The MSSM without μ term

A. Nelson, N.R., V. Sanz, M. Unsal

SUSY 2002

Contents

- The $\not\mu$SSM and its low energy spectrum
- $U(1)_R$ Symmetric Gauge Mediation
- Contribution to precision electroweak parameters
  - T parameter
  - Muon anomalous magnetic moment
- Unification of couplings

The $\not\mu$SSM

- No supersymmetric μ term in the superpotential
- Approximate $U(1)_R$ symmetry forbids Majorana masses
- Additional chiral superfields: S, T (adjoint of SU(2)) and O (adjoint of SU(3))
- Superpotential couplings

$$\int d^2\theta \;\; h_S S H_1 H_2 + h_T H_1 T H_2$$

- Usual MSSM superpotential for quarks and leptons allowed

$U(1)_R$ charges

Ψ_{H_1}	Ψ_{H_2}	$\Psi_T^{\pm}$	H_1	H_2	$\lambda^{\pm}$
1	-1	-1	2	0	1

Trilinear terms prohibited by $U(1)_R$ symmetry $\Longrightarrow$ suppresses tadpole for the T scalar

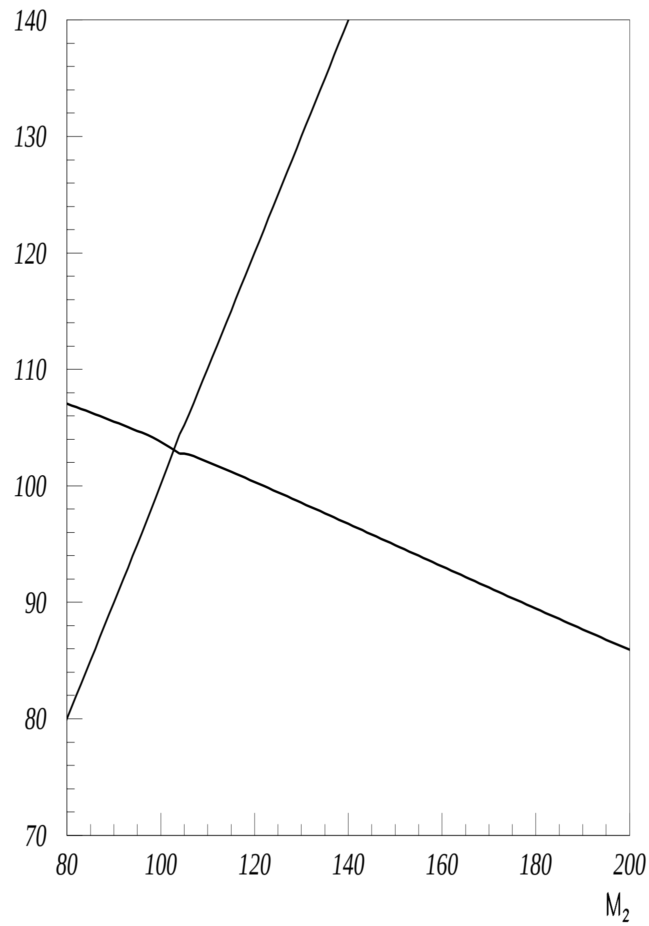
Small $U(1)_R$ breaking effects $\mu B H_1 H_2$ set $\tan\beta \sim 60 \Longrightarrow$ explains top/bottom mass hierachy

Chargino mass matrix

	Ψ_T^+	$-i\lambda^+$	$\Psi_{H_2}^+$
Ψ_T^-	0	$\tilde{M}_2$	$-h_T\, v_1$
$-i\lambda^-$	$\tilde{M}_2$	$\tilde{m}_2$	$\sqrt{2}\, m_W\, s_\beta$
$\Psi_{H_1}^-$	$h_T\, v_2$	$\sqrt{2}\, m_W\, c_\beta$	0

$\mu\!\!\!/$SSM

Lighter chargino masses ($\tilde{m}_2 = 5$ GeV)



LEP II limit $m_{\chi^\pm} > 104\text{GeV} \Longrightarrow$

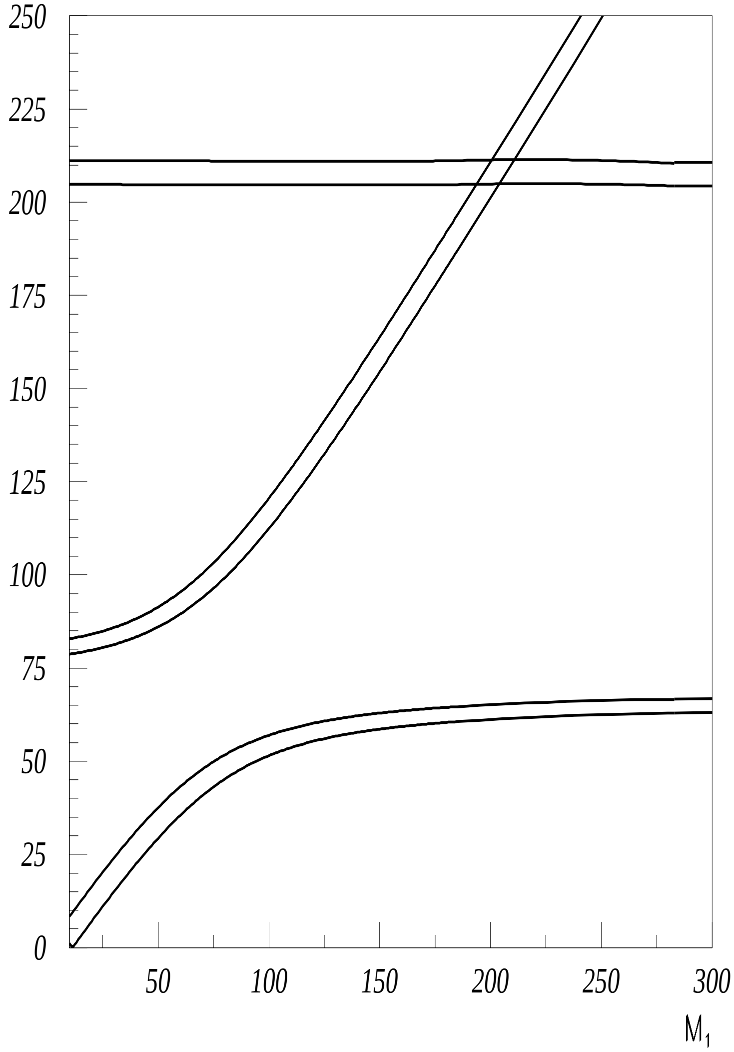
104 GeV $< \tilde{M}_2 <$ 120 GeV and $h_T \sim 1$

μSSM

$\not\mu$SSM

	Ψ_T^3	Ψ_S	$-i\lambda'$	$-i\lambda^3$	$\Psi_{H_1}^1$	$\Psi_{H_2}^2$
Ψ_T^3	0	0	0	$\tilde{M}_2$	$h_T \frac{v_2}{\sqrt{2}}$	$h_T \frac{v_1}{\sqrt{2}}$
Ψ_S	0	0	$\tilde{M}_1$	0	$h_S \frac{v_2}{\sqrt{2}}$	$h_S \frac{v_1}{\sqrt{2}}$
$-i\lambda'$	0	$\tilde{M}_1$	$\tilde{m}_1$	0	$-m_Z\, s_W\, c_\beta$	$m_Z\, s_W\, s_\beta$
$-i\lambda^3$	$\tilde{M}_2$	0	0	$\tilde{m}_2$	$m_Z\, c_W\, c_\beta$	$-m_Z\, c_W\, s_\beta$
$\Psi_{H_1}^1$	$h_T \frac{v_2}{\sqrt{2}}$	$h_S \frac{v_2}{\sqrt{2}}$	$-m_Z\, s_W\, c_\beta$	$m_Z\, c_W\, c_\beta$	0	0
$\Psi_{H_2}^2$	$h_T \frac{v_1}{\sqrt{2}}$	$h_S \frac{v_1}{\sqrt{2}}$	$m_Z\, s_W\, s_\beta$	$-m_Z\, c_W\, s_\beta$	0	0

Neutralino masses



$$h_T = 1, h_S = 0.1, \tilde{M}_2 = 104 \text{ GeV}$$

$$\tilde{m}_1 = \tilde{m}_2 = 5 \text{ GeV} \ , \ \tan\beta = 60$$

$\mu\!\!\!/$SSM

$U(1)_R$ Gauge Mediation

- No singlet messengers

- SB mediated by some gauge U(1) group also carried by the messengers $\Longrightarrow$ nonholomorphic scalar SUSY breaking masses for the messangers

- Tr $T_Y T_{new} = 0 \Longrightarrow$ no D term for hypercharge

Messengers: $L, \bar{L}$ $(D, \bar{D})$ transform as the fundamental of SU(2) (SU(3))

$$\lambda_S S\bar{L}L + \lambda'_S S\bar{D}D + \lambda_T T\bar{L}L + \lambda_O O\bar{D}D + M_L\bar{L}L + M_D\bar{D}D$$

$L, \bar{L}$ mass matrix

$$\begin{pmatrix} M_L^2 + \tilde{m}_L^2 & 0 \\ 0 & M_L^2 + \tilde{m}_{\bar{L}}^2 \end{pmatrix}$$

soft SUSY breaking masses $\tilde{m}_{\bar{L}}^2 + \tilde{m}_L^2 < 0$

$\Longrightarrow$ scalar superpartner masses

Large soft masses for the scalar S, T, O

$$\tilde{m}_a \sim \frac{g_a^2}{16\pi^2} M_L$$

$$\tilde{m}_a \lesssim 10 \text{ TeV} \to M_L \sim 10^6 \text{ GeV}$$

Dirac SUSY breaking masses couple gauginos and fermionic components of S, T, O :

$$\tilde{M}_2 \sim S_L \frac{g_2 \lambda_T}{4\pi^2} \frac{\tilde{m}_{\bar{L}}^2 - \tilde{m}_L^2}{M_L}$$

- small μ and μB terms induced, without the usual problem of gauge mediated models

$\not\mu$SSM

The $\not\mu$SSM model may also arise in hidden sector models with gravity mediated SUSY breaking

- hidden SUSY breaking sector does NOT contain any SINGLET
- gauged U(1) with a non-vanishing D-term

T parameter

h_T and h_S superpotential couplings break custodial SU(2) symmetry $\Longrightarrow$ large one-loop contributions to T parameter

$$T \sim \frac{h_T^2 v^2}{16\pi m_Z^2 s_W^2 c_W^2} \log\left(\frac{h_T^2 v^2}{m_Z^2}\right)$$

$m_{\chi^\pm} > 104\mathrm{GeV} \rightarrow h_T \sim 1 \rightarrow T \sim 2.5$

$m_{\chi^\pm} > 90\mathrm{GeV} \rightarrow h_T \sim 0.6 \rightarrow T \sim 0.6$

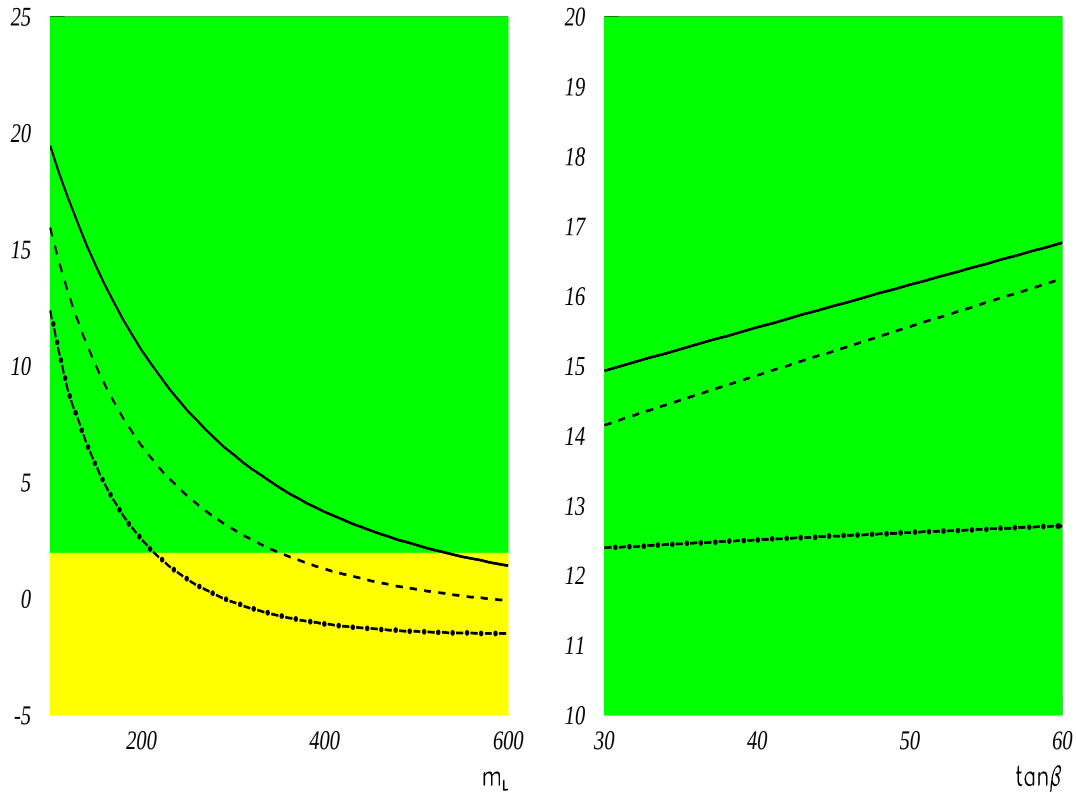
But ...

- Non standard contributions to Z width from lightest nearly Dirac neutralinos
- Oblique approximation not appropriate for light superpartners
- More careful study needed

$\not\mu$SSM

Maximum $\delta a_\mu \times 10^{10}$

$\tan\beta = 60$ $m_L = 100$ GeV



$\tilde{m}_2 = 0$ GeV $\tilde{m}_2 = 5$ GeV

$\tilde{m}_2 = 10$ GeV

Strong suppression due to small Majorana masses

μ̸SSM

Unification of couplings

One can embed the T, S, O fields into a complete adjoint multiplet of $SU(3)^3$ or $SU(5)$

$$(1, 2, \pm 1/2) + (1, 1, \pm 1) + (1, 1, \pm 1)$$

$$(3, 2, -5/6) + (\bar{3}, 2, 5/6)$$

GUT scale $\sim 10^{18}$

messenger scale $\sim 10^{7}$