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

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

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

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

[65] Superseded by ADRIANI 93M.
[66] Superseded by DECAMP 92.

Indirect Limits for Excited μ (μ^*)

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

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

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

MASS LIMITS for Excited τ (τ^*)

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

These limits are obtained from $e^+e^- \to \tau^{*+}\tau^{*-}$ 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 $\tau^* \to \tau\gamma$ 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)).

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

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

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

These limits are from $e^+e^- \to \tau^*\tau$ 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.

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

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

MASS LIMITS for Excited Neutrino (ν^*)

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

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

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

[76] Limit is based on $B(Z \to \nu^*\overline{\nu}^*) \times B(\nu^* \to \nu\gamma)^2 < 5 \times 10^{-5}$ (95%CL) assuming Dirac ν^*, $B(\nu^* \to \nu\gamma) = 1$.
[77] BARDADIN-OTWINOWSKA 92 limit is for Dirac ν^*. Based on $\Delta\Gamma(Z)$<36 MeV. The limit is 36.4 GeV for Majorana ν^*, 45.4 GeV for homodoublet ν^*.
[78] Limit is for Dirac ν^*. The limit is 34.6 GeV for Majorana ν^*, 45.4 GeV for homodoublet ν^*.
[79] DECAMP 90O limit is from excess $\Delta\Gamma(Z) < 89$ MeV. The above value is for Dirac ν^*; 26.6 GeV for Majorana ν^*; 44.8 GeV for homodoublet ν^*.
[80] Superseded by DECAMP 92.
[81] DECAMP 90O limit based on $B(Z \to \nu^*\nu^*) \cdot B(\nu^* \to \nu\gamma)^2 < 7 \times 10^{-5}$ (95%CL), assuming Dirac ν^*, $B(\nu^* \to \nu\gamma) = 1$.

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

These limits are from $Z \to \nu\nu^*$ 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.

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

[82] DECAMP 92 limit is based on $B(Z \to \nu^*\overline{\nu}) \times B(\nu^* \to \nu\gamma) < 2.7 \times 10^{-5}$ (95%CL) assuming Dirac ν^*, $B(\nu^* \to \nu\gamma) = 1$.
[83] ABT 93 search for single ν^* production via $\nu^* eW$ coupling in ep collisions with the decays $\nu^* \to \nu\gamma$, νZ, eW. See their Fig. 4 for exclusion plot in the $m_{\nu^*} - \lambda_W$ plane.
[84] See Fig. 5 of BARDADIN-OTWINOWSKA 92 for combined limit of ADEVA 90O, DECAMP 90O, and DECAMP 92.
[85] Limit is either for $\nu^* \to \nu\gamma$ or $\nu^* \to eW$.
[86] Superseded by ADRIANI 93M.
[87] DECAMP 90O limit based on $B(Z \to \nu\nu^*) \cdot B(\nu^* \to \nu\gamma) < 6 \times 10^{-5}$ (95%CL), assuming $B(\nu^* \to \nu\gamma) = 1$.
[88] Superseded by DECAMP 92.

MASS LIMITS for Excited q (q^*)

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

These limits are obtained from $e^+e^- \to q^*\overline{q}^*$ 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.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>45.6	95	[89] ADRIANI	93M	L3	u or d type, $Z \to q^*q^*$
>45	95	[90] DECAMP	92	ALEP	u or d type, $Z \to q^*q^*$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[91] ADRIANI	92F	L3	$Z \to q^*q^*$
>41.7	95	[92] BARDADIN-...	92	RVUE	u-type, $\Gamma(Z)$
>44.7	95	[92] BARDADIN-...	92	RVUE	d-type, $\Gamma(Z)$
>40.6	95	[93] DECAMP	92	ALEP	u-type, $\Gamma(Z)$
>44.2	95	[93] DECAMP	92	ALEP	d-type, $\Gamma(Z)$
>45	95	[93] ABREU	91F	DLPH	u-type, $\Gamma(Z)$
>45	95	[93] ABREU	91F	DLPH	d-type, $\Gamma(Z)$
>21.1	95	[94] BEHREND	86C	CELL	$e(q^*) = -1/3$, $q^* \to qg$
>22.3	95	[94] BEHREND	86C	CELL	$e(q^*) = 2/3$, $q^* \to qg$
>22.5	95	[94] BEHREND	86C	CELL	$e(q^*) = -1/3$, $q^* \to q\gamma$
>23.2	95	[94] BEHREND	86C	CELL	$e(q^*) = 2/3$, $q^* \to q\gamma$

[89] ADRIANI 93M limit is valid for $B(q^* \to qg) > 0.25$ (0.17) for up (down) type.
[90] Limit is for $B(q^* \to qg) + B(q^* \to q\gamma) = 1$.