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# SEARCHES FOR MONOPOLES, SUPERSYMMETRY, TECHNICOLOR, COMPOSITENESS, etc.

## Magnetic Monopole Searches

Isolated supermassive monopole candidate events have not been confirmed. The most sensitive experiments obtain negative results.

Best cosmic-ray supermassive monopole flux limit:

$$< 1.0 \times 10^{-15} \text{ cm}^{-2} \text{sr}^{-1} \text{s}^{-1} \quad \text{for } 1.1 \times 10^{-4} < \beta < 0.1$$

## Supersymmetric Particle Searches

Limits are based on the Minimal Supersymmetric Standard Model.

Assumptions include: 1)  $\tilde{\chi}_1^0$  (or  $\tilde{\gamma}$ ) is lightest supersymmetric particle; 2)  $R$ -parity is conserved; 3) With the exception of  $\tilde{t}$  and  $\tilde{b}$ , all scalar quarks are assumed to be degenerate in mass and  $m_{\tilde{q}_R} = m_{\tilde{q}_L}$ . 4) Limits for sleptons refer to the  $\tilde{\ell}_R$  states.

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  $m_{\tilde{\chi}_1^0} > 32.5 \text{ GeV}$ , CL = 95%

$$[\tan\beta > 0.7, m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} > 5 \text{ GeV}]$$

Mass  $m_{\tilde{\chi}_2^0} > 55.9 \text{ GeV}$ , CL = 95%

$$[\tan\beta > 1.5, m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} > 10 \text{ GeV}]$$

Mass  $m_{\tilde{\chi}_3^0} > 106.6 \text{ GeV}$ , CL = 95%

$$[\tan\beta > 1.5, m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} > 10 \text{ GeV}]$$

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

Mass  $m_{\tilde{\chi}_1^\pm} > 67.7 \text{ GeV}$ , CL = 95%

$$[\tan\beta > 0.7, m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} > 3 \text{ GeV}]$$

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

$$\text{Mass } m > 87.1 \text{ GeV, CL} = 95\% \quad [m_{\tilde{e}_R} - m_{\tilde{\chi}_1^0} > 5 \text{ GeV}]$$

$\tilde{\mu}$  — scalar muon (smuon)

$$\text{Mass } m > 82.3 \text{ GeV, CL} = 95\% \quad [m_{\tilde{\mu}_R} - m_{\tilde{\chi}_1^0} > 3 \text{ GeV}]$$

$\tilde{\tau}$  — scalar tau (stau)

$$\text{Mass } m > 81.0 \text{ GeV, CL} = 95\% \quad [m_{\tilde{\tau}_R} - m_{\tilde{\chi}_1^0} > 8 \text{ GeV}]$$

$\tilde{q}$  — scalar quark (squark)

These limits include the effects of cascade decays, evaluated assuming a fixed value of the parameters  $\mu$  and  $\tan\beta$ . The limits are weakly sensitive to these parameters over much of parameter space. Limits assume GUT relations between gaugino masses and the gauge coupling.

$$\text{Mass } m > 250 \text{ GeV, CL} = 95\% \quad [\tan\beta = 2, \mu < 0, A = 0]$$

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

$$\text{Mass } m \text{ none } 40\text{--}75 \text{ GeV, CL} = 95\%$$

$$[\tilde{b} \rightarrow b\tilde{\chi}_1^0, \text{ all } \theta_b, m_{\tilde{b}} - m_{\tilde{\chi}_1^0} > 10 \text{ GeV}]$$

$\tilde{t}$  — scalar top (stop)

$$\text{Mass } m > 86.4 \text{ GeV, CL} = 95\%$$

$$[\tilde{t} \rightarrow t\tilde{\chi}_1^0, \text{ all } \theta_t, m_{\tilde{t}} - m_{\tilde{\chi}_1^0} > 5 \text{ GeV}]$$

$\tilde{g}$  — gluino

There is some controversy on whether gluinos in a low-mass window ( $1 \lesssim m_{\tilde{g}} \lesssim 5 \text{ GeV}$ ) are excluded or not. See the Supersymmetry Listings for details.

The limits summarised here refer to the high-mass region ( $m_{\tilde{g}} \gtrsim 5 \text{ GeV}$ ), and include the effects of cascade decays, evaluated assuming a fixed value of the parameters  $\mu$  and  $\tan\beta$ . The limits are weakly sensitive to these parameters over much of parameter space. Limits assume GUT relations between gaugino masses and the gauge coupling,

$$\text{Mass } m > 190 \text{ GeV, CL} = 95\% \quad [\tan\beta = 2, \mu < 0, A = 0]$$

$$\text{Mass } m > 260 \text{ GeV, CL} = 95\% \quad [m_{\tilde{q}} = m_{\tilde{g}}, \tan\beta = 2, \mu < 0, A = 0]$$

## **Technicolor**

Searches for a color-octet techni- $\rho$  constrain its mass to be greater than 260 to 480 GeV, depending on allowed decay channels. Similar bounds exist on the color-octet techni- $\omega$ .

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## 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.

$\Lambda_{LL}^+(eeee)$	> 3.5 TeV, CL = 95%
$\Lambda_{LL}^-(eeee)$	> 3.8 TeV, CL = 95%
$\Lambda_{LL}^+(ee\mu\mu)$	> 4.5 TeV, CL = 95%
$\Lambda_{LL}^-(ee\mu\mu)$	> 4.7 TeV, CL = 95%
$\Lambda_{LL}^+(ee\tau\tau)$	> 3.9 TeV, CL = 95%
$\Lambda_{LL}^-(ee\tau\tau)$	> 4.0 TeV, CL = 95%
$\Lambda_{LL}^+(\ell\ell\ell\ell)$	> 5.3 TeV, CL = 95%
$\Lambda_{LL}^-(\ell\ell\ell\ell)$	> 5.5 TeV, CL = 95%
$\Lambda_{LL}^+(eeqq)$	> 5.4 TeV, CL = 95%
$\Lambda_{LL}^-(eeqq)$	> 6.2 TeV, CL = 95%
$\Lambda_{LL}^+(eebb)$	> 5.6 TeV, CL = 95%
$\Lambda_{LL}^-(eebb)$	> 4.9 TeV, CL = 95%
$\Lambda_{LL}^+(\mu\mu qq)$	> 2.9 TeV, CL = 95%
$\Lambda_{LL}^-(\mu\mu qq)$	> 4.2 TeV, CL = 95%
$\Lambda_{LR}^\pm(\nu_\mu \nu_e \mu e)$	> 3.1 TeV, CL = 90%
$\Lambda_{LL}^+(qqqq)$	> 2.7 TeV, CL = 95%
$\Lambda_{LL}^-(qqqq)$	> 2.4 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, except for the third limit for  $e^*$  which is for nonchiral coupling. For chiral coupling, this limit corresponds to  $\lambda_\gamma = \sqrt{2}$ .

$e^{*\pm}$  — excited electron

- Mass  $m > 90.7$  GeV, CL = 95% (from  $e^{*+} e^{*-}$ )
- Mass  $m =$  none 30–200 GeV, CL = 95% (from  $e p \rightarrow e^* X$ )
- Mass  $m > 91$  GeV, CL = 95% (if  $\lambda_Z > 1$ )
- Mass  $m > 306$  GeV, CL = 95% (if  $\lambda_\gamma = 1$ )

$\mu^{*\pm}$  — excited muon

- Mass  $m > 90.7$  GeV, CL = 95% (from  $\mu^{*+} \mu^{*-}$ )
- Mass  $m > 91$  GeV, CL = 95% (if  $\lambda_Z > 1$ )

$\tau^{*\pm}$  — excited tau

- Mass  $m > 89.7$  GeV, CL = 95% (from  $\tau^{*+} \tau^{*-}$ )
- Mass  $m > 90$  GeV, CL = 95% (if  $\lambda_Z > 0.18$ )

$\nu^*$  — excited neutrino

- Mass  $m > 90.0$  GeV, CL = 95% (from  $\nu^* \bar{\nu}^*$ )
- Mass  $m > 91$  GeV, CL = 95% (if  $\lambda_Z > 1$ )
- Mass  $m =$  none 40–96 GeV, CL = 95% (from  $e p \rightarrow \nu^* X$ )

$q^*$  — excited quark

- Mass  $m > 45.6$  GeV, CL = 95% (from  $q^* \bar{q}^*$ )
- Mass  $m > 88$  GeV, CL = 95% (if  $\lambda_Z > 1$ )
- Mass  $m > 570$  GeV, CL = 95% ( $p \bar{p} \rightarrow q^* X$ )

## 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% ( $\nu_8 \rightarrow \nu g$ )