A Gauge-Mediated Embedding of the S-MSSM

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Based on publications arXiv:1005.1282 and arXiv:1005.XXXX by Antonio Delgado, Christopher Kolda, J. P. O. and Alejandro de la Puente.

Goal of Embedding S-MSSM

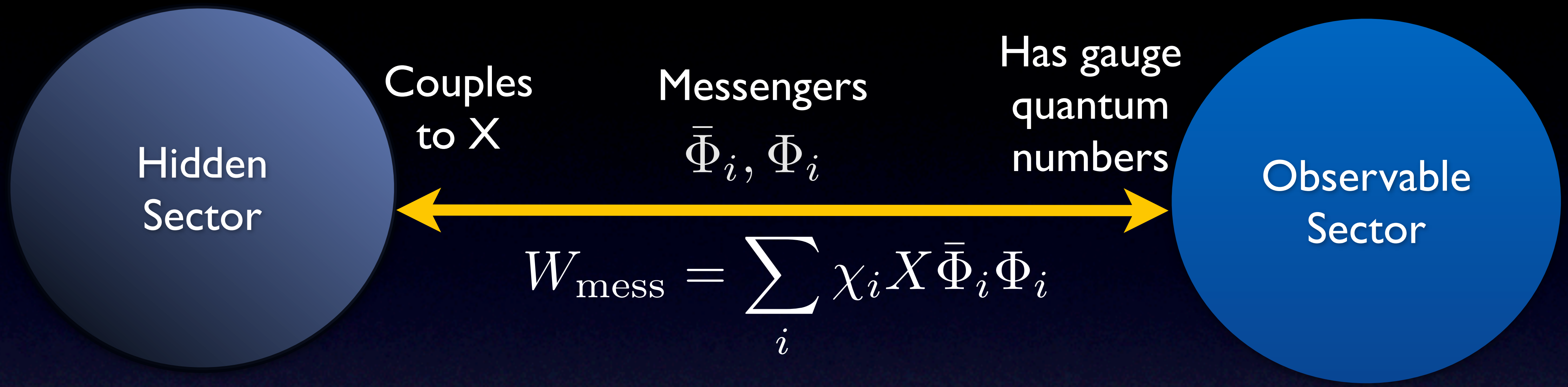
Previous talk discussed advantages of S-MSSM as a low energy theory.

We wish to embed the S-MSSM in a predictive SUSY breaking scheme: Gauge Mediation.

Review history of embedding singlet models in GMSB.

Discuss scanning the S-MSSM parameter space, lifting lightest Higgs mass without heavy stops.

Gauge Mediated Supersymmetry Breaking



$$\bar{\Phi}_i, \Phi_i$$

$$W_{\text{mess}} = \sum_i \chi_i X \bar{\Phi}_i \Phi_i$$

$$\langle X \rangle = M + \theta^2 F$$

?

Chiral Superfield X

Quarks
Leptons
Higgs
Superpartners

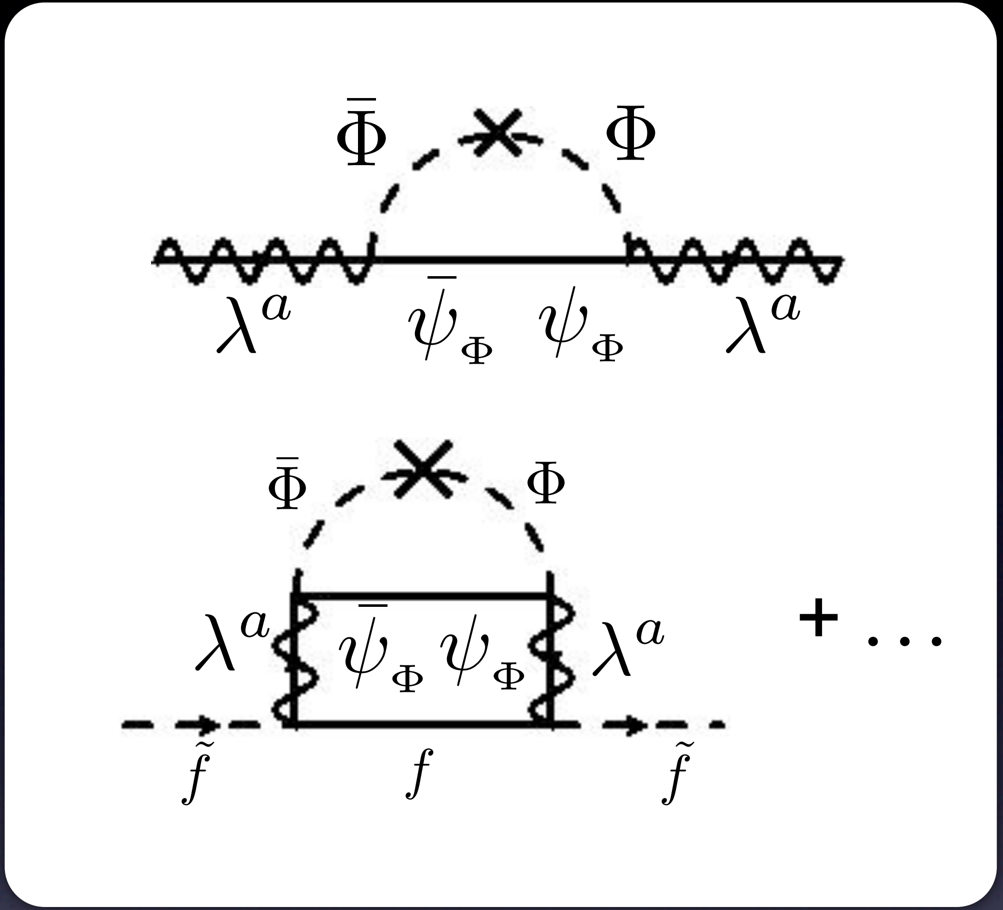
GMSB flavor blind

Soft Breaking Terms

$$M_i(M) = n\frac{\alpha_i}{4\pi}\frac{F}{M}$$

$$m^2_{\tilde{f}}(M) = 2n\sum_i C_i^{\tilde{f}}\frac{\alpha_i^2}{16\pi^2}\left(\frac{F}{M}\right)^2$$

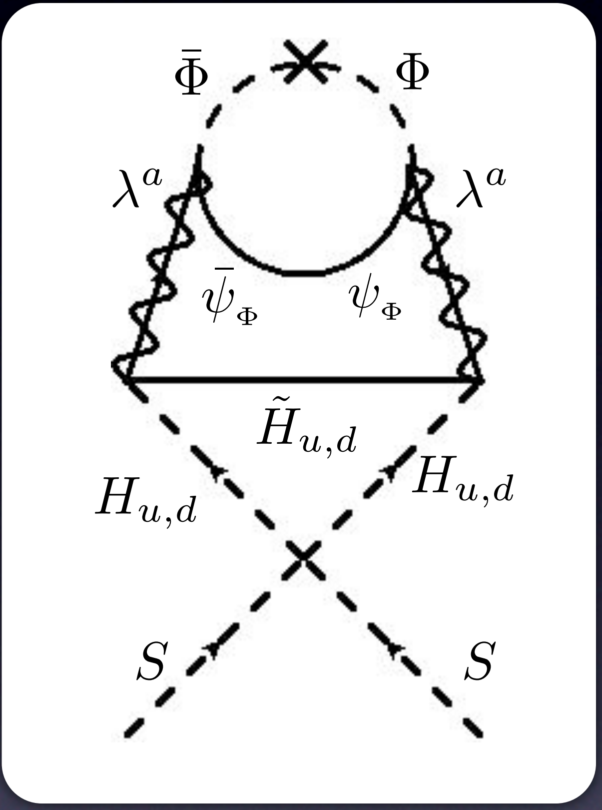
$$A_i(M) = 0$$



n number of messenger pairs, $C_i^{\tilde{f}}$ quadratic Casimir

Minimal Form

$$W = \lambda S H_u H_d + \frac{1}{3}\kappa S^3 + \chi X \bar{\Phi}\Phi$$



Generates m_s^2 at 3-loops

Problem: m_s^2 too small

⇒ m_s^2 gives the Singlet a vev

⇒ $\mu_{\text{eff}} \equiv \lambda v_s$ needed to give mass to charginos

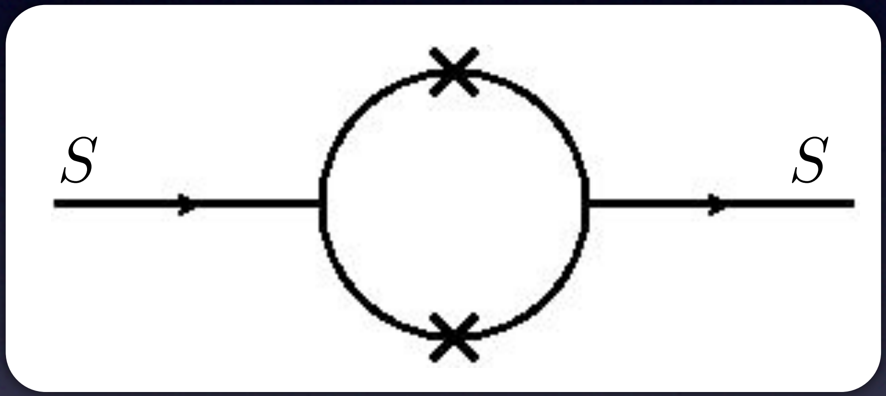
⇒ ruled out by experiment

(de Gouvea, Friedland and Murayama 1998)

Couple Singlet to Messengers

$$W = \lambda S H_u H_d + \frac{1}{3}\kappa S^3$$
$$+\chi X \bar{\Phi}\Phi + \underline{\chi_s S \bar{\Phi}\Phi}$$

Generates m_s^2 at 1-loop



Problem: m_s^2 too big

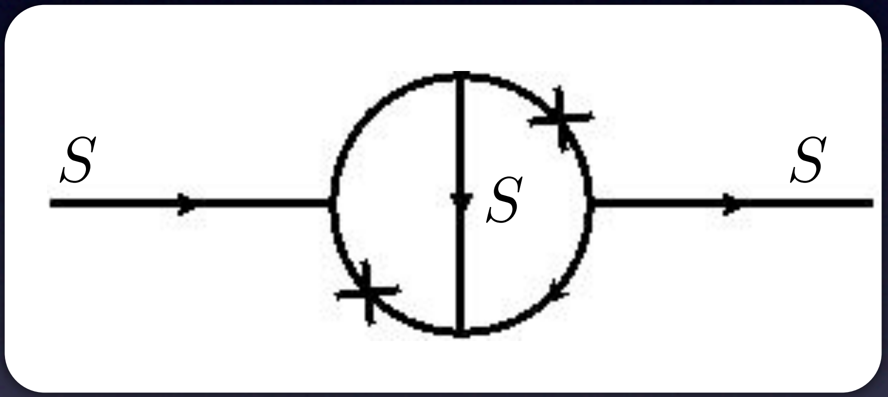
$\Rightarrow$ vacuum overstabilized

Can generate tadpoles, to cancel part of m_s^2, but not calculable.

Increase Number of Messengers

$$W = \lambda S H_u H_d + \frac{1}{3}\kappa S^3$$
$$+\chi X(\bar{\Phi}_1\Phi_1 + \bar{\Phi}_2\Phi_2) + \chi_s S\bar{\Phi}_1\Phi_2$$

Generates m_s^2 at 2-loops



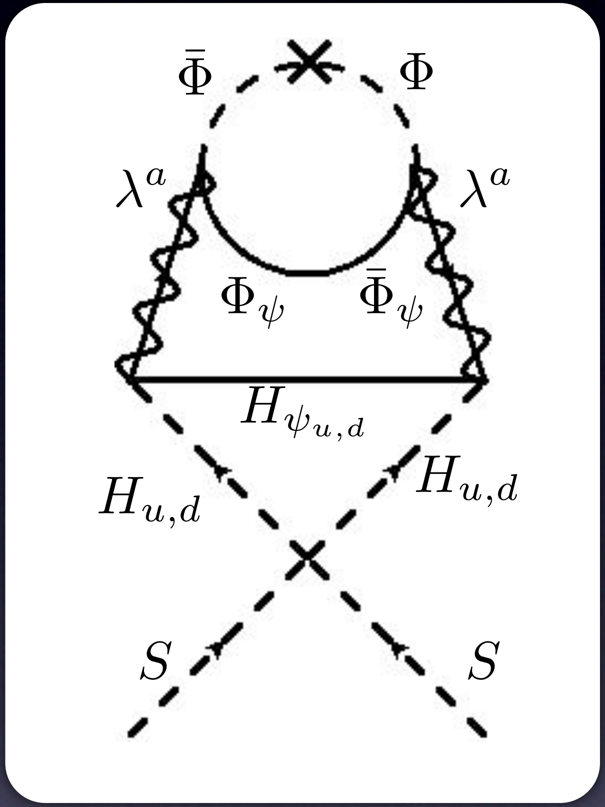
Problem:

Generates μ_{eff} of right order, but need a heavy spectrum to get m_h above LEP bound

(Delgado, Giudice and Slavich 2007)

S-MSSM Can Use Minimal GMSB

$$W = (\mu + \lambda S) H_u H_d + \frac{1}{2}\mu_s S^2 + \chi X \bar{\Phi}\Phi$$



Generates m_s^2 at 3-loops

No Problem:

m_s^2 is allowed to be small,
not needed to generate μ term.

S-MSSM Potential

Neutral Scalar Higgs Potential

$$V_H^0 = \frac{1}{8}(g^2 + g'^2)(|H_d^0|^2 - |H_u^0|^2)^2$$
$$+ (m_u^2 + |\mu + \lambda S|^2)|H_u^0|^2 + (m_d^2 + |\mu + \lambda S|^2)|H_d^0|^2$$
$$+ m_s^2|S|^2 + |\mu_s S - \lambda H_u^0 H_d^0|^2$$
$$+ (B_s S^2 - (B_\mu + \lambda A_\lambda S)(H_u^0 H_d^0) + h.c.)$$

g, g′ are gauge couplings in SU(2) and U(1)

soft-breaking terms

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Inputs: F, M determine soft-breaking terms

μ, μ_s, B_s, tanβ

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Inputs: F, M determine soft-breaking terms

μ, μ_s, B_s , tanβ

Outputs: λ, B_μ, v_s

Scanning Parameter Space

For a given M, μ, μ_s, tanβ,

- Fix λ to be largest λ still perturbative at GUT scale
- Fix F/M so that v = 174 GeV
- Derive B_μ as an output

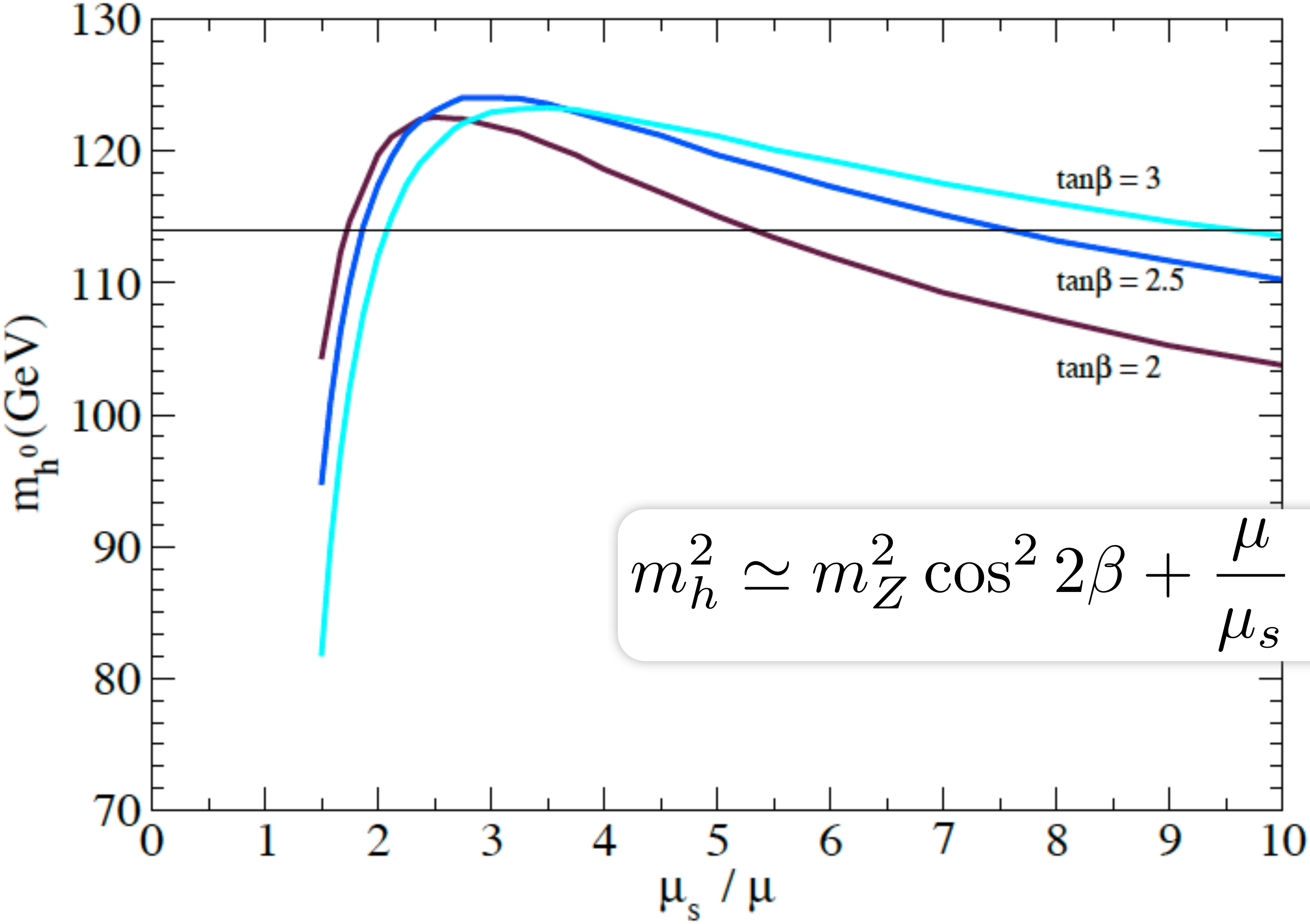
Numerically calculate spectrum

Predominant LEP constraints:

- NLSP (lightest neutralino), depends where decays
  - outside detector ($\sqrt{F} \gtrsim 10^6$ GeV) 46 GeV
  - inside detector ($\sqrt{F} \lesssim 10^6$ GeV) 96 GeV
- Chargino (tanβ<40) 94 GeV

Scanning Parameter Space

Maximize m_h using μ_s



$m_{\tilde{t}} < 1 \text{ TeV}$

$$m_h^2 \simeq m_Z^2 \cos^2 2\beta + \frac{\mu}{\mu_s}\left(4\lambda^2 v^2 \sin 2\beta\right)$$

Sampling of Results

M	$\tan\beta$	μ	μ_s/μ	$m_{\tilde{t}}$	MSSM m_h	m_h
10^8	2	600	2.5	920, 790	86	123
10^8	6	500	6	900, 750	110	117
10^{13}	2	400	2.5	460, 360	74	115
10^{13}	2	850	2.5	960, 710	85	123
10^{13}	2.5	750	2.75	960, 730	94	124
10^{13}	3	700	3.5	970, 730	100	123
10^{13}	6	400	6	630, 470	107	114
10^{13}	6	600	6	940, 720	111	118

(all masses in GeV)

Not sensitive to number of messenger pairs

Phenomenology of S-MSSM is same as MSSM, but with heavier Higgs than would be expected for the stop masses

Conclusion

By sacrificing the solution to the μ-problem, we find in the S-MSSM a solution to the little hierarchy problem.

We have successfully embedded the S-MSSM in Gauge Mediation.

There are large regions of parameter space, where the stops are below a TeV and the lightest Higgs is above the LEP bound.