The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

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1854-25

Workshop on Grand Unification and Proton Decay

22 - 26 July 2007

Manifestation of X and Y in Superpartner Masses

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in Masses of Superpartners

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Introduction

X and Y in SU(5):

$$24 \rightarrow (8,1)_0 + (1,3)_0 + (1,1)_0 + (3,2)_{-5/3} + (\bar{3},2)_{5/3}$$

$$g \qquad W \qquad B \qquad \begin{pmatrix} X \\ Y \end{pmatrix} \quad \begin{pmatrix} \bar{X} \\ \bar{Y} \end{pmatrix}$$

$\longrightarrow$ PROTON DECAY!

Introduction

X and Y in SU(5):

$$24 \longrightarrow (8,1)_0 + (1,3)_0 + (1,1)_0 + (3,2)_{-5/3} + (\bar{3},2)_{5/3}$$

$$g \qquad W \qquad B \qquad \begin{pmatrix} X \\ Y \end{pmatrix} \quad \begin{pmatrix} \bar{X} \\ \bar{Y} \end{pmatrix}$$

$\longrightarrow$ PROTON DECAY!

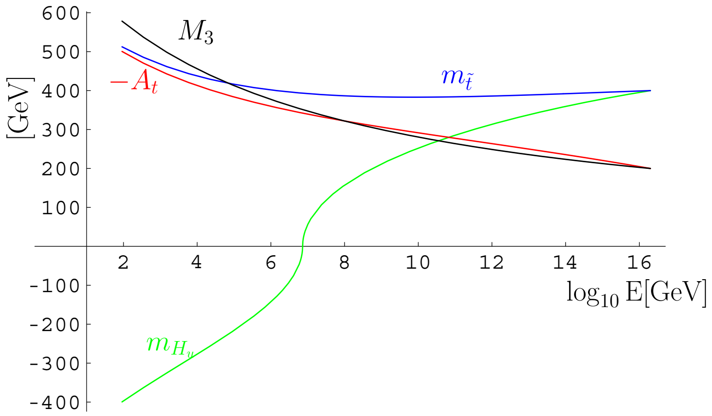
If SUSY mass relation between X and Y gauge bosons and gauginos is broken then X and Y contribute to

MASSES of SUPERPARTNERS!

Outline

- Motivation for gauge messengers
  - possible manifestation of X and Y at the LHC
  - alleviate fine tuning of EWSB
- SU(5) Gauge Messenger Model
- Features
  - highly predictive SUSY breaking scenario
  - spectrum
  - dark matter
- Conclusions

EWSB in MSSM



Minimum of the Higgs potential:

$$\frac{1}{2} M_Z^2 = -\mu^2 + \frac{m_{H_d}^2 - \tan^2\beta\, m_{H_u}^2}{\tan^2\beta - 1}\,, \qquad \tan\beta = \frac{v_u}{v_d}$$

$\tan\beta = 10$: $\qquad m_{\tilde t}^2(M_G) \simeq m_{\tilde t_L}^2(M_G) \simeq m_{\tilde t_R}^2(M_G)$

$$M_Z^2 \simeq -1.9\,\mu^2(M_G) + 5.9\,M_3^2(M_G) + 1.5\,m_{\tilde t}^2(M_G)$$
$$-1.2\,m_{H_u}^2(M_G) - 0.8\,M_3(M_G)A_t(M_G) + \ldots$$

EWSB in MSSM

$\tan\beta = 10$: $m^2_{\tilde{t}}(M_G) \simeq m^2_{\tilde{t}_L}(M_G) \simeq m^2_{\tilde{t}_R}(M_G)$

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$$m^2_{\tilde{t}}(M_Z) \simeq 5.0M_3^2(M_G) + 0.6m^2_{\tilde{t}}(M_G) + 0.2A_t(M_G)M_3(M_G) + \ldots$$
$$m_{\tilde{g}} \simeq M_3(M_Z) \simeq 3.0M_3(M_G) + \ldots$$
$$A_t(M_Z) \simeq -2.3M_3(M_G) + 0.2A_t(M_G) + \ldots$$

Without specific relations between SSB parameters and/or μ:

$$M_Z \sim m_{\tilde{g}},\, m_{\tilde{t}}$$

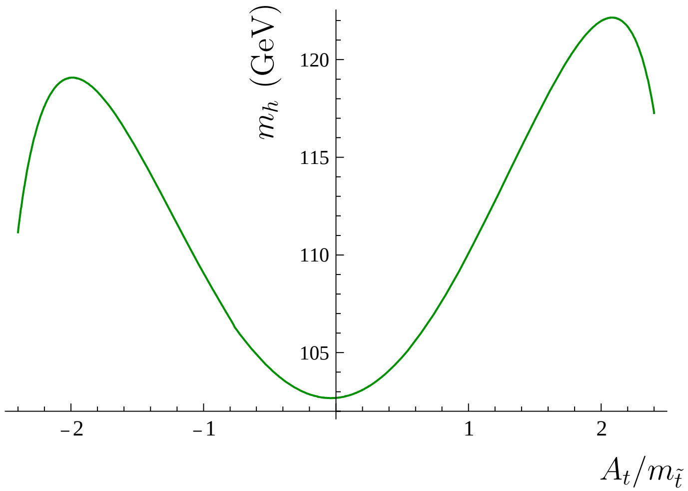
natural EWSB $\rightarrow$ light gluino and stop!

Higgs Mass in MSSM

$$m_h^2 \simeq M_Z^2 \cos^2 2\beta + \frac{3G_F m_t^4}{\sqrt{2}\pi^2}\left[\log\frac{m_{\tilde{t}}^2}{m_t^2} + \frac{A_t^2}{m_{\tilde{t}}^2}\left(1 - \frac{A_t^2}{12 m_{\tilde{t}}^2}\right)\right]$$

Effect of large mixing:

[FeynHiggs-2.5.1: $\tan\beta = 10$, $m_{\tilde{t}} = 400$ GeV]



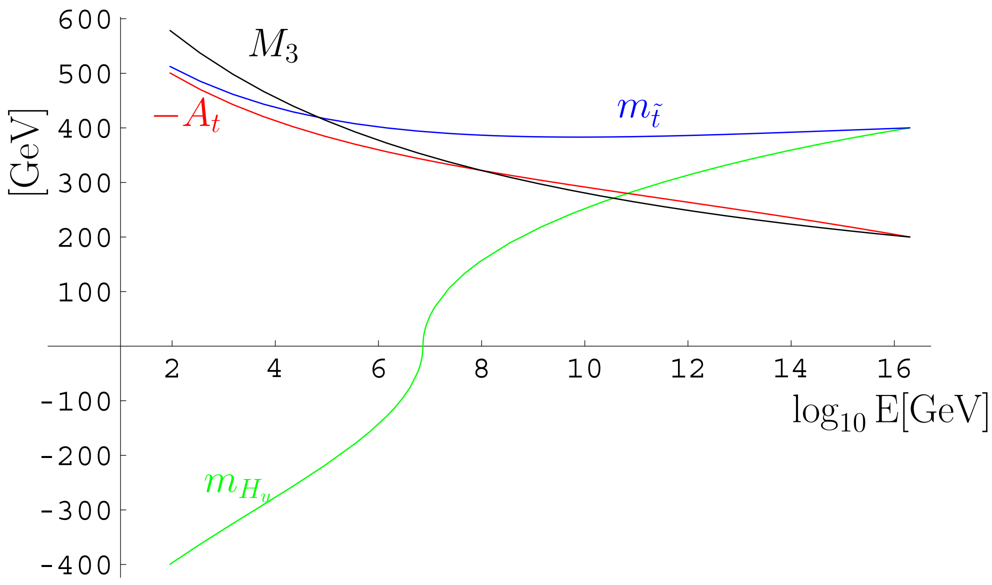
m_h maximized for $A_t/m_{\tilde{t}} \simeq \pm 2$

Higgs Mass in MSSM

$$m_h^2 \simeq M_Z^2 \cos^2 2\beta + \frac{3G_F m_t^4}{\sqrt{2}\pi^2}\left[\log \frac{m_{\tilde{t}}^2}{m_t^2} + \frac{A_t^2}{m_{\tilde{t}}^2}\left(1 - \frac{A_t^2}{12 m_{\tilde{t}}^2}\right)\right]$$

Typical mixing $|A_t/m_{\tilde{t}}| \lesssim 1$:

$$m_{\tilde{t}}^2(M_Z) \simeq 5.0 M_3^2(M_G) + 0.6 m_{\tilde{t}}^2(M_G)$$
$$A_t(M_Z) \simeq -2.3 M_3(M_G) + 0.2 A_t(M_G)$$



Higgs Mass in MSSM

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LEP limit: $m_h \gtrsim 114.4$ GeV

satisfied for $A_t/m_{\tilde{t}} \lesssim 1$ with:

$$m_{\tilde{t}} \gtrsim 900\,\mathrm{GeV}$$

LEP $\longrightarrow$ heavy stop!

Unusual SUSY $\longrightarrow$ maximal mixing

$$m_h^2 \simeq M_Z^2 \cos^2 2\beta + \frac{3 G_F m_t^4}{\sqrt{2}\pi^2}\left[\log\frac{m_{\tilde{t}}^2}{m_t^2} + \frac{A_t^2}{m_{\tilde{t}}^2}\left(1 - \frac{A_t^2}{12 m_{\tilde{t}}^2}\right)\right]$$

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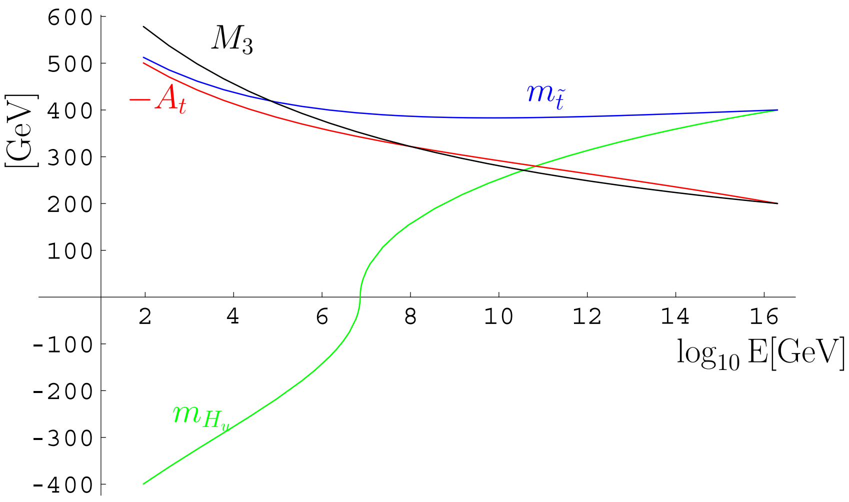
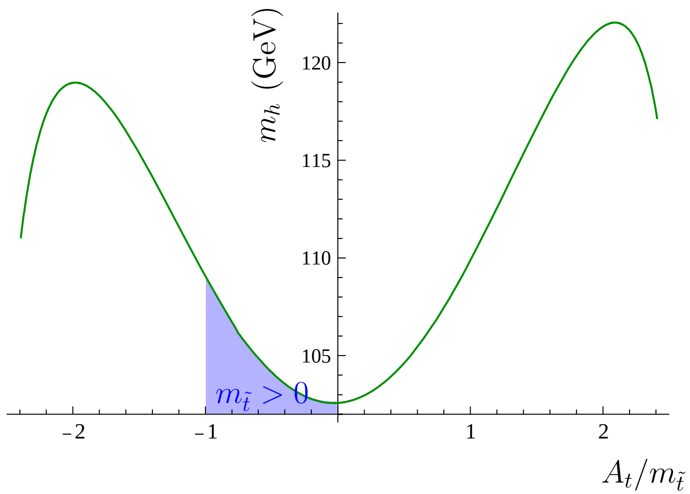


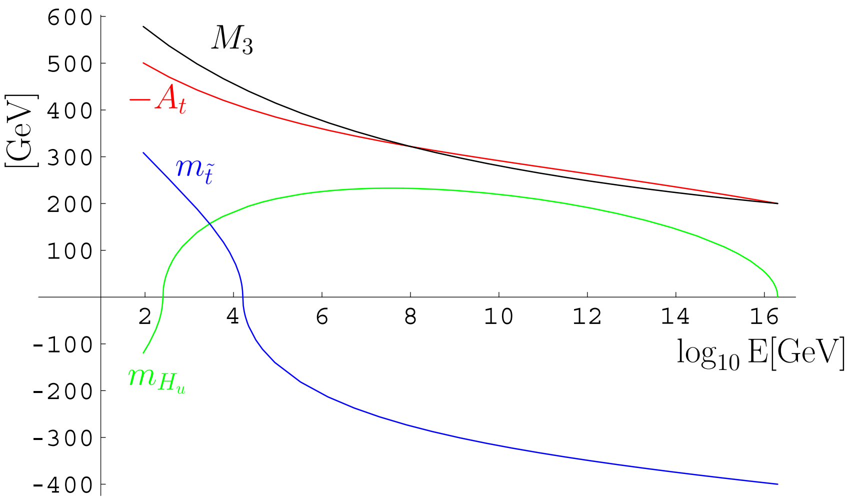


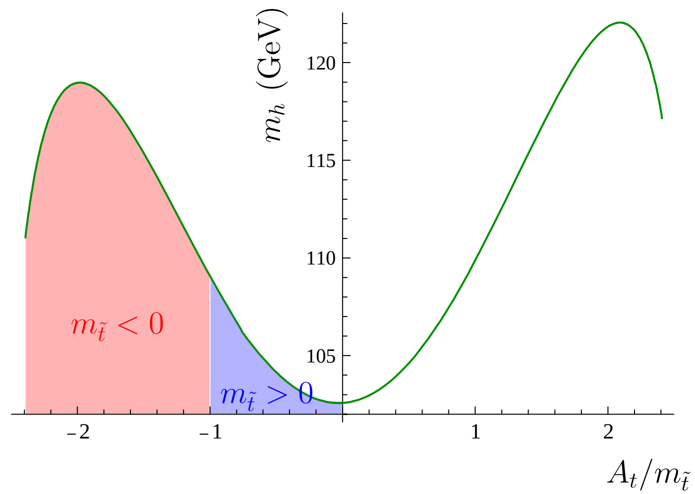
Unusual SUSY $\longrightarrow$ maximal mixing

$$m_h^2 \simeq M_Z^2 \cos^2 2\beta + \frac{3G_F m_t^4}{\sqrt{2}\pi^2}\left[\log\frac{m_{\tilde{t}}^2}{m_t^2} + \frac{A_t^2}{m_{\tilde{t}}^2}\left(1 - \frac{A_t^2}{12 m_{\tilde{t}}^2}\right)\right]$$

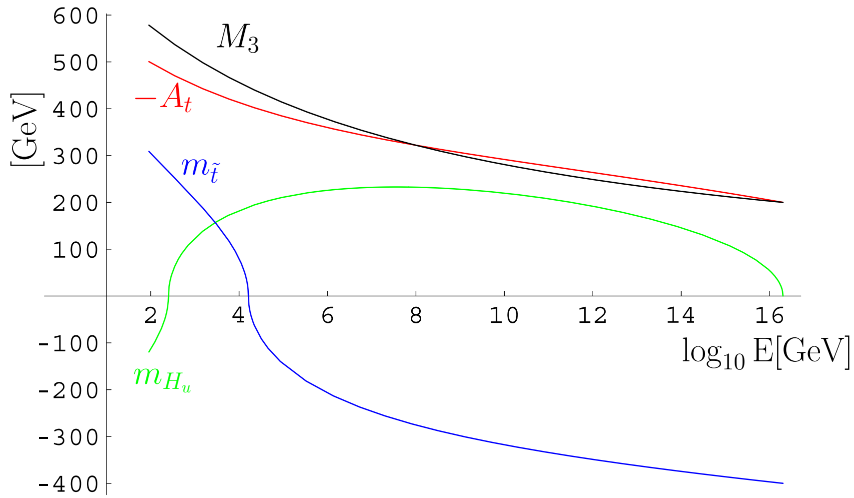
Large mixing $|A_t/m_{\tilde{t}}| \gtrsim 1$:

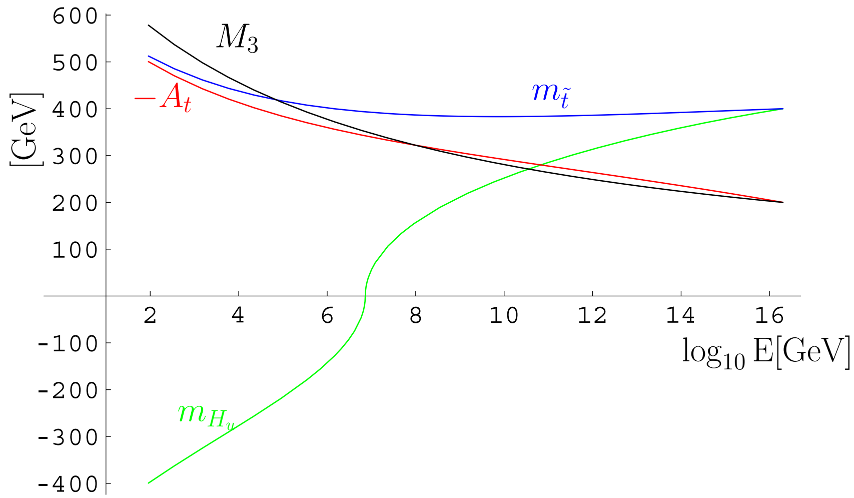
$$m_{\tilde{t}}^2(M_Z) \simeq 5.0 M_3^2(M_G) + 0.6 m_{\tilde{t}}^2(M_G)$$
$$A_t(M_Z) \simeq -2.3 M_3(M_G) + 0.2 A_t(M_G)$$





Unusual SUSY: $m_{\tilde{t}}^2(M_{\rm GUT}) < 0$





$$\frac{dm_{H_u}^2}{d\log Q} \sim \frac{3\lambda_t^2}{8\pi^2} f, \qquad f \equiv m_{\tilde{t}_L}^2 + m_{\tilde{t}_R}^2 + m_{H_u}^2 + A_t^2$$

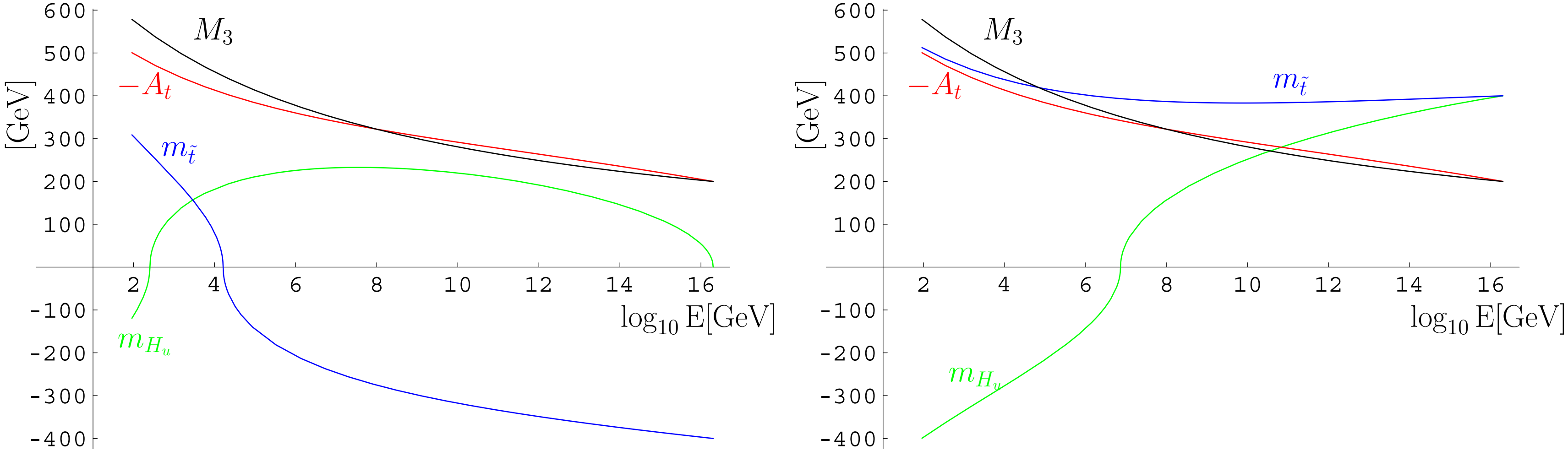
$\delta m_{H_u}^2 \sim -\frac{3\lambda_t^2}{8\pi^2} f \log \frac{M_G}{M_{f=0}} - \frac{3\lambda_t^2}{8\pi^2} f \log \frac{M_{f=0}}{M_Z}$

$\delta m_{H_u}^2 \sim$ *any*

$\delta m_{H_u}^2 \sim -\frac{3\lambda_t^2}{8\pi^2} f \log \frac{M_G}{M_Z}$

$\delta m_{H_u}^2 \sim -m_{\tilde{t}}^2$

Unusual SUSY: $m^2_{\tilde{t}}(M_{\text{GUT}}) < 0$



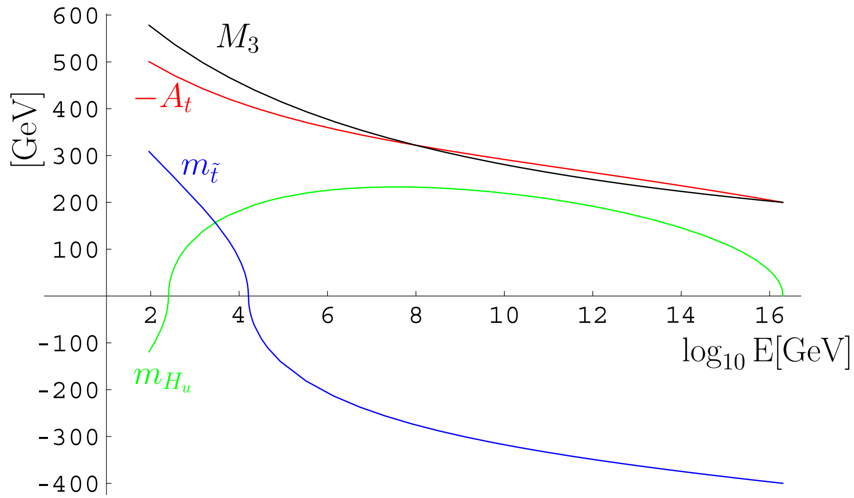
$\delta m^2_{H_u} \sim 0$

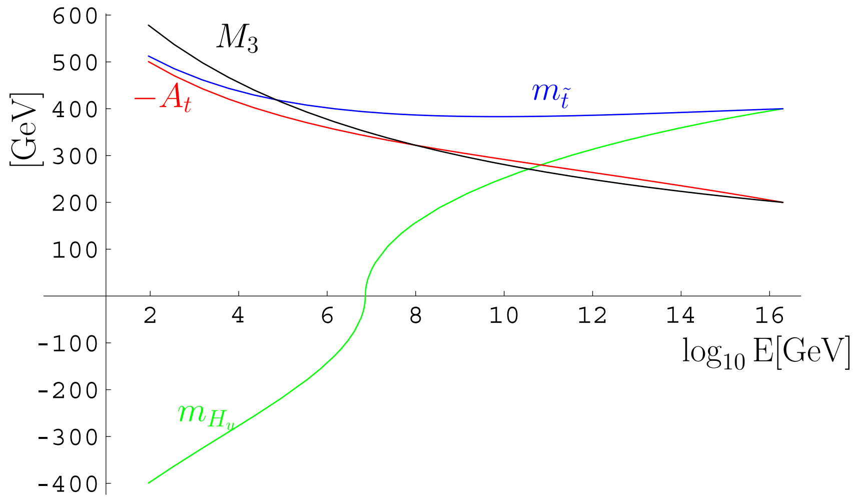
no cancellation necessary

$\delta m^2_{H_u} \sim -(500\text{GeV})^2$

must be cancelled by μ^2 or $m^2_{H_u}(M_{GUT})$ to 3%

Unusual SUSY: $m^2_{\tilde{t}}(M_{\rm GUT}) < 0$





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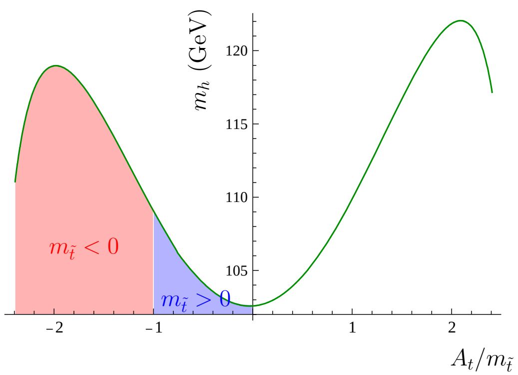
$m_h \simeq 115.4$ GeV

$A_t/m_{\tilde{t}} > 1$



$m_h \simeq 112.0$ GeV

$A_t/m_{\tilde{t}} \lesssim 1$

Large Stop Mixing: $m^2_{\tilde{t}}(M_{\rm GUT}) < 0$

$\tan\beta = 10$:

$$M_Z^2 \simeq -1.9\,\mu^2(M_G) + 5.9\,M_3^2(M_G) + 1.5\,m^2_{\tilde{t}}(M_G) -1.2\,m^2_{H_u}(M_G) - 0.8\,M_3(M_G)A_t(M_G) + \ldots$$

$$m^2_{\tilde{t}}(M_Z) \simeq 5.0M_3^2(M_G) + 0.6m^2_{\tilde{t}}(M_G) + 0.2A_t(M_G)M_3(M_G) + \ldots$$

$$m_{\tilde{g}} \simeq M_3(M_Z) \simeq 3.0M_3(M_G) + \ldots$$

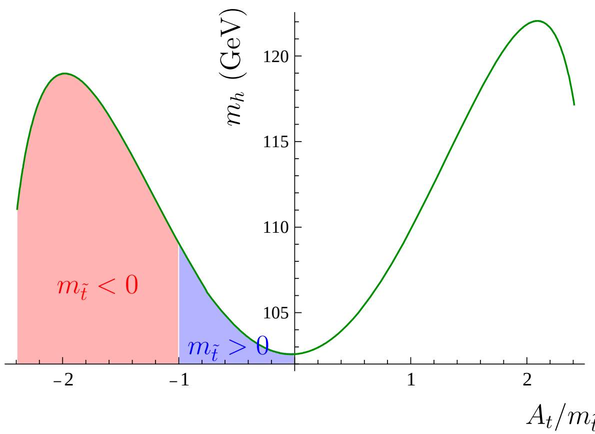
$$A_t(M_Z) \simeq -2.3M_3(M_G) + 0.2A_t(M_G) + \ldots$$

$m^2_{\tilde{t}}(M_G) < 0$:

$M_Z < m_{\tilde{g}}, m_{\tilde{t}}$

$|A_t/m_{\tilde{t}}|(M_Z) > 1$

$m_h > 114.4$ GeV easily!



$m^2_{\tilde{t}}(M_G) > 0$:

$M_Z \sim m_{\tilde{g}}, m_{\tilde{t}}$

$|A_t/m_{\tilde{t}}|(M_Z) \lesssim 1$

$m_h < 114.4$ GeV

Gauge mediation with gauge messengers

Minimal SU(5) content: $V(24),\ 5_H,\ \bar{5}_H,\ 3\times(10+\bar{5}),\ \Sigma(24)$

$$M_{\rm GUT} \ \frac{}{MSSM}$$

$$\langle\Sigma\rangle = \left(M+\theta^2 F\right)\times diag(2,2,2,-3,-3)$$

$M \sim \mathcal{O}(M_{\rm GUT})$ breaks GUT symmetry

F splits masses of heavy gauge bosons and gauginos

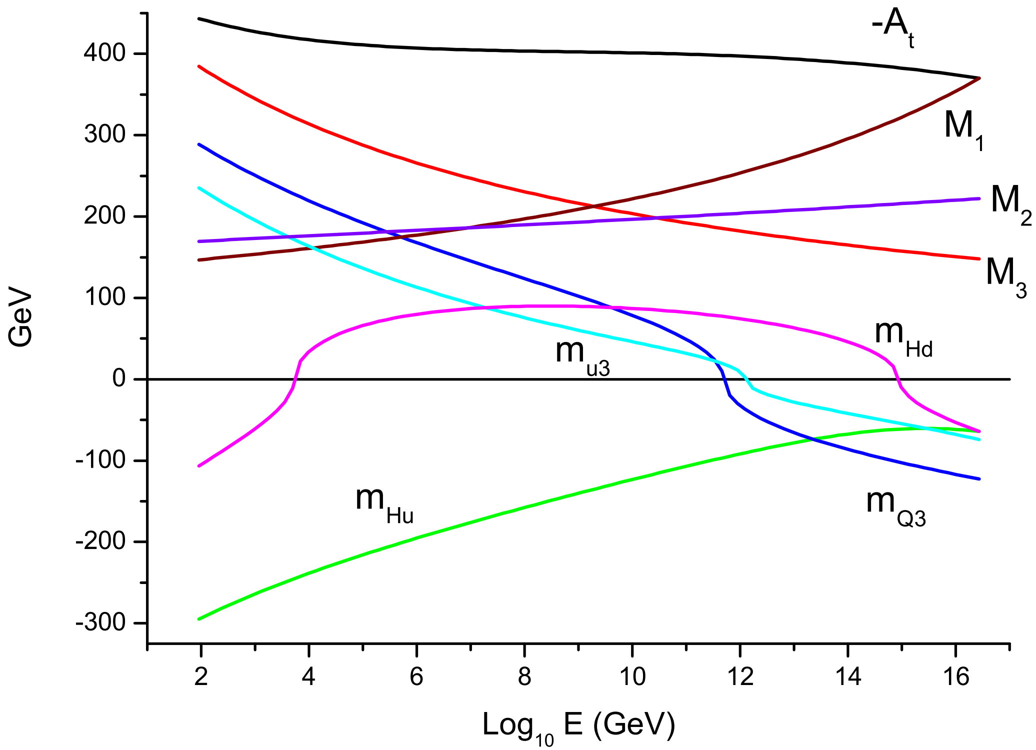
SUSY breaking communicated to MSSM through loops:

$$M_i, A_i \propto M_{\rm SUSY}, \qquad m_\phi^2 \propto M_{\rm SUSY}^2$$

$$M_{\rm SUSY} \equiv \frac{\alpha_G}{4\pi}\frac{F}{M}$$

Gauge mediation with gauge messengers

$\tan\beta = 23,\ M_{\rm SUSY} = 37$ GeV



$$M_3 = 4\ M_{\rm SUSY}$$
$$M_2 = 6\ M_{\rm SUSY}$$
$$M_1 = 10\ M_{\rm SUSY}$$
$$A_t = -10\ M_{\rm SUSY}$$
$$m_Q^2 = -11\ M_{\rm SUSY}^2$$
$$m_u^2 = -4\ M_{\rm SUSY}^2$$
$$m_d^2 = -6\ M_{\rm SUSY}^2$$
$$m_L^2 = -3\ M_{\rm SUSY}^2$$
$$m_e^2 = +6\ M_{\rm SUSY}^2$$
$$m_{H_u,H_d}^2 = -3\ M_{\rm SUSY}^2$$

Gauge mediation with gauge messengers

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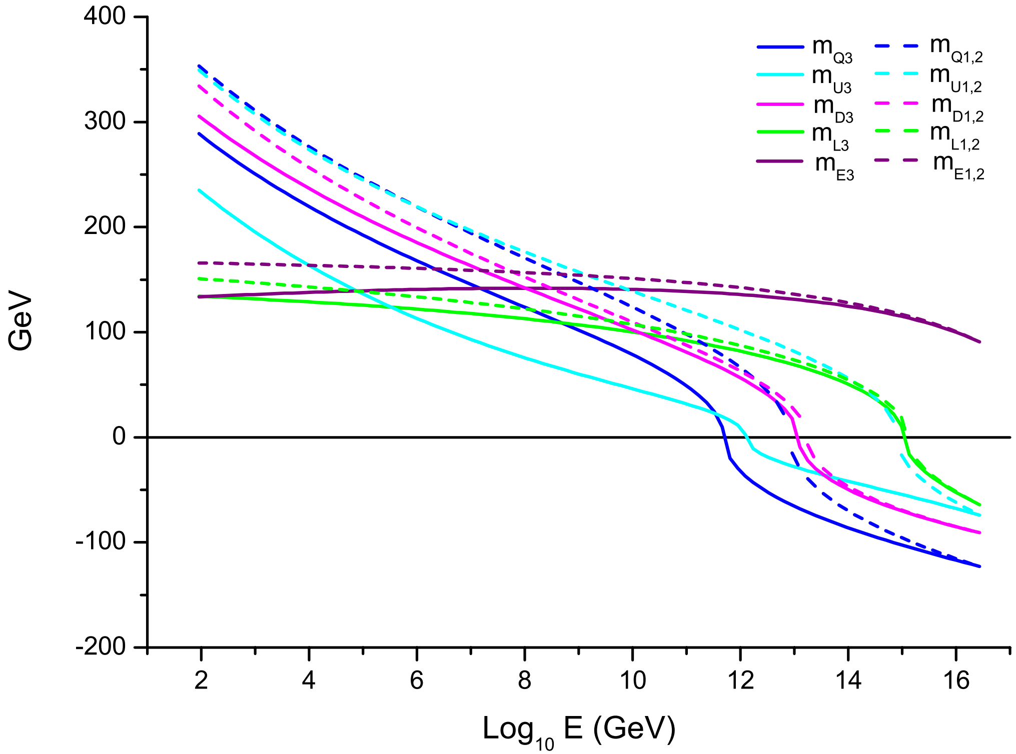

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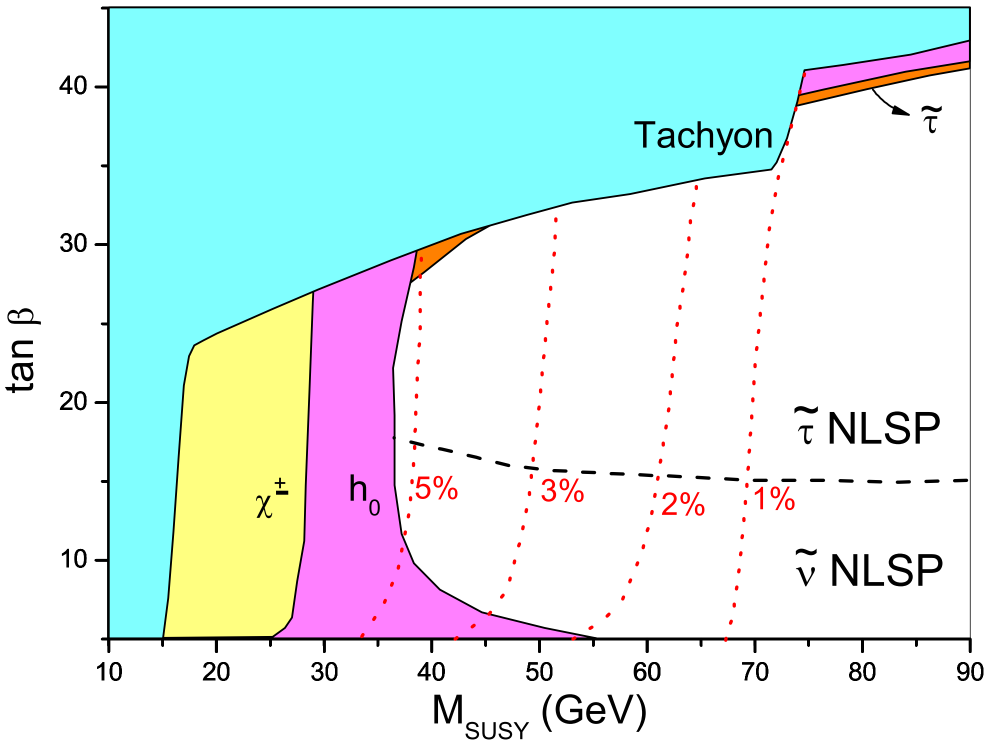
Gauge mediation with gauge messengers



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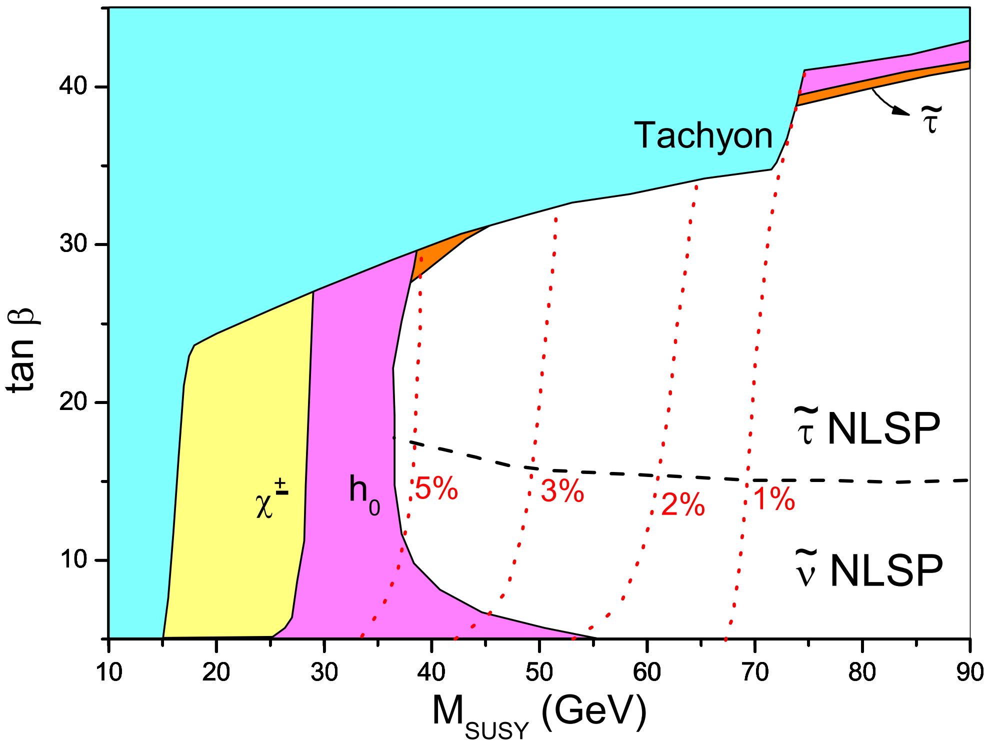
Gauge mediation with gauge messengers



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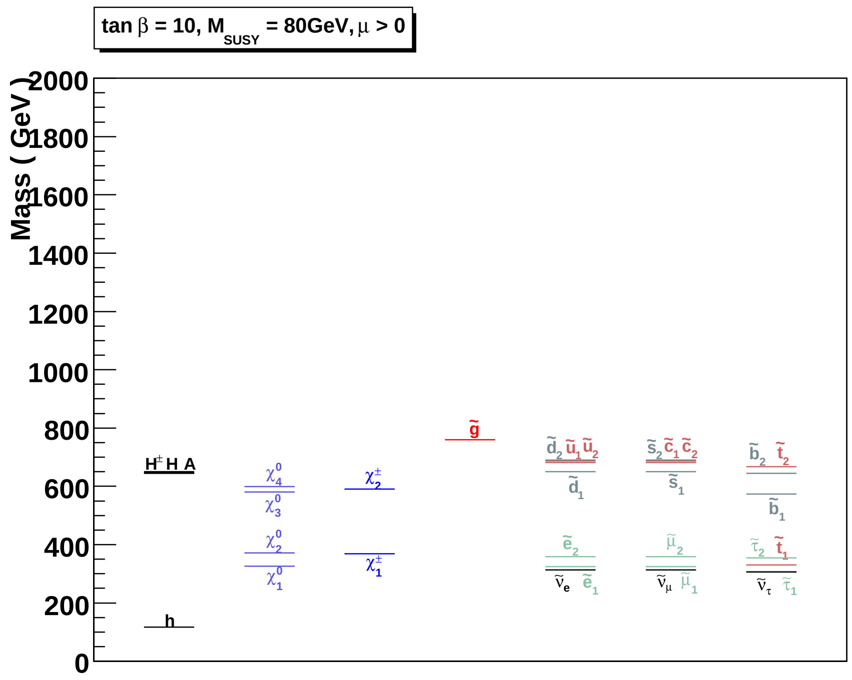
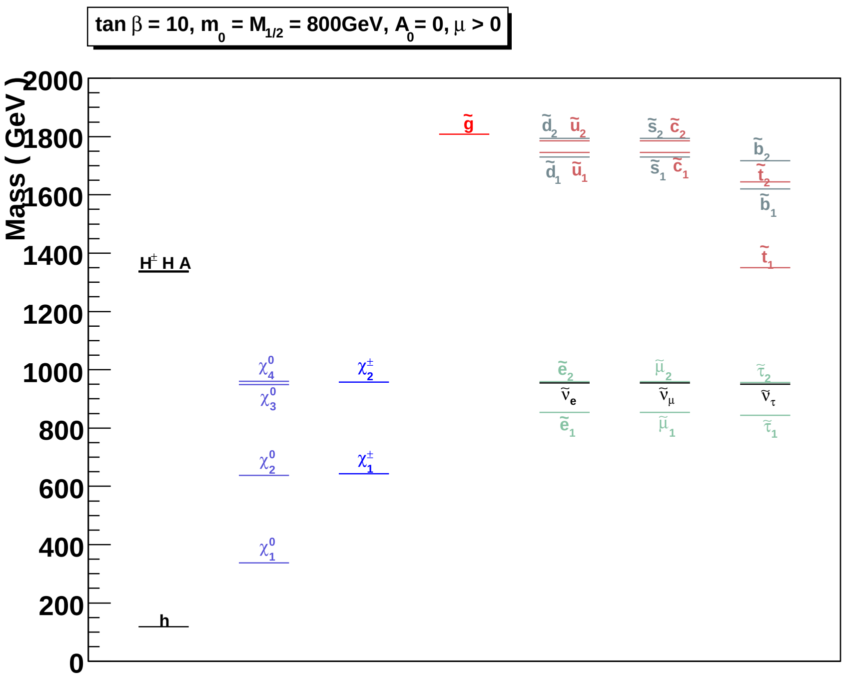
gravitino LSP, ~ 60 GeV
$\tilde{\tau}$ or $\tilde{\nu}$ NLSP

Spectrum



Gauge Messenger Model



mSUGRA

Contribution from gravity mediation

gauge mediation

$M_{\rm SUSY} = \frac{\alpha_G}{4\pi}\frac{F}{M}$

gravity mediation

$m_{3/2} = \frac{F}{\sqrt{3}M_{\rm Pl}}$

$$\frac{m_{3/2}}{\mathcal{O}(5) * M_{\rm SUSY}} = \frac{4\pi M_{\rm GUT}}{\mathcal{O}(5) * \sqrt{3}\alpha_{\rm GUT} M_{\rm Pl}} \simeq 0.3$$

gravity contribution naturally $\sim 30\%$ of gauge contribution!

Giudice - Masiero (1988)

$$K \supset \frac{1}{M_{\rm Pl}} H_u \Sigma^\dagger H_d + \frac{1}{M_{\rm Pl}^2} \Sigma^\dagger \Sigma H_u H_d$$

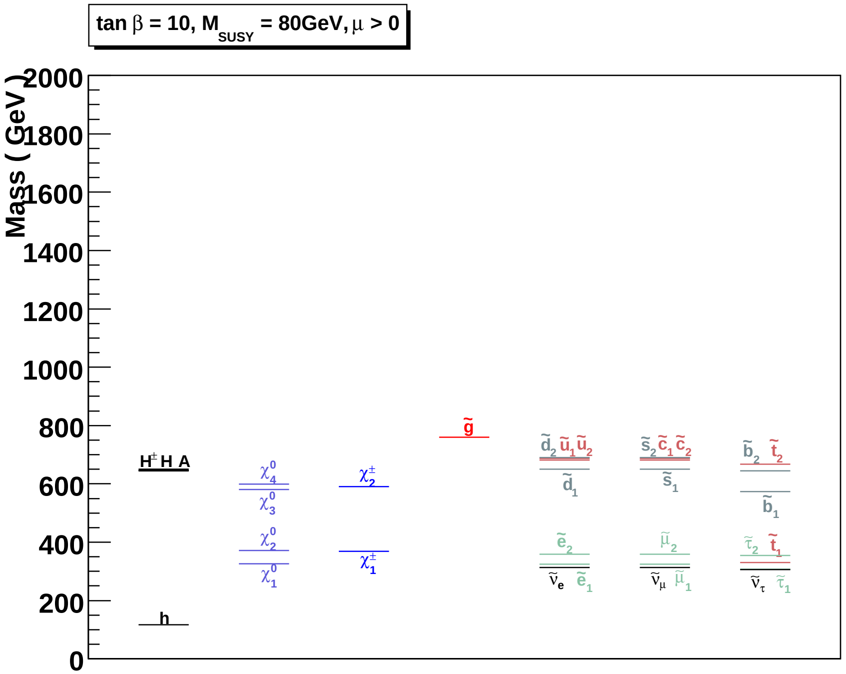
$\mu \sim m_{3/2}$ and $B\mu \sim m_{3/2}^2$

Contribution from gravity mediation

parameters of the model:

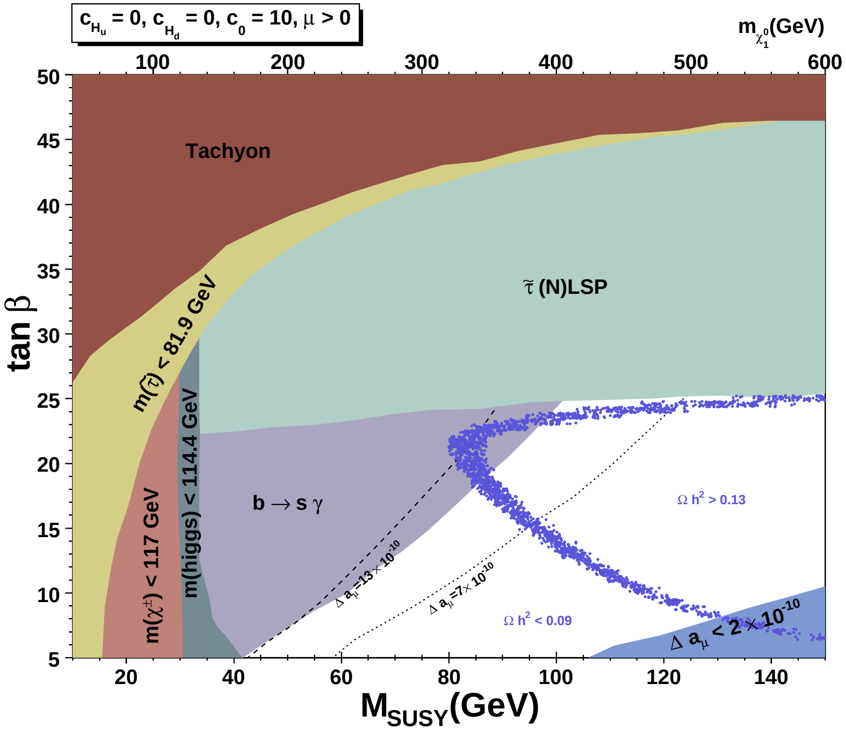
$$M_{\rm SUSY}, \quad \tan\beta, \quad c_0, \quad c_{H_u}, \quad c_{H_d}, \quad sign(\mu)$$

$$m^2_{H_u} = -3M^2_{\rm SUSY} + c_{H_u} M^2_{\rm SUSY}$$
$$m^2_{H_d} = -3M^2_{\rm SUSY} + c_{H_d} M^2_{\rm SUSY}$$
$$m^2_{\tilde{Q}} = -11M^2_{\rm SUSY} + c_0 M^2_{\rm SUSY}$$
$$\ldots$$

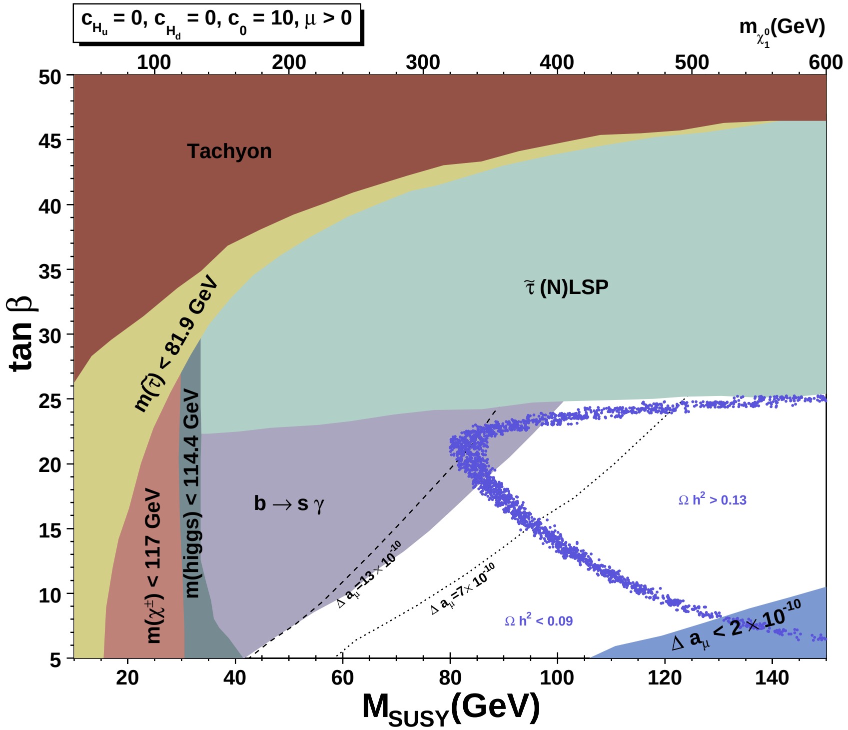


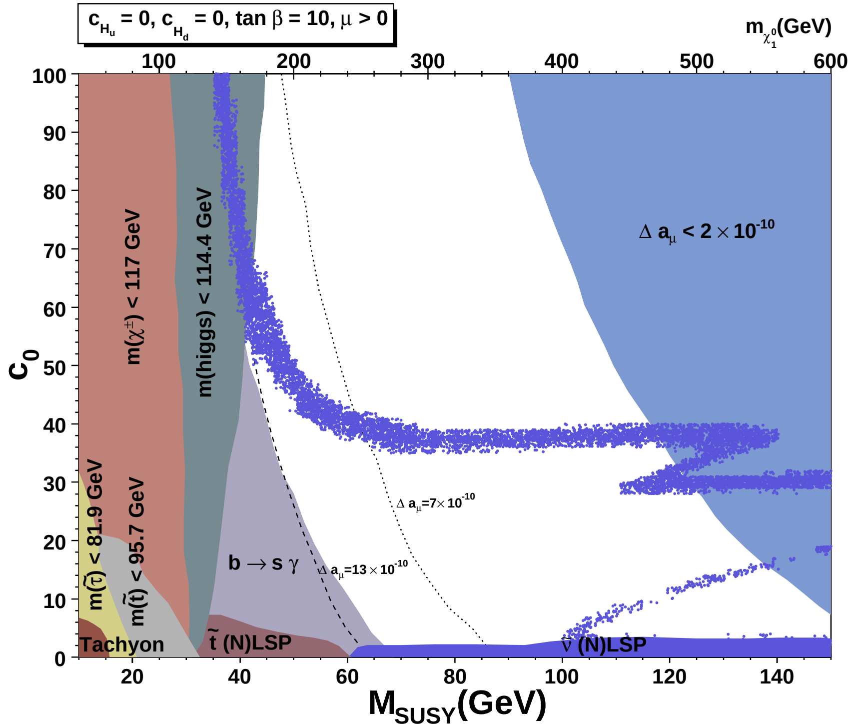
(N)LSP changes with small contribution from gravity

Mixed Bino-Wino-Higgsino dark matter



Mixed Bino-Wino-Higgsino dark matter





Conclusions

Gauge Messenger Model:

- possible manifestation of X and Y at the LHC
- highly predictive SUSY breaking scenario
- leads to squeezed spectrum
- predicts negative scalar masses squared at the GUT scale
- leads to large mixing in the stop sector
- highly enhances the Higgs boson mass
- alleviates fine tuning of EWSB
- interesting source of dark matter