Signatures of the Least Superymmetric Standard Model

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- Introduction
- The model: two sources of SUSY breaking
- Signatures: the third family of sfermions
- Conclusions

Worked based on:

AD and M. Quirós PRD 85 (2012) 015001

J. de Blas, AD and B. Ostdiek PRD 87 (2013) 115026

Introduction

- With the discovery of the Higgs the SM is now a complete description for particle physics (forgetting DM).
- On the other hand that same discovery by itself makes the theory fine-tuned.
- The lack of any other experimental evidence makes us believe that either the SM is the only theory above the Fermi scale or....

- We need to explain why the EW scale is still natural without any new particle at the EW scale.

- One possibility that I will follow in this talk is that, in fact, in the MSSM, the mass of the Higgs points to a heavy stop spectrum.

$$m_h^2 \simeq m_z^2 \cos^2 2\beta + \frac{3 y_t^2 m_t^2}{4\pi^2} \log\left(\frac{m_S^2}{m_t^2}\right) + \dots$$

- Therefore since the stops have to be heavy one can allow the first and second generations of sparticles to be much heavier than the third one since their contribution to the fine-tuning is small. This will explain why we have not seen them.

- On the other hand the stops cannot be arbitrarily heavy because of the Higgs mass.

- This kind of scenarios in where the first two generations are heavy are known as natural susy scenarios.
- They have different phenomenology since there are much less cascade decays.
- Can these scenarios be realized on a top-down approach?

- Yes (if not I won't be giving this talk)
- In general one needs, at least, two different sources of susy breaking:
  - One for the heavy sfermions
  - Another one for the third family (plus gauginos)

The Model

- Supersymmetry is broken in a hidden sector
- And communicated via two mechanisms:
  - Gauge mediation (flavorful) to the first two generations
  - Gravity mediation to the third one and gauginos

$$X = M_* + \theta^2 F$$

- This scenario has the following key features:
  - No flavor problem in the first two families since gauge mediation is flavor blind.
  - Possibility of using the Giudice-Masiero mechanism to generate μ and B, for this to happen the Higgses should not get masses from gauge mediation.
  - Generation of A-terms for the third family.

- The realization is as follows:
  - There is a new gauge group U(1) under which the first two families are charged with opposite charges.
  - The third family and the Higgses are uncharged under this new group.

	ψ_1	ψ_2	ψ_3	$H_{u,d}$	φ_1	φ_2	S
Q'	$+1$	-1	0	0	$+1$	-1	0

- $\psi_{1,2}$ represent the first and second generation ψ_3 the third generation, $\varphi_{1,2}$ and S are needed to break the extra U(1)

- Assuming the usual superpotencial with some messengers charged under the U(1):

$$W = \Phi_2 X \Phi_1$$

- One generates the following mass for all third generation scalars (plus the extra gaugino):

$$m^2 = \frac{g^2}{128\pi^4}\frac{F^2}{M_*^2}$$

- The existence of the extra U(1) forbids some Yukawa couplings for the first and second generations but they can be generated via non-renormalizable operators.

$$\frac{1}{M_*^2}\left(y_{11}\varphi_2^2\,\psi_1 H\psi_1^c + y_{22}\varphi_1^2\,\psi_2 H\psi_2^c\right) + \frac{1}{M_*}\left(y_{13}\varphi_2\,\psi_1 H\psi_3^c + y_{23}\varphi_1\,\psi_2 H\psi_3^c\right)$$

- To reproduce the CKM one needs to break the U(1) and:

$$v/M_* \sim 10^{-2}$$

- One can break the extra U(1) group via the following superpotential:

$$W = \lambda S(\varphi_1 \varphi_2 - v^2)$$

- Once the gauge group is broken all extra fields (φ, S, gauge bosons and its superparners) get a mass of order v.

- The gravitino will get a mass (from the cancelation of the cosmological constant).

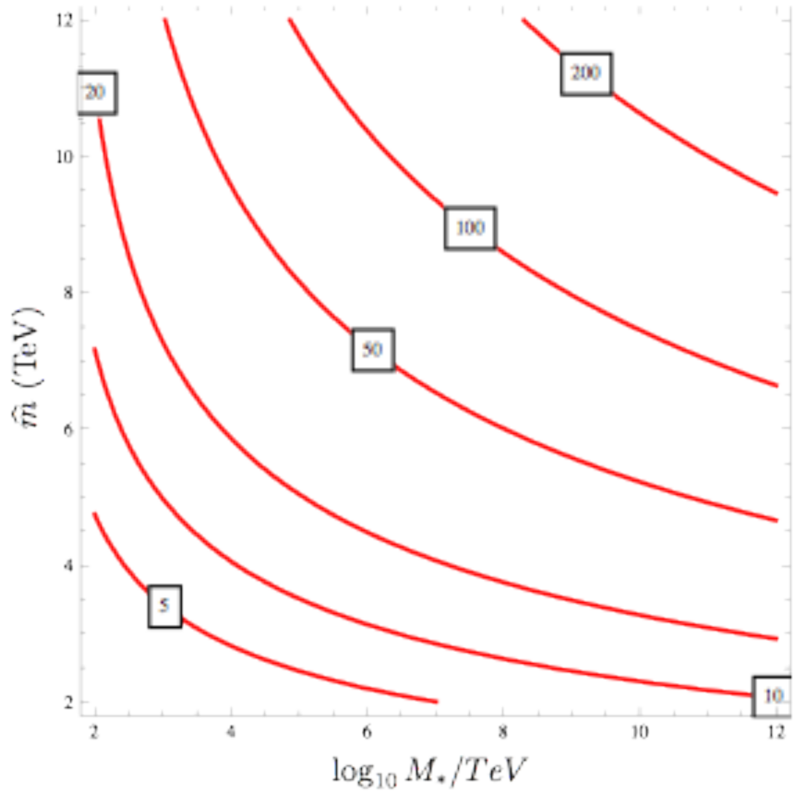
$$m_{3/2} \simeq \frac{F}{\sqrt{3}M_P}$$

- It will be comunicated to the third family via the operators:

$$\frac{1}{M_P^2}\int d^4\theta X X^\dagger Q_i^\dagger Q_j, \quad \frac{1}{M_P}\int d^2\theta X Q_i H_2 U_j^c, \quad \frac{1}{M_P}\int d^2\theta X W^A W^A \quad \int d^4\theta X^\dagger H_1 H_2, \quad \int d^4 X^\dagger X (H_1 H_2 + h.c.)$$

$$m_0 = M_{1/2} = A_0 = \mu = B = O(m_{3/2})$$

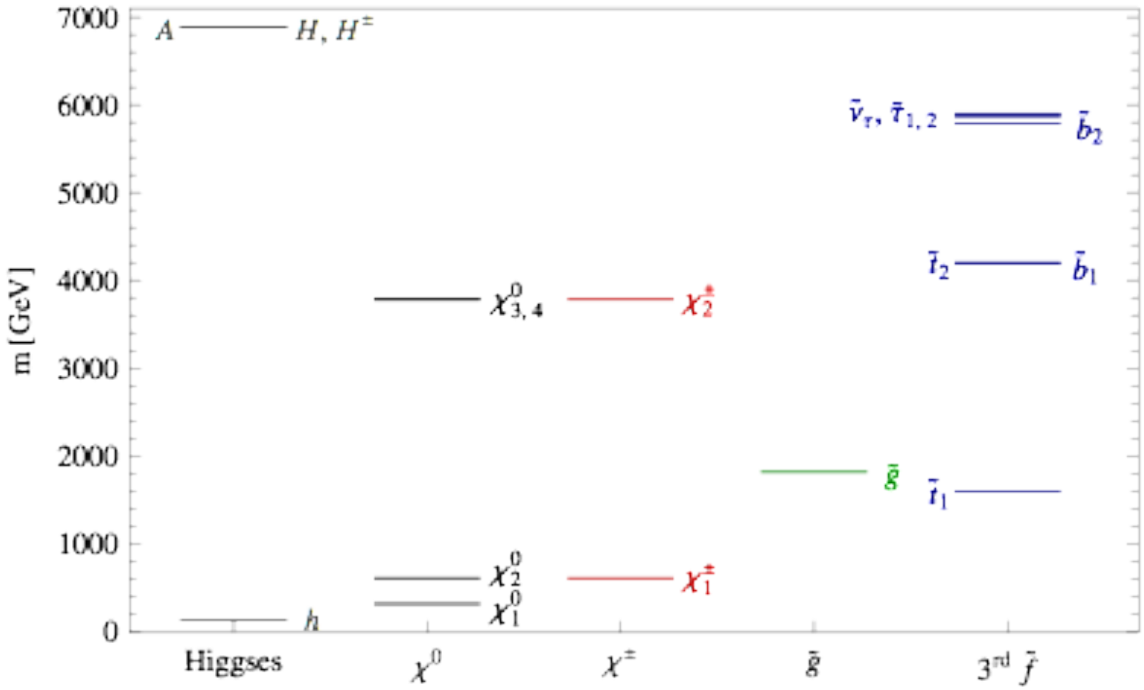
How to fix the overall scale?



- To fix the scale of the first two families, a fine-tuning less than .5% is imposed.

- This fixes all the scales:
  - $M_* = 10^{15}$ GeV
  - $v = 10^{13}$ GeV
  - $F = (10^{10})^2$ GeV
  - $m_{1,2} = O(10\text{ TeV})$
  - $m_3, M_{1/2} = O(1\text{ TeV})$

- In order to study the phenomenology of the model:
    - EW breaking is imposed
    - The Higgs mass is imposed to be 125 GeV
    - All experimental constrains are satisfied
    - $m_{1,2}$>10 TeV



tan β=10

- This is scenario A, scenario B is similar but with the mass of the gluino of 2.25 TeV

Phenomenology of the LSSM

- Not having the first of second generation makes most of the cascade decays unavailable
- For EWinos we have the following processes:

$$\chi' \to \begin{cases} \chi\, W/Z \\ \chi\, h \\ f\bar{f}\ (f = \tau, t, b) \end{cases}$$

- But the cross-section is too low:

$$\sigma(pp \to \chi + X) = 0.7 \text{ ab}$$

- We are left with either direct production of stops or production of gluinos which then decay into stops (sbottoms are heavier)

- But:

$$\sigma(pp \to \tilde{g}\tilde{g}) = 1.612 \text{ fb}, \ \sigma(pp \to \tilde{t}\tilde{t}) = 0.1 \text{ fb}$$

- Therefore the signal we will look for is:

$$pp \to \tilde{g}\tilde{g}, \ \tilde{g} \to t\tilde{t} \to b\bar{b}W^+W^-\chi$$

- The signal is calculated with Feynrules and Madgraph5, Pythia6 for hadronization and PGS for detector simulation

- The main backgrounds are:

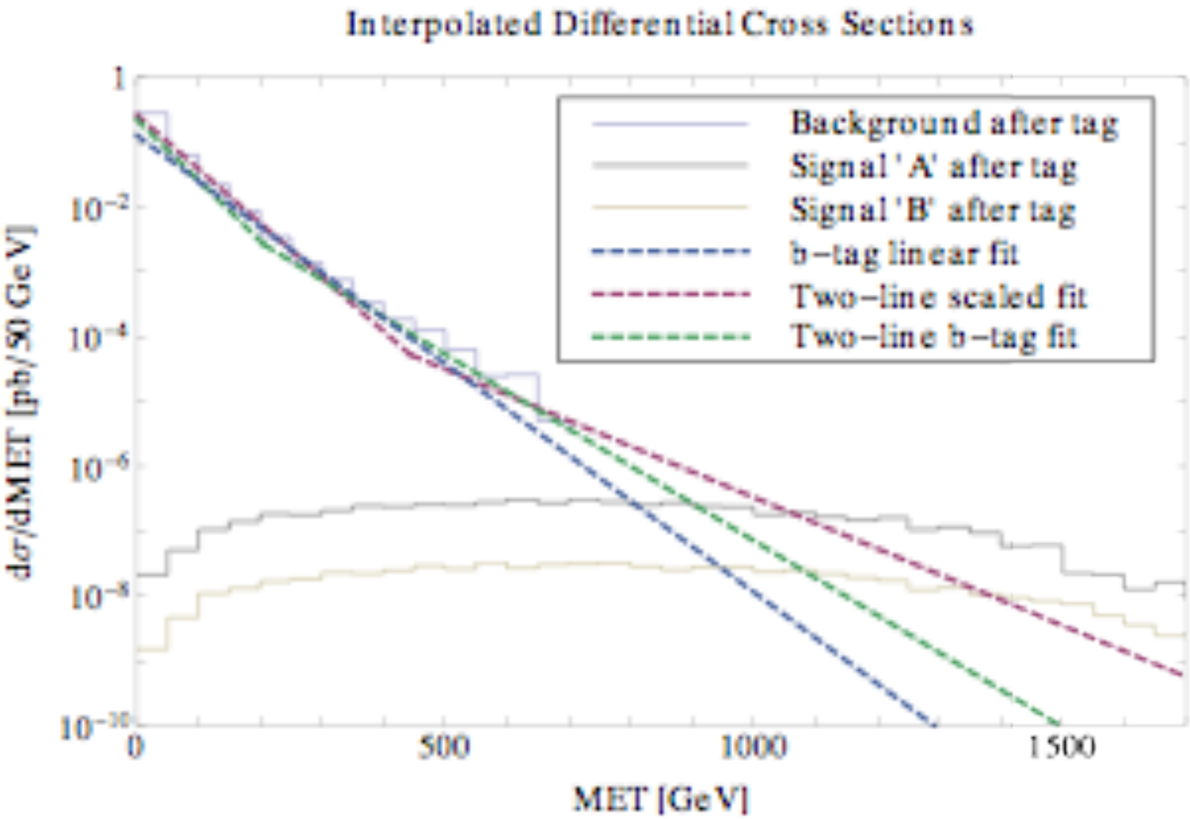
  - tops+jets: calculated with ALPGEN

  - tops+W/Z+jets: calculated with Madgraph

	Before b-tag	After b-tag
Signal Point A	1.612 fb	0.286 fb
Signal Point B	0.170 fb	0.032 fb
Background	1477 pb	19.18 pb

A: m_g=1.75 TeV
B: m_g=2.25 TeV

- We will demand three loose b-tags.
- We will demand four other jets and no photons in the final state.



- Due to lack of computing power we had to extrapolate the background

Estimation Method	$\not{E}_T^{\rm Cut}$ [GeV]	$\sigma_{\rm B}^{\rm Estimated}$ [ab]	$\sigma_{\rm S}$ [ab]	S	B	$\mathrm{S}/\sqrt{\mathrm{B}}$
				$\mathcal{L} = 200$ fb^{-1} (1000 fb^{-1})		
Linear	850 (950)	17.1 (3.73)	106.6 (10.8)	21 (11)	3 (4)	11.5 (5.6)
Two-Line	950 (1100)	10.4 (1.43)	80.7 (7.01)	16 (7)	2 (1)	11.2 (5.9)
Two-Line (Scaled)	1100 (1400)	14.7 (0.96)	50.3 (2.26)	10 (2)	3 (1)	5.9 (2.3)

- Whereas a gluino of 1.75 TeV (A) seems feasible in LHC14, a 2.25 (B) seems more doubtful in this conservative analysis.

Conclusions

- In this talk I have introduced a realization for 'natural susy' based on two sources of susy breaking
  - Gauge mediation for the first two families
  - Gravity mediation for the third family, gauginos and Higgses
- In this top-down approach I have shown the prospects for discovery at the LHC producing gluinos that decays to stops. The reach seems to be for masses around 2 TeV.