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

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) \( \tilde{\chi}_1^0 \) is lightest supersymmetric particle; 2) \( R \)-parity is conserved;

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

\[ \tilde{\chi}_i^0 \rightarrow \text{neutralinos (mixtures of } \tilde{\gamma}, \tilde{Z}^0, \text{ and } \tilde{H}_i^0) \]

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

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

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

Mass \( m_{\tilde{\chi}_2^0} > 345 \text{ GeV, CL = 95\%} \)

[\( \tilde{\chi}_2^0 \rightarrow W \tilde{\chi}_1^0 Z \tilde{\chi}_1^0 \), simplified model, \( m_{\tilde{\chi}_1^0} = m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0} = 0 \text{ GeV} \) ]
Mass $m_{\tilde{\chi}^0_1} > 99.9$ GeV, CL = 95%

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

Mass $m_{\tilde{\chi}^0_2} > 116$ GeV, CL = 95%

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

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

Mass $m_{\tilde{\chi}^\pm_1} > 94$ GeV, CL = 95%

[$\tan \beta < 40$, $m_{\tilde{\chi}^\pm_1} - m_{\tilde{\chi}^0_1} > 3$ GeV, all $m_0$]

Mass $m_{\tilde{\chi}^\pm_1} > 345$ GeV, CL = 95%

[simplified model, $m_{\tilde{\chi}^\pm_1} = m_{\tilde{\chi}^0_2}, m_{\tilde{\chi}^0_1} = 0$ GeV]

$\tilde{\nu}$ — sneutrino

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

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

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

Mass $m(\tilde{e}_L) > 107$ GeV, CL = 95%

[all $m_{\tilde{e}_R} - m_{\tilde{\chi}^0_1}$]

Mass $m(\tilde{e}_R) > 97.5$ GeV, CL = 95%

[$\Delta m > 11$ GeV, $|\mu| > 100$ GeV, $\tan \beta = 1.5$]

$\tilde{\mu}$ — scalar muon (smuon)

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

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

$\tilde{\tau}$ — scalar tau (stau)

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

[$m_{\tilde{\tau}_R} - m_{\tilde{\chi}^0_1} > 15$ GeV, all $\theta$, $B(\tilde{\tau} \rightarrow \tau \tilde{\chi}^0_1) = 100\%$]

$\tilde{q}$ — 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 $\mu$ and $\tan \beta$. The first two limits assume two-generations of mass degenerate squarks ($\tilde{q}_L$ and $\tilde{q}_R$) 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 $\tilde{q} \rightarrow q \tilde{\chi}^0_1$.

Mass $m > 1450$ GeV, CL = 95%

[CMSSM, $\tan \beta = 30$, $A_0 = -2\max(m_0, m_{1/2})$, $\mu > 0$]

Mass $m > 850$ GeV, CL = 95%

[jets + $E_T$, $\tilde{q} \rightarrow q \tilde{\chi}^0_1$, simplified model, $m_{\tilde{\chi}^0_1} = 0$ GeV]

Mass $m > 520$ GeV, CL = 95%

[$\tilde{q} \rightarrow q \tilde{\chi}^0_1$, simplified model, single light squark, $m_{\tilde{\chi}^0_1} = 0$]
\( \tilde{b} \) — scalar bottom (sbottom)

Mass \( m > 650 \text{ GeV}, \text{ CL} = 95\% \quad [\tilde{b} \to b\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 0] \)

Mass \( m > 600 \text{ GeV}, \text{ CL} = 95\% \quad [\tilde{b} \to b\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} < 250 \text{ GeV}] \)

\( \tilde{t} \) — scalar top (stop)

Mass \( m > 730 \text{ GeV}, \text{ CL} = 95\% \quad [\tilde{t} \to t\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 100 \text{ GeV}, m_{\tilde{t}} > m_t + m_{\tilde{\chi}_1^0}] \)

Mass \( m > 500 \text{ GeV}, \text{ CL} = 95\% \quad [\ell^\pm + \text{jets} + E_T, \tilde{t}_1 \to b\tilde{\chi}_1^\pm, m_{\tilde{\chi}_1^\pm} = 2 m_{\tilde{\chi}_1^0}, 100 \text{ GeV} < m_{\tilde{\chi}_1^0} < 150 \text{ GeV}] \)

Mass \( m > 240 \text{ GeV}, \text{ CL} = 95\% \quad [\tilde{t}_1 \to c\tilde{\chi}_1^0, m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < 85 \text{ GeV}] \)

\( \tilde{g} \) — 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 \( m_{\tilde{g}} \gtrsim 5 \text{ GeV} \)), and includes the effects of cascade decays, evaluated assuming a fixed value of the parameters \( \mu \) and \( \tan\beta \). The limit assumes GUT relations between gaugino masses and the gauge couplings. The third limit is based on a combination of searches.

Mass \( m > 1225 \text{ GeV}, \text{ CL} = 95\% \quad [\tilde{g} \to q\tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} = 0] \)

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

Mass \( m > 1150 \text{ GeV}, \text{ CL} = 95\% \quad [\text{general RPC } \tilde{g} \text{ decays, } m_{\tilde{\chi}_1^0} < 100 \text{ GeV}] \)

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**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 $\Lambda \equiv \Lambda^{\pm}_{LL}$. 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%
- $\Lambda^+_{LL}(eell) > 9.1$ TeV, CL = 95%
- $\Lambda^-_{LL}(eell) > 10.3$ 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%
- $\Lambda^+_{LL}(\mu\muqq) > 12.5$ TeV, CL = 95%
- $\Lambda^-_{LL}(\mu\muqq) > 16.7$ TeV, CL = 95%
- $\Lambda(\bar{\ell}\nu\bar{\nu}\ell\nu) > 3.10$ TeV, CL = 90%
- $\Lambda(e\nuqq) > 2.81$ TeV, CL = 95%
- $\Lambda^+_{LL}(qqqq) > 9.0$ TeV, CL = 95%
- $\Lambda^-_{LL}(qqqq) > 12.0$ TeV, CL = 95%
- $\Lambda^+_{LL}(\nu\nuqq) > 5.0$ TeV, CL = 95%
- $\Lambda^-_{LL}(\nu\nuqq) > 5.4$ 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 $m > 3.000 \times 10^3$ 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 $m > 3.000 \times 10^3$ GeV, CL = 95% (from $\mu\mu^*$)

$\tau^{\pm*}$ — excited tau

- Mass $m > 103.2$ GeV, CL = 95% (from $\tau^*\tau^*$)
- Mass $m > 2.500 \times 10^3$ 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 $q^*\nu^*$)
- Mass $m > 4.060 \times 10^3$ 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% ($\nu_8 \rightarrow \nu g$)

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

- $R < 30 \mu$m, CL = 95% (direct tests of Newton’s law)
- $R < 15 \mu$m, CL = 95% ($pp \rightarrow jG$)
- $R < 0.16$–916 nm (astrophysics; limits depend on technique and assumptions)
Constraints on the fundamental gravity scale

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

Constraints on the Kaluza-Klein graviton in warped extra dimensions

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

Constraints on the Kaluza-Klein gluon in warped extra dimensions

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