# Searches for GMSB SUSY

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# Overview

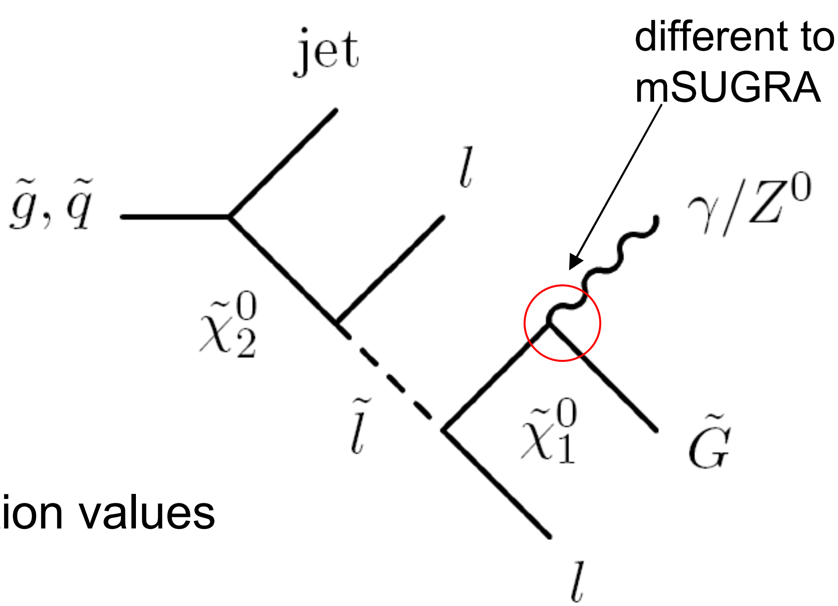
- GMSB – Model
- Search for di-photon events
- Other signatures
- Summary

# GMSB – Model I

Gauge mediated SUSY breaking can be understood in terms of loop effects in a renormalizable framework (in contrast to mSUGRA).

- Lightest SUSY particle (LSP): Gravitino
- 2nd lightest SUSY particle (NLSP): Neutralino or Slepton
- Missing energy from Gravitino

Typical decay chain for Neutralino NLSP

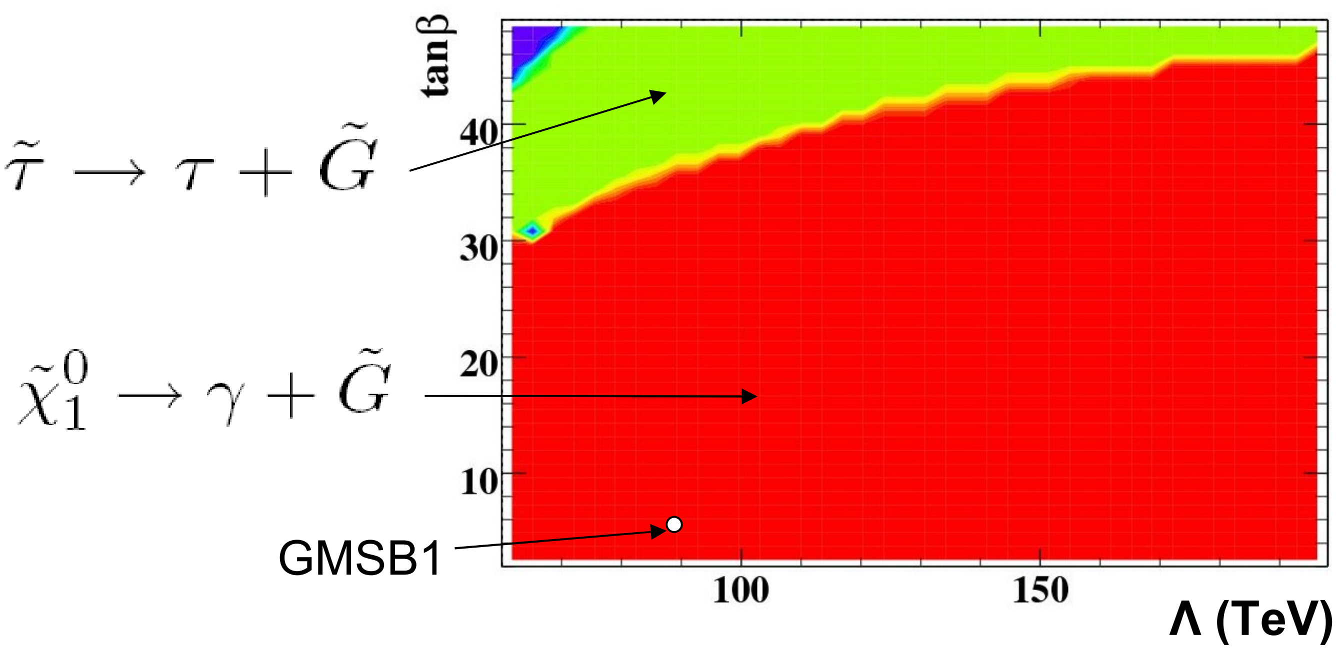



Parameters (general model has 124):

→ Λ: Breaking scale
→ M: Mass scale of the messengers
→ tanβ: Ratio of Higgs vacuum expectation values
→ N: Number of messenger multiplets
→ sign(μ): Sign of the Higgs mass parameter
→ $C_{grav}$: Scale factor of the Gravitino mass → lifetime of NLSP

# GMSB – Model II

- 4 main topologies in GMSB:
  - prompt decay: di-photon events (e.g. GMSB1, tanβ = 5, N = 1)
  - non-pointing photons (e.g. GMSB3, tanβ = 5, N = 1)
  - prompt decay: di-tau final states (e.g. GMSB6, tanβ = 30, N = 3)
  - long lifetime sleptons: quasi stable staus (e.g. GMSB5, tanβ = 5, N = 3)




M = 500 TeV, N = 1, sign(μ) = 1, $C_{grav}$ = 1

For N > 1, always Stau NLSP

# Data Samples

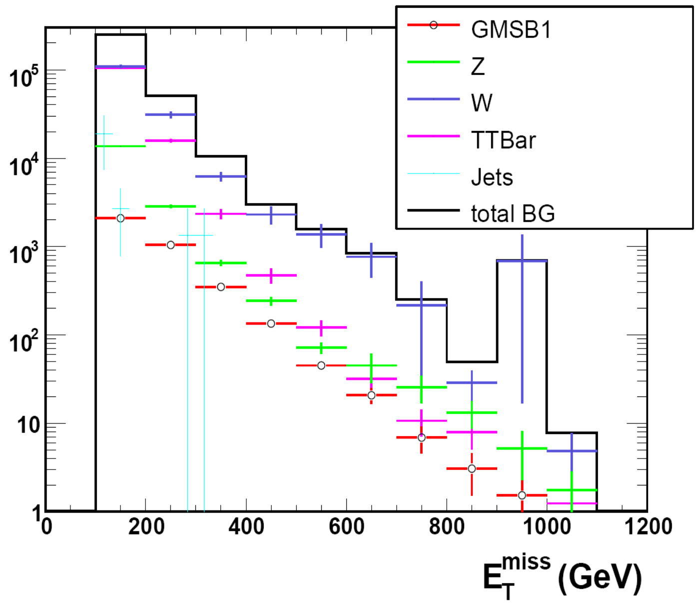
- Use officially produced Alpgen samples of the SUSY group.
→ Precuts are: $E_T^{miss} > 80$ GeV, $N_{jets} > 4$, $p_T$(jet) > 50 GeV, $p_T$(leading jet) > 100 GeV for the background

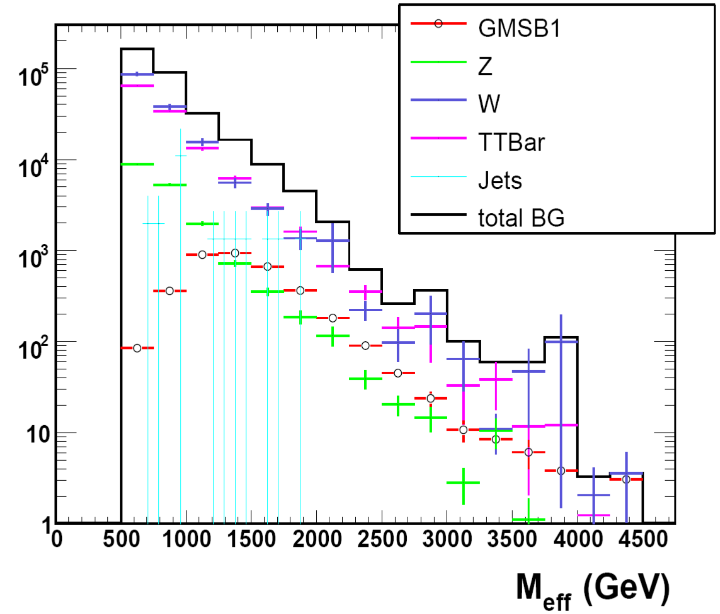
- Typical SUSY background is W+jets, Z+jets, ttbar, QCD jets.
→ QCD+photons doesn't contribute.

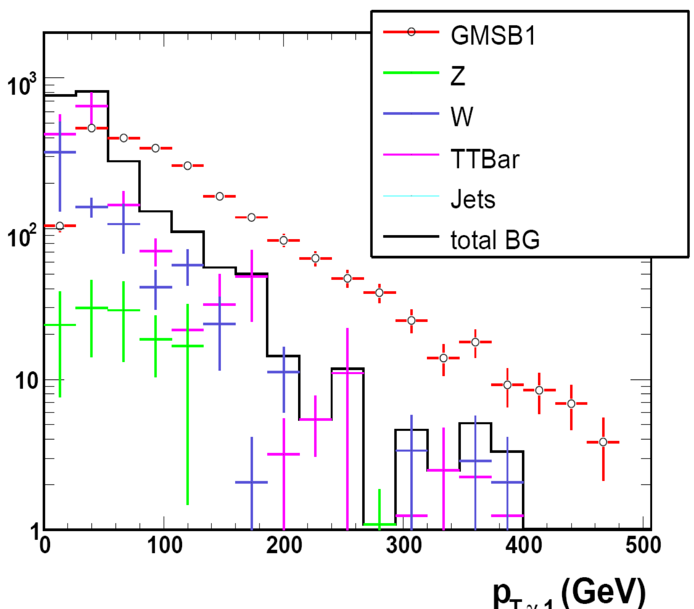
- NTuples produced with HighPtView.

- The official Alpgen samples have 1mm bug.
→ Corrected with HighPtView.

# GMSB1 Distributions ($1fb^{-1}$)



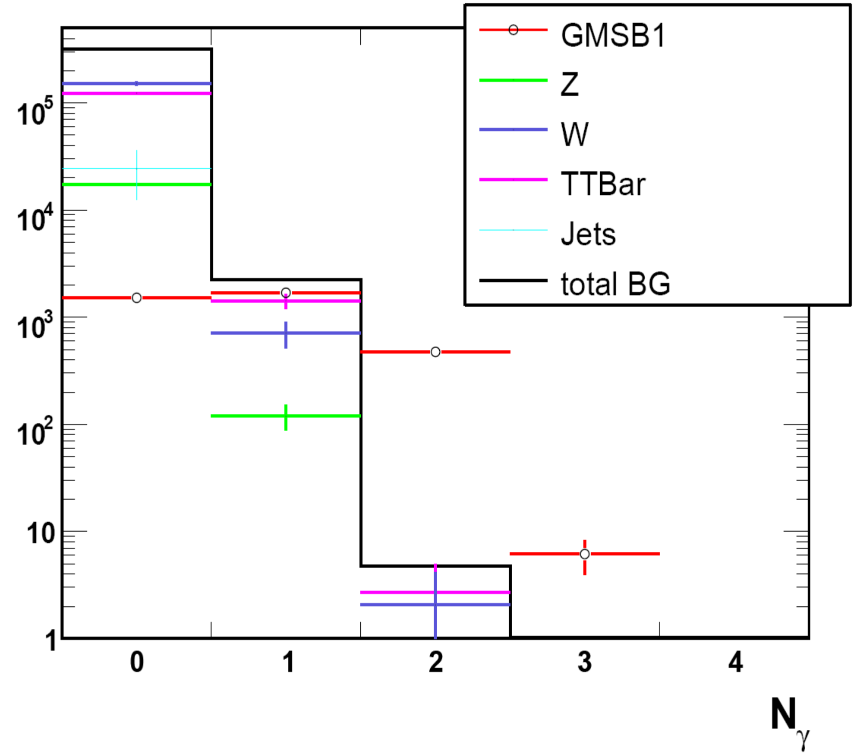

- Standard cuts on missing energy and effective mass not sufficient to reject background.
- Large amount of high momentum photons
  → good cut objects

# GMSB1 Selection

- Photons: $p_T$ > 20 GeV, |η| < 2.5

- Many hard photon events in GMSB1.

- Additional cuts on effective mass, missing energy, number of photons and number of OSSF lepton pairs.




- Example cutflow with significance (normalized to 1 $fb^{-1}$):

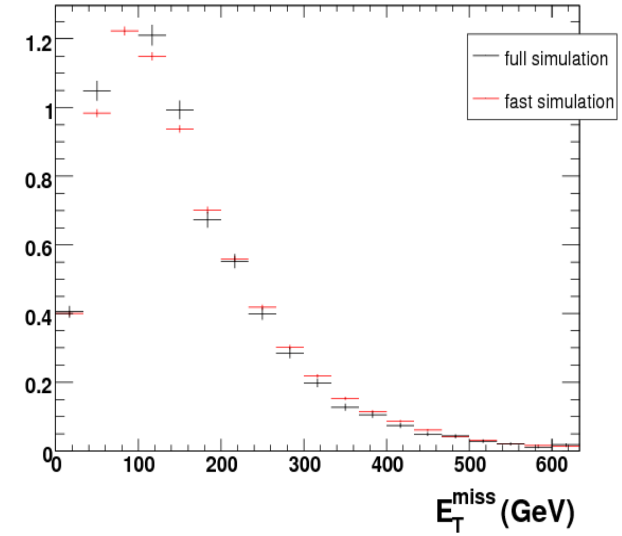
| Meff | MET | nP | LP | Signal | BG | Sig | nW | nZ | nttbar | nJets |
|---|---|---|---|---|---|---|---|---|---|---|
| 600 | 20% | 0 | 0 | 3180.5 | 189349 | 7.3 | 97415.8 | 11244 | 72041.8 | 8646.9 |
| 600 | 20% | 1 | 0 | 1877.7 | 1434.0 | 49.6 | 575.4 | 49.0 | 809.6 | 0 |
| 600 | 20% | 2 | 0 | 413.0 | 0.5 | 614.5 | 0 | 0 | 0.5 | 0 |
| 600 | 20% | 2 | 1 | 50.7 | 0 | 50.7 | 0 | 0 | 0 | 0 |

Large significance $S = \frac{\#\text{Signal}}{\sqrt{\#\text{BG}}}$ with simple cuts!

→2 hard photons: channel almost BG free

# Fast vs. full simulation

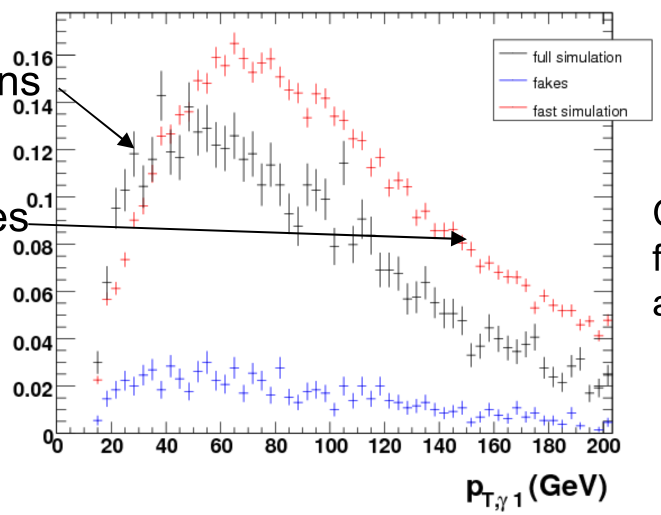
- Fast simulation needed for parameter scans.
  → What is the performance for the signal in study?
  → What are the efficiencies, which have to be put in by hand?



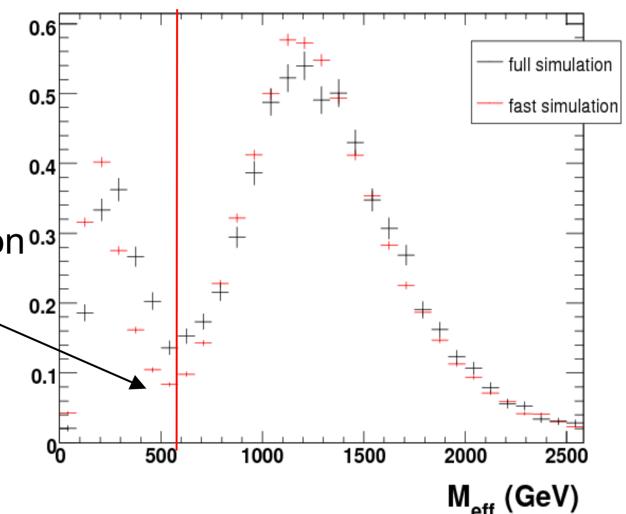

- Full vs. fast simulation for GMSB1.

Fake photons

Inefficiencies




Cut value, no further correction applied




→ Agreement is achieved by correcting fast simulation by known efficiencies

# GMSB discovery potential

- GMSB simulation with ATLFAST
- Generation with ISAJET 7.74 (M = 500 TeV, N = 1, sign(μ) = 1, $C_{grav}$ = 1)
- MC Data normalized to 1 $fb^{-1}$, the assumed photon efficiency is 70%.

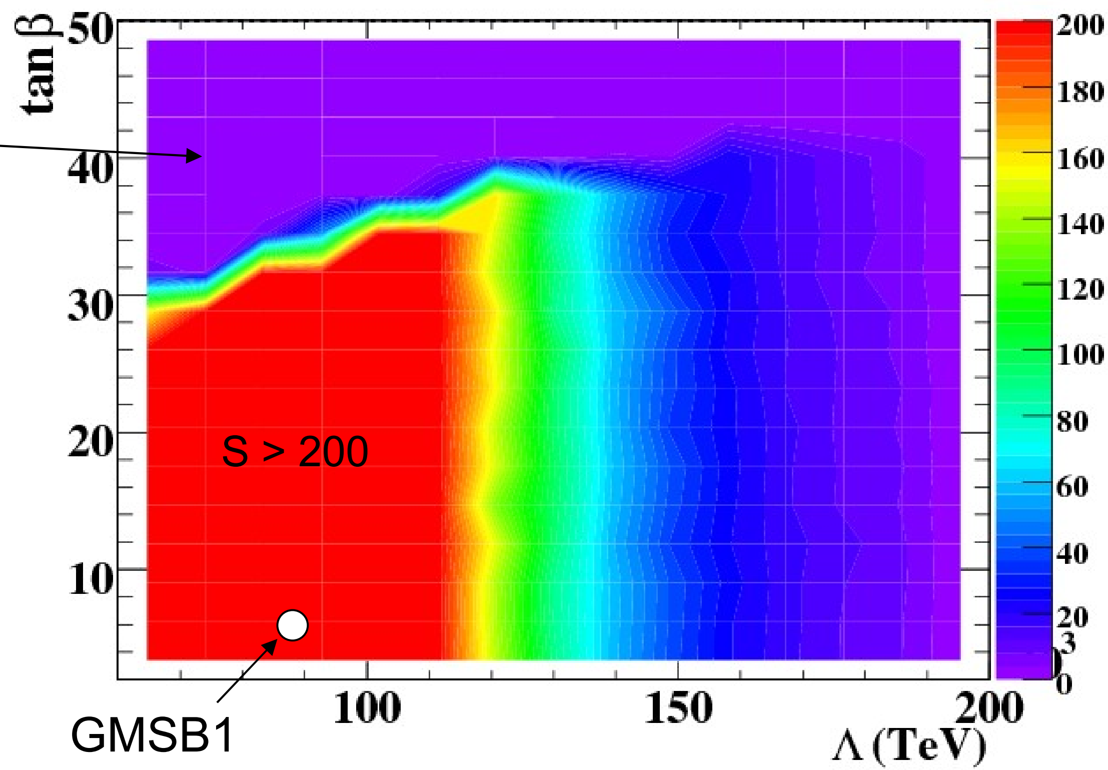
$\tilde{\tau}$ NLSP

→ no photons

Decrease of cross section with Λ

→ Decrease of significance

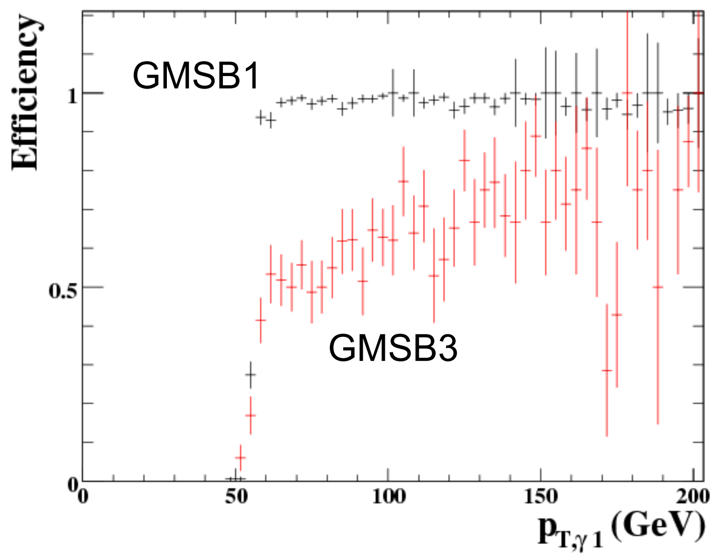
**→ Large discovery potential of di-photon signature in part of parameter space.**

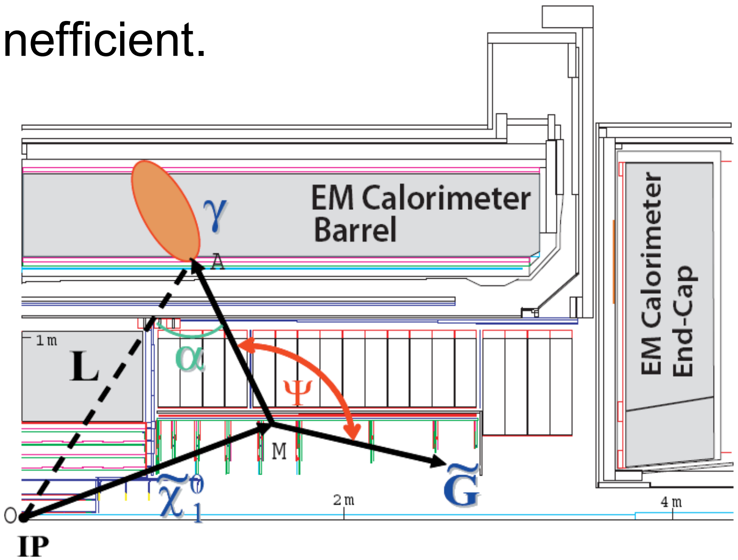


# Trigger Efficiencies

- In GMSB the NLSP can have different lifetimes due to $C_{grav}$.
  - → Non-pointing (to the IP) photons in the calorimeters, as in GMSB3.
  - → Shower shapes etc. look different!
  - → normal photon triggers (here g60) maybe inefficient.

Efficiency wrt offline




Total efficiency

| | | EF |
|---|---|---|
| GMSB1 | g60 | 80.5 ± 1.4 |
| | 2g20i | 47.9 ± 1.8 |
| GMSB3 | g60 | 36.9 ± 1.8 |
| | 2g20i | 12.9 ± 1.2 |

- For prompt photons photon triggers as good as standard SUSY trigger, e.g. $E_T^{miss}$, jets etc.
- For non-pointing photons efficiency loss for standard g60 and 2g20i trigger.

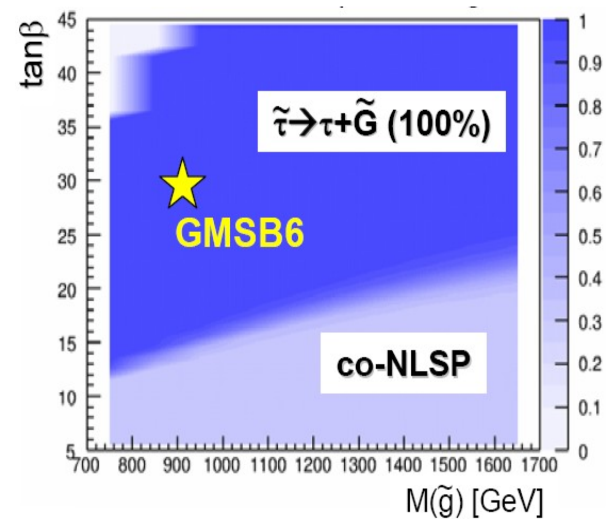
# Other possible GMSB signatures

- In some GMSB scenarios NLSP = Slepton (e.g. N >1, large tanβ).

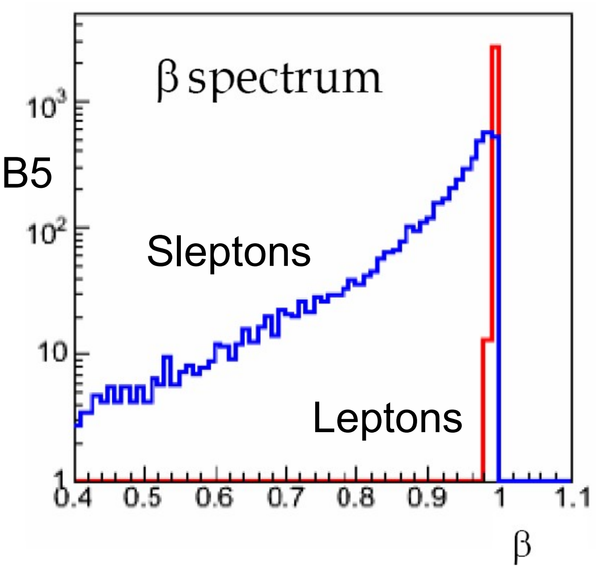
- 2 taus in final state:
  - e.g. GMSB6 (tanβ = 30, N = 3).
  - BG rejection with 4 high $p_T$ jets, missing energy and 2 tau jets.
  - Since gravitino is massless, downstream tau is hard and invariant mass can be reconstructed.

- Quasi stable staus:
  - e.g. GMSB5 (tanβ = 5, N = 3).
  - For β ~ 1 not distinguishable from ordinary muons, use muon triggers.
  - Bunch crossing identification challenging for β < 1, but most events contain a high β (> 0.7) slepton.

Tarem, Nomoto et al.




GMSB5



# Summary

- GMSB breaks supersymmetry radiatively.
- Different final states in GMSB
  - Di-photon (prompt)
  - Non-pointing di-photon
  - Di-tau final state
  - Quasi stable staus
- Study of di-photon signatures presented in detail.
- Large discovery potential for some parameter regions → perhaps even with a few $pb^{-1}$ of data.
- Presented studies are part of SUSY-CSC8 note.

# GMSB theory in a nutshell

- Messenger fields are chiral superfields which transform under SM as

$$q \sim (\mathbf{3}, \mathbf{1}, -\frac{1}{3}); \quad \overline{q} \sim (\overline{\mathbf{3}}, \mathbf{1}, \frac{1}{3}); \quad \ell \sim (\mathbf{1}, \mathbf{2}, \frac{1}{2}); \quad \overline{\ell} \sim (\mathbf{1}, \mathbf{2}, -\frac{1}{2})$$

- Coupling to a gauge singlet chiral superfield S: $W_{\text{mess}} = y_2 S \ell \overline{\ell} + y_3 S q \overline{q}$
- Scalar components of S aquire VEVs and produce massterms

$$\begin{aligned} \ell, \overline{\ell}: \quad & m^2_{\text{fermions}} = |y_2 \langle S \rangle|^2, \quad & m^2_{\text{scalars}} = |y_2 \langle S \rangle|^2 \pm |y_2 \langle F_S \rangle| \\ q, \overline{q}: \quad & m^2_{\text{fermions}} = |y_3 \langle S \rangle|^2, \quad & m^2_{\text{scalars}} = |y_3 \langle S \rangle|^2 \pm |y_3 \langle F_S \rangle| \end{aligned}$$

- One loop contributions to gaugino masses
  → Gauge mediated breaking
  → Scalars aquire 2-loop masses