SEARCHES FOR FREE QUARKS, MONOPOLES, SUPERSYMMETRY, COMPOSITENESS, etc.

Free Quark Searches

All searches since 1977 have had negative results.

Magnetic Monopole Searches

Isolated candidate events have not been confirmed. Most experiments obtain negative results.

Supersymmetric Particle Searches

Limits are based on the Minimal Supersymmetric Standard Model.

Assumptions include: 1) $\widetilde{\chi}_1^0$ (or $\widetilde{\gamma}$) is lightest supersymmetric particle; 2) R-parity is conserved; 3) $m_{\widetilde{f}_L} = m_{\widetilde{f}_R}$, and all scalar quarks (except $\widetilde{t}_L$ and $\widetilde{t}_R$) are degenerate in mass.

See the Full 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 $m_{\widetilde{\gamma}} > 15$ GeV, CL = 90% [if $m_{\widetilde{f}} = 100$ GeV (from cosmology)]
- Mass $m_{\widetilde{\chi}_1^0} > 18$ GeV, CL = 90% [GUT relations assumed]
- Mass $m_{\widetilde{\chi}_2^0} > 45$ GeV, CL = 95% [GUT relations assumed]
- Mass $m_{\widetilde{\chi}_3^0} > 70$ GeV, CL = 95% [GUT relations assumed]
- Mass $m_{\widetilde{\chi}_4^0} > 108$ GeV, CL = 95% [GUT relations assumed]

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

- Mass $m_{\widetilde{\chi}_1^\pm} > 45$ GeV, CL = 95% [all $m_{\widetilde{\chi}_1^0}$]
- Mass $m_{\widetilde{\chi}_2^\pm} > 99$ GeV, CL = 95% [GUT relations assumed]

$\widetilde{\nu}$ — scalar neutrino (sneutrino)

- Mass $m > 37.1$ GeV, CL = 95% [one flavor]
- Mass $m > 41.8$ GeV, CL = 95% [three degenerate flavors]

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

- Mass $m > 65$ GeV, CL = 95% [if $m_{\widetilde{\gamma}} = 0$]
- Mass $m > 50$ GeV, CL = 95% [if $m_{\widetilde{\gamma}} < 5$ GeV]
- Mass $m > 45$ GeV, CL = 95% [if $m_{\widetilde{\chi}_1^0} < 41$ GeV]

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

- Mass $m > 45$ GeV, CL = 95% [if $m_{\widetilde{\chi}_1^0} < 41$ GeV]

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

- Mass $m > 45$ GeV, CL = 95% [if $m_{\widetilde{\chi}_1^0} < 38$ GeV]

$\widetilde{q}$ — scalar quark (squark)

These limits include the effects of cascade decay, for a particular choice of parameters, $\mu = -250$ GeV, $\tan\beta = 2$. The limits are weakly sensitive to these parameters over much of parameter space. Limits assume GUT relations between gaugino masses and the gauge coupling; in particular that for $|\mu|$ not small, $m_{\widetilde{\chi}_1^0} \approx m_{\widetilde{g}}/6$.

- Mass $m > 90$ GeV, CL = 90% [any $m_{\widetilde{g}} < 410$ GeV]
- Mass $m > 218$ GeV, CL = 90% [if $m_{\widetilde{g}} = m_{\widetilde{q}}$]

$\widetilde{g}$ — gluino

There is some controversy about a low-mass window ($1 \lesssim m_{\widetilde{g}} \lesssim 4$ GeV). Several experiments cast doubt on the existence of this window.

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- Mass $m > 100$ GeV, CL = 90% [any $m_{\widetilde{q}}$]
- Mass $m > 218$ GeV, CL = 90% [if $m_{\widetilde{q}} \leq m_{\widetilde{g}}$]

Searches for Quark and Lepton Compositeness

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 $\Lambda \equiv \Lambda_{LL}^\pm$. 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.

- $\Lambda_{LL}^+(eeee) > 1.6$ TeV, CL = 95%
- $\Lambda_{LL}^-(eeee) > 3.6$ TeV, CL = 95%
- $\Lambda_{LL}^+(ee\mu\mu) > 2.6$ TeV, CL = 95%
- $\Lambda_{LL}^-(ee\mu\mu) > 1.9$ TeV, CL = 95%
- $\Lambda_{LL}^+(ee\tau\tau) > 1.9$ TeV, CL = 95%
- $\Lambda_{LL}^-(ee\tau\tau) > 2.9$ TeV, CL = 95%
- $\Lambda_{LL}^+(\ell\ell\ell\ell) > 3.5$ TeV, CL = 95%
- $\Lambda_{LL}^-(\ell\ell\ell\ell) > 2.8$ TeV, CL = 95%
- $\Lambda_{LL}^+(eeqq) > 1.7$ TeV, CL = 95%
- $\Lambda_{LL}^-(eeqq) > 2.2$ TeV, CL = 95%
- $\Lambda_{LL}^+(\mu\mu qq) > 1.4$ TeV, CL = 95%
- $\Lambda_{LL}^-(\mu\mu qq) > 1.6$ TeV, CL = 95%
- $\Lambda_{LR}^\pm(\nu_\mu \nu_e \mu e) > 3.1$ TeV, CL = 90%
- $\Lambda_{LL}^\pm(qqqq) > 1.4$ 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, 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 $m > 46.1$ GeV, CL = 95% (from $e^{*+}e^{*-}$)
- Mass $m > 91$ GeV, CL = 95% (if $\lambda_Z > 1$)
- Mass $m > 127$ GeV, CL = 95% (if $\lambda_\gamma = 1$)

$\mu^{*\pm}$ — excited muon

- Mass $m > 46.1$ GeV, CL = 95% (from $\mu^{*+}\mu^{*-}$)
- Mass $m > 91$ GeV, CL = 95% (if $\lambda_Z > 1$)

$\tau^{*\pm}$ — excited tau

- Mass $m > 46.0$ GeV, CL = 95% (from $\tau^{*+}\tau^{*-}$)
- Mass $m > 90$ GeV, CL = 95% (if $\lambda_Z > 0.18$)

ν^* — excited neutrino

- Mass $m > 47$ GeV, CL = 95% (from $\nu^*\overline{\nu}^*$)
- Mass $m > 91$ GeV, CL = 95% (if $\lambda_Z > 1$)

q^* — excited quark

- Mass $m > 45.6$ GeV, CL = 95% (from $q^*\overline{q}^*$)
- Mass $m > 88$ GeV, CL = 95% (if $\lambda_Z > 1$)
- Mass $m > 540$ GeV, CL = 95% ($p\overline{p} \rightarrow q^*X$)

Color Sextet and Octet Particles

Color Sextet Quarks (q_6)

- Mass $m > 84$ GeV, CL = 95% (Stable q_6)

Color Octet Charged Leptons (ℓ_8)

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

Color Octet Neutrinos (ν_8)

- Mass $m > 110$ GeV, CL = 90% ($\nu_8 \rightarrow \nu g$)