATRY...	15AE	CMS	$(\mu\mu qq)$
>12.5	>16.7	95	[9] AAD	14BE	ATLS	$(\mu\mu qq)$
> 9.6	>12.9	95	[10] AAD	13E	ATLS	$(\mu\mu qq)$ (isosinglet)
> 9.5	>13.1	95	[11] CHATRCHYAN	13K	CMS	$(\mu\mu qq)$ (isosinglet)
> 8.0	>7.0	95	[12] AAD	12AB	ATLS	$(\mu\mu qq)$ (isosinglet)

[1] SIRUNYAN 21N limits are from $\mu^+ \mu^-$ mass distribution in pp collisions at $\sqrt{s} = 13$ TeV. NODE=S054CTS;LINKAGE=K

[2] AAD 21AU search for new phenomena in final states with $\mu^+ \mu^-$ and one or no b-tagged jets in pp collisions at $\sqrt{s} = 13$ TeV. The quoted limits assume $g^2_* = 4\,\pi$. NODE=S054CTS;LINKAGE=L

[3] AAD 21Q limits are from pp collisions at $\sqrt{s} = 13$ TeV. A frequentist statistical framework is used to remove the prior dependence. NODE=S054CTS;LINKAGE=J

[4] AAD 20AP limits are from $\mu^+ \mu^-$ mass distribution in pp collisions at $\sqrt{s} = 13$ TeV. NODE=S054CTS;LINKAGE=I

[5] SIRUNYAN 19AC limits are from $\mu^+ \mu^-$ mass distribution in pp collisions at $\sqrt{s} = 13$ TeV. NODE=S054CTS;LINKAGE=H

[6] AABOUD 17AT limits are from pp collisions at $\sqrt{s} = 13$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$. NODE=S054CTS;LINKAGE=G

[7] AABOUD 16U limits are from pp collisions at $\sqrt{s} = 13$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$. NODE=S054CTS;LINKAGE=F

[8] KHACHATRYAN 15AE limit is from $\mu^+ \mu^-$ mass distribution in pp collisions at $E_{\rm cm} = 8$ TeV. NODE=S054CTS;LINKAGE=E

[9] AAD 14BE limits are from pp collisions at $\sqrt{s} = 8$ TeV. The quoted limit uses a uniform positive prior in $1/\Lambda^2$. NODE=S054CTS;LINKAGE=D

[10] AAD 13E limis are from $\mu^+ \mu^-$ mass distribution in pp collisions at $E_{\rm cm} = 7$ TeV. NODE=S054CTS;LINKAGE=B

[11] CHATRCHYAN 13K limis are from $\mu^+ \mu^-$ mass distribution in pp collisions at $E_{\rm cm} = 7$ TeV. NODE=S054CTS;LINKAGE=C

[12] AAD 12AB limis are from $\mu^+ \mu^-$ mass distribution in pp collisions at $E_{\rm cm} = 7$ TeV. NODE=S054CTS;LINKAGE=A

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

NODE=S054CTN
NODE=S054CTN

VALUE (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>3.10	90	[1] JODIDIO	86	SPEC	$\Lambda^{\pm}_{LR}(\nu_\mu \nu_e \mu e)$

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

>3.8	[2] DIAZCRUZ	94	RVUE	$\Lambda^{+}_{LL}(\tau\nu_\tau e\nu_e)$	
>8.1	[2] DIAZCRUZ	94	RVUE	$\Lambda^{-}_{LL}(\tau\nu_\tau e\nu_e)$	OCCUR=2
>4.1	[3] DIAZCRUZ	94	RVUE	$\Lambda^{+}_{LL}(\tau\nu_\tau \mu\nu_\mu)$	OCCUR=3
>6.5	[3] DIAZCRUZ	94	RVUE	$\Lambda^{-}_{LL}(\tau\nu_\tau \mu\nu_\mu)$	OCCUR=4

[1] JODIDIO 86 limit is from $\mu^+ \to \overline{\nu}_\mu e^+ \nu_e$. Chirality invariant interactions $L = (g^2/\Lambda^2)$ $[\eta_{LL}\ (\overline{\nu}_{\mu L}\gamma^\alpha \mu_L)\ (\overline{e}_L\gamma_\alpha\nu_{eL}) + \eta_{LR}\ (\overline{\nu}_{\mu L}\gamma^\alpha\nu_{eL}\ (\overline{e}_R\gamma_\alpha\mu_R)]$ with $g^2/4\pi = 1$ and $(\eta_{LL},\eta_{LR}) = (0,\pm1)$ are taken. No limits are given for $\Lambda^{\pm}_{LL}$ with $(\eta_{LL},\eta_{LR}) = (\pm1,0)$. For more general constraints with right-handed neutrinos and chirality nonconserving contact interactions, see their text. NODE=S054CTN;LINKAGE=B

[2] DIAZCRUZ 94 limits are from $\Gamma(\tau \to e\nu\nu)$ and assume flavor-dependent contact interactions with $\Lambda(\tau\nu_\tau e\nu_e) \ll \Lambda(\mu\nu_\mu e\nu_e)$. NODE=S054CTN;LINKAGE=A

[3] DIAZCRUZ 94 limits are from $\Gamma(\tau \to \mu\nu\nu)$ and assume flavor-dependent contact interactions with $\Lambda(\tau\nu_\tau \mu\nu_\mu) \ll \Lambda(\mu\nu_\mu e\nu_e)$. NODE=S054CTN;LINKAGE=C

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

NODE=S054CQN
NODE=S054CQN

VALUE (TeV)	*CL%*	*DOCUMENT ID*		*TECN*
>2.81	95	[1] AFFOLDER	01I	CDF

[1] AFFOLDER 00I bound is for a scalar interaction $\overline{q}_R q_L \overline{\nu} e_L$. NODE=S054CQN;LINKAGE=LI

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

NODE=S054CTQ
NODE=S054CTQ

Λ^{+}_{LL}(TeV)	Λ^{-}_{LL}(TeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*	
>13.1 none 17.4–29.5	**>21.8**	95	[1] AABOUD	17AK	ATLS	pp dijet angl.	OCCUR=2
• • • We do not use the following data for averages, fits, limits, etc. • • •							
			[2] AABOUD	18AV	ATLS	$pp \to t\overline{t}t\overline{t}$	
>12.8	>17.5	95	[3] SIRUNYAN	18DD	CMS	pp dijet angl.	
>11.5	>14.7	95	[4] SIRUNYAN	17F	CMS	pp dijet angl.	
>12.0	>17.5	95	[5] AAD	16S	ATLS	pp dijet angl.	
			[6] AAD	15AR	ATLS	$pp \to t\overline{t}t\overline{t}$	
			[7] AAD	15BY	ATLS	$pp \to t\overline{t}t\overline{t}$	
> 8.1	>12.0	95	[8] AAD	15L	ATLS	pp dijet angl.	
> 9.0	>11.7	95	[9] KHACHATRY...	15J	CMS	pp dijet angl.	
> 5		95	[10] FABBRICHESI	14	RVUE	$q\overline{q}t\overline{t}$	

[1] AABOUD 17AK limit is from dijet angular distribution in pp collisions at $\sqrt{s} = 13$ TeV. u, d, and s quarks are assumed to be composite. NODE=S054CTQ;LINKAGE=X

[2] AABOUD 18AV obtain limit on t_R compositeness $2\pi/\Lambda^2_{RR} < 1.6\ \text{TeV}^{-2}$ at 95% CL from $t\overline{t}t\overline{t}$ production in the pp collisions at $E_{\text{cm}} = 13$ TeV. NODE=S054CTQ;LINKAGE=Y

[3] SIRUNYAN 18DD limit is from dijet angular distribution in pp collisions at $\sqrt{s} = 13$ TeV. NODE=S054CTQ;LINKAGE=Z

[4] SIRUNYAN 17F limit is from dijet angular cross sections in pp collisions at $E_{\text{cm}} = 13$ TeV. All quarks are assumed to be composite. NODE=S054CTQ;LINKAGE=U

[5] AAD 16S limit is from dijet angular selections in pp collisions at $E_{\text{cm}} = 13$ TeV. u, d, and s quarks are assumed to be composite. NODE=S054CTQ;LINKAGE=T

[6] AAD 15AR obtain limit on the t_R compositeness $2\pi/\Lambda^2_{RR} < 6.6\ \text{TeV}^{-2}$ at 95% CL from the $t\overline{t}t\overline{t}$ production in the pp collisions at $E_{\text{cm}} = 8$ TeV. NODE=S054CTQ;LINKAGE=S

[7] AAD 15BY obtain limit on the t_R compositeness $2\pi/\Lambda^2_{RR} < 15.1\ \text{TeV}^{-2}$ at 95% CL from the $t\overline{t}t\overline{t}$ production in the pp collisions at $E_{\text{cm}} = 8$ TeV. NODE=S054CTQ;LINKAGE=P

[8] AAD 15L limit is from dijet angular distribution in pp collisions at $E_{\text{cm}} = 8$ TeV. u, d, and s quarks are assumed to be composite. NODE=S054CTQ;LINKAGE=Q

[9] KHACHATRYAN 15J limit is from dijet angular distribution in pp collisions at $E_{\text{cm}} = 8$ TeV. u, d, s, c, and b quarks are assumed to be composite. NODE=S054CTQ;LINKAGE=R

[10] FABBRICHESI 14 obtain bounds on chromoelectric and chromomagnetic form factors of the top-quark using $pp \to t\overline{t}$ and $p\overline{p} \to t\overline{t}$ cross sections. The quoted limit on the $q\overline{q}t\overline{t}$ contact interaction is derived from their bound on the chromoelectric form factor. NODE=S054CTQ;LINKAGE=O

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

NODE=S054CTD

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

NODE=S054CTD
NODE=S054CTD;CHECK LIMITS

Λ^{+}_{LL}(TeV)	Λ^{-}_{LL}(TeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>2.23	>2.13	95	[1] AAD	24AC	ATLS	$t\overline{t}\nu\overline{\nu}$
>5.0	**>5.4**	95	[2] MCFARLAND	98	CCFR	νN scattering

[1] AAD 24AC limit is from the measurement of the $t\overline{t}$ production cross section with large missing $\not{E}_T$ in pp collisions at $\sqrt{s} = 13$ TeV. NODE=S054CTD;LINKAGE=B

[2] MCFARLAND 98 assumed a flavor universal interaction. Neutrinos were mostly of muon type. NODE=S054CTD;LINKAGE=A

MASS LIMITS for Excited e (e^*)

NODE=S054220

NODE=S054220

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

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

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

NODE=S054EXP

NODE=S054EXP

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

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

NODE=S054EXP

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>103.2	95	[1] ABBIENDI	02G	OPAL	$e^+ e^- \rightarrow e^* e^*$ Homodoublet type
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>102.8	95	[2] ACHARD	03B	L3	$e^+ e^- \rightarrow e^* e^*$ Homodoublet type

[1] From $e^+ e^-$ collisions at $\sqrt{s}$ = 183–209 GeV. $f = f'$ is assumed. NODE=S054EXP;LINKAGE=GN

[2] From $e^+ e^-$ collisions at $\sqrt{s}$ = 189–209 GeV. $f = f'$ is assumed. ACHARD 03B also obtain limit for $f = -f'$: $m_{e^*} > 96.6$ GeV. NODE=S054EXP;LINKAGE=CR

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

NODE=S054EXS

NODE=S054EXS

ATLAS and CMS limits are from $q\overline{q} \rightarrow e e^*$. Other limits are from $e^+ e^- \rightarrow e^* e$, $W \rightarrow e^* \nu$, or $e p \rightarrow e^* X$ and depend on transition magnetic coupling between e and e^*. All limits assume $e^* \rightarrow e\gamma$ decay except as noted. Limits from LEP, UA2, and H1 are for chiral coupling, whereas all other limits are for nonchiral coupling, $\eta_L = \eta_R = 1$. In most papers, the limit is expressed in the form of an excluded region in the $\lambda - m_{e^*}$ plane. See the original papers. For limits prior to 1987, see our PDG 92 edition (Physical Review **D45** S1 (1992)).

NODE=S054EXS

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>5600	95	[1] SIRUNYAN	20AJ	CMS	$pp \rightarrow e e^* X$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>4800	95	[2] AABOUD	19AZ	ATLS	$pp \rightarrow e e^* X$
>3900	95	[3] SIRUNYAN	19Z	CMS	$pp \rightarrow e e^* X$
>2450	95	[4] KHACHATRY...	16AQ	CMS	$pp \rightarrow e e^* X$
>3000	95	[5] AAD	15AP	ATLS	$pp \rightarrow e^{(*)} e^* X$
>2200	95	[6] AAD	13BB	ATLS	$pp \rightarrow e e^* X$
>1900	95	[7] CHATRCHYAN	13AE	CMS	$pp \rightarrow e e^* X$
>1870	95	[8] AAD	12AZ	ATLS	$pp \rightarrow e^{(*)} e^* X$

[1] SIRUNYAN 20AJ search for e^* production in $2e2j$ final states in pp collisions at $\sqrt{s}$ = 13 TeV. The quoted limit assumes $\Lambda = m_{e^*}$, $f = f' = 1$. The contact interaction is included. See their Fig.11 for exclusion limits in m_{e^*}–Λ plane. NODE=S054EXS;LINKAGE=P

[2] AABOUD 19AZ search for single e^* production in pp collisions at $\sqrt{s}$ = 13 TeV. The limit quoted above is from $e^* \rightarrow e q\overline{q}$ and $e^* \rightarrow \nu W$ decays assuming $f = f' = 1$ and $m_{e^*} = \Lambda$. The contact interaction is included in e^* production and decay amplitudes. See their Fig.6 for exclusion limits in $m_{e^*} - \Lambda$ plane. NODE=S054EXS;LINKAGE=O

[3] SIRUNYAN 19Z search for e^* production in $\ell\ell\gamma$ final states in pp collisions at $\sqrt{s}$ = 13 TeV. The quoted limit assumes $\Lambda = m_{e^*}$, $f = f' = 1$. The contact interaction is included in the e^* production and decay amplitudes. NODE=S054EXS;LINKAGE=M

[4] KHACHATRYAN 16AQ search for single e^* production in pp collisions at $\sqrt{s}$ = 8 TeV. The limit above is from the $e^* \rightarrow e\gamma$ search channel assuming $f = f' = 1$, $m_{e^*} = \Lambda$. See their Table 7 for limits in other search channels or with different assumptions. NODE=S054EXS;LINKAGE=K

[5] AAD 15AP search for e^* production in evens with three or more charged leptons in pp collisions at $\sqrt{s}$ = 8 TeV. The quoted limit assumes $\Lambda = m_{e^*}$, $f = f' = 1$. The contact interaction is included in the e^* production and decay amplitudes. NODE=S054EXS;LINKAGE=F

[6] AAD 13BB search for single e^* production in pp collisions with $e^* \rightarrow e\gamma$ decay. $f = f' = 1$, and e^* production via contact interaction with $\Lambda = m_{e^*}$ are assumed. NODE=S054EXS;LINKAGE=E

[7] CHATRCHYAN 13AE search for single e^* production in pp collisions with $e^* \to e\gamma$ decay. $f = f' = 1$, and e^* production via contact interaction with $\Lambda = m_{e^*}$ are assumed. NODE=S054EXS;LINKAGE=D

[8] AAD 12AZ search for e^* production via four-fermion contact interaction in pp collisions with $e^* \to e\gamma$ decay. The quoted limit assumes $\Lambda = m_{e^*}$. See their Fig. 8 for the exclusion plot in the mass-coupling plane. NODE=S054EXS;LINKAGE=B

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

NODE=S054EXG

These limits are derived from indirect effects due to e^* exchange in the t channel and depend on transition magnetic coupling between e and e^*. All limits are for $\lambda_\gamma = 1$. All limits except ABE 89J and ACHARD 02D are for nonchiral coupling with $\eta_L = \eta_R = 1$. We choose the chiral coupling limit as the best limit and list it in the Summary Table. NODE=S054EXG

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

NODE=S054EXG

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>356	95	[1] ABDALLAH	04N	DLPH	$\sqrt{s}$= 161–208 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>310	95	ACHARD	02D	L3	$\sqrt{s}$= 192–209 GeV

[1] ABDALLAH 04N also obtain a limit on the excited electron mass with ee^* chiral coupling, $m_{e^*} > 295$ GeV at 95% CL. NODE=S054EXG;LINKAGE=AB

Indirect Limits for Excited e (e^*)

NODE=S054EXI

These limits make use of loop effects involving e^* and are therefore subject to theoretical uncertainty. NODE=S054EXI

NODE=S054EXI

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[1] DORENBOS...	89	CHRM	$\overline{\nu}_\mu e \to \overline{\nu}_\mu e$, $\nu_\mu e \to \nu_\mu e$
	[2] GRIFOLS	86	THEO	$\nu_\mu e \to \nu_\mu e$
	[3] RENARD	82	THEO	$g-2$ of electron

[1] DORENBOSCH 89 obtain the limit $\lambda_\gamma^2 \Lambda_{\rm cut}^2 / m_{e^*}^2 < 2.6$ (95% CL), where $\Lambda_{\rm cut}$ is the cutoff scale, based on the one-loop calculation by GRIFOLS 86. If one assumes that $\Lambda_{\rm cut} = 1$ TeV and $\lambda_\gamma = 1$, one obtains $m_{e^*} > 620$ GeV. However, one generally expects $\lambda_\gamma \approx m_{e^*}/\Lambda_{\rm cut}$ in composite models. NODE=S054EXI;LINKAGE=DD

[2] GRIFOLS 86 uses $\nu_\mu e \to \nu_\mu e$ and $\overline{\nu}_\mu e \to \overline{\nu}_\mu e$ data from CHARM Collaboration to derive mass limits which depend on the scale of compositeness. NODE=S054EXI;LINKAGE=H

[3] RENARD 82 derived from $g-2$ data limits on mass and couplings of e^* and μ^*. See figures 2 and 3 of the paper. NODE=S054EXI;LINKAGE=E

MASS LIMITS for Excited μ (μ^*)

NODE=S054225

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

NODE=S054MXP

These limits are obtained from $e^+e^- \to \mu^{*+}\mu^{*-}$ and thus rely only on the (electroweak) charge of μ^*. Form factor effects are ignored unless noted. For the case of limits from Z decay, the μ^* coupling is assumed to be of sequential type. All limits assume a dominant $\mu^* \to \mu\gamma$ decay except the limits from $\Gamma(Z)$. NODE=S054MXP

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

NODE=S054MXP

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>103.2	95	[1] ABBIENDI	02G	OPAL	$e^+e^- \to \mu^*\mu^*$ Homodoublet type
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>102.8	95	[2] ACHARD	03B	L3	$e^+e^- \to \mu^*\mu^*$ Homodoublet type

[1] From e^+e^- collisions at $\sqrt{s}$ = 183–209 GeV. $f = f'$ is assumed. NODE=S054MXP;LINKAGE=GN

[2] From e^+e^- collisions at $\sqrt{s}$ = 189–209 GeV. $f = f'$ is assumed. ACHARD 03B also obtain limit for $f = -f'$: $m_{\mu^*} > 96.6$ GeV. NODE=S054MXP;LINKAGE=CR

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

NODE=S054MXS

ATLAS and CMS limits are from $q\overline{q} \to \mu^*\mu$. Other limits are from $e^+e^- \to \mu^*\mu$ and depend on transition magnetic coupling between μ and μ^*. All limits assume $\mu^* \to \mu\gamma$ decay. Limits from LEP are for chiral coupling, whereas all other limits are for nonchiral coupling, $\eta_L = \eta_R = 1$. In most papers, the limit is expressed in the form of an excluded region in the $\lambda - m_{\mu^*}$ plane. See the original papers. For limits prior to 1987, see our PDG 92 edition (Physical Review **D45** S1 (1992)). NODE=S054MXS

NODE=S054MXS

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>5700	95	[1] SIRUNYAN	20AJ	CMS	$pp \to \mu\mu^* X$

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

>3800	95	[2] SIRUNYAN	19Z	CMS	$pp \to \mu \mu^* X$	
>2800	95	[3] AAD	16BM	ATLS	$pp \to \mu \mu^* X$	
>2470	95	[4] KHACHATRY...	16AQ	CMS	$pp \to \mu \mu^* X$	
>3000	95	[5] AAD	15AP	ATLS	$pp \to \mu^{(*)} \mu^* X$	
>2200	95	[6] AAD	13BB	ATLS	$pp \to \mu \mu^* X$	
>1900	95	[7] CHATRCHYAN	13AE	CMS	$pp \to \mu \mu^* X$	
>1750	95	[8] AAD	12AZ	ATLS	$pp \to \mu^{(*)} \mu^* X$	

[1] SIRUNYAN 20AJ search for μ^* production in $2\mu 2j$ final states in pp collisions at $\sqrt{s}=$ 13 TeV. The quoted limit assumes $\Lambda = m_{\mu^*}$, $f = f' = 1$. The contact interaction is included. See their Fig.11 for exclusion limits in m_{μ^*}–Λ plane. NODE=S054MXS;LINKAGE=J

[2] SIRUNYAN 19Z search for μ^* production in $\ell\ell\gamma$ final states in pp collisions at $\sqrt{s}=$ 13 TeV. The quoted limit assumes $\Lambda = m_{\mu^*}$, $f = f' = 1$. The contact interaction is included in the μ^* production and decay amplitudes. NODE=S054MXS;LINKAGE=I

[3] AAD 16BM search for μ^* production in $\mu\mu jj$ events in pp collisions at $\sqrt{s} = 8$ TeV. Both the production and decay are assumed to occur via a contact interaction with $\Lambda = m_{\mu^*}$. NODE=S054MXS;LINKAGE=H

[4] KHACHATRYAN 16AQ search for single μ^* production in pp collisions at $\sqrt{s} = 8$ TeV. The limit above is from the $\mu^* \to \mu\gamma$ search channel assuming $f = f' = 1$, $m_{\mu^*} = \Lambda$. See their Table 7 for limits in other search channels or with different assumptions. NODE=S054MXS;LINKAGE=G

[5] AAD 15AP search for μ^* production in evens with three or more charged leptons in pp collisions at $\sqrt{s} = 8$ TeV. The quoted limit assumes $\Lambda = m_{\mu^*}$, $f = f' = 1$. The contact interaction is included in the μ^* production and decay amplitudes. NODE=S054MXS;LINKAGE=F

[6] AAD 13BB search for single μ^* production in pp collisions with $\mu^* \to \mu\gamma$ decay. $f = f' = 1$, and μ^* production via contact interaction with $\Lambda = m_{\mu^*}$ are assumed. NODE=S054MXS;LINKAGE=E

[7] CHATRCHYAN 13AE search for single μ^* production in pp collisions with $\mu^* \to \mu\gamma$ decay. $f = f' = 1$, and μ^* production via contact interaction with $\Lambda = m_{\mu^*}$ are assumed. NODE=S054MXS;LINKAGE=D

[8] AAD 12AZ search for μ^* production via four-fermion contact interaction in pp collisions with $\mu^* \to \mu\gamma$ decay. The quoted limit assumes $\Lambda = m_{\mu^*}$. See their Fig. 8 for the exclusion plot in the mass-coupling plane. NODE=S054MXS;LINKAGE=A

Indirect Limits for Excited μ (μ^*)

NODE=S054MXI

These limits make use of loop effects involving μ^* and are therefore subject to theoretical uncertainty. NODE=S054MXI

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

NODE=S054MXI

[1] RENARD 82 derived from $g-2$ data limits on mass and couplings of e^* and μ^*. See figures 2 and 3 of the paper. NODE=S054MXI;LINKAGE=O

MASS LIMITS for Excited τ (τ^*)

NODE=S054230

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

NODE=S054TXP

Except for CHEKHOVSKY 25E, these limits are obtained from $e^+ e^- \to \tau^{*+} \tau^{*-}$ and thus rely only on the (electroweak) charge of τ^*. Form factor effects are ignored unless noted. For the case of limits from Z decay, the τ^* coupling is assumed to be of sequential type. All limits assume a dominant $\tau^* \to \tau\gamma$ decay except the limits from $\Gamma(Z)$. For limits prior to 1987, see our PDG 92 edition (Physical Review **D45** S1 (1992)). NODE=S054TXP

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>103.2	95	[1] ABBIENDI	02G	OPAL	$e^+ e^- \to \tau^* \tau^*$ Homodoublet type
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[2] CHEKHOVSKY	25E	CMS	$\tau' \to \tau a_\tau$, $a_\tau \to \gamma\gamma$
>102.8	95	[3] ACHARD	03B	L3	$e^+ e^- \to \tau^* \tau^*$ Homodoublet type

NODE=S054TXP

[1] From $e^+ e^-$ collisions at $\sqrt{s} = 183$–209 GeV. $f = f'$ is assumed. NODE=S054TXP;LINKAGE=GN

[2] CHEKHOVSKY 25E search for pair production of vector-like τ' in pp collisions at $\sqrt{s}=$ 13 TeV. τ' is assumed to be an $SU(2)_W$ singlet decaying to τ and light pseudoscalar a_τ decaying to $\gamma\gamma$. See their Fig. 5 for limits on σ. NODE=S054TXP;LINKAGE=B

[3] From $e^+ e^-$ collisions at $\sqrt{s} = 189$–209 GeV. $f = f'$ is assumed. ACHARD 03B also obtain limit for $f = -f'$: $m_{\tau^*} > 96.6$ GeV. NODE=S054TXP;LINKAGE=CR

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

NODE=S054TXS

ATLAS and CMS limits are from $q\overline{q} \to \tau^* \tau$ including contact interactions. Other limits are from $e^+ e^- \to \tau^* \tau$ and depend on transition magnetic coupling between τ and τ^*. All limits assume $\tau^* \to \tau \gamma$ 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.

NODE=S054TXS

NODE=S054TXS

> 4.700 × 10^3 (CL = 95%) [>4.600 × 10^3 GeV (CL = 95%) OUR 2025 BEST LIMIT]

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>4700	95	[1] HAYRAPETY...	25Y	CMS	$pp \to \tau\tau^*$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>4600	95	[2] AAD	23BJ	ATLS	$pp \to \tau\tau^*$
>2500	95	[3] AAD	15AP	ATLS	$pp \to \tau^{(*)}\tau^* X$
> 180	95	[4] ACHARD	03B	L3	$e^+ e^- \to \tau\tau^*$
> 185	95	[5] ABBIENDI	02G	OPAL	$e^+ e^- \to \tau\tau^*$

[1] HAYRAPETYAN 25Y search for τ^* produced in association with τ via a contact interaction and decaying into $\tau\gamma$. The limit quoted above assumes $f = f' = 1$ and $\Lambda = m_{\tau^*}$.

NODE=S054TXS;LINKAGE=E

[2] AAD 23BJ search for τ^* produced in association with τ and decaying into $\tau q \overline{q}$ via a contact interaction with $g^2_{\text{contact}} = (4\pi)^2$. The limit quoted above assumes $\Lambda = m_{\tau^*}$.

NODE=S054TXS;LINKAGE=D

[3] AAD 15AP search for τ^* production in events with three or more charged leptons in pp collisions at $\sqrt{s} = 8$ TeV. The quoted limit assumes $\Lambda = m_{\tau^*}$, $f = f' = 1$. The contact interaction is included in the τ^* production and decay amplitudes.

NODE=S054TXS;LINKAGE=C

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

NODE=S054TXS;LINKAGE=CR

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

NODE=S054TXS;LINKAGE=GN

MASS LIMITS for Excited Neutrino (ν^*)

NODE=S054233

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

NODE=S054EXN

These limits are obtained from $e^+ e^- \to \nu^* \nu^*$ and thus rely only on the (electroweak) charge of ν^*. Form factor effects are ignored unless noted. The ν^* coupling is assumed to be of sequential type unless otherwise noted. All limits assume a dominant $\nu^* \to \nu\gamma$ decay except the limits from $\Gamma(Z)$.

NODE=S054EXN

NODE=S054EXN

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>1600	95	[1] AAD	15AP	ATLS	$pp \to \nu^*\nu^* X$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[2] ABBIENDI	04N	OPAL	
> 102.6	95	[3] ACHARD	03B	L3	$e^+ e^- \to \nu^*\nu^*$ Homodoublet type

[1] AAD 15AP search for ν^* pair production in evens with three or more charged leptons in pp collisions at $\sqrt{s} = 8$ TeV. The quoted limit assumes $\Lambda = m_{\nu^*}$, $f = f' = 1$. The contact interaction is included in the ν^* production and decay amplitudes.

NODE=S054EXN;LINKAGE=D

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

NODE=S054EXN;LINKAGE=AB

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

NODE=S054EXN;LINKAGE=CR

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

NODE=S054EXO

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

NODE=S054EXO

NODE=S054EXO

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
> 213	95	[1] AARON	08	H1	$ep \to \nu^* X$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>6000	95	[2] TUMASYAN	23AL	CMS	$pp \to \ell\nu^* \to \ell\ell qq$, $\ell = e$
> 190	95	[3] ACHARD	03B	L3	$e^+ e^- \to \nu\nu^*$
none 50–150	95	[4] ADLOFF	02	H1	$ep \to \nu^* X$
> 158	95	[5] CHEKANOV	02D	ZEUS	$ep \to \nu^* X$

[1] AARON 08 search for single ν^* production in ep collisions with the decays $\nu^* \to \nu\gamma$, νZ, eW. The quoted limit assumes $f = -f' = \Lambda/m_{\nu^*}$. See their Fig. 3 and Fig. 4 for the exclusion plots in the mass-coupling plane. NODE=S054EXO;LINKAGE=AA

[2] TUMASYAN 23AL search for Majorana excited neutrino ν^* produced and decaying via gauge and contact interactions. The limit quoted above is for $\ell = e$ with $\Lambda = M_{\nu^*}$. The limit becomes $M_{\nu^*} > 6.1$ TeV for $\ell = \mu$. NODE=S054EXO;LINKAGE=B

[3] ACHARD 03B result is from e^+e^- collisions at $\sqrt{s}$ = 189–209 GeV. The quoted limit is for ν^*_e. $f = -f' = \Lambda/m_{\nu^*}$ is assumed. See their Fig. 4 for the exclusion plot in the mass-coupling plane. NODE=S054EXO;LINKAGE=CR

[4] ADLOFF 02 search for single ν^* production in ep collisions with the decays $\nu^* \to \nu\gamma$, νZ, eW. The quoted limit assumes $f = -f' = \Lambda/m_{\nu^*}$. See their Fig. 1 for the exclusion plots in the mass-coupling plane. NODE=S054EXO;LINKAGE=LF

[5] CHEKANOV 02D search for single ν^* production in ep collisions with the decays $\nu^* \to \nu\gamma$, νZ, eW. $f = -f' = \Lambda/m_{\nu^*}$ is assumed for the e^* coupling. CHEKANOV 02D also obtain limit for $f = f' = \Lambda/m_{\nu^*}$: m_{ν^*} >135 GeV. See their Fig. 5c and Fig. 5d for the exclusion plot in the mass-coupling plane. NODE=S054EXO;LINKAGE=KD

MASS LIMITS for Excited q (q^*)

NODE=S054235

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

NODE=S054EQP
NODE=S054EQP

Limits from CDF and CMS are from $q^* q^*$ production via strong interactions. Other limits are mostly obtained from $e^+e^- \to q^*\overline{q}^*$ 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.

NODE=S054EQP

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>1050	95	[1] HAYRAPETY...	25AA	CMS	$t^* \to tg$	
>1700	95	[2] HAYRAPETY...	25AA	CMS	$pp \to t^*_{3/2}\overline{t}^*_{3/2} \to t\overline{t}gg$	OCCUR=2
none 700–1200	95	[3] SIRUNYAN	18V	CMS	$pp \to t^*_{3/2}\overline{t}^*_{3/2} \to t\overline{t}gg$	
> 338	95	[4] AALTONEN	10H	CDF	$q^* \to tW^-$	
		[5] BARATE	98U	ALEP	$Z \to q^* q^*$	
> 45.6	95	[6] ADRIANI	93M	L3	u or d type, $Z \to q^* q^*$	
> 41.7	95	[7] BARDADIN-...	92	RVUE	u-type, $\Gamma(Z)$	
> 44.7	95	[7] BARDADIN-...	92	RVUE	d-type, $\Gamma(Z)$	OCCUR=2
> 40.6	95	[8] DECAMP	92	ALEP	u-type, $\Gamma(Z)$	OCCUR=3
> 44.2	95	[8] DECAMP	92	ALEP	d-type, $\Gamma(Z)$	OCCUR=4
> 45	95	[9] DECAMP	92	ALEP	u or d type, $Z \to q^* q^*$	OCCUR=5
> 45	95	[8] ABREU	91F	DLPH	u-type, $\Gamma(Z)$	
> 45	95	[8] ABREU	91F	DLPH	d-type, $\Gamma(Z)$	OCCUR=2

[1] HAYRAPETYAN 25AA search for pair production of vector-like t^* in pp collisions at $\sqrt{s}$ = 13 TeV. t^* is assumed to be an SU(2)$_W$ singlet decaying to tg. See their Fig. 7 for limits on $\sigma \cdot B^2$. NODE=S054EQP;LINKAGE=D

[2] HAYRAPETYAN 25AA search for pair production of spin 3/2 excited top quark $t^*_{3/2}$ in pp collisions at $\sqrt{s}$ = 13 TeV. See their Fig. 8 for limits on $\sigma \cdot B^2$. NODE=S054EQP;LINKAGE=F

[3] SIRUNYAN 18V search for pair production of spin 3/2 excited top quarks. B($t^*_{3/2} \to tg$) = 1 is assumed. NODE=S054EQP;LINKAGE=C

[4] AALTONEN 10H obtain limits on the $q^* q^*$ production cross section in $p\overline{p}$ collisions. See their Fig. 3. NODE=S054EQP;LINKAGE=AA

[5] BARATE 98U obtain limits on the form factor. See their Fig. 16 for limits in mass-form factor plane. NODE=S054EQP;LINKAGE=BU

[6] ADRIANI 93M limit is valid for B($q^* \to qg$)> 0.25 (0.17) for up (down) type. NODE=S054EQP;LINKAGE=E

[7] BARDADIN-OTWINOWSKA 92 limit based on $\Delta\Gamma(Z)$<36 MeV. NODE=S054EQP;LINKAGE=BO

[8] These limits are independent of decay modes. NODE=S054EQP;LINKAGE=I

[9] Limit is for B($q^* \to qg$)+B($q^* \to q\gamma$)=1. NODE=S054EQP;LINKAGE=J

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

NODE=S054EQS
NODE=S054EQS

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

NODE=S054EQS

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT	
>6700 (CL = 95%) OUR LIMIT						→ UNCHECKED ←
none 1800–2500	95	[1] TUMASYAN	23AF	CMS	$pp \to b^* X$, $b^* \to bg$	
none 1000–6000	95	[2] TUMASYAN	23BC	CMS	$pp \to q^* X$, $q^* \to q\gamma$	
none 1000–2200	95	[3] TUMASYAN	23BC	CMS	$pp \to b^* X$, $b^* \to b\gamma$	OCCUR=2
none 2000–6700	95	[4] AAD	20T	ATLS	$pp \to q^* X$, $q^* \to qg$	

none 1250–3200	95	[4] AAD	20T	ATLS	$pp \to b^* X$, $b^* \to bg$, $b\gamma$, bZ, tW	OCCUR=2
none 1800–6300	95	[5] SIRUNYAN	20AI	CMS	$pp \to q^* X$, $q^* \to qg$	
none 1500–2600	95	[6] AABOUD	18AB	ATLS	$pp \to b^* X$, $b^* \to bg$	
none 1500–5300	95	[7] AABOUD	18BA	ATLS	$pp \to q^* X$, $q^* \to q\gamma$	
none 1000–5500	95	[8] SIRUNYAN	18AG	CMS	$pp \to q^* X$, $q^* \to q\gamma$	
none 1000–1800	95	[9] SIRUNYAN	18AG	CMS	$pp \to b^* X$, $b^* \to b\gamma$	OCCUR=2
none 600–6000	95	[10] SIRUNYAN	18BO	CMS	$pp \to q^* X$, $q^* \to qg$	
none 1200–5000	95	[11] SIRUNYAN	18P	CMS	$pp \to q^* X$, $q^* \to qW$	
none 1200–4700	95	[11] SIRUNYAN	18P	CMS	$pp \to q^* X$, $q^* \to qZ$	OCCUR=2
$>$6000	95	[12] AABOUD	17AK	ATLS	$pp \to q^* X$, $q^* \to qg$	

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

		[13] HAYRAPETY...	24G	CMS	$pp \to q^* X$, $q^* \to qY$, $Y \to q\overline{q}$	
none 700–3000	95	[14] TUMASYAN	22O	CMS	$pp \to b^* X$, $b^* \to tW$	
$>$2600	95	[15] SIRUNYAN	21AG	CMS	$pp \to b^* X$, $b^* \to tW$	
none 600–5400	95	[16] KHACHATRY...	17W	CMS	$pp \to q^* X$, $q^* \to qg$	
none 1100–2100	95	[17] AABOUD	16	ATLS	$pp \to b^* X$, $b^* \to bg$	
$>$1500	95	[18] AAD	16AH	ATLS	$pp \to b^* X$, $b^* \to tW$	
$>$4400	95	[19] AAD	16AI	ATLS	$pp \to q^* X$, $q^* \to q\gamma$	
		[20] AAD	16AV	ATLS	$pp \to q^* X$, $q^* \to Wb$	
$>$5200	95	[21] AAD	16S	ATLS	$pp \to q^* X$, $q^* \to qg$	
$>$1390	95	[22] KHACHATRY...	16I	CMS	$pp \to b^* X$, $b^* \to tW$	
$>$5000	95	[23] KHACHATRY...	16K	CMS	$pp \to q^* X$, $q^* \to qg$	
none 500–1600	95	[24] KHACHATRY...	16L	CMS	$pp \to q^* X$, $q^* \to qg$	
$>$4060	95	[25] AAD	15V	ATLS	$pp \to q^* X$, $q^* \to qg$	
$>$3500	95	[26] KHACHATRY...	15V	CMS	$pp \to q^* X$, $q^* \to qg$	
$>$3500	95	[27] AAD	14A	ATLS	$pp \to q^* X$, $q^* \to q\gamma$	
$>$3200	95	[28] KHACHATRY...	14	CMS	$pp \to q^* X$, $q^* \to qW$	
$>$2900	95	[29] KHACHATRY...	14	CMS	$pp \to q^* X$, $q^* \to qZ$	OCCUR=2
none 700–3500	95	[30] KHACHATRY...	14J	CMS	$pp \to q^* X$, $q^* \to q\gamma$	
$>$2380	95	[31] CHATRCHYAN	13AJ	CMS	$pp \to q^* X$, $q^* \to qW$	
$>$2150	95	[32] CHATRCHYAN	13AJ	CMS	$pp \to q^* X$, $q^* \to qZ$	OCCUR=2

[1] TUMASYAN 23AF limit quoted above assumes $bg \to b^*$ production. The limit becomes $m_{b^*} > 4$ TeV if contact interaction is included in the b^* production cross section. See their Fig. 5 for limits on $\sigma{\cdot}B$. NODE=S054EQS;LINKAGE=TA

[2] TUMASYAN 23BC search for excited light flavor quark q^* in pp collisions at $\sqrt{s} = 13$ TeV. $f = 1.0$ is assumed. NODE=S054EQS;LINKAGE=UA

[3] TUMASYAN 23BC search for excited b quark b^* in pp collisions at $\sqrt{s} = 13$ TeV. b^* production via gauge interactions and $f = 1.0$ are assumed. The limit becomes $m_{b^*} > 3.8$TeV if contact interaction is included in the b^* production cross section. NODE=S054EQS;LINKAGE=VA

[4] AAD 20T search for resonances decaying into dijets in pp collisions at $\sqrt{s} = 13$ TeV. Assume $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. NODE=S054EQS;LINKAGE=OA

[5] SIRUNYAN 20AI search for resonances decaying into dijets in pp collisions at $\sqrt{s} = 13$ TeV. Assume $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. NODE=S054EQS;LINKAGE=QA

[6] AABOUD 18AB assume $\Lambda = m_{b^*}$, $f_s = f = f' = 1$. The contact interactions are not included in b^* production and decay amplitudes. NODE=S054EQS;LINKAGE=HA

[7] AABOUD 18BA search for first-generation excited quarks (u^* and d^*) with degenerate mass, assuming $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes. NODE=S054EQS;LINKAGE=IA

[8] SIRUNYAN 18AG search for first-generation excited quarks (u^* and d^*) with degenerate mass, assuming $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. NODE=S054EQS;LINKAGE=JA

[9] SIRUNYAN 18AG search for excited b quark assuming $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. NODE=S054EQS;LINKAGE=KA

[10] SIRUNYAN 18BO assume $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes. NODE=S054EQS;LINKAGE=LA

[11] SIRUNYAN 18P use the hadronic decay of W or Z, assuming $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. NODE=S054EQS;LINKAGE=MA

[12] AABOUD 17AK assume $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes. Only the decay of $q^* \to gu$ and $q^* \to gd$ is simulated as the benchmark signals in the analysis. NODE=S054EQS;LINKAGE=GA

[13] HAYRAPETYAN 24G search for singly produced narrow resonances decaying to jjj in pp collisions at $\sqrt{s} = 13$ TeV. See their Fig. 3 for limits on $\sigma{\cdot}B$. NODE=S054EQS;LINKAGE=WA

[14] TUMASYAN 22O search for b^* decaying to tW in pp collisions at $\sqrt{s} = 13$ TeV. The limit quoted above assumes $\kappa^b_L = g_L = 1$, $\kappa^b_R = g_R = 0$. The limit becomes $m_{b^*} >$ NODE=S054EQS;LINKAGE=SA

3.0 TeV (>3.2 TeV) if we assume $\kappa_L^b = g_L = 0$, $\kappa_R^b = g_R = 1$ ($\kappa_L^b = g_L = 1$, $\kappa_R^b = g_R = 1$). See their Fig. 3 for limits on $\sigma \cdot B$.

[15] SIRUNYAN 21AG search for b^* decaying to tW in pp collisions at $\sqrt{s} = 13$ TeV. The limit quoted above assumes $\kappa_L^b = g_L = 1$, $\kappa_R^b = g_R = 0$. The limit becomes $m_{b^*} >$ 2.8 TeV (> 3.1 TeV) if we assume $\kappa_L^b = g_L = 0$, $\kappa_R^b = g_R = 1$ ($\kappa_L^b = g_L = \kappa_R^b = g_R = 1$). See their Fig. 5 for limits on $\sigma \cdot B$. NODE=S054EQS;LINKAGE=RA

[16] KHACHATRYAN 17W assume $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes. NODE=S054EQS;LINKAGE=FA

[17] AABOUD 16 assume $\Lambda = m_{b^*}$, $f_s = f = f' = 1$. The contact interactions are not included in the b^* production and decay amplitudes. NODE=S054EQS;LINKAGE=EA

[18] AAD 16AH search for b^* decaying to tW in pp collisions at $\sqrt{s} = 8$ TeV. $f_g = f_L = f_R = 1$ are assumed. See their Fig. 12b for limits on $\sigma \cdot B$. NODE=S054EQS;LINKAGE=X

[19] AAD 16AI assume $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. NODE=S054EQS;LINKAGE=Y

[20] AAD 16AV search for single production of vector-like quarks decaying to Wb in pp collisions. See their Fig. 8 for the limits on couplings and mixings. NODE=S054EQS;LINKAGE=DA

[21] AAD 16S assume $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes. NODE=S054EQS;LINKAGE=Z

[22] KHACHATRYAN 16I search for b^* decaying to tW in pp collisions at $\sqrt{s} = 8$ TeV. $\kappa_L^b = g_L = 1$, $\kappa_R^b = g_R = 0$ are assumed. See their Fig. 8 for limits on $\sigma \cdot B$. NODE=S054EQS;LINKAGE=W

[23] KHACHATRYAN 16K assume $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes. NODE=S054EQS;LINKAGE=BA

[24] KHACHATRYAN 16L search for resonances decaying to dijets in pp collisions at $\sqrt{s} =$ 8 TeV using the data scouting technique which increases the sensitivity to the low mass resonances. NODE=S054EQS;LINKAGE=CA

[25] AAD 15V assume $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes. NODE=S054EQS;LINKAGE=U

[26] KHACHATRYAN 15V assume $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. The contact interactions are not included in q^* production and decay amplitudes. NODE=S054EQS;LINKAGE=V

[27] AAD 14A assume $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. NODE=S054EQS;LINKAGE=Q

[28] KHACHATRYAN 14 use the hadronic decay of W, assuming $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. NODE=S054EQS;LINKAGE=S

[29] KHACHATRYAN 14 use the hadronic decay of Z, assuming $\Lambda = m_{q^*}$, $f_s = f = f' = 1$. NODE=S054EQS;LINKAGE=T

[30] KHACHATRYAN 14J assume $f_s = f = f' = \Lambda / m_{q^*}$. NODE=S054EQS;LINKAGE=R

[31] CHATRCHYAN 13AJ use the hadronic decay of W. NODE=S054EQS;LINKAGE=J

[32] CHATRCHYAN 13AJ use the hadronic decay of Z. NODE=S054EQS;LINKAGE=M

MASS LIMITS for Color Sextet Quarks (q_6)

NODE=S054CQ

NODE=S054CQ

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>84	95	[1] ABE	89D	CDF	$p\overline{p} \rightarrow q_6 \overline{q}_6$

[1] 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. NODE=S054CQ;LINKAGE=A

MASS LIMITS for Color Octet Charged Leptons (ℓ_8)

NODE=S054CL

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

NODE=S054CL

NODE=S054CL

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>86	95	[1] ABE	89D	CDF	Stable ℓ_8: $p\overline{p} \rightarrow \ell_8 \overline{\ell}_8$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[2] ABT	93	H1	e_8: $ep \rightarrow e_8 X$

[1] 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. NODE=S054CL;LINKAGE=AC

[2] ABT 93 search for e_8 production via e-gluon fusion in ep collisions with $e_8 \rightarrow eg$. See their Fig. 3 for exclusion plot in the m_{e_8}–Λ plane for m_{e_8} = 35–220 GeV. NODE=S054CL;LINKAGE=G2

MASS LIMITS for Color Octet Neutrinos (ν_8)

NODE=S054CN

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

NODE=S054CN
NODE=S054CN

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>110	90	[1] BARGER	89	RVUE	ν_8: $p\overline{p} \to \nu_8 \overline{\nu}_8$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
none 3.8–29.8	95	[2] KIM	90	AMY	ν_8: $e^+ e^- \to$ acoplanar jets
none 9–21.9	95	[3] BARTEL	87B	JADE	ν_8: $e^+ e^- \to$ acoplanar jets

OCCUR=3

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

NODE=S054CN;LINKAGE=C

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

NODE=S054CN;LINKAGE=D

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

NODE=S054CN;LINKAGE=A

MASS LIMITS for W_8 (Color Octet W Boson)

NODE=S054CW
NODE=S054CW

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

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

NODE=S054CW;LINKAGE=A

REFERENCES FOR Searches for Quark and Lepton Compositeness

NODE=S054

CHEKHOVSKY	25E	JHEP 2508 156	V. Chekhovsky *et al.*	(CMS Collab.)	REFID=63555
HAYRAPETY...	25AA	EPJ C85 342	A. Hayrapetyan *et al.*	(CMS Collab.)	REFID=63504
HAYRAPETY...	25Y	JHEP 2506 006	A. Hayrapetyan	(CMS Collab.)	REFID=63475
AAD	24AC	JHEP 2403 139	G. Aad *et al.*	(ATLAS Collab.)	REFID=62843
HAYRAPETY...	24G	PRL 133 011801	A. Hayrapetyan *et al.*	(CMS Collab.)	REFID=62737
AAD	23BJ	JHEP 2306 199	G. Aad *et al.*	(ATLAS Collab.)	REFID=62117
TUMASYAN	23AF	PR D108 012009	A. Tumasyan *et al.*	(CMS Collab.)	REFID=62293
TUMASYAN	23AL	PL B843 137803	A. Tumasyan *et al.*	(CMS Collab.)	REFID=62365
TUMASYAN	23BC	JHEP 2312 189	A. Tumasyan *et al.*	(CMS Collab.)	REFID=62577
TUMASYAN	22O	JHEP 2204 048	A. Tumasyan *et al.*	(CMS Collab.)	REFID=61788
AAD	21AU	PRL 127 141801	G. Aad *et al.*	(ATLAS Collab.)	REFID=61498
AAD	21Q	JHEP 2104 142	G. Aad *et al.*	(ATLAS Collab.)	REFID=61298
SIRUNYAN	21AG	JHEP 2112 106	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=61565
SIRUNYAN	21N	JHEP 2107 208	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=61317
AAD	20AP	JHEP 2011 005	G. Aad *et al.*	(ATLAS Collab.)	REFID=60764
AAD	20T	JHEP 2003 145	G. Aad *et al.*	(ATLAS Collab.)	REFID=60484
SIRUNYAN	20AI	JHEP 2005 033	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=60492
SIRUNYAN	20AJ	JHEP 2005 052	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=60495
AABOUD	19AZ	EPJ C79 803	M. Aaboud *et al.*	(ATLAS Collab.)	REFID=60109
ABRAMOWICZ	19	PR D99 092006	H. Abramowicz *et al.*	(ZEUS Collab.)	REFID=59876
SIRUNYAN	19AC	JHEP 1904 114	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=59676
SIRUNYAN	19Z	JHEP 1904 015	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=59666
AABOUD	18AB	PR D98 032016	M. Aaboud *et al.*	(ATLAS Collab.)	REFID=58982
AABOUD	18AV	JHEP 1807 089	M. Aaboud *et al.*	(ATLAS Collab.)	REFID=59130
AABOUD	18BA	EPJ C78 102	M. Aaboud *et al.*	(ATLAS Collab.)	REFID=59157
SIRUNYAN	18AG	PL B781 390	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=59020
SIRUNYAN	18BO	JHEP 1808 130	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=59142
SIRUNYAN	18DD	EPJ C78 789	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=59318
SIRUNYAN	18P	PR D97 072006	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=58918
SIRUNYAN	18V	PL B778 349	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=58997
AABOUD	17AK	PR D96 052004	M. Aaboud *et al.*	(ATLAS Collab.)	REFID=58217
AABOUD	17AT	JHEP 1710 182	M. Aaboud *et al.*	(ATLAS Collab.)	REFID=58331
KHACHATRY...	17W	PL B769 520	V. Khachatryan *et al.*	(CMS Collab.)	REFID=57899
SIRUNYAN	17F	JHEP 1707 013	A.M. Sirunyan *et al.*	(CMS Collab.)	REFID=57820
AABOUD	16	PL B759 229	M. Aaboud *et al.*	(ATLAS Collab.)	REFID=57233
AABOUD	16U	PL B761 372	M. Aaboud *et al.*	(ATLAS Collab.)	REFID=57570
AAD	16AH	JHEP 1602 110	G. Aad *et al.*	(ATLAS Collab.)	REFID=57318
AAD	16AI	JHEP 1603 041	G. Aad *et al.*	(ATLAS Collab.)	REFID=57322
AAD	16AV	EPJ C76 442	G. Aad *et al.*	(ATLAS Collab.)	REFID=57383
AAD	16BM	NJP 18 073021	G. Aad *et al.*	(ATLAS Collab.)	REFID=57783
AAD	16S	PL B754 302	G. Aad *et al.*	(ATLAS Collab.)	REFID=57206
KHACHATRY...	16AQ	JHEP 1603 125	V. Khachatryan *et al.*	(CMS Collab.)	REFID=57323
KHACHATRY...	16I	JHEP 1601 166	V. Khachatryan *et al.*	(CMS Collab.)	REFID=57141
KHACHATRY...	16K	PRL 116 071801	V. Khachatryan *et al.*	(CMS Collab.)	REFID=57181
KHACHATRY...	16L	PRL 117 031802	V. Khachatryan *et al.*	(CMS Collab.)	REFID=57195
AAD	15AP	JHEP 1508 138	G. Aad *et al.*	(ATLAS Collab.)	REFID=56646
AAD	15AR	JHEP 1508 105	G. Aad *et al.*	(ATLAS Collab.)	REFID=56648
AAD	15BY	JHEP 1510 150	G. Aad *et al.*	(ATLAS Collab.)	REFID=56863
AAD	15L	PRL 114 221802	G. Aad *et al.*	(ATLAS Collab.)	REFID=56474
AAD	15V	PR D91 052007	G. Aad *et al.*	(ATLAS Collab.)	REFID=56551
KHACHATRY...	15AE	JHEP 1504 025	V. Khachatryan *et al.*	(CMS Collab.)	REFID=56632
KHACHATRY...	15J	PL B746 79	V. Khachatryan *et al.*	(CMS Collab.)	REFID=56510
KHACHATRY...	15V	PR D91 052009	V. Khachatryan *et al.*	(CMS Collab.)	REFID=56535
AAD	14A	PL B728 562	G. Aad *et al.*	(ATLAS Collab.)	REFID=55629
AAD	14BE	EPJ C74 3134	G. Aad *et al.*	(ATLAS Collab.)	REFID=56304

FABBRICHESI	14	PR D89 074028	M. Fabbrichesi, M. Pinamonti, A. Tonero		REFID=55808
KHACHATRY...	14	JHEP 1408 173	V. Khachatryan *et al.*	(CMS Collab.)	REFID=55735
KHACHATRY...	14J	PL B738 274	V. Khachatryan *et al.*	(CMS Collab.)	REFID=56123
AAD	13BB	NJP 15 093011	G. Aad *et al.*	(ATLAS Collab.)	REFID=55539
AAD	13E	PR D87 015010	G. Aad *et al.*	(ATLAS Collab.)	REFID=54828
CHATRCHYAN	13AE	PL B720 309	S. Chatrchyan *et al.*	(CMS Collab.)	REFID=55069
CHATRCHYAN	13AJ	PL B723 280	S. Chatrchyan *et al.*	(CMS Collab.)	REFID=55077
CHATRCHYAN	13K	PR D87 032001	S. Chatrchyan *et al.*	(CMS Collab.)	REFID=54943
AAD	12AB	PL B712 40	G. Aad *et al.*	(ATLAS Collab.)	REFID=54172
AAD	12AZ	PR D85 072003	G. Aad *et al.*	(ATLAS Collab.)	REFID=54355
AARON	11C	PL B705 52	F. D. Aaron *et al.*	(H1 Collab.)	REFID=53845
ABDALLAH	11	EPJ C71 1555	J. Abdallah *et al.*	(DELPHI Collab.)	REFID=16401
AALTONEN	10H	PRL 104 091801	T. Aaltonen *et al.*	(CDF Collab.)	REFID=53271
ABDALLAH	09	EPJ C60 1	J. Abdallah *et al.*	(DELPHI Collab.)	REFID=52838
AARON	08	PL B663 382	F.D. Aaron *et al.*	(H1 Collab.)	REFID=52458
SCHAEL	07A	EPJ C49 411	S. Schael *et al.*	(ALEPH Collab.)	REFID=51743
ABDALLAH	06C	EPJ C45 589	J. Abdallah *et al.*	(DELPHI Collab.)	REFID=51224
ABULENCIA	06L	PRL 96 211801	A. Abulencia *et al.*	(CDF Collab.)	REFID=51233
ABBIENDI	04G	EPJ C33 173	G. Abbiendi *et al.*	(OPAL Collab.)	REFID=49915
ABBIENDI	04N	PL B602 167	G. Abbiendi *et al.*	(OPAL Collab.)	REFID=50288
ABDALLAH	04N	EPJ C37 405	J. Abdallah *et al.*	(DELPHI Collab.)	REFID=50302
ACHARD	03B	PL B568 23	P. Achard *et al.*	(L3 Collab.)	REFID=49521
BABICH	03	EPJ C29 103	A.A. Babich *et al.*		REFID=49461
ABBIENDI	02G	PL B544 57	G. Abbiendi *et al.*	(OPAL Collab.)	REFID=48917
ACHARD	02D	PL B531 28	P. Achard *et al.*	(L3 Collab.)	REFID=48663
ADLOFF	02	PL B525 9	C. Adloff *et al.*	(H1 Collab.)	REFID=48526
CHEKANOV	02D	PL B549 32	S. Chekanov *et al.*	(ZEUS Collab.)	REFID=49089
AFFOLDER	01I	PRL 87 231803	T. Affolder *et al.*	(CDF Collab.)	REFID=48438
BOURILKOV	01	PR D64 071701	D. Bourilkov		REFID=48368
CHEUNG	01B	PL B517 167	K. Cheung		REFID=48289
ACCIARRI	00P	PL B489 81	M. Acciarri *et al.*	(L3 Collab.)	REFID=47757
AFFOLDER	00I	PR D62 012004	T. Affolder *et al.*	(CDF Collab.)	REFID=47663
BARATE	98U	EPJ C4 571	R. Barate *et al.*	(ALEPH Collab.)	REFID=46150
BARGER	98E	PR D57 391	V. Barger *et al.*		REFID=48063
MCFARLAND	98	EPJ C1 509	K.S. McFarland *et al.*	(CCFR/NuTeV Collab.)	REFID=46144
DIAZCRUZ	94	PR D49 2149	J.L. Diaz Cruz, O.A. Sampayo	(CINV)	REFID=43731
ABT	93	NP B396 3	I. Abt *et al.*	(H1 Collab.)	REFID=43371
ADRIANI	93M	PRPL 236 1	O. Adriani *et al.*	(L3 Collab.)	REFID=43644
BARDADIN-...	92	ZPHY C55 163	M. Bardadin-Otwinowska	(CLER)	REFID=42109
DECAMP	92	PRPL 216 253	D. Decamp *et al.*	(ALEPH Collab.)	REFID=41877
PDG	92	PR D45 S1	K. Hikasa *et al.*	(KEK, LBL, BOST+)	REFID=41900
ABREU	91F	NP B367 511	P. Abreu *et al.*	(DELPHI Collab.)	REFID=41840
KIM	90	PL B240 243	G.N. Kim *et al.*	(AMY Collab.)	REFID=41211
ABE	89B	PRL 62 1825	F. Abe *et al.*	(CDF Collab.)	REFID=40784
ABE	89D	PRL 63 1447	F. Abe *et al.*	(CDF Collab.)	REFID=40799
ABE	89J	ZPHY C45 175	K. Abe *et al.*	(VENUS Collab.)	REFID=41056
ALBAJAR	89	ZPHY C44 15	C. Albajar *et al.*	(UA1 Collab.)	REFID=40860
BARGER	89	PL B220 464	V. Barger *et al.*	(WISC, KEK)	REFID=40973
DORENBOS...	89	ZPHY C41 567	J. Dorenbosch *et al.*	(CHARM Collab.)	REFID=41055
BARTEL	87B	ZPHY C36 15	W. Bartel *et al.*	(JADE Collab.)	REFID=40455
GRIFOLS	86	PL 168B 264	J.A. Grifols, S. Peris	(BARC)	REFID=10625
JODIDIO	86	PR D34 1967	A. Jodidio *et al.*	(LBL, NWES, TRIU)	REFID=40309
Also		PR D37 237 (errat.)	A. Jodidio *et al.*	(LBL, NWES, TRIU)	REFID=40467
RENARD	82	PL 116B 264	F.M. Renard	(CERN)	REFID=10609