

# SEARCHES

## not in other sections

### Magnetic Monopole Searches

The most sensitive experiments obtain negative results.

Best cosmic-ray supermassive monopole flux limit:

$$< 1.4 \times 10^{-16} \text{ cm}^{-2}\text{sr}^{-1}\text{s}^{-1} \quad \text{for } 1.1 \times 10^{-4} < \beta < 1$$

### Supersymmetric Particle Searches

All supersymmetric mass bounds here are model dependent.

The limits assume:

1)  $\tilde{\chi}_1^0$  is the lightest supersymmetric particle; 2)  $R$ -parity is conserved, unless stated otherwise;

See the Particle Listings for a Note giving details of supersymmetry.

$\tilde{\chi}_i^0$  — neutralinos (mixtures of  $\tilde{\gamma}$ ,  $\tilde{Z}^0$ , and  $\tilde{H}_i^0$ )

Mass  $m_{\tilde{\chi}_1^0} > 0$  GeV, CL = 95%

[general MSSM, non-universal gaugino masses]

Mass  $m_{\tilde{\chi}_1^0} > 46$  GeV, CL = 95%

[all  $\tan\beta$ , all  $m_0$ , all  $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$ ]

Mass  $m_{\tilde{\chi}_2^0} > 62.4$  GeV, CL = 95%

[ $1 < \tan\beta < 40$ , all  $m_0$ , all  $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$ ]

Mass  $m_{\tilde{\chi}_3^0} > 99.9$  GeV, CL = 95%

[ $1 < \tan\beta < 40$ , all  $m_0$ , all  $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$ ]

Mass  $m_{\tilde{\chi}_4^0} > 116$  GeV, CL = 95%

[ $1 < \tan\beta < 40$ , all  $m_0$ , all  $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$ ]

Mass  $m_{\tilde{\chi}}$  none 200–670 GeV, CL = 95% [R-Parity Violating]

[wino production,  $\tilde{\chi} \rightarrow b + \ell/\nu + t/b$  via  $\lambda'_{i33}$  coupling]

$\tilde{\chi}_i^\pm$  — charginos (mixtures of  $\tilde{W}^\pm$  and  $\tilde{H}_i^\pm$ )

Mass  $m_{\tilde{\chi}_1^\pm} > 94$  GeV, CL = 95%

[ $\tan\beta < 40$ ,  $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} > 3$  GeV, all  $m_0$ ]

Mass  $m_{\tilde{\chi}_1^\pm} > 1000$  GeV, CL = 95%

[ $2\ell + \cancel{E}_T$ , Tchi1chi1C,  $m_{\tilde{\chi}_1^0} = 0$  GeV]

Mass  $m_{\tilde{\chi}_1^\pm} > 1600$  GeV, CL = 95% [R-Parity Violating]

[Tchi1n2l,  $\tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \nu$ ,  $\lambda_{12k} \neq 0$ ,  $m_{\tilde{\chi}_1^0} = 1200$  GeV]

$\tilde{\chi}^\pm$  — long-lived chargino

Mass  $m_{\tilde{\chi}^\pm} > 1050$  GeV, CL = 95%

[ $\tilde{\chi}^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm$ , wino LSP, stable]

Mass  $m_{\tilde{\chi}^\pm} > 1050$  GeV, CL = 95%

[ $\tilde{\chi}^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm$ , wino LSP,  $\tau = 20$  ns]

$\tilde{\nu}$  — sneutrino

Mass  $m > 41$  GeV, CL = 95% [model independent]

Mass  $m > 94$  GeV, CL = 95%

[CMSSM,  $1 \leq \tan\beta \leq 40$ ,  $m_{\tilde{e}_R} - m_{\tilde{\chi}_1^0} > 10$  GeV]

Mass  $m > 4200$  GeV, CL = 95% [R-Parity Violating]

[ $1e + 1\mu, \nu_\tau \rightarrow e\mu$ ,  $\lambda = \lambda' = 0.1$ ]

$\tilde{e}$  — scalar electron (selectron)

Mass  $m > 107$  GeV, CL = 95% [all  $m_{\tilde{e}_L} - m_{\tilde{\chi}_1^0}$ ]

Mass  $m > 700$  GeV, CL = 95%

[ $2\ell + \cancel{E}_T$ ,  $m_{\tilde{\ell}_R} = m_{\tilde{\ell}_L}$  and  $\tilde{\ell} = \tilde{e}, \tilde{\mu}$ ,  $m_{\tilde{\chi}_1^0} = 0$  GeV]

Mass  $m > 250$  GeV, CL = 95%

[ $\ell^\pm \ell^\mp + \cancel{E}_T$ ,  $\tilde{e}_R$ ,  $m_{\tilde{\chi}_1^0} = 0$  GeV]

Mass  $m > 410$  GeV, CL = 95% [R-Parity Violating]

[ $\geq 4\ell^\pm$ ,  $\tilde{\ell} \rightarrow l\tilde{\chi}_1^0$ ,  $\tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \nu$ ]

Mass  $m > 1200$  GeV, CL = 95% [R-Parity Violating]

[ $\geq 4\ell$ ,  $\lambda_{12k} \neq 0$ ,  $m_{\tilde{\chi}_1^0} = 900$  GeV (m-degenerate  $\tilde{\ell}_L, \tilde{\nu}$ )]

$\tilde{\mu}$  — scalar muon (smuon)

- Mass  $m > 700$  GeV, CL = 95%  
[ $2\ell + \cancel{E}_T$ ,  $m_{\tilde{\ell}_R} = m_{\tilde{\ell}_L}$  and  $\tilde{\ell} = \tilde{e}$ ,  $\tilde{\mu}$ ,  $m_{\tilde{\chi}_1^0} = 0$  GeV]
- Mass  $m > 210$ , CL = 95%  
[ $\ell^\pm \ell^\mp + \cancel{E}_T$ ,  $\tilde{\mu}_R$ ,  $m_{\tilde{\chi}_1^0} = 0$  GeV]
- Mass  $m > 94$  GeV, CL = 95%  
[CMSSM,  $1 \leq \tan\beta \leq 40$ ,  $m_{\tilde{\mu}_R} - m_{\tilde{\chi}_1^0} > 10$  GeV]
- Mass  $m > 410$  GeV, CL = 95% [R-Parity Violating]  
[ $\geq 4\ell^\pm$ ,  $\tilde{\ell} \rightarrow l\tilde{\chi}_1^0$ ,  $\tilde{\chi}_1^0 \rightarrow \ell^\pm \ell^\mp \nu$ ]
- Mass  $m > 1200$  GeV, CL = 95% [R-Parity Violating]  
[ $\geq 4\ell$ ,  $\lambda_{12k} \neq 0$ ,  $m_{\tilde{\chi}_1^0} = 900$  GeV (m-degenerate  $\tilde{\ell}_L, \tilde{\nu}$ )]

$\tilde{\tau}$  — scalar tau (stau)

- Mass  $m > 81.9$  GeV, CL = 95%  
[ $m_{\tilde{\tau}_R} - m_{\tilde{\chi}_1^0} > 15$  GeV, all  $\theta_\tau$ ,  $B(\tilde{\tau} \rightarrow \tau\tilde{\chi}_1^0) = 100\%$ ]
- Mass  $m > 400$  GeV, CL = 95%  
[2 hadronic  $\tau + \cancel{E}_T$ ,  $\tilde{\tau}_{R,L} \rightarrow \tau\tilde{\chi}_1^0$ ,  $m_{\tilde{\chi}_1^0} = 1$  GeV]
- Mass  $m > 90$  GeV, CL = 95% [R-Parity Violating]  
[ $\tilde{\tau}_R$ , indirect,  $\Delta m > 5$  GeV]
- Mass  $m > 1200$ , CL = 95% [R-Parity Violating]  
[ $\geq 4\ell$ ,  $\lambda_{12k} \neq 0$ ,  $m_{\tilde{\chi}_1^0} = 900$  GeV (m-degenerate  $\tilde{\ell}_L, \tilde{\nu}$ )]
- Mass  $m > 286$  GeV, CL = 95% [long-lived  $\tilde{\tau}$ ]

$\tilde{q}$  — squarks of the first two quark generations

- Mass  $m > 1.220 \times 10^3$  GeV, CL = 95%  
[jets +  $\cancel{E}_T$ , Tsqk1, 1 non-degenerate  $\tilde{q}$ ,  $m_{\tilde{\chi}_1^0} = 0$  GeV]
- Mass  $m > 1.600 \times 10^3$  GeV, CL = 95% [R-Parity Violating]  
[ $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ ,  $\tilde{\chi}_1^0 \rightarrow \ell\ell\nu$ ,  $\lambda_{121}, \lambda_{122} \neq 0$ ,  $m_{\tilde{g}} = 2400$  GeV]

$\tilde{q}$  — long-lived squark

- Mass  $m > 1340$ , CL = 95% [ $\tilde{t}$  R-hadrons]
- Mass  $m > 1250$ , CL = 95% [ $\tilde{b}$  R-hadrons]

$\tilde{b}$  — scalar bottom (sbottom)

- Mass  $m > 1.270 \times 10^3$  GeV, CL = 95%  
[b-jets +  $\cancel{E}_T$ , Tsb0t1,  $m_{\tilde{\chi}_1^0} = 0$  GeV]
- Mass  $m > 307$  GeV, CL = 95% [R-Parity Violating]  
[ $\tilde{b} \rightarrow td$  or  $ts$ ,  $\lambda''_{332}$  or  $\lambda''_{331}$  coupling]

$\tilde{t}$  — scalar top (stop)

Mass  $m > 1.310 \times 10^3$  GeV, CL = 95%

[jets +  $\cancel{E}_T$ , Tstop1,  $m_{\tilde{\chi}_1^0} < 300$  GeV]

Mass  $m > 1100$  GeV, CL = 95% [R-Parity Violating]

$[\tilde{t} \rightarrow be, \text{Tstop2RPV, prompt}]$

Mass  $m > 460$  GeV, CL = 95%

[R-Parity Violating, long-lived  $\tilde{t}, \tilde{t} \rightarrow d\bar{l}, 0.01\text{cm} < c\tau < 1000$  cm]

$\tilde{g}$  — gluino

Mass  $m > 2.300 \times 10^3$  GeV, CL = 95%

[jets +  $\cancel{E}_T$ , Tglu1A,  $m_{\tilde{\chi}_1^0} < 200$  GeV]

Mass  $m > 2.260 \times 10^3$  GeV, CL = 95% [R-Parity Violating]

$[\geq 4\ell, \lambda_{12k} \neq 0, m_{\tilde{\chi}_1^0} > 1000$  GeV]

## Technicolor

The limits for technicolor (and top-color) particles are quite varied depending on assumptions. See the Technicolor section of the full *Review* (the data listings).

## Quark and Lepton Compositeness, Searches for

### Scale Limits $\Lambda$ for Contact Interactions (the lowest dimensional interactions with four fermions)

If the Lagrangian has the form

$$\pm \frac{g^2}{2\Lambda^2} \bar{\psi}_L \gamma_\mu \psi_L \bar{\psi}_L \gamma^\mu \psi_L$$

(with  $g^2/4\pi$  set equal to 1), then we define  $\Lambda \equiv \Lambda_{LL}^\pm$ . For the full definitions and for other forms, see the Note in the Listings on Searches for Quark and Lepton Compositeness in the full *Review* and the original literature.

$$\Lambda_{LL}^+(eeee) > 8.3 \text{ TeV, CL} = 95\%$$

$$\Lambda_{LL}^-(eeee) > 10.3 \text{ TeV, CL} = 95\%$$

$$\Lambda_{LL}^+(ee\mu\mu) > 8.5 \text{ TeV, CL} = 95\%$$

$$\Lambda_{LL}^-(ee\mu\mu) > 9.5 \text{ TeV, CL} = 95\%$$

$$\Lambda_{LL}^+(ee\tau\tau) > 7.9 \text{ TeV, CL} = 95\%$$

$\Lambda_{LL}^-(ee\tau\tau)$	$> 7.2$ TeV, CL = 95%
$\Lambda_{LL}^+(\ell\ell\ell\ell)$	$> 9.1$ TeV, CL = 95%
$\Lambda_{LL}^-(\ell\ell\ell\ell)$	$> 10.3$ TeV, CL = 95%
$\Lambda_{LL}^+(eeqq)$	$> 24$ TeV, CL = 95%
$\Lambda_{LL}^-(eeqq)$	$> 37$ TeV, CL = 95%
$\Lambda_{LL}^+(eeuu)$	$> 23.3$ TeV, CL = 95%
$\Lambda_{LL}^-(eeuu)$	$> 12.5$ TeV, CL = 95%
$\Lambda_{LL}^+(eedd)$	$> 11.1$ TeV, CL = 95%
$\Lambda_{LL}^-(eedd)$	$> 26.4$ TeV, CL = 95%
$\Lambda_{LL}^+(eccc)$	$> 9.4$ TeV, CL = 95%
$\Lambda_{LL}^-(eccc)$	$> 5.6$ TeV, CL = 95%
$\Lambda_{LL}^+(eebb)$	$> 9.4$ TeV, CL = 95%
$\Lambda_{LL}^-(eebb)$	$> 10.2$ TeV, CL = 95%
$\Lambda_{LL}^+(\mu\mu qq)$	$> 23.3$ TeV, CL = 95%
$\Lambda_{LL}^-(\mu\mu qq)$	$> 40.0$ TeV, CL = 95%
$\Lambda(\ell\nu\ell\nu)$	$> 3.10$ TeV, CL = 90%
$\Lambda(e\nu qq)$	$> 2.81$ TeV, CL = 95%
$\Lambda_{LL}^+(qqqq)$	$> 13.1$ none 17.4–29.5 TeV, CL = 95%
$\Lambda_{LL}^-(qqqq)$	$> 21.8$ TeV, CL = 95%
$\Lambda_{LL}^+(\nu\nu qq)$	$> 5.0$ TeV, CL = 95%
$\Lambda_{LL}^-(\nu\nu qq)$	$> 5.4$ TeV, CL = 95%

### Excited Leptons

The limits from  $\ell^{*+}\ell^{*-}$  do not depend on  $\lambda$  (where  $\lambda$  is the  $\ell\ell^*$  transition coupling). The  $\lambda$ -dependent limits assume chiral coupling.

$e^{*\pm}$  — excited electron

Mass  $m > 103.2$  GeV, CL = 95% (from  $e^*e^*$ )

Mass  $m > 5.600 \times 10^3$  GeV, CL = 95% (from  $ee^*$ )

Mass  $m > 356$  GeV, CL = 95% (if  $\lambda_\gamma = 1$ )

$\mu^{*\pm}$  — excited muon

Mass  $m > 103.2$  GeV, CL = 95% (from  $\mu^*\mu^*$ )

Mass  $m > 5.700 \times 10^3$  GeV, CL = 95% (from  $\mu\mu^*$ )

$\tau^{*\pm}$  — excited tau

Mass  $m > 103.2$  GeV, CL = 95% (from  $\tau^* \tau^*$ )

Mass  $m > 4.600 \times 10^3$  GeV, CL = 95% (from  $\tau \tau^*$ )

$\nu^*$  — excited neutrino

Mass  $m > 1.600 \times 10^3$  GeV, CL = 95% (from  $\nu^* \nu^*$ )

Mass  $m > 213$  GeV, CL = 95% (from  $\nu^* X$ )

$q^*$  — excited quark

Mass  $m > 338$  GeV, CL = 95% (from  $q^* q^*$ )

Mass  $m > 6700$  GeV, CL = 95% (from  $q^* X$ )

### Color Sextet and Octet Particles

Color Sextet Quarks ( $q_6$ )

Mass  $m > 84$  GeV, CL = 95% (Stable  $q_6$ )

Color Octet Charged Leptons ( $\ell_8$ )

Mass  $m > 86$  GeV, CL = 95% (Stable  $\ell_8$ )

Color Octet Neutrinos ( $\nu_8$ )

Mass  $m > 110$  GeV, CL = 90% ( $\nu_8 \rightarrow \nu g$ )

## Extra Dimensions

Please refer to the Extra Dimensions section of the full *Review* for a discussion of the model-dependence of these bounds, and further constraints.

### Constraints on the radius of the extra dimensions, for the case of two-flat dimensions of equal radii

(direct tests of Newton's law)

$R < 3.8 \mu\text{m}$ , CL = 95% ( $pp \rightarrow jG$ )

$R < 0.16\text{--}916$  nm (astrophysics; limits depend on technique and assumptions)

### Constraints on the fundamental gravity scale

$M_{TT} > 9.02$  TeV, CL = 95% ( $pp \rightarrow$  dijet, angular distribution)

$M_c > 4.16$  TeV, CL = 95% ( $pp \rightarrow \ell\bar{\ell}$ )

### Constraints on the Kaluza-Klein graviton in warped extra dimensions

$M_G > 4.78$  TeV, CL = 95% ( $pp \rightarrow e^+ e^-, \mu^+ \mu^-$ )

### Constraints on the Kaluza-Klein gluon in warped extra dimensions

$$M_{g_{KK}} > 3.8 \text{ TeV, CL} = 95\% \quad (g_{KK} \rightarrow t\bar{t})$$

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### WIMP and Dark Matter Searches

No confirmed evidence found for galactic WIMPs from the GeV to the TeV mass scales and down to  $1 \times 10^{-10}$  pb spin independent cross section at  $M = 100$  GeV.

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