What does g-2 tell us about Supersymmetry?

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1. Supersymmetry dependences (tanβ)
2. Higgs Exempt No-Scale Supersymmetry
3. Importance of a good measurement of g-2

Supersymmetry Predictions

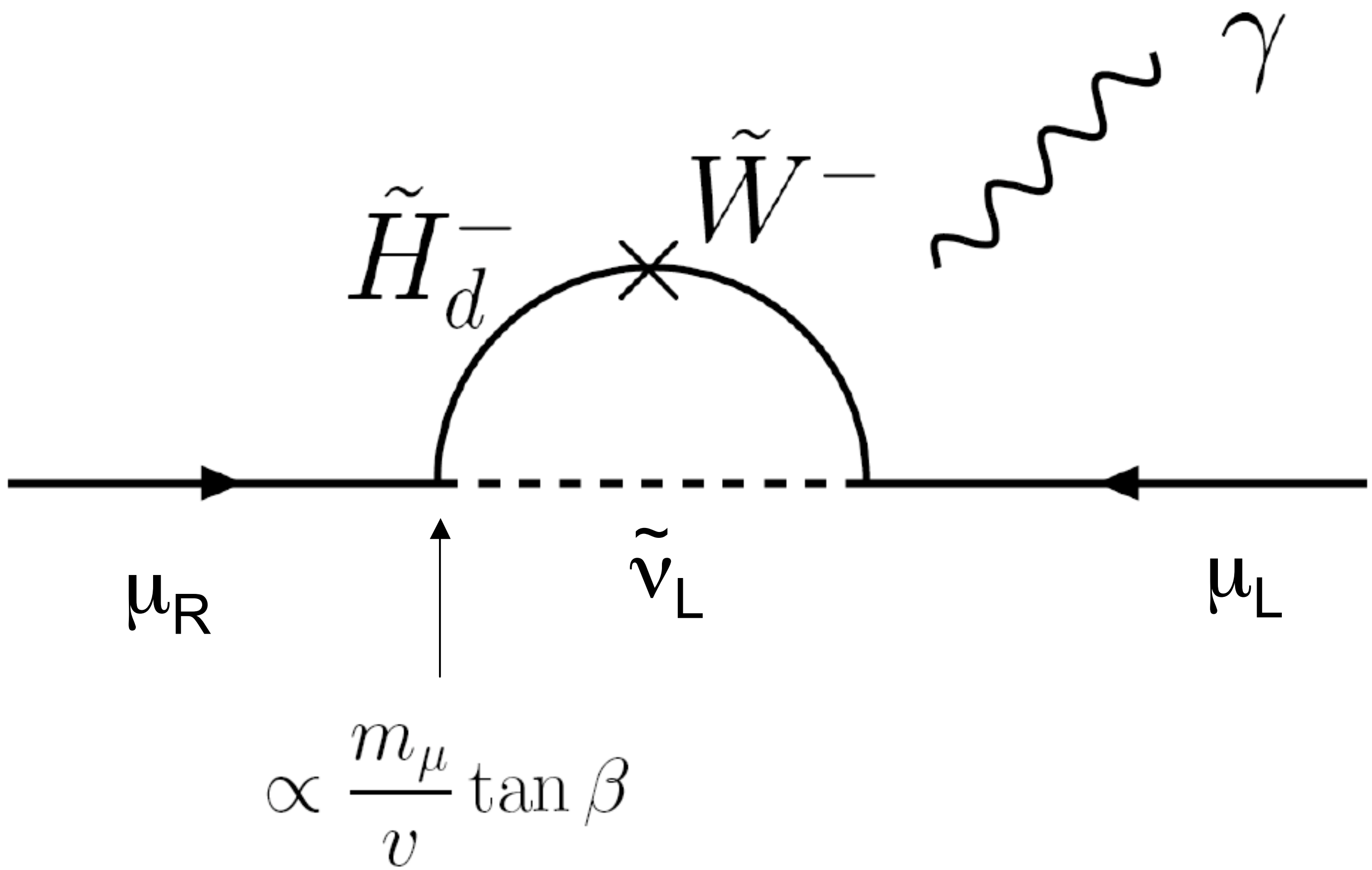
If all superpartners have the same mass, the SUSY prediction for a_μ is

$$\delta a_\mu^{SUSY} = 14 \tan\beta \left(\frac{100\,\mathrm{GeV}}{M_{SUSY}} \right)^2 \times 10^{-10}$$

Where $\tan\beta$ is ratio of vacuum expectation values of the two Higgs doublets of the MSSM:

$\tan\beta = \langle H_u \rangle / \langle H_d \rangle$

Chiral Flip brings tanβ



Large tanβ theories

Large values of tanβ generically required for SUSY to have an effect on g-2.

What theories of Supersymmetry like or require large values of tanβ?

1. No-scale Supersymmetry

2. Yukawa Unified Supersymmetry

We shall consider viable versions of these theories, and ask if “large” g-2 contributions are allowed.

SUSY breaking resides in <F> of chiral multiplet

$$X = x + \sqrt{2}\psi\theta + F\theta^2$$

This leads to gravitino mass: $m_{3/2}^2 \sim \frac{F^\dagger F}{M_{\rm Pl}^2}$

Gaugino masses: $\int d^2\theta \frac{X}{M_{\rm Pl}} \mathcal{W}\mathcal{W} \sim m_{3/2}\lambda\lambda$

Scalar masses: $\int d^2\theta d^2\bar{\theta} \frac{X^\dagger X}{M_{\rm Pl}^2} \Phi_i^\dagger \Phi_i \rightarrow m_{3/2}^2 \phi_i^* \phi_i$

Everybody $\sim m_{3/2}$, and $m_{3/2} \sim m_W$ for naturalness.

Challenges for Low-Energy SUSY

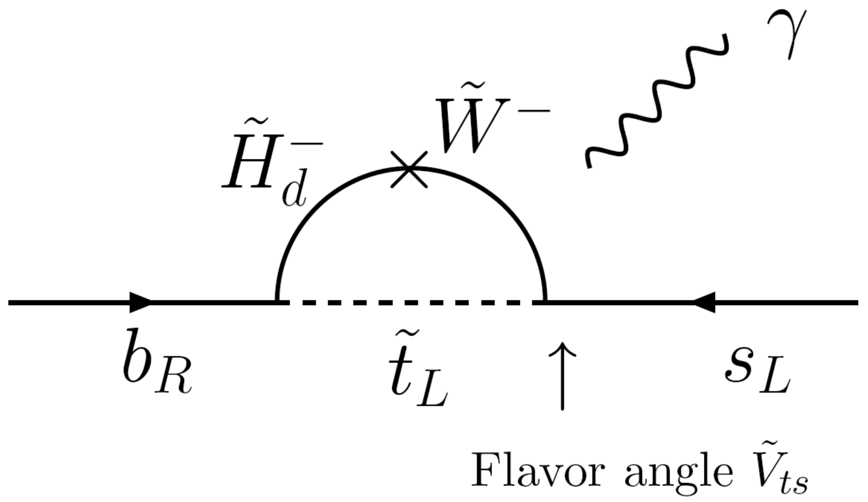
Throw a dart into Minimal SUSY parameter space,
And what do you get?

Observable predictions would be wildly Incompatible with experiment.

Briefly review these challenges ….

Flavor Changing Neutral Currents

Random superpartner masses and mixing angles would generate FCNC far beyond what is measured:



However: heavy or universal scalars would squash these FCNCs

Higgs boson mass

In minimal supersymmetry the lightest Higgs mass is computable:

$$m_h^2 = m_Z^2 \cos^2 2\beta + \frac{3G_F m_t^4}{\sqrt{2}\pi^2} \log \frac{\tilde{m}_t^2}{m_t^2} + \cdots$$

Tree-level value is bounded by $m_Z = 91\,\mathrm{GeV}$. Current lower limit on Higgs boson mass is $114\,\mathrm{GeV}$. Thus, we need $\sim (70\,\mathrm{GeV})^2$ contribution from quantum correction.

Need $\tilde{m}_t \gtrsim 5\,\mathrm{TeV}(0.8\,\mathrm{TeV})$ for $\tan\beta = 2(30)$

Large tanβ especially needed if scalar masses small

Higgs-exempt No Scale

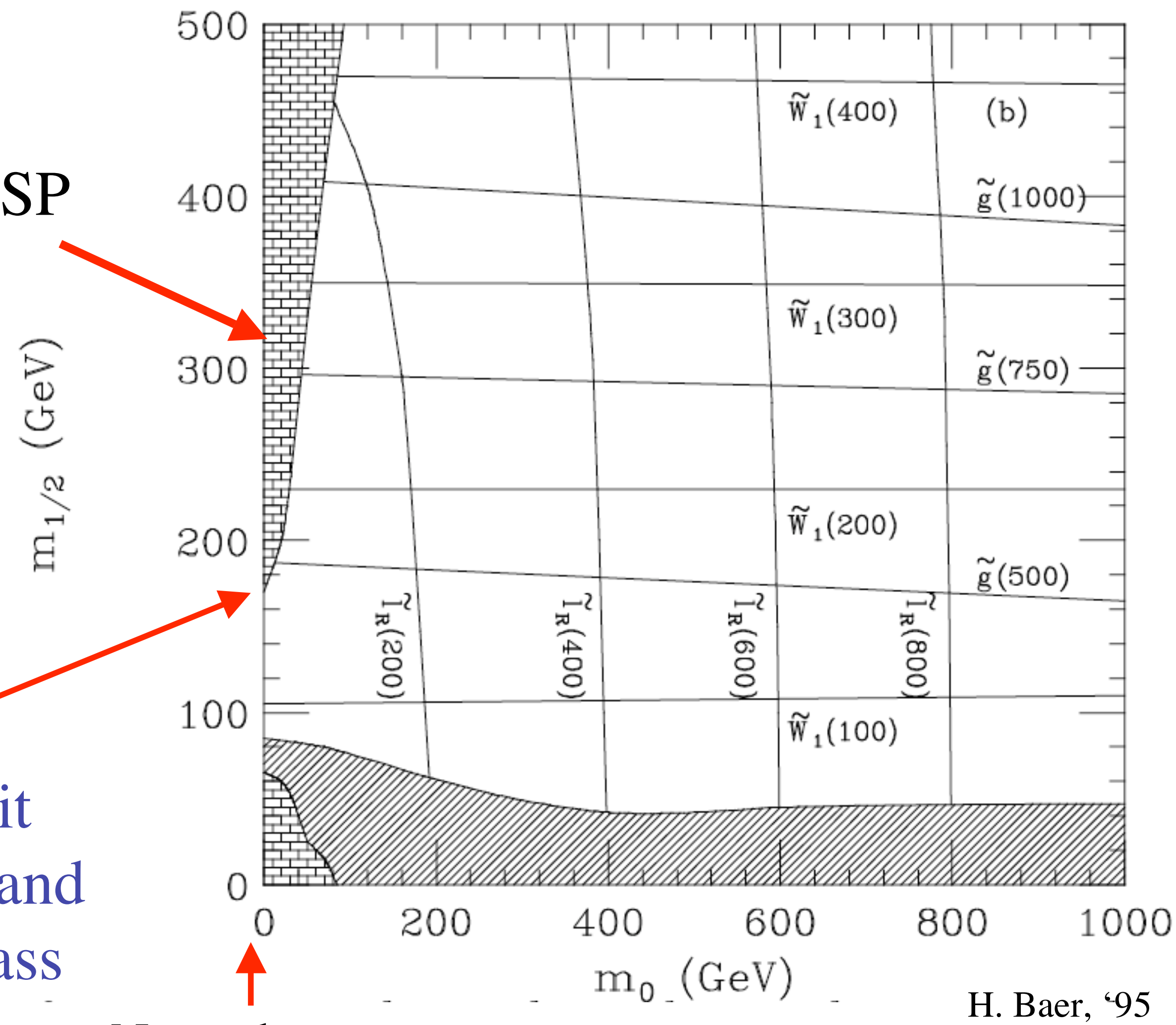
Goal is to increase the $m_{1/2}$ (gaugino masses) which then can increase scalar superpartner masses via RGE flow, and can increase Higgs mass.

FCNC under control if slepton,squarks mass = 0

Pure no-scale minimal susy does not work.
Exempt the Higgs bosons from no-scale constraint.

What's wrong with no-scale supersymmetry?

Charged LSP



Upper limit on $m_{1/2}$ which leads to upper limit on superpartners, and too light Higgs mass

No scale

H. Baer, '95

Relevant Equations

The scalar RGE equations with non-universal soft masses:

$$(4\pi)^2 \frac{dm_i^2}{dt} \simeq X_i - 8 \sum_a C_i^a \, g_a^2 \, |M_a|^2 + \frac{6}{5} \, g_1^2 \, Y_i \, S$$

$$S = (m_{H_u}^2 - m_{H_d}^2) + tr_F (m_Q^2 - 2m_U^2 + m_E^2 + m_D^2 - m_L^2)$$

This induces a potentially significant shift in masses:

$$\Delta m_i^2 = -\frac{Y_i}{11} \left[1 - \left(\frac{g_1}{g_{GUT}} \right)^2 \right] S_{GUT} \simeq -(0.052) \, Y_i \, S_{GUT}$$

Some numbers

Compare gaugino masses …

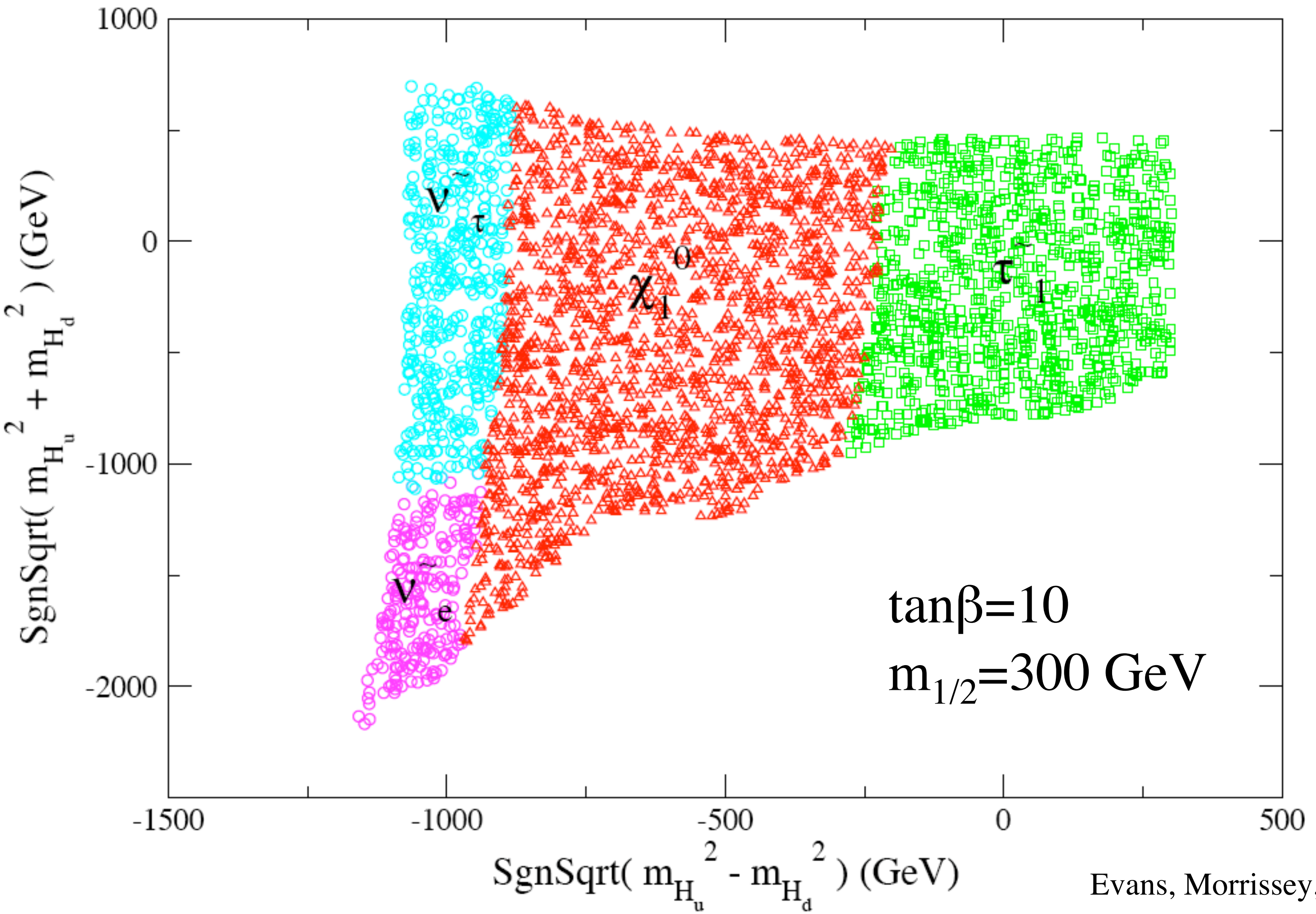
$$M_1 \simeq (0.43)\, M_{1/2}, \quad M_2 \simeq (0.83)\, M_{1/2}, \quad M_3 \simeq (2.6)\, M_{1/2}$$

With slepton masses (negative S helps lift m_E):

$$\begin{aligned} m_L^2 &\simeq \left[(0.68)\, M_{1/2}\right]^2 + \frac{1}{2}(0.052)\, S_{GUT} \\ m_E^2 &\simeq \left[(0.39)\, M_{1/2}\right]^2 - (0.052)\, S_{GUT}. \end{aligned}$$

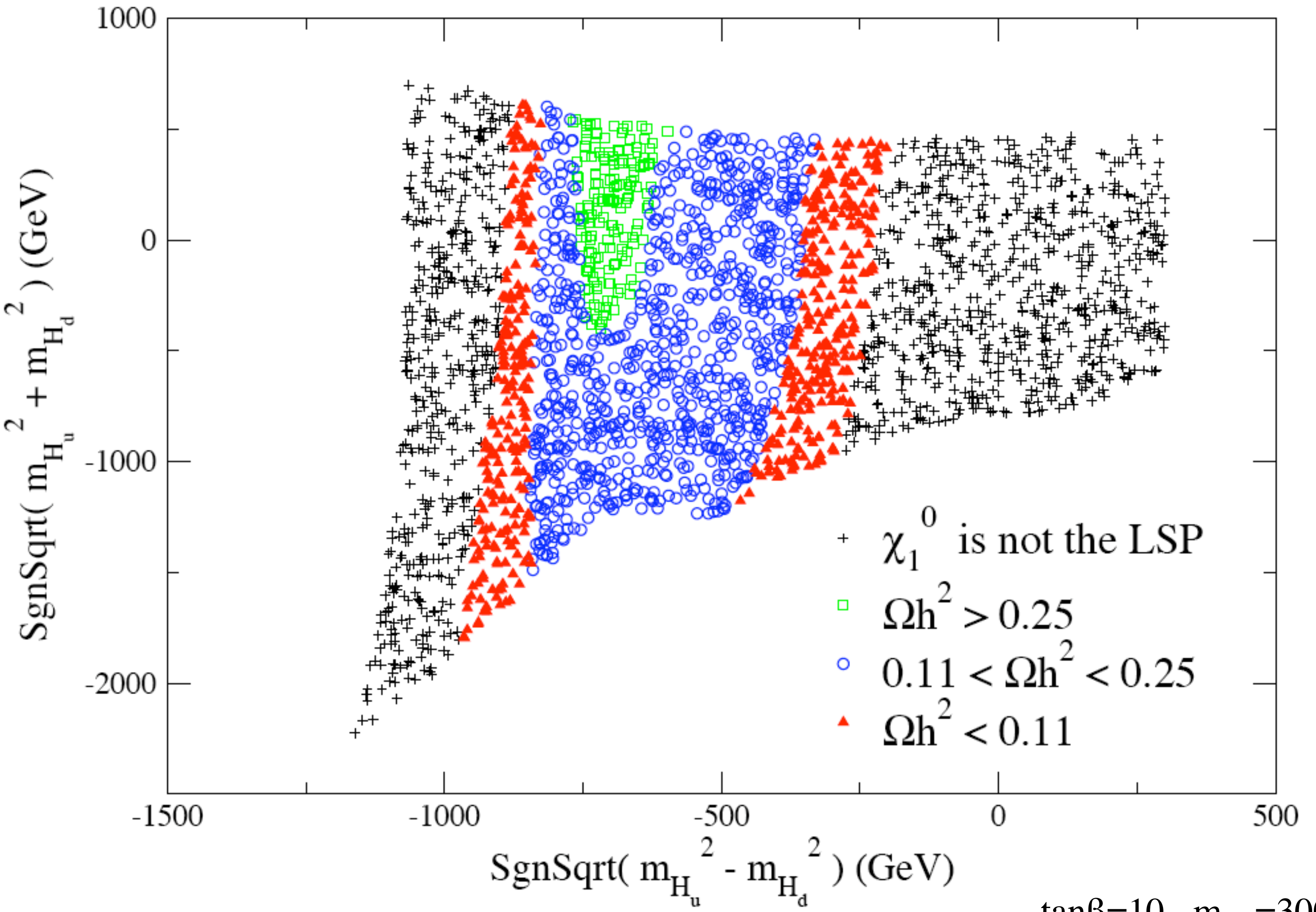
$$S_{GUT} = (m_{H_u}^2 - m_{H_d}^2)$$

LSP in Higgs-exempt No-Scale

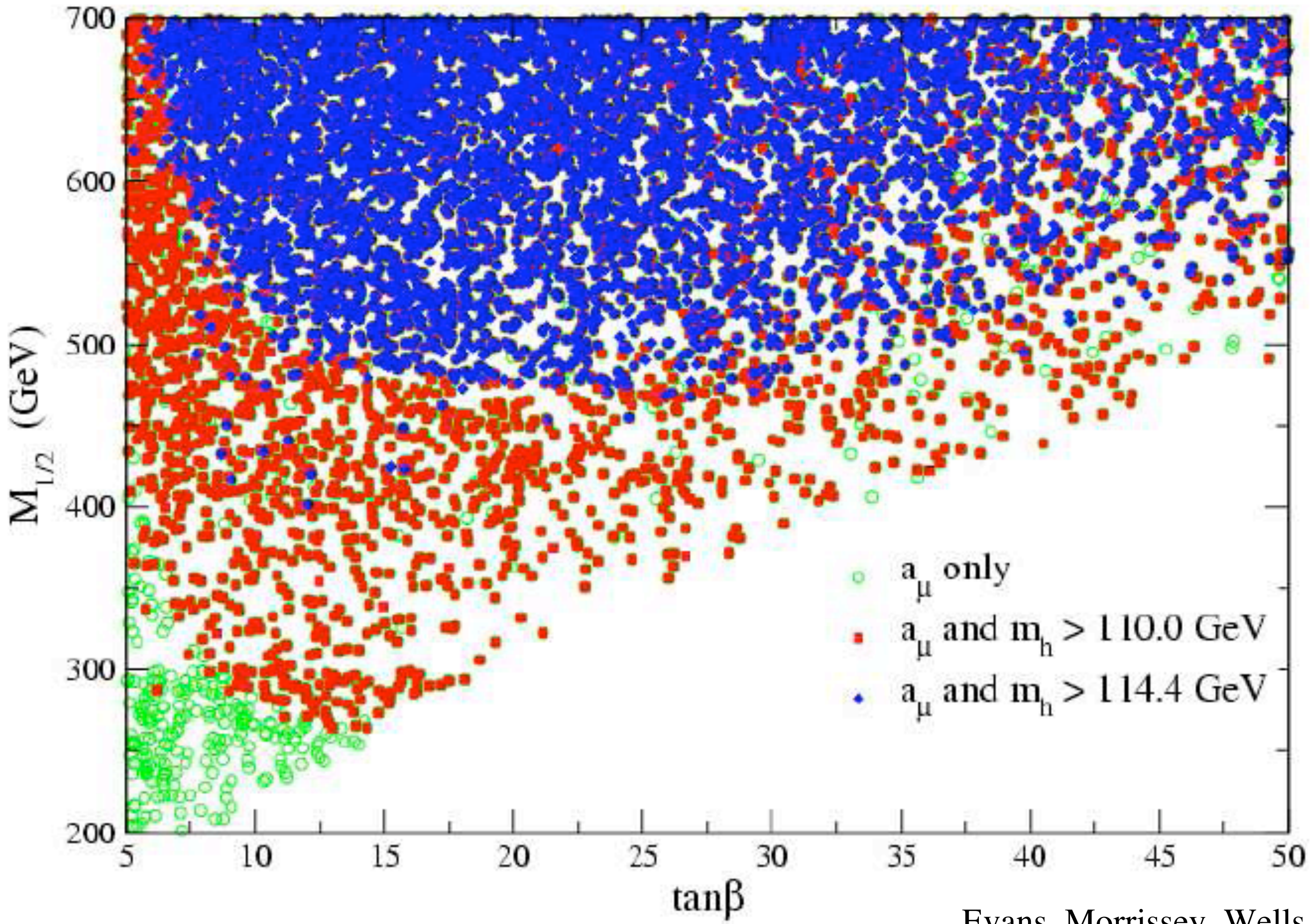


Evans, Morrissey, JW

Dark Matter Relic Abundance



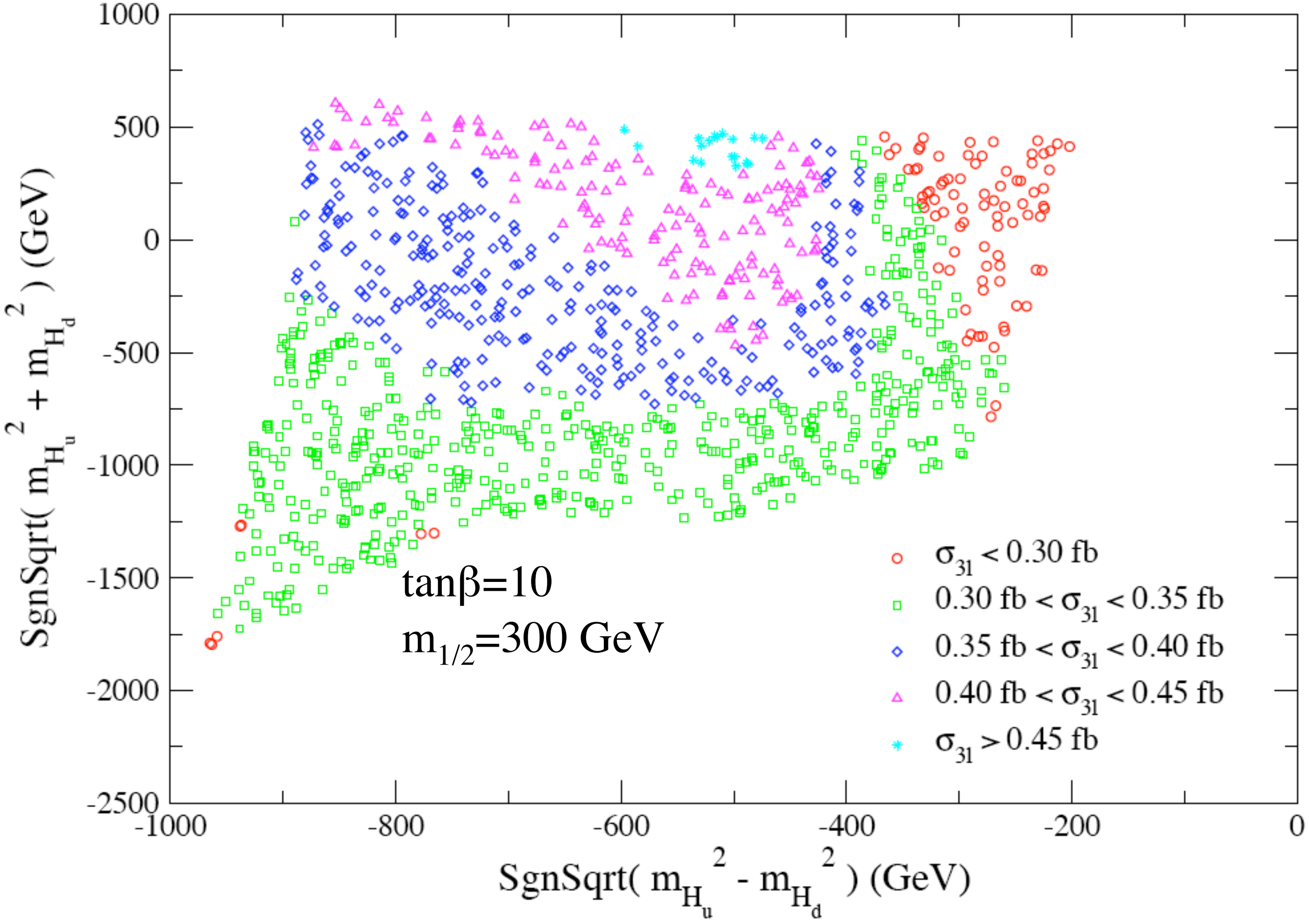
$\tan\beta=10$, $m_{1/2}=300$ GeV



Evans, Morrissey, Wells

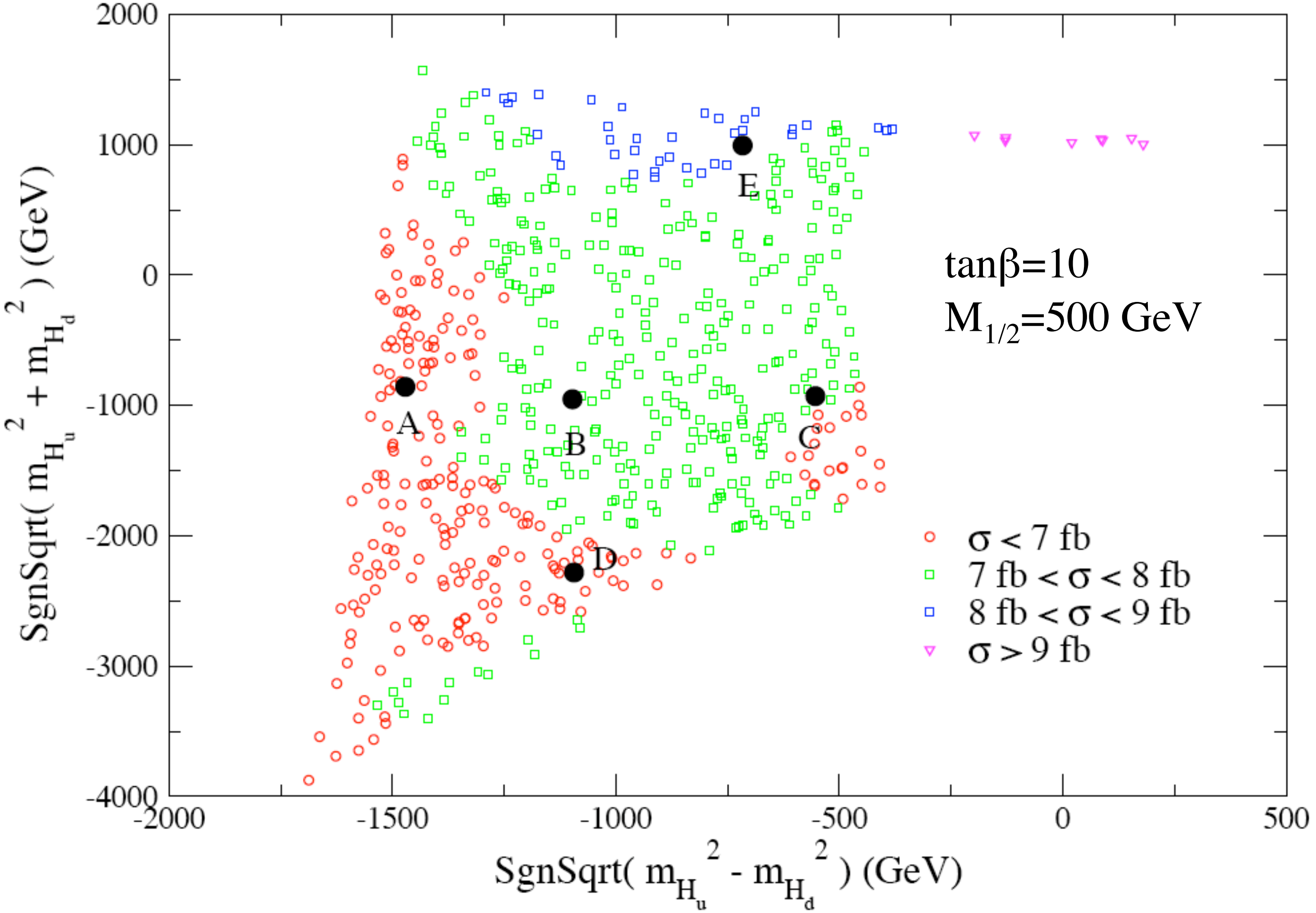
Scatter plot in the $M_{1/2} - \tan\beta$ plane of solutions that respect the bounds of $\Delta a_\mu^{SUSY} < 50 \times 10^{-10}$ and $m_h > 114.4\,\mathrm{GeV}$. Due to uncertainty in the top quark mass, and the theoretical uncertainty in the computation of m_h, a more conservative constraint on this theoretically computed value of m_h is $110\,\mathrm{GeV}$, which is also shown in the figure.

Tevatron 3l Signal



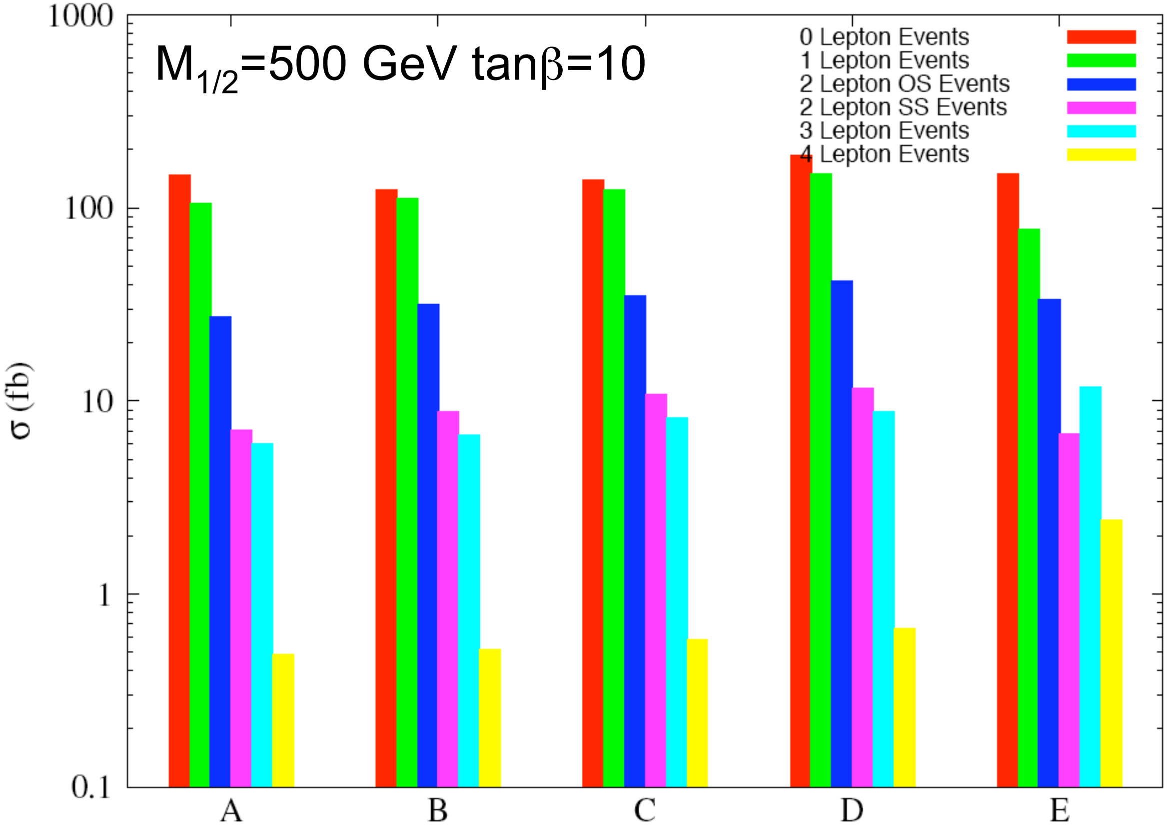
3 leptons plus missing energy. After cuts, 0.49 fb background. Marginal to find HENS scenario at Tevatron with 10 fb^{-1}

LHC 3l Signal



3 leptons plus missing energy. After cuts, 0.1 fb background.
For this value of $M_{1/2}$ it is promising at LHC with 10 fb^{-1}

Multi-lepton Signatures



Evans, Morrissey, JW, `07

- ISAJET 7.74 using CALSIM and CALINI
- $|\eta| < 5$ coverage
- Cal cells of size $\Delta\eta \times \Delta\phi = 0.05 \times 0.05$.
- E-Cal: $0.1/\sqrt{E/\mathrm{GeV}} \oplus 0.01$.
- Had-cal with $|\eta| < 3$: $0.5/\sqrt{E/\mathrm{GeV}} \oplus 0.03$
- Had-cal with $|\eta| > 3$: $1.0/\sqrt{E/\mathrm{GeV}} \oplus 0.07$
- jets: $E_T > 100\,\mathrm{GeV}$, $|\eta| < 3$, $\Delta R < 0.7$
- leptons: $p_T > 10\,\mathrm{GeV}$, $|\eta| < 2.5$, $E_T < 5\,\mathrm{GeV}$ within $\Delta R = 0.3$
- events: $n_j \geq 2$ with $E_T, ME_T > 200\,\mathrm{GeV}$, $S_T > 0.2$
- additional cuts for each channel (Baer et al.)

Background

0l : 400 fb
1l : 26 fb
2lOS : 9 fb
2lSS : 0.25 fb
3l : 0.1 fb
4l : 0.002 fb

Superconservative g-2 Supersymmetry exclusions

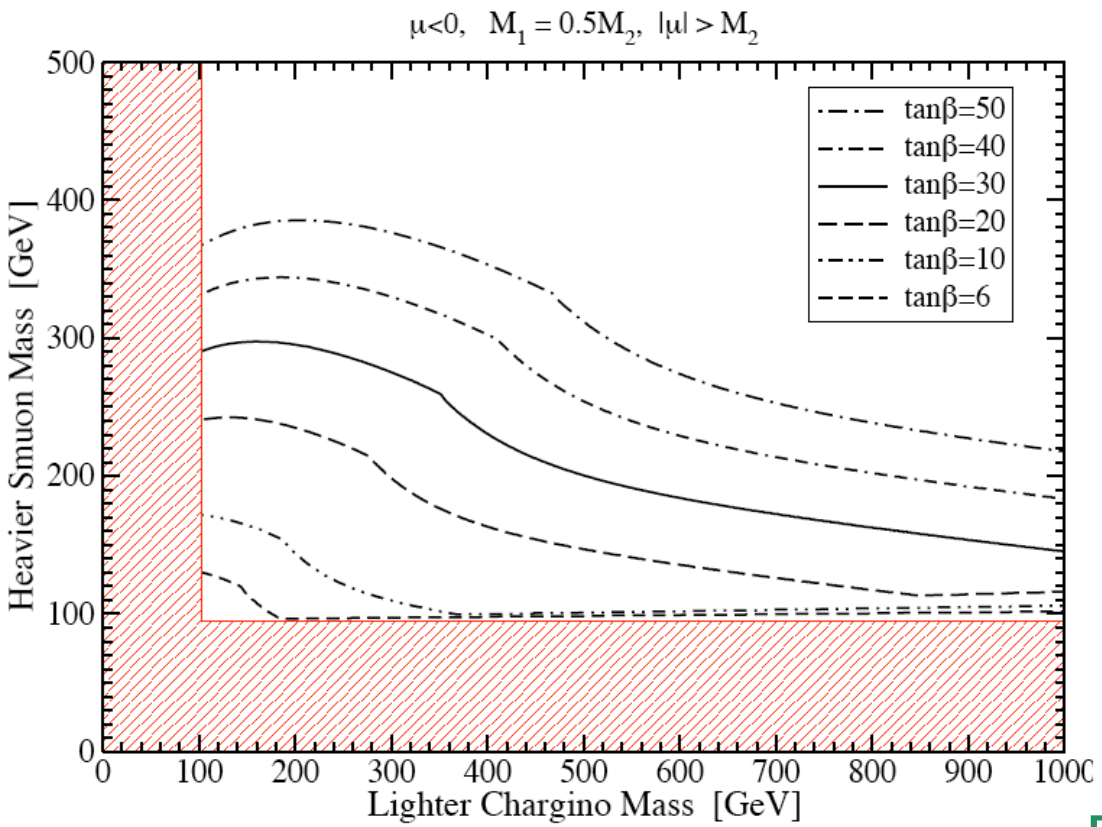
The g-2 experiment is independent powerful probe of supersymmetry.

Dark matter relic abundance, $b \to s\gamma$, Higgs mass, etc. not necessarily correlated with SUSY g-2.

Assume:
- Real SUSY parameters (M_2, μ, etc.)
- $|\mu| > M_2$ (expected generically for much of pam. space)
- $M_1 = 0.5 M_2$ (gaugino unification at high scale)
- $|A|/m < 3$ to avoid charge-violating vacua
- Smuon mass greater than 95 GeV

Superconservative: $-37 \times 10^{-10} < a_\mu(\text{susy}) < 90 \times 10^{-10}$ (5σ allowed region)

Exclusion Plot for $\mu<0$



a_μ(susy) < 0 when μ < 0.

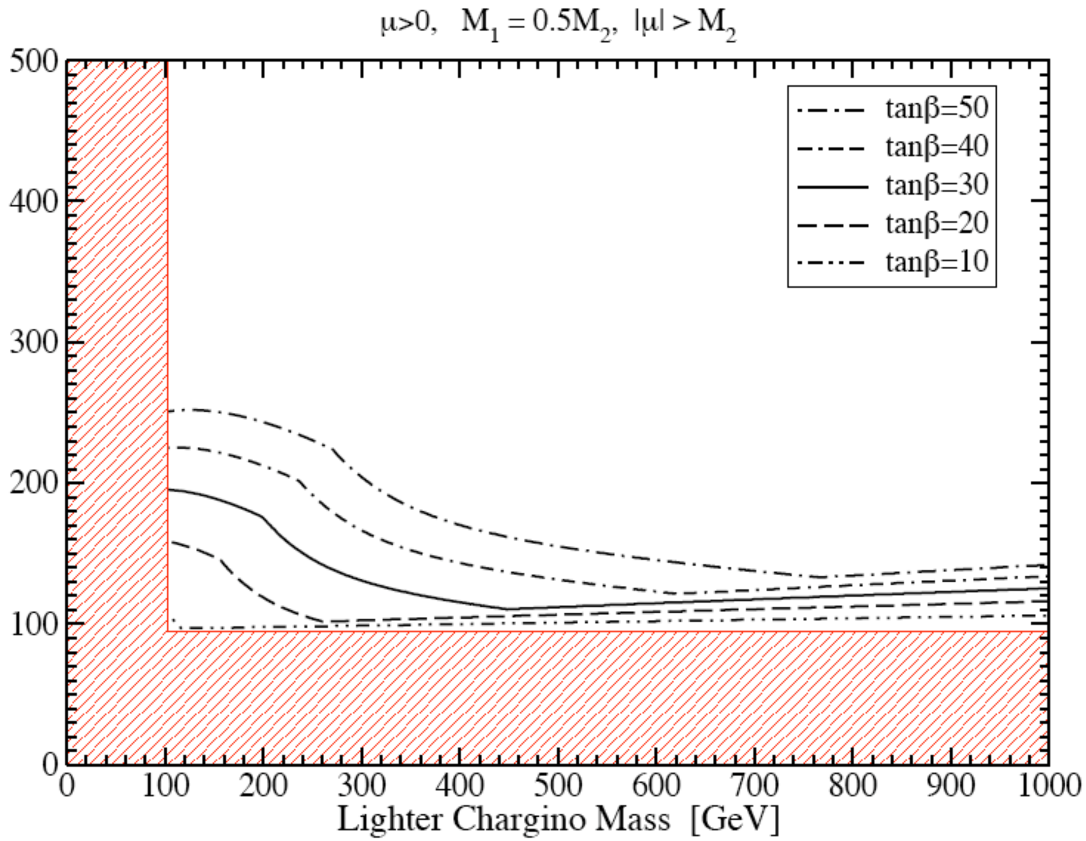
Sizeable negative contributions are not allowed, and so μ< 0 is constrained.

Red region is ruled out by LEP.

Region under curves is excluded by g-2 and nothing else.

Martin, JW, '02

Exclusion Plot for $\mu>0$



Martin, JW, '02

a_μ(susy) > 0
when μ > 0.

More sizeable negative contributions *are* allowed, and so
μ > 0 is less constrained.

Red region is ruled out by LEP.

Region under curves is excluded by g-2 and nothing else.

Comments

Results could significantly enlighten collider analyses. For example, $\tan\beta > 30$ and $\mu < 0$, and chargino is found below 360 GeV. Implication: no slepton state below 250 GeV. ILC-500 cannot find sleptons.

g-2 is an independent probe of susy, and meaningful even if measurement turns out to be consistent with SM. This is especially true of high $\tan\beta$ theories, such as no-scale susy and b-τ unification susy, etc.

A good measurement, no matter what the result, is very constraining to supersymmetry.