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:
\[ < 1.0 \times 10^{-15} \text{ cm}^{-2} \text{sr}^{-1} \text{s}^{-1} \] 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. 5) Gaugino mass unification at the GUT scale.

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

\[
\tilde{\chi}_i^0 \rightarrow \text{neutralinos (mixtures of } \tilde{\gamma}, \tilde{Z}^0, \text{ and } \tilde{\eta}_i^0) \\
\text{Mass } m_{\tilde{\chi}_1^0} > 46 \text{ GeV, CL } = 95\% \\
\quad [\text{all } \tan \beta, \text{ all } m_0, \text{ all } m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}] \\
\text{Mass } m_{\tilde{\chi}_2^0} > 62.4 \text{ GeV, CL } = 95\% \\
\quad [1 < \tan \beta < 40, \text{ all } m_0, \text{ all } m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}] \\
\text{Mass } m_{\tilde{\chi}_3^0} > 99.9 \text{ GeV, CL } = 95\% \\
\quad [1 < \tan \beta < 40, \text{ all } m_0, \text{ all } m_{\tilde{\chi}_3^0} - m_{\tilde{\chi}_1^0}] \\
\text{Mass } m_{\tilde{\chi}_4^0} > 116 \text{ GeV, CL } = 95\% \\
\quad [1 < \tan \beta < 40, \text{ all } m_0, \text{ all } m_{\tilde{\chi}_4^0} - m_{\tilde{\chi}_1^0}]
\]
\(\tilde{\chi}_1^\pm\) — charginos (mixtures of \(\tilde{W}^\pm\) and \(\tilde{H}^\pm\))

Mass \(m_{\tilde{\chi}_1^1} > 94\) GeV, CL = 95%

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

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

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

\(\tilde{\mu}\) — scalar muon (smuon)

Mass \(m > 94\) GeV, CL = 95%

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

\(\tilde{\tau}\) — scalar tau (stau)

Mass \(m > 81.9\) GeV, CL = 95%

\([m_{\tilde{\tau}_R} - m_{\tilde{\chi}_1^0} > 15\) GeV, all \(\theta_\tau\)]

\(\tilde{q}\) — 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.

Mass \(m > 1.100 \times 10^3\) GeV, CL = 95% \(\) \([\tan \beta = 10, \mu > 0, A_0 = 0]\)

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

Mass \(m > 89\) GeV, CL = 95%

\([m_{\tilde{b}_1} - m_{\tilde{\chi}_1^0} > 8\) GeV, all \(\theta_b\) ]

\(\tilde{t}\) — scalar top (stop)

Mass \(m > 95.7\) GeV, CL = 95%

\([\tilde{t} \to c \tilde{\chi}_1^0, all \theta_t, m_{\tilde{t}} - m_{\tilde{\chi}_1^0} > 10\) GeV]
The limits summarised here refer to the high-mass region ($m_{\tilde{g}} \gtrsim 5$ 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.

Mass $m > 500$ GeV, CL = 95% [any $m_{\tilde{q}}$]

### 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-$\omega$.

### 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

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

(with $g^2/4\pi$ set equal to 1), then we define $\Lambda \equiv \Lambda_{LL}^\pm$. 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.

- $\Lambda_{LL}^+(eeee) > 8.3$ 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%
\( \Lambda_{LL}^{-}(eedd) > 26.4 \text{ TeV}, \text{ CL} = 95\% \)
\( \Lambda_{LL}^{+}(eecc) > 9.4 \text{ TeV}, \text{ CL} = 95\% \)
\( \Lambda_{LL}^{-}(eecc) > 5.6 \text{ TeV}, \text{ CL} = 95\% \)
\( \Lambda_{LL}^{+}(eebb) > 9.4 \text{ TeV}, \text{ CL} = 95\% \)
\( \Lambda_{LL}^{-}(eebb) > 10.2 \text{ TeV}, \text{ CL} = 95\% \)
\( \Lambda_{LL}^{-}(\mu\mu qq) > 4.5 \text{ TeV}, \text{ CL} = 95\% \)
\( \Lambda_{LL}^{+}(\mu\mu qq) > 4.9 \text{ TeV}, \text{ CL} = 95\% \)
\( \Lambda_{LL}(\ell\nu\ell\nu) > 3.10 \text{ TeV}, \text{ CL} = 90\% \)
\( \Lambda_{LL}(e\nu qq) > 2.81 \text{ TeV}, \text{ CL} = 95\% \)
\( \Lambda_{LL}^{+}(qqqq) > 5.6 \text{ TeV}, \text{ CL} = 95\% \)
\( \Lambda_{LL}^{-}(qqqq) > 6.7 \text{ TeV}, \text{ CL} = 95\% \)
\( \Lambda_{LL}^{+}(\nu\nu qq) > 5.0 \text{ TeV}, \text{ CL} = 95\% \)
\( \Lambda_{LL}^{-}(\nu\nu qq) > 5.4 \text{ TeV}, \text{ CL} = 95\% \)

**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 \( m > 103.2 \text{ GeV}, \text{ CL} = 95\% \) (from \( e^* e^* \))
- Mass \( m > 1.070 \times 10^3 \text{ GeV}, \text{ CL} = 95\% \) (from \( e e^* \))
- Mass \( m > 356 \text{ GeV}, \text{ CL} = 95\% \) (if \( \lambda_\gamma = 1 \))

**\( \mu \)**\(^*\pm\) — excited muon

- Mass \( m > 103.2 \text{ GeV}, \text{ CL} = 95\% \) (from \( \mu^* \mu^* \))
- Mass \( m > 1.090 \times 10^3 \text{ GeV}, \text{ CL} = 95\% \) (from \( \mu \mu^* \))

**\( \tau \)**\(^*\pm\) — excited tau

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

\( \nu^* \) — excited neutrino

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

\( q^* \) — excited quark

- Mass \( m > 338 \text{ GeV}, \text{ CL} = 95\% \) (from \( q^* q^* \))
- Mass \( m > 2.490 \times 10^3 \text{ GeV}, \text{ CL} = 95\% \) (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 fundamental gravity scale
$M_{TT} > 1.74$ TeV, CL = 95% (dim-8 ops; $\Lambda = +1$; $pp \rightarrow \gamma\gamma$)
$M_C > 1.59$ TeV, CL = 95% (compactification scale with TeV extra dimensions; $p\bar{p} \rightarrow$ dijet, angular distr.)
$M_D > 1.63$ TeV, CL = 95% ($pp \rightarrow G \rightarrow \ell\ell$)

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)
$R < 72$ $\mu$m, CL = 95% ($pp \rightarrow jG$)
$R < 0.16$–916 nm (astrophysics; limits depend on technique and assumptions)