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# Searches for GMSB with the ATLAS detector

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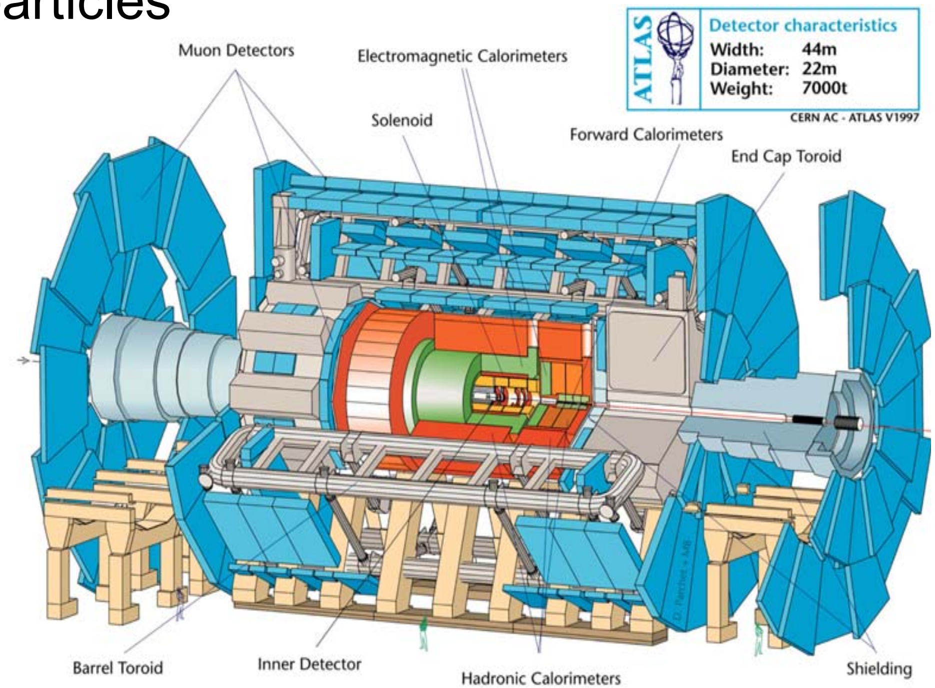
# Outline

- GMSB Model
- GMSB signatures and discovery potential
    - Photon final states
    - Heavy stable charged particles
- Summary



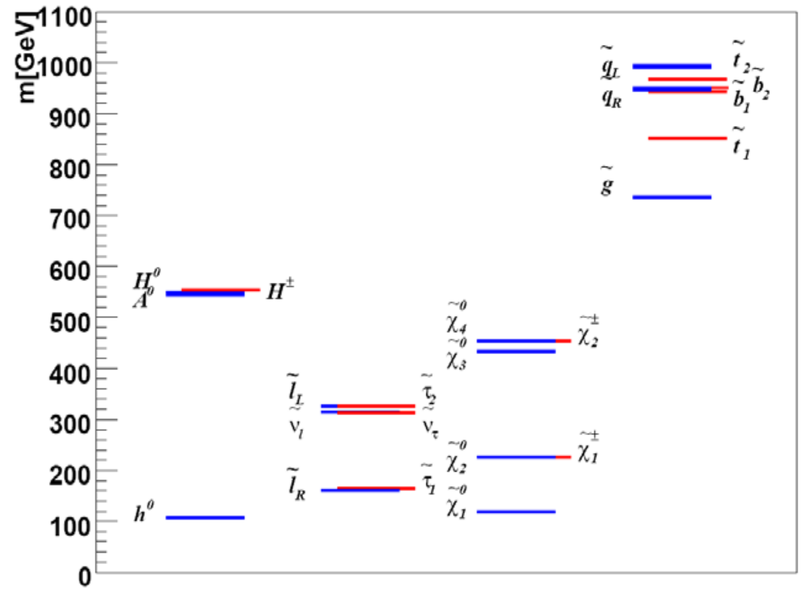
# GMSB – Model I

- SUSY good candidate for BSM physics
- SUSY breaking: mediated via gravity, gauge interactions, ...
- GMSB described by 6 fundamental parameters

| Par. | Description |
|---|---|
| $\Lambda$ | SUSY breaking scale |
| **M** | Messenger mass scale |
| **tan$\beta$** | Ratio of Higgs VEVs |
| **N** | Number of messenger multiplets |
| **sign($\mu$)** | Sign of Higgs mass parameter |
| $C_{grav}$ | Scale factor of Gravitino coupling ($\sim 1/C^2_{grav}$) |

Present GMSB limits from TeVatron searches:

| Par. | $\Lambda$ | $m_{Neutralino}$ | $m_{Chargino}$ |
|---|---|---|---|
| Limit | > 80 TeV | > 110 GeV | > 200 GeV |

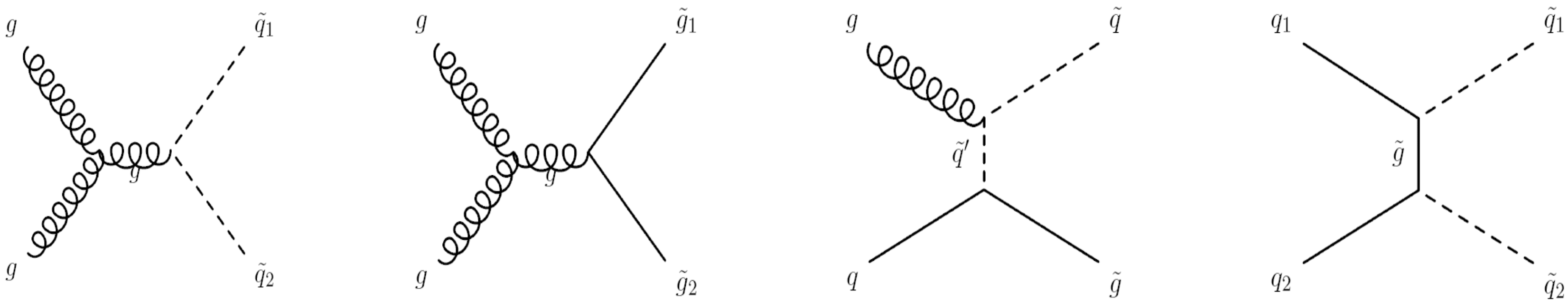



Features:

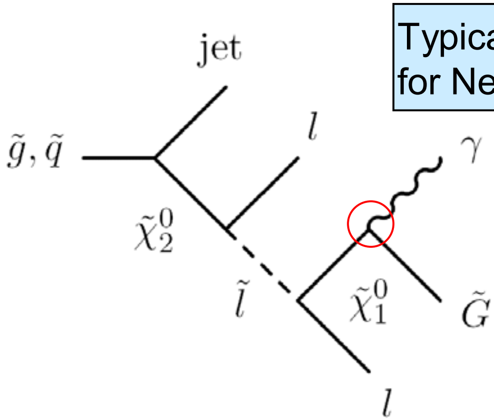
- Lightest SUSY particle (LSP): Goldstino/Gravitino (m ≤ keV)
- 2nd lightest SUSY particle (NLSP): Neutralino or Slepton
- Missing energy from Gravitino
- Final state: hard photons, leptons

# GMSB – Model II

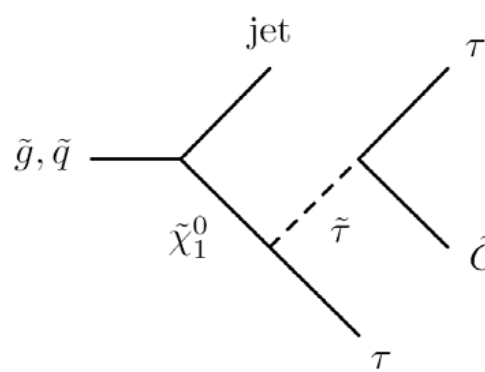
- LHC will probe new energy range in pp@14 TeV
- Squarks and gluinos will be produced (cross section: a few pb) e.g. via




- Different final states compared to mSUGRA




Typical decay chain for Neutralino NLSP



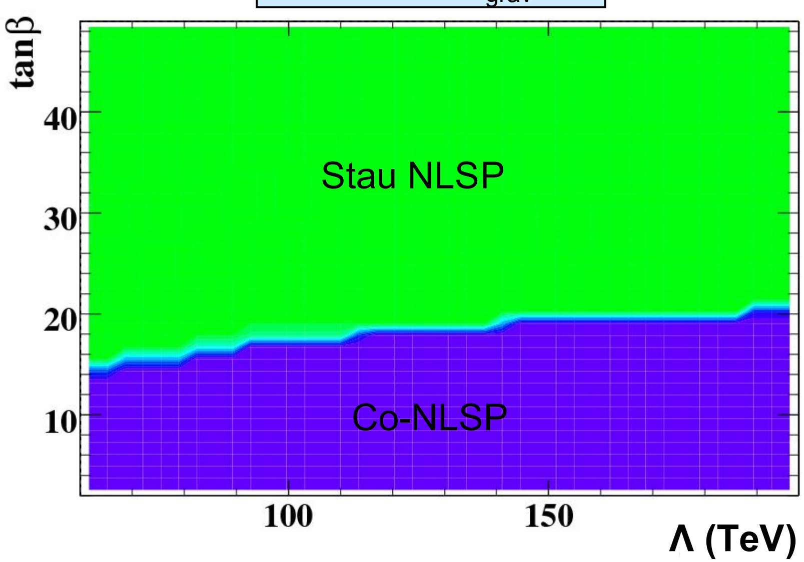

Typical decay chain for Stau NLSP

→ This talk: Results of simulation studies of ATLAS

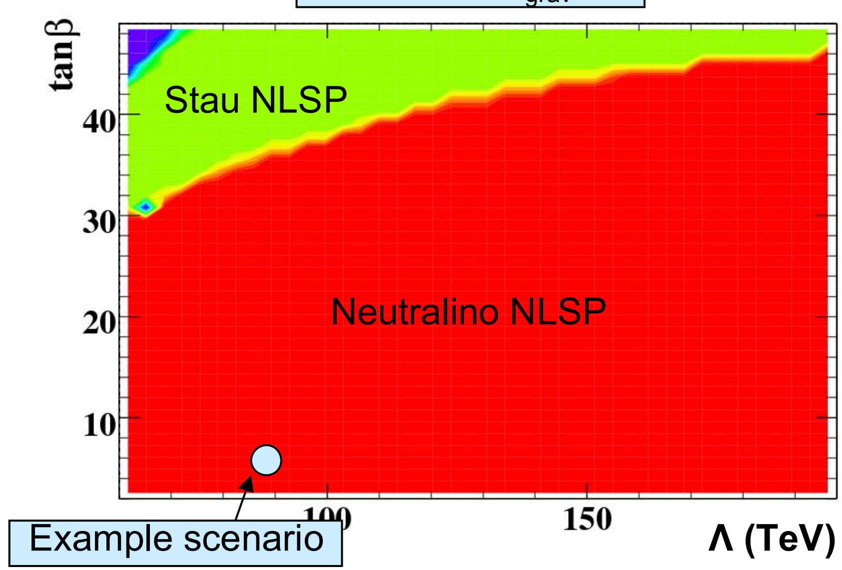
# GMSB – Model III

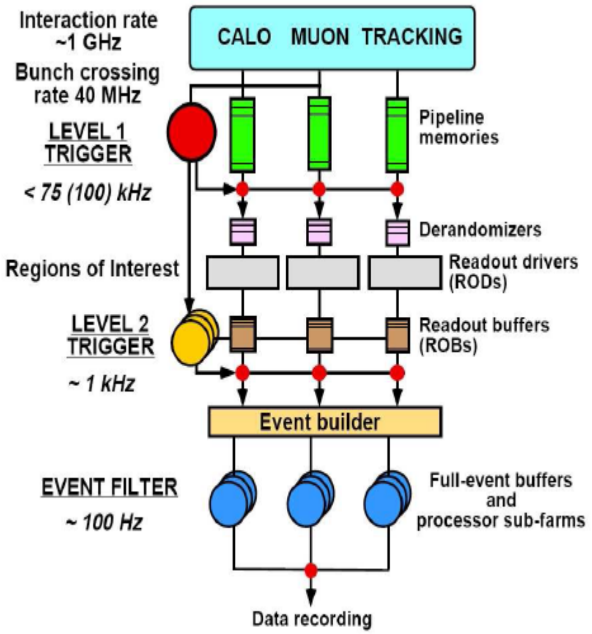
- 4 main topologies in GMSB (red covered in this talk):
  - Neutralino NLSP:
    - -Prompt decay: di-photon events (e.g. N = 1, $C_{grav}$ = 1) (**GMSB1**)
    - -Non-pointing photons (e.g. N = 1, $C_{grav}$ = 55)
  - Slepton NLSP:
    - -Prompt decay: di-lepton final state (e.g. N = 3, $C_{grav}$ = 1)
    - -Long lifetime sleptons: quasi stable sleptons (e.g. N = 3, $C_{grav}$ = 5000)

M = 250 TeV, N = 3, sign(μ) = 1, $C_{grav}$ = 1



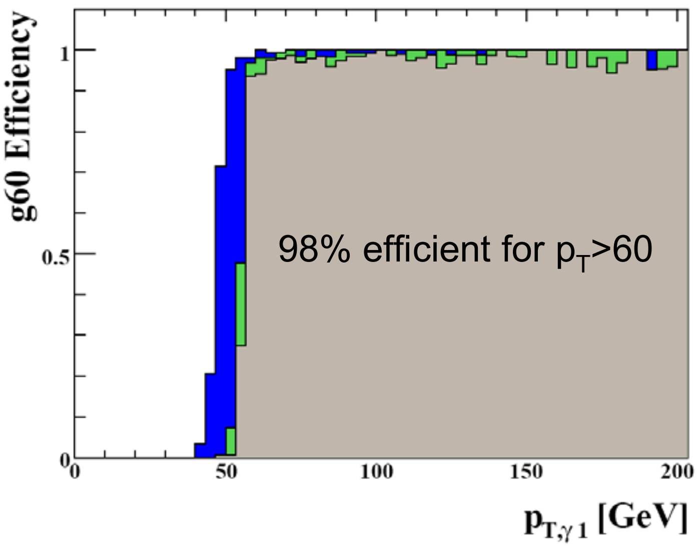

M = 500 TeV, N = 1, sign(μ) = 1, $C_{grav}$ = 1






- Due to high $p_T$ photons: Use of photon triggers possible.
- Also missing energy and jet triggers can be used.

| Trigger item | L1 | L1+L2 | L1+L2+EF |
|---|---|---|---|
| g55 | 97.18±0.60 | 84.47±1.32 | 80.47±1.44 |
| 2g17i | 71.13±1.65 | 55.07±1.81 | 47.91±1.81 |
| j65+xE70 | 80.66±0.40 | 80.63±0.40 | 69.53±0.46 |
| 3j65 | 83.63±0.37 | 83.55±0.37 | 83.37±0.37 |



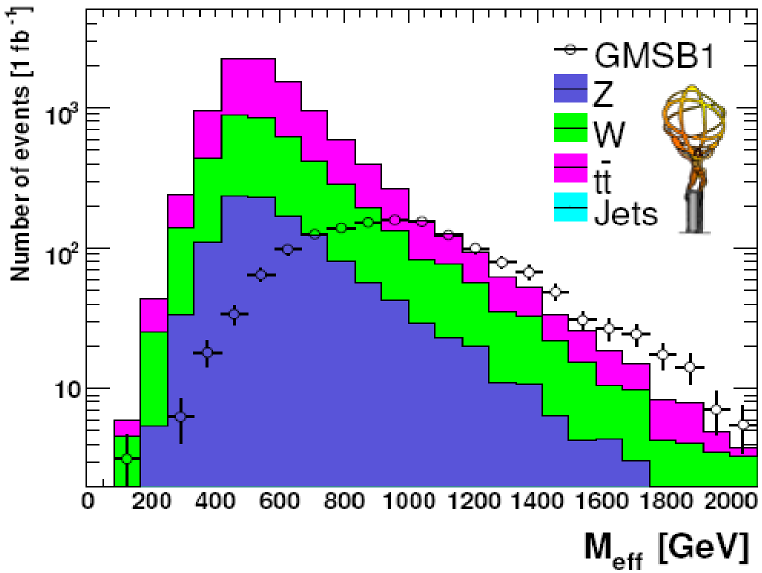

- Photon triggers: As efficient as "std." SUSY trigger, e.g. $E_T^{miss}$, jets.
- What do we understand in early data? $E_T^{miss}$? Jets? ECAL?

→ Prefer to use photon triggers instead of complicated objects like $E_T^{miss}$

→ Good BG rejection with trigger

# SM Background (GMSB1)





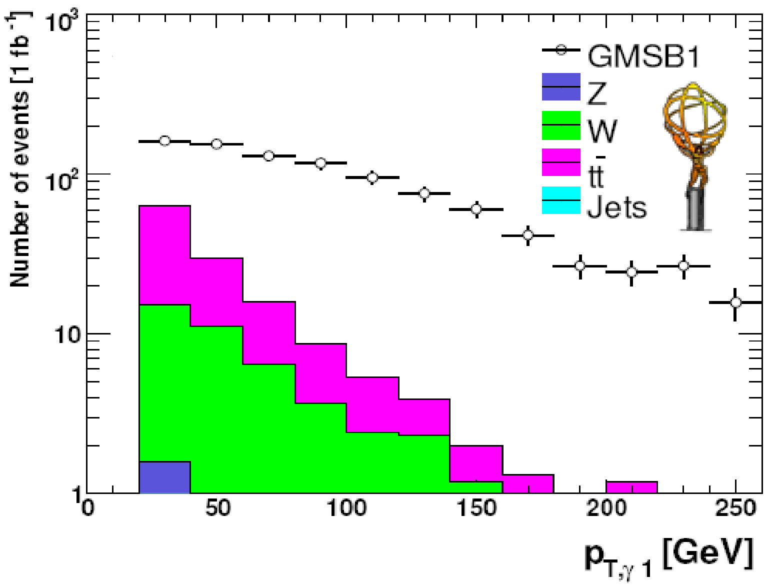

**Prompt photon scenario (7.8 pb)**

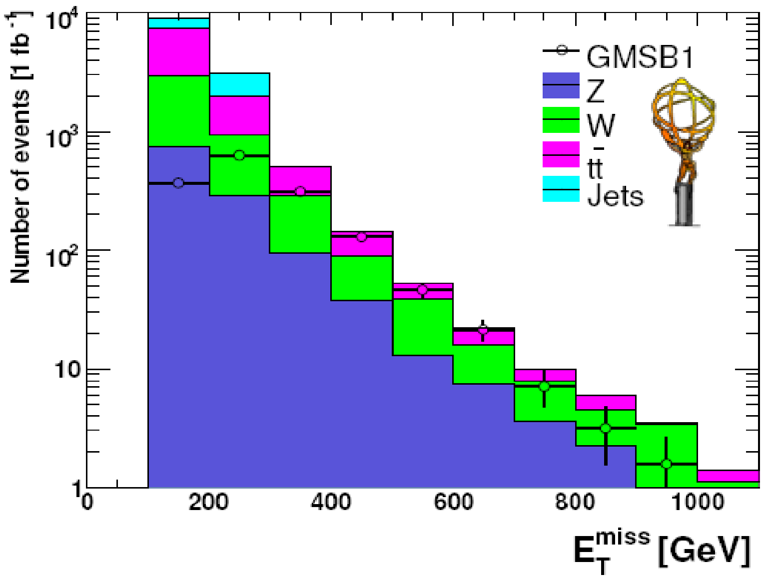
- How to select the signal events?

  → Missing transverse energy from gravitinos, hard jets, hard photons, ...

- Background: SM processes with fake photons, mismeasured jets ($E_T^{miss}$)

  → Mainly top-production: neutrinos ($E_T^{miss}$), jets or leptons faking photons



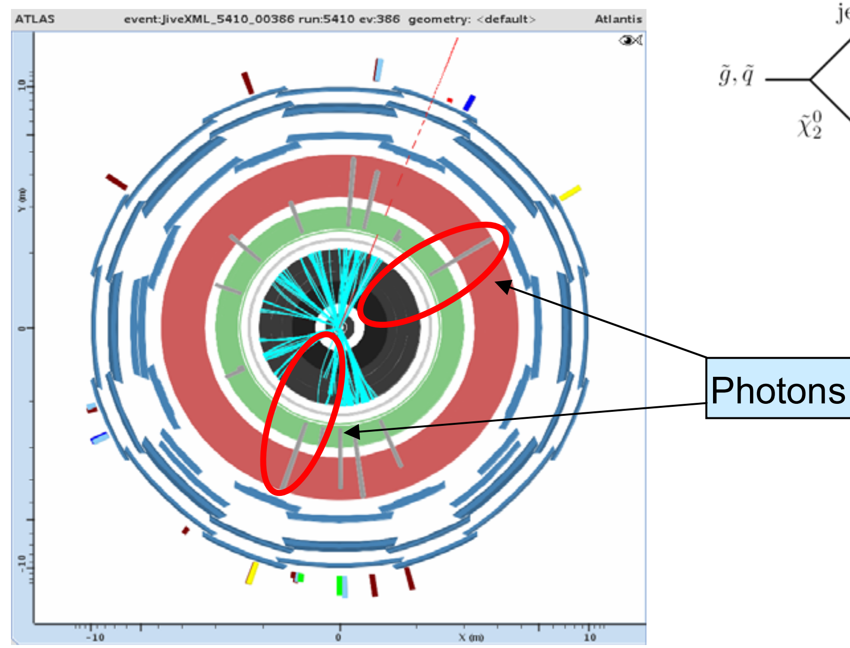



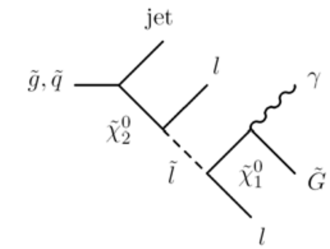
# Prompt photon selection ($1fb^{-1}$)

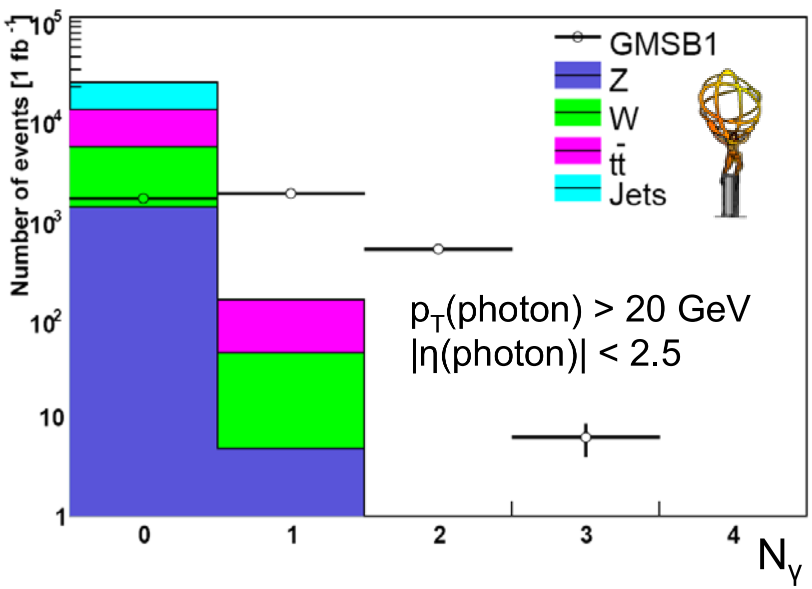
Prompt photon scenario (7.8 pb)

"Standard" SUSY cuts:

- $E_T^{miss} > 100$ GeV
- $E_T^{miss} > 0.2\, M_{eff}$
- $N_{jets} > 3$
- $p_T(\text{jets}) > 50$ GeV
- $p_T(\text{leading jet}) > 100$ GeV



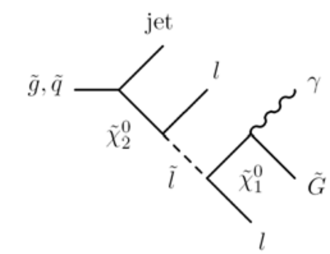




- Cuts on missing energy and effective mass reject BG.
- Striking feature in GMSB1: Prompt photons with high momentum.
- Additional requirement of 2 photons:

→ 252.9 signal events, 0.1 BG events

# Di-photon discovery potential ($1fb^{-1}$)





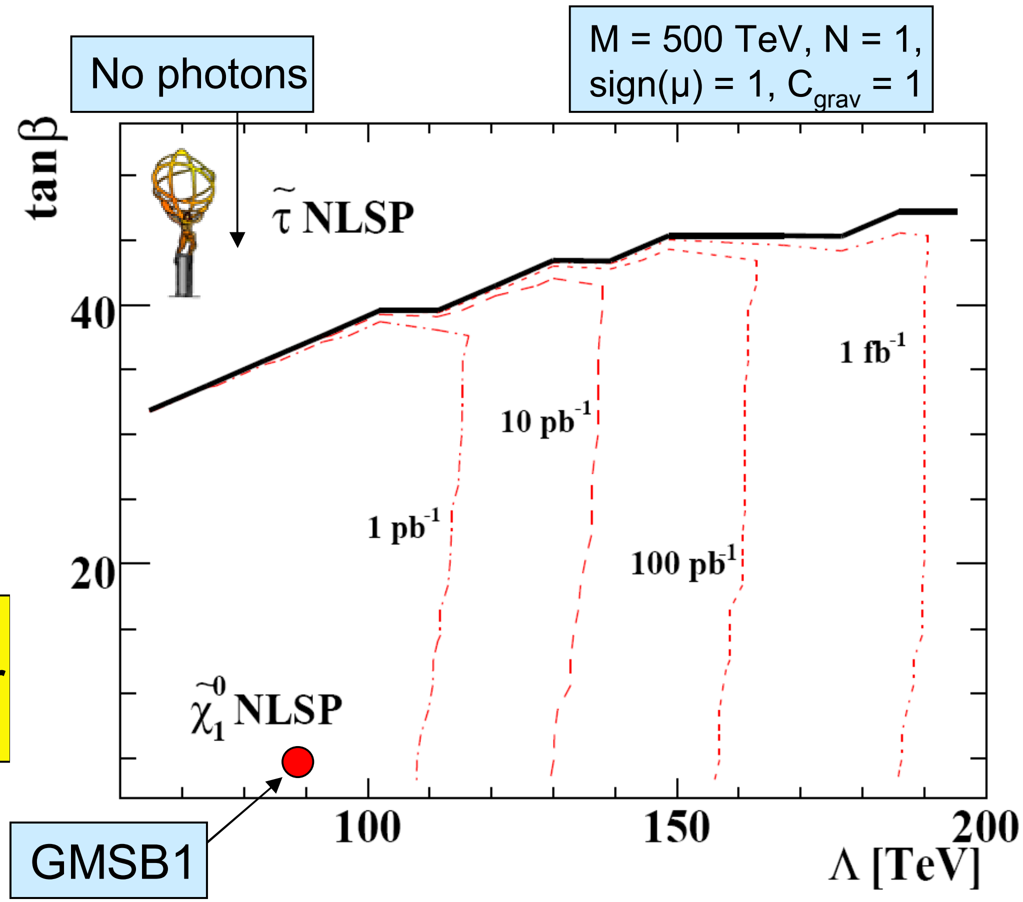

- Discovery potential in di-photon channel?
  - → Scan of GMSB parameter space using a fast simulation.

Contour lines with 5 signal events.

Decrease of cross section with Λ

→ Decrease of significance

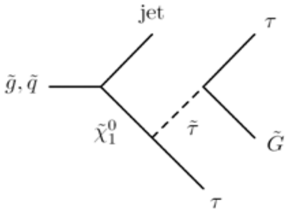
**→ Large discovery potential of di-photon signature in part of parameter space.**

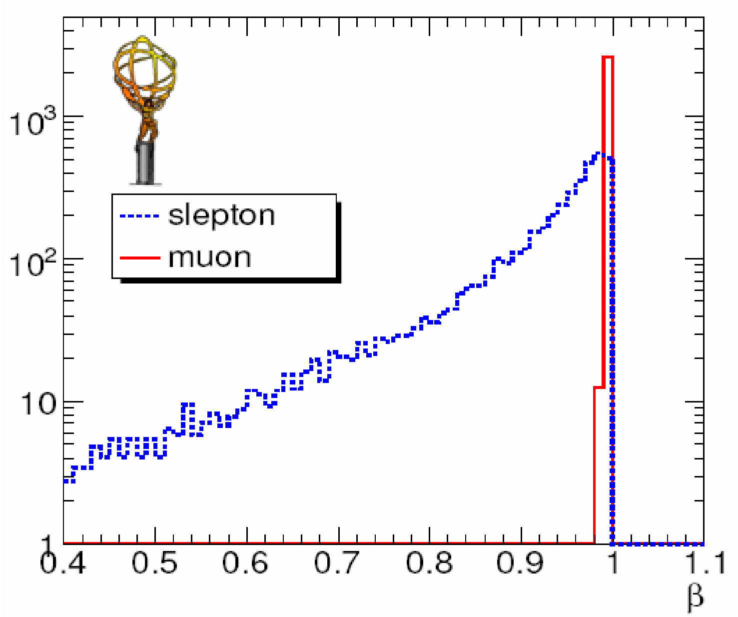


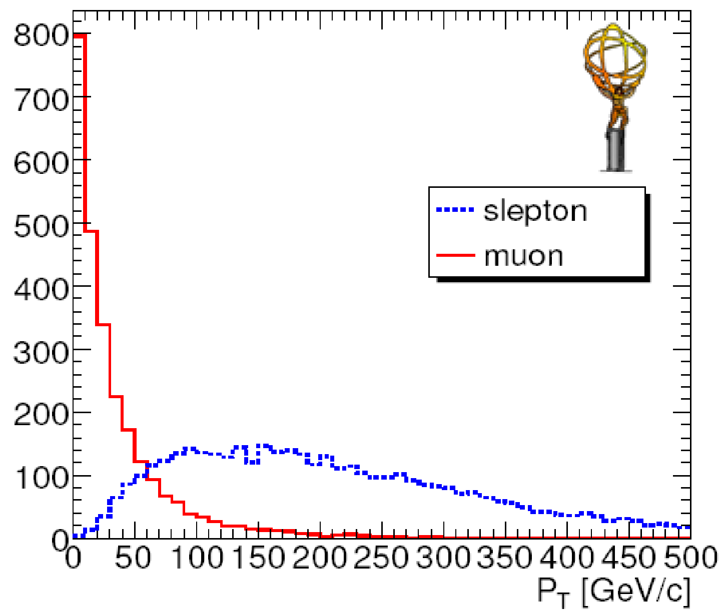
# Heavy stable charged particles (HSCPs)

S. Tarem et al

- Some GMSB scenarios: NLSP = Slepton (N >1, large tanβ).
- Sleptons that couple weakly to Gravitino have long lifetime:
  - Heavy stable charged particle with β < 1.
  - For β ~ 1 not distinguishable from ordinary muons
    → use muon triggers (besides missing energy triggers).
  - For β < 1 bunch crossing identification challenging, but most events contain a high β slepton.



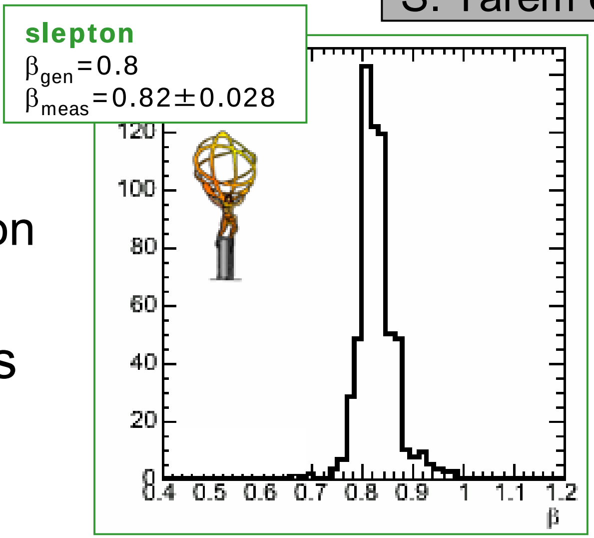



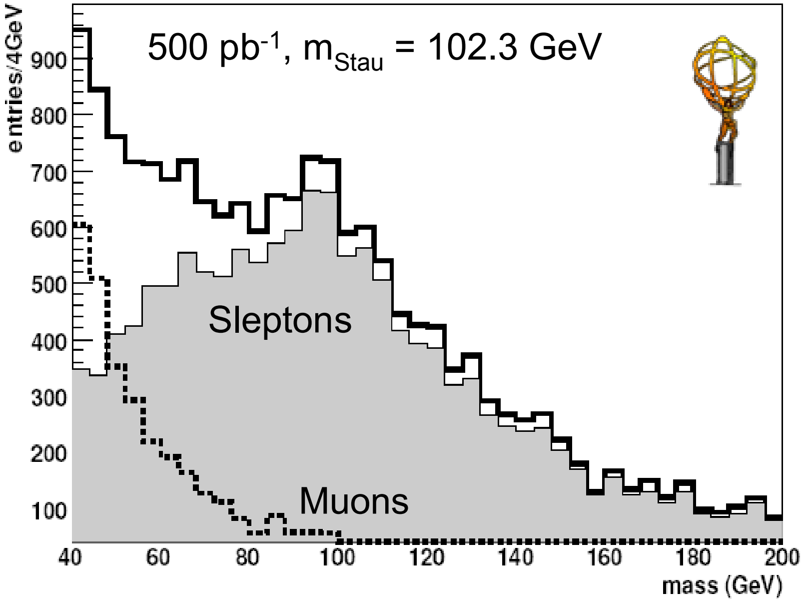
# HSCP β and mass measurement



S. Tarem et al

- 2 strategies for measurement of β:
  1. β from time of flight (muon system)
  2. β from time over threshold in transition radiation tracker.
- Use of hits from next bunch crossing improves efficiency from 65% to 97% for β = 0.6.




- Stau mass can be estimated from β and p

$$m = p\sqrt{\frac{1}{\beta^2} - 1}$$

→ Measureable already at trigger level

- Selection:
  - β < 0.97, $p_T$ > 40 GeV, m > 40 GeV

# Summary

- GMSB possible model for SUSY breaking.
- Striking signatures expected at the LHC:
  - Di-photon (prompt)
    → Clean signal, low background.
  - Quasi stable staus
    → Promising results in selection, mass and velocity measurement.
- Discovery possible already with early data!

# GMSB theory in a nutshell

- Messenger fields are chiral superfields which transform under SM as

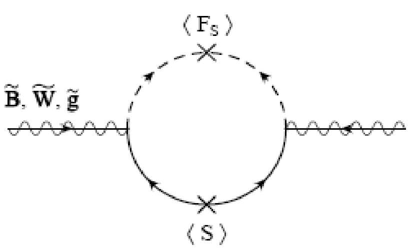
$$q \sim (\mathbf{3}, \mathbf{1}, -\frac{1}{3}); \quad \overline{q} \sim (\overline{\mathbf{3}}, \mathbf{1}, \frac{1}{3}); \quad \ell \sim (\mathbf{1}, \mathbf{2}, \frac{1}{2}); \quad \overline{\ell} \sim (\mathbf{1}, \mathbf{2}, -\frac{1}{2})$$

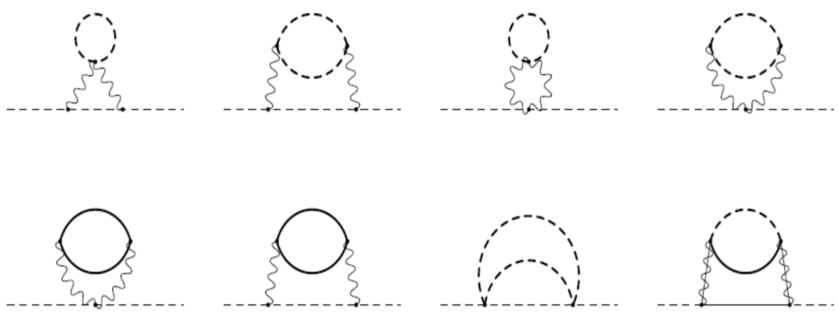
- Coupling to a gauge singlet chiral superfield S: $W_{\text{mess}} = y_2 S \ell \overline{\ell} + y_3 S q \overline{q}$

- Scalar / auxiliary components of S aquire VEVs and produce massterms

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

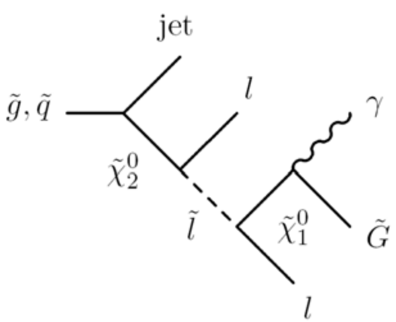
- One loop contributions to gaugino masses
  - → Gauge mediated breaking
  - → Scalars aquire 2-loop masses



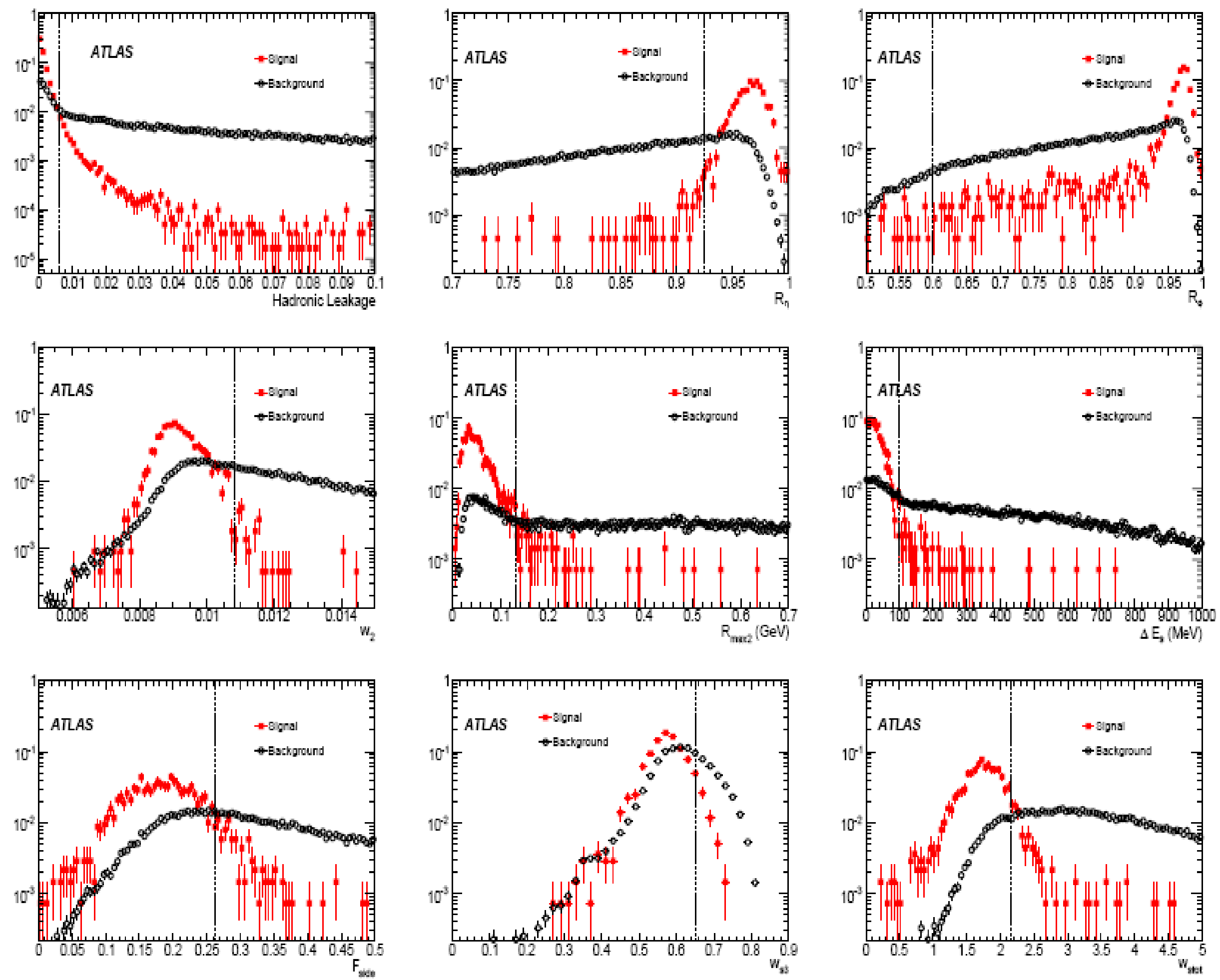



# Photon Identification

- GMSB with photons in final state (GMSB1)

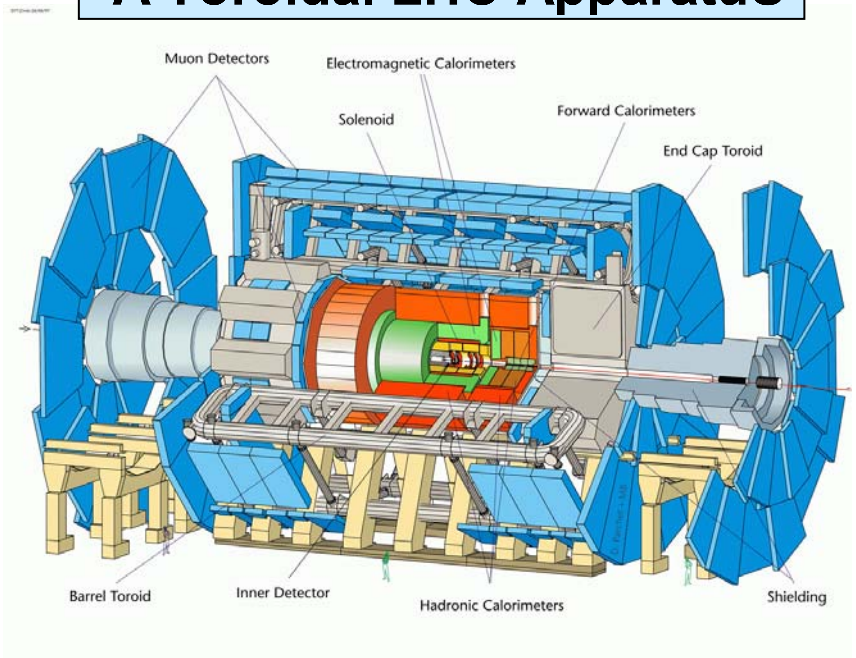



- Photon ID with calorimeter variables:
  → Energy deposition
  → Shower shapes
  → Shower sub-structures from 1st sampling



# The ATLAS detector

**A Toroidal LHC ApparatuS**




| | |
|---|---|
| **Total weight** | **7000 t** |
| **Overall diameter** | **25 m** |
| **Barrel toroid length** | **26 m** |
| **End-cap span** | **46 m** |
| **Magnetic field** | **2 Tesla** |