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

Presently all supersymmetric mass bounds are model dependent. This table contains a selection of bounds indicating the range of possibilities. For a more extensive set of cases consult the detailed listings.

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

1) $\widetilde{\chi}^0_1$ is lightest supersymmetric particle; 2) R-parity is conserved;

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

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

Mass $m_{\widetilde{\chi}^0_1} > 0$ GeV, CL = 95%
[general MSSM, non-universal gaugino masses]

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

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

Mass $m_{\widetilde{\chi}^0_2} > 345$ GeV, CL = 95%
[$\widetilde{\chi}^\pm_1 \widetilde{\chi}^0_2 \rightarrow W \widetilde{\chi}^0_1 Z \widetilde{\chi}^0_1$, simplified model, $m_{\widetilde{\chi}^\pm_1} = m_{\widetilde{\chi}^0_2}$, $m_{\widetilde{\chi}^0_1} = 0$ GeV]

Mass $m_{\widetilde{\chi}^0_3}$ $>$ 99.9 GeV, CL = 95%
[1<tanβ <40, all m_0, all $m_{\widetilde{\chi}^0_2} - m_{\widetilde{\chi}^0_1}$]
Mass $m_{\widetilde{\chi}^0_4}$ $>$ 116 GeV, CL = 95%
[1<tanβ <40, all m_0, all $m_{\widetilde{\chi}^0_2} - m_{\widetilde{\chi}^0_1}$]

$\widetilde{\chi}^\pm_i$ — charginos (mixtures of $\widetilde{W}^\pm$ and $\widetilde{H}^\pm_i$)
Mass $m_{\widetilde{\chi}^\pm_1}$ $>$ 94 GeV, CL = 95%
[tan$\beta < 40$, $m_{\widetilde{\chi}^\pm_1} - m_{\widetilde{\chi}^0_1} > 3$ GeV, all m_0]
Mass $m_{\widetilde{\chi}^\pm_1}$ $>$ 345 GeV, CL = 95%
[simplified model, $m_{\widetilde{\chi}^\pm_1} = m_{\widetilde{\chi}^0_2}$, $m_{\widetilde{\chi}^0_1} = 0$ GeV]

$\widetilde{\nu}$ — sneutrino
Mass $m >$ 94 GeV, CL = 95%
[CMSSM, $1 \leq$ tan$\beta \leq 40$, $m_{\widetilde{e}_R} - m_{\widetilde{\chi}^0_1}$ >10 GeV]

$\widetilde{e}$ — scalar electron (selectron)
Mass $m(\widetilde{e}_L) >$ 107 GeV, CL = 95% [all $m_{\widetilde{e}_R} - m_{\widetilde{\chi}^0_1}$]
Mass $m(\widetilde{e}_R) >$ 97.5 GeV, CL = 95%
[$\Delta m >$ 11 GeV, $|\mu|$ >100 GeV, tanβ=1.5]

$\widetilde{\mu}$ — scalar muon (smuon)
Mass $m >$ 94 GeV, CL = 95%
[CMSSM, $1 \leq$ tan$\beta \leq 40$, $m_{\widetilde{\mu}_R} - m_{\widetilde{\chi}^0_1}$ $>$ 10 GeV]

$\widetilde{\tau}$ — scalar tau (stau)
Mass $m >$ 81.9 GeV, CL = 95%
[$m_{\widetilde{\tau}_R} - m_{\widetilde{\chi}^0_1}$ >15 GeV, all θ_τ, B($\widetilde{\tau} \rightarrow \tau \widetilde{\chi}^0_1$) = 100%]

$\widetilde{q}$ – 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 μ and tanβ. The first two 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 third limit assumes a simplified model with a 100% branching ratio for the prompt decay $\widetilde{q} \rightarrow q \widetilde{\chi}^0_1$.

Mass $m >$ 1450 GeV, CL = 95%
[CMSSM, tanβ = 30, $A_0 = -2\max(m_0,\, m_{1/2})$, $\mu > 0$]
Mass $m >$ 850 GeV, CL = 95%
[jets + $\not{E}_T$, $\widetilde{q} \rightarrow q \widetilde{\chi}^0_1$ simplified model, $m_{\widetilde{\chi}^0_1}$= 0 GeV]
Mass $m >$ 520 GeV, CL = 95%
[$\widetilde{q} \rightarrow q \widetilde{\chi}^0_1$, simplified model, single light squark, $m_{\widetilde{\chi}^0_1} = 0$]

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

Mass $m >$ 650 GeV, CL = 95% $[\widetilde{b} \to b\widetilde{\chi}_1^0,\ m_{\widetilde{\chi}_1^0} = 0]$

Mass $m >$ 600 GeV, CL = 95% $[\widetilde{b} \to b\widetilde{\chi}_1^0,\ m_{\widetilde{\chi}_1^0} < 250$ GeV$]$

$\widetilde{t}$ — scalar top (stop)

Mass $m >$ 730 GeV, CL = 95%
$[\widetilde{t} \to t\widetilde{\chi}_1^0,\ m_{\widetilde{\chi}_1^0} = 100$ GeV, $m_{\widetilde{t}} > m_t + m_{\widetilde{\chi}_1^0}]$

Mass $m >$ 500 GeV, CL = 95%
$[\ell^\pm$ + jets + $\not{E}_T$, $\widetilde{t}_1 \to b\widetilde{\chi}_1^\pm$, $m_{\widetilde{\chi}_1^\pm} = 2\ m_{\widetilde{\chi}_1^0}$, 100 GeV $< m_{\widetilde{\chi}_1^0} <$ 150 GeV$]$

Mass $m >$ 240 GeV, CL = 95%
$[\widetilde{t}_1 \to c\widetilde{\chi}_1^0, m_{\widetilde{t}_1} - m_{\widetilde{\chi}_1^0} <$85 GeV$]$

$\widetilde{g}$ — gluino

The first limit assumes a simplified model with a 100% branching ratio for the prompt 3 body decay, independent of the squark mass. The second 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 μ and tanβ. The limit assumes GUT relations between gaugino masses and the gauge couplings. The third limit is based on a combination of searches.

Mass $m >$ 1225 GeV, CL = 95% $[\widetilde{g} \to q\overline{q}\widetilde{\chi}_1^0,\ m_{\widetilde{\chi}_1^0} = 0]$

Mass $m >$ 1150 GeV, CL = 95%
[CMSSM, tanβ=30, $A_0 = -2\max(m_0, m_{1/2})$, $\mu > 0$]

Mass $m >$ 1150 GeV, CL = 95%
[general RPC $\widetilde{g}$ decays, $m_{\widetilde{\chi}_1^0} <$ 100 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%
$\Lambda^+_{LL}(qqqq)$	$>$ 9.0 TeV, CL = 95%
$\Lambda^-_{LL}(qqqq)$	$>$ 12.0 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 λ (where λ is the $\ell\ell^*$ transition coupling). The λ-dependent limits assume chiral coupling.

$e^{*\pm}$ — excited electron

Mass $m >$ 103.2 GeV, CL = 95% (from $e^* e^*$)
Mass $m >$ 3.000×10^3 GeV, CL = 95% (from $e e^*$)
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 $m >$ 3.000×10^3 GeV, CL = 95% (from $\mu \mu^*$)

$\tau^{*\pm}$ — excited tau

Mass $m >$ 103.2 GeV, CL = 95% (from $\tau^* \tau^*$)
Mass $m >$ 2.500×10^3 GeV, CL = 95% (from $\tau \tau^*$)

ν^* — excited neutrino

Mass $m >$ 1.600×10^3 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 $m >$ 4.060×10^3 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 (ℓ_8)

Mass $m >$ 86 GeV, CL = 95% (Stable ℓ_8)

Color Octet Neutrinos (ν_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

$R <$ 30 μm, CL = 95% (direct tests of Newton's law)
$R <$ 15 μm, CL = 95% ($p p \rightarrow j G$)
$R <$ 0.16–916 nm (astrophysics; limits depend on technique and assumptions)

Constraints on the fundamental gravity scale

M_{TT} > 6.3 TeV, CL = 95% ($p p \rightarrow$ dijet, angular distribution)
M_c > 4.16 TeV, CL = 95% ($p p \rightarrow \ell \overline{\ell}$)

Constraints on the Kaluza-Klein graviton in warped extra dimensions

M_G > 2.73 TeV, CL = 95% ($p p \rightarrow e^+ e^-, \mu^+ \mu^-$)

Constraints on the Kaluza-Klein gluon in warped extra dimensions

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