# SEARCHES FOR MONOPOLES, SUPERSYMMETRY, TECHNICOLOR, COMPOSITENESS, EXTRA DIMENSIONS, 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:

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

---

## Supersymmetric Particle Searches

Limits are based on the Minimal Supersymmetric Standard Model (MSSM) with additional assumptions as follows:

1) $\widetilde{\chi}_1^0$ (or $\widetilde{\gamma}$) is lightest supersymmetric particle; 2) $R$-parity is conserved; 3) With the exception of $\widetilde{t}$ and $\widetilde{b}$, all scalar quarks are assumed to be degenerate in mass and $m_{\widetilde{q}_R} = m_{\widetilde{q}_L}$. 4) Limits for charged sleptons refer to the $\widetilde{\ell}_R$ states. 5) Unless otherwise stated, gaugino mass unification at the GUT scale is assumed. For squarks and gluinos, the Constrained MSSM (CMSSM) limits and simplified model limits are presented.

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

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

Mass $m_{\widetilde{\chi}_1^0} > 46$ GeV, CL = 95%
[all $\tan\beta$, all $m_0$, all $m_{\widetilde{\chi}_2^0} - m_{\widetilde{\chi}_1^0}$]

Mass $m_{\widetilde{\chi}_2^0} > 62.4$ GeV, CL = 95%
[$1 < \tan\beta < 40$, all $m_0$, all $m_{\widetilde{\chi}_2^0} - m_{\widetilde{\chi}_1^0}$]

Mass $m_{\widetilde{\chi}_3^0} > 99.9$ GeV, CL = 95%
[$1 < \tan\beta < 40$, all $m_0$, all $m_{\widetilde{\chi}_2^0} - m_{\widetilde{\chi}_1^0}$]

Mass $m_{\widetilde{\chi}_4^0} > 116$ GeV, CL = 95%
[$1 < \tan\beta < 40$, all $m_0$, all $m_{\widetilde{\chi}_2^0} - m_{\widetilde{\chi}_1^0}$]

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

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

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

$\widetilde{\nu}$ — sneutrino

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

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

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

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

$\widetilde{\mu}$ — scalar muon (smuon)

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

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

$\widetilde{\tau}$ — scalar tau (stau)

Mass $m >$ 81.9 GeV, CL = 95%

[$m_{\widetilde{\tau}_R} - m_{\widetilde{\chi}_1^0}$ >15 GeV, all $\theta_\tau$]

$\widetilde{q}$ – scalar quark partners (squarks) of the first two quark generations

The first of these limits is within CMSSM with cascade decays, evaluated assuming a fixed value of the parameters $\mu$ and $\tan\beta$. Limits assume two-generations of mass degenerate squarks ($\widetilde{q}_L$ and $\widetilde{q}_R$) and gaugino mass parameters that are constrained by the unification condition at the grand unification scale. The second limit assumes a simplified model with a 100% branching ratio for the prompt decay $\widetilde{q} \rightarrow q\widetilde{\chi}_1^0$.

Mass $m >$ 1110 GeV, CL = 95% [$\tan\beta$=10, $\mu$ >0, $A_0$=0]

Mass $m >$ 750 GeV, CL = 95%

[jets + $\not\!\!E_T$, $\widetilde{q} \rightarrow q\widetilde{\chi}_1^0$ simplified model, $m_{\widetilde{\chi}_1^0}$= 0 GeV]

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

Mass $m >$ 89 GeV, CL = 95%

[$\widetilde{b} \rightarrow b\widetilde{\chi}_1^0$, $m_{\widetilde{b}_1} - m_{\widetilde{\chi}_1^0} > 8$ GeV, all $\theta_b$]

Mass $m >$ 600 GeV, CL = 95%

[ jets + $\not\!\!E_T$, $\widetilde{b} \rightarrow b\widetilde{\chi}_1^0$ simplified model, $m_{\widetilde{\chi}_1^0}$= 0 GeV ]

$\widetilde{t}$ — scalar top (stop)

Mass $m >$ 95.7 GeV, CL = 95%

[$\widetilde{t} \rightarrow c\widetilde{\chi}_1^0$, $m_{\widetilde{t}} - m_{\widetilde{\chi}_1^0} > 10$ GeV, all $\theta_t$]

Mass $m >$ 650 GeV, CL = 95%

[1 $\ell^{\pm}$ + jets + $\not\!\!E_T$, $\widetilde{t} \rightarrow t\widetilde{\chi}_1^0$ simplified model, $m_{\widetilde{\chi}_1^0}$=0 GeV]

$\widetilde{g}$ — gluino

The first of these limits is within the CMSSM for ($m_{\widetilde{g}} \gtrsim 5$ GeV), and includes the effects of cascade decays, evaluated assuming a fixed value of the parameters $\mu$ and tan$\beta$. Limit assumes GUT relations between gaugino masses and the gauge couplings. The second limit assumes a simplified model with a 100% branching ratio for the prompt 3 body decay $\widetilde{g} \rightarrow q\overline{q}\widetilde{\chi}_1^0$, independent of the squark mass.

Mass $m >$ 800 GeV, CL = 95% [any $m_{\widetilde{q}}$]

Mass $m >$ 950 GeV, CL = 95%

[jets + $\not{E}_T$, $\widetilde{g} \rightarrow q\overline{q}\widetilde{\chi}_1^0$ simplified model, $m_{\widetilde{\chi}_1^0} = 0$ 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 Λ for Contact Interactions (the lowest dimensional interactions with four fermions)

If the Lagrangian has the form

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

(with $g^2/4\pi$ set equal to 1), then we define $\Lambda \equiv \Lambda^{\pm}_{LL}$. 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 TeV, CL = 95%

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

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

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

$\Lambda^+_{LL}(ee\tau\tau)$ > 7.9 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%

$\Lambda^{+}_{LL}(eeuu)$ > 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%

$\Lambda^{+}_{LL}(eecc)$ > 9.4 TeV, CL = 95%

$\Lambda^{-}_{LL}(eecc)$ > 5.6 TeV, CL = 95%

$\Lambda^{+}_{LL}(eebb)$ > 9.4 TeV, CL = 95%

$\Lambda^{-}_{LL}(eebb)$ > 10.2 TeV, CL = 95%

$\Lambda^{+}_{LL}(\mu\mu qq)$ > 12.5 TeV, CL = 95%

$\Lambda^{-}_{LL}(\mu\mu qq)$ > 16.7 TeV, CL = 95%

$\Lambda(\ell\nu\ell\nu)$ > 3.10 TeV, CL = 90%

$\Lambda(e\nu qq)$ > 2.81 TeV, CL = 95%

$\Lambda^{+}_{LL}(qqqq)$ > 7.6 TeV, CL = 95%

$\Lambda^{-}_{LL}(qqqq)$ > 7.6 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 $m >$ $2.200 \times 10^{3}$ 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 $m >$ $2.200 \times 10^{3}$ GeV, CL = 95% (from $\mu\mu^{*}$)

$\tau^{*\pm}$ — excited tau

Mass $m >$ 103.2 GeV, CL = 95% (from $\tau^{*}\tau^{*}$)
Mass $m >$ 185 GeV, CL = 95% (from $\tau\tau^{*}$)

$\nu^{*}$ — excited neutrino

Mass $m >$ 102.6 GeV, CL = 95% (from $\nu^{*}\nu^{*}$)
Mass $m >$ 213 GeV, CL = 95% (from $\nu\nu^{*}$)

$q^*$ — excited quark

Mass $m >$ 338 GeV, CL = 95% (from $q^* q^*$)
Mass $m >$ $3.500 \times 10^3$ 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% ($\nu_8 \to \nu g$)

## 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**

$R <$ 30 $\mu$m, CL = 95% (direct tests of Newton's law)
$R <$ 23 $\mu$m, CL = 95% ($pp \to jG$)
$R <$ 0.16–916 nm (astrophysics; limits depend on technique and assumptions)

**Constraints on the fundamental gravity scale**

$M_{TT} >$ 3.8 TeV, CL = 95% ($pp \to e^+ e^-, \mu^+ \mu^-$)
$M_c >$ 4.16 TeV, CL = 95% ($pp \to \ell \overline{\ell}$)

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

$M_G >$ 2.68 TeV, CL = 95% ($pp \to e^+ e^-, \mu^+ \mu^-$)

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

$M_{g_{KK}} >$ 2.5 TeV, CL = 95% ($g_{KK} \to t \overline{t}$)