Higgs and Sparticle Spectroscopy

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The SM Higgs Boson Mass

\[ m_h = \sqrt{\lambda} \, v \]

From the condition of perturbativity and triviality

\[ 0.8 < \sqrt{\lambda} < 1.1 \quad \Rightarrow \quad 130 < m_h < 180 \]

\[ \frac{d}{dt} \lambda = \frac{\lambda}{16\pi^2} \left[ 12\lambda^2 - 12h_t^4 + \ldots \right] \]
The MSSM Higgs Boson Mass

In the MSSM, the lightest CP-even Higgs boson mass is (when $M_A \sim M_{SUSY}$)

$$m_h^2 = \frac{g^2 + g'^2}{2} v^2 \cos^2 2\beta \left( 1 - \frac{3}{8\pi^2} \frac{m_t^2}{v^2} t \right)$$

$$+ \frac{3}{4\pi^2} \frac{m_t^4}{v^2} \left[ \frac{1}{2} \tilde{X}_t + t \right]$$

$$+ \frac{1}{16\pi^2} \left( \frac{3}{2} \frac{m_t^2}{v^2} - 32\pi \alpha_3 \right) \left( \tilde{X}_t t + t^2 \right)$$

where

$$t = \log \frac{M_{SUSY}^2}{m_t^2}, \quad \tilde{A}_t = A_t - \mu \cot \beta$$

$$\tilde{X}_t = \frac{2\tilde{A}_t^2}{M_{SUSY}^2} \left( 1 - \frac{\tilde{A}_t^2}{12M_{SUSY}^2} \right)$$
The MSSM case

\[ M_{\text{SUSY}} = M_A = 1 \text{ TeV} \]

\[ m_t = 178 \text{ GeV} \]
The CMSSM

\[ m_0, \ m_{1/2}, \ A_0, \tan \beta, \ \text{sign}(\mu), \]
\[ M_{GUT} \simeq 2 \times 10^{16}\text{GeV} \]

Scanning procedure

Bounds from the LEP2 experiment

Chargino mass to be \( m_{\tilde{W}_1^+} \geq 103.5 \text{ GeV} \), the lighter stop squark mass \( m_{\tilde{t}_1} \geq 101.5 \text{ GeV} \) and \( m_{\tilde{\tau}_1} \geq 98.8 \text{ GeV} \) for the lighter stau slepton mass provided the mass difference \( m_{\tilde{\tau}_1} - m_{\tilde{W}^0_1} > 10 \text{ GeV} \).

We use constraints coming from combination of WMAP and the Sloan Digital Sky Survey data

\[ \Omega_{\text{CDM}}h^2 = 0.111^{+0.011}_{-0.015} \ (2\sigma) \]
We use the following range for the muon anomalous magnetic moment $a_\mu = \frac{(g-2)_\mu}{2}$

$$-5.7 \cdot 10^{-10} \leq \alpha_{\mu,SUSY} \leq 4.7 \cdot 10^{-9}$$

Combining experimental and theoretical errors in quadratures we apply the following constraints at $2\sigma$ level in our study:

$$2.85 \cdot 10^{-4} \leq Br(b \to s\gamma) \leq 4.24 \cdot 10^{-4}.$$
Numerical calculation

\[ 0 \leq m_0 \leq 5 \text{ TeV}, \quad 0 \leq m_{1/2} \leq 2 \text{ TeV} \]
\[ A_0 = 0, \quad -1 - 2 \text{ TeV}, \quad \tan \beta = 10, 30, 50 \]

with \( \mu > 0 \) and \( m_t = 171.4 \text{ GeV} \).
FIG. 1: Allowed region for CP odd Higgs mass versus $m_h$ (with $\tan \beta = 30$). Red (+), green (x) and blue (*) correspond to $A_0 = 0, -1$ and $-2$ TeV respectively.
FIG. 1: Allowed region for neutral Higgs mass versus $m_h$ (with $\tan\beta = 30$). Red (+), green (x) and blue (*) correspond to $A_0 = 0, -1$ and $-2$ TeV respectively.

FIG. 2: Allowed region for gluino mass versus $m_h$ (with $\tan\beta = 30$). Red (+), green (x) and blue (*) correspond to $A_0 = 0, -1$ and $-2$ TeV respectively.
FIG. 1: Allowed region for wino mass versus $m_h$ (with tan $\beta = 30$). Red (+), green (x) and blue (*) correspond to $A_0 = 0, -1$ and $-2$ TeV respectively.

FIG. 2: Allowed region for lightest neutralino mass versus $m_h$ (with tan $\beta = 30$). Red (+), green (x) and blue (*) correspond to $A_0 = 0, -1$ and $-2$ TeV respectively.
FIG. 1: Allowed region for top squark mass $m_{\tilde{t}}$ versus $m_h$ (with $\tan \beta = 30$). Red (+), green (x) and blue (*) correspond to $A_0 = 0, -1$ and $-2 \text{ TeV}$ respectively.

FIG. 2: Allowed region for up squark mass $m_{\tilde{u}}$ versus $m_h$ (with $\tan \beta = 30$). Red (+), green (x) and blue (*) correspond to $A_0 = 0, -1$ and $-2 \text{ TeV}$ respectively.
FIG. 1: Allowed region for stau mass versus $m_h$ (with $\tan \beta = 30$). Red (+), green (x) and blue (*) correspond to $A_0 = 0, -1$ and $-2$ TeV respectively.

FIG. 2: Allowed region for selectron mass versus $m_h$ (with $\tan \beta = 30$). Red (+), green (x) and blue (*) correspond to $A_0 = 0, -1$ and $-2$ TeV respectively.
Conclusion

We present an updated scan of the CMSSM parameter space, taking into account the revised (lower) value of $m_t$, new information on the sign of the matrix element for $b \to s + \gamma$ decay, and dark matter abundance constraint from WMAP3. With $\mu > 0$, and for a plausible range of values for $m_0$, $m_{1/2}$ and $|A_0|$ and for $\tan \beta = 30$, we have provided bounds on the masses of Higgs bosons and sparticles in CMSSM.