Kinetically-Enhanced Anomaly Mediation

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1109.1565

Outline

Anomaly mediation

Model

Phenomenology

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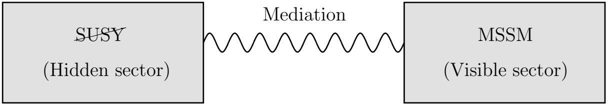
Mediation of SUSY breaking



- Gravity: higher-dimensional operators

$$m_{\lambda_i} \sim \frac{F}{M_{Pl}}, \qquad m_i^2 \sim \left(\frac{F}{M_{Pl}}\right)^2$$

- Gauge: chiral superfields

$$m_{\lambda_i} \sim \frac{g_i^2}{16\pi^2}\left(\frac{F}{M}\right), \qquad m_i^2 \sim \left(\frac{g_i^2}{16\pi^2}\right)^2\left(\frac{F}{M}\right)^2$$

- Anomaly: supergravity

$$m_{\lambda_i} \sim b_i \frac{g_i^2}{16\pi^2} m_{3/2}, \qquad m_i^2 \sim \beta_i \frac{g_i}{16\pi^2} m_{3/2}^2$$

Anomaly mediation (AMSB)

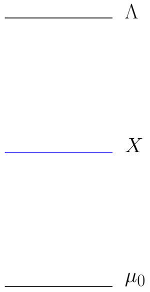
- More gravity mediation than gravity mediation
- Conformal compensator: $\phi = 1 + \theta^2 F_\phi$
  - $M \to M\phi$
  - $\Lambda \to \Lambda\phi$
- Introduce ϕ dependence at loop-level via cut-off Λ

$$m_{\lambda_i}(\mu) = \frac{1}{16\pi^2} b_i g_i(\mu)^2 m_{3/2}$$

$$m_i(\mu)^2 = \frac{1}{16\pi^2} \beta_i(\mu) g_i(\mu) m_{3/2}^2$$

AMSB spectrum

- Boundary Conditions at $\mu = \Lambda$
- "AMSB trajectories"
- UV insensitivity
- Negative slepton squared masses
  - $m_{L,e}(\mu)^2 < 0$
- "Non-decoupling" effects deflect off AMSB trajectory



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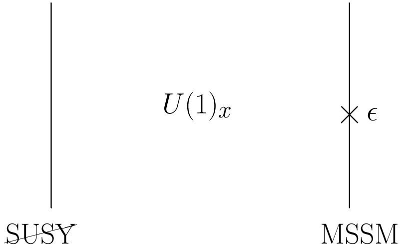
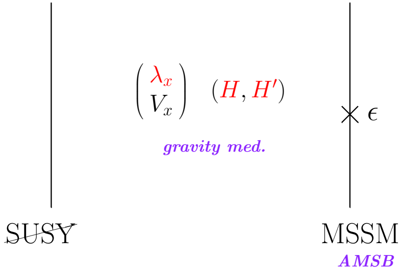
A sequestered setup



- $U(1)_x$ gauge multiplet mediates SUSY-breaking effects to MSSM via kinetic mixing

- These contributions do not decouple at low energies

Model



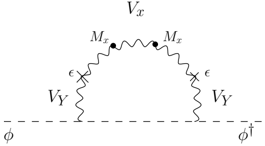
$$M_x \sim \mu \sim m_{3/2} \qquad m_H^2 \sim m_{H'}^2 \sim m_{3/2}^2$$

$U(1)_x$ Higgsed at $\sim m_{3/2}$

- Non-SUSY threshold generated by a vev at $\sim m_{3/2}$
- $U(1)_x$ gauge multiplet contributions do not decouple from visible sector at low energies

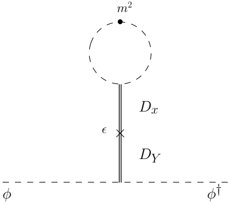
3 contributions from $U(1)_x$

- 1-loop gaugino contribution



$$\sim \varepsilon^2 Y_i^2 g_1^2 M_x^2$$

- "S_x" term



$$\sim \varepsilon Y_i g_1 g_x (m_H^2 - m_{H'}^2)$$

- D_x term mass-shift

$$\Delta m_i^2 = -\sqrt{\frac{3}{5}} Y_i \varepsilon g_1 \xi_x$$

Modified RGEs

$$(4\pi)^2 \frac{d}{dt} m_i^2 = (\dots)_{MSSM} - \frac{24}{5} Y_i^2 \varepsilon^2 g_1^2 |M_x|^2 - 2\sqrt{\frac{3}{5}} Y_i \varepsilon g_1 g_x S_x$$

$$m_i(\mu)^2 \to m_i(\mu)^2 + \frac{\varepsilon}{2}\sqrt{\frac{3}{5}} Y_i \frac{g_1}{g_x} m_x^2 \cos 2\alpha$$

- Parametrize in terms of A, B

$$m_i(\mu)^2 = m_i^{AMSB}(\mu)^2 + Y_i^2 A + Y_i B$$

- Exact analytic expression for 1st two generations

Analysis

- Scan over the hidden sector

  $\epsilon, g_x, M_x, S_x, m_x, \mu', \tan\alpha$

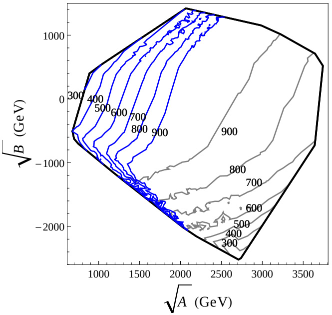
  $m_{3/2} = 60\,\mathrm{TeV}$

Parameter	Range
ϵ	[0.01,0.1]
g_x	[0.7,0.9]
M_x	$[0.5,5]\times m_{3/2}$

Parameter	Range
S_x	$[-5,5]\times m_{3/2}^2$
m_x	$[0.1,10]\times m_{3/2}$
μ'	$[0.5,5]\times m_{3/2}$
$\tan\alpha$	[0,50]

- Numerically integrate modified RGEs
- Interface with SuSpect for physical spectrum
- Parametrize spectra in terms of A, B

Viable parameter space



- Lightest squarks: $\tilde{t}_L, \tilde{b}_L$ (gray)
- Lightest sleptons: $\tilde{\nu}_\tau, \tilde{\tau}_R$ (blue)

- Every point in (A,B) plane gives a unique MSSM spectrum

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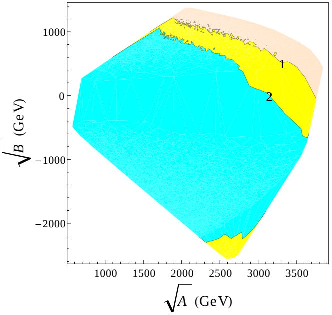
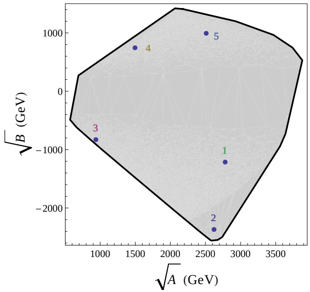
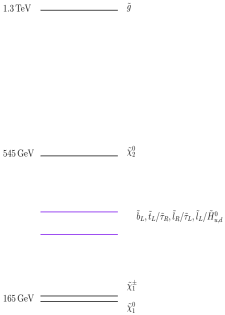
Charged tracks

- $\tilde{\chi}_1^{\pm} - \tilde{\chi}_1^0$ nearly degenerate at tree-level
- Radiative corrections important!
- At 1 loop, $\Delta m = m_{\tilde{\chi}_1^{\pm}} - m_{\tilde{\chi}_1^0} > m_\pi$
- Two body decay: $\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0 \pi^{\pm}$ leaves short charged stubs in detector



Benchmark points





- Squark and slepton masses modified, gaugino masses unchanged
- SUSY-HIT for decay tables, Pythia for SUSY production

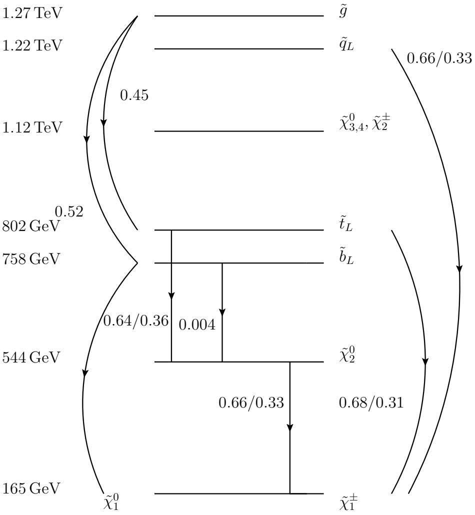
Qualitative features

- Large electroweak production

- Short stubs

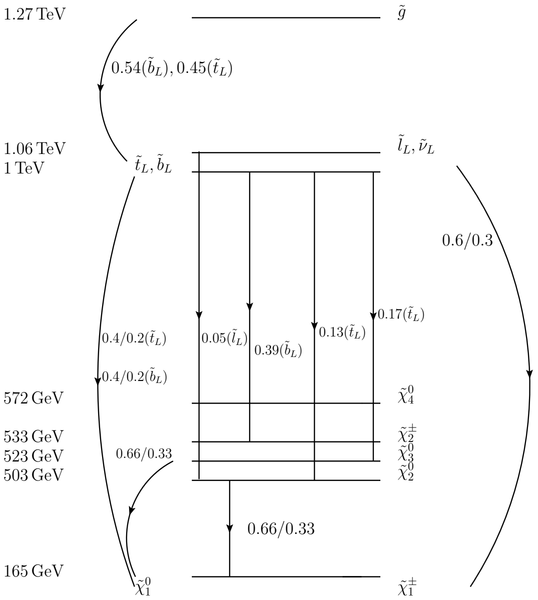
- Direct stop/sbottom production

Example: Spectrum 1



σ_{SUSY}	1.35 pb
$\tilde{\chi}^0_1\tilde{\chi}^\pm_1 + \tilde{\chi}^\mp_1\tilde{\chi}^\pm_1$	1.34 pb
$\tilde{q}_L\tilde{q}_L^{(*)}$	2.4 fb
$\tilde{\chi}^0_1\tilde{q}_L + \tilde{\chi}^\pm_1\tilde{q}_L$	1.36 fb
$\tilde{g}\tilde{q}_L$	1.2 fb
$\tilde{g}\tilde{g}$	0.1 fb
$\tilde{b}_L\tilde{b}_L^{(*)}$	0.9 fb
$\tilde{t}_L\tilde{t}_L^{(*)}$	0.7 fb

Example: Spectrum 2



σ_{SUSY}	1.5 pb
$\tilde{\chi}_1^0\tilde{\chi}_1^\pm + \tilde{\chi}_1^\mp\tilde{\chi}_1^\pm$	1.49 pb
$\tilde{\chi}_3^0\tilde{\chi}_2^\pm$	1.4 fb
$\tilde{\chi}_2^0\tilde{\chi}_2^\pm$	0.9 fb
$\tilde{b}_1\bar{\tilde{b}}_1$	0.04 fb
$\tilde{t}_1\bar{\tilde{t}}_1$	0.03 fb

Sum Rules

- Kinetic mixing effects parametrized in terms of A, B
- Exact analytic expression for first 2 generations

$$m_i(\mu)^2 = m_i^{AMSB}(\mu)^2 + Y_i^2 A + Y_i B$$

- Eliminate A, B $-$ 5 equations and 2 unknowns

$$3m_{\tilde{Q}}^2 - 3m_{\tilde{u}}^2 + 5m_{\tilde{L}}^2 = -12\frac{g_2^4}{(4\pi)^4}m_{3/2}^2 = -(550\ \mathrm{GeV})^2$$

$$m_{\tilde{u}}^2 + 5m_{\tilde{d}}^2 - m_{\tilde{e}}^2 = 48\frac{g_3^4}{(4\pi)^4}m_{3/2}^2 = (3.1\ \mathrm{TeV})^2$$

Conclusion

- Kinetic mixing with a heavy $U(1)_x$ gives a number of contributions to the MSSM soft masses
- Viable parameter space with positive soft masses
- Interesting and varied collider signals