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Search for heavy long lived sleptons with ATLAS at $\sqrt{s} = 8$ TeV

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A search for heavy long-lived sleptons has been performed on a data sample of 15.9± 0.45 fb^{-1} from proton-proton collisions at a center-of-mass energy $\sqrt{s}$ = 8 TeV collected by the ATLAS detector at the LHC in 2012

Physics motivations

- Heavy long lived particles (LLPs) are predicted by many Standard Model (SM) extensions.
- In Supersymmetry (SUSY), sleptons ($\tilde{l}$, superpartners of leptons), squarks and gluinos ($\tilde{q}$, $\tilde{g}$, superpartners of quarks and gluons, respectively) might have long lifetimes and decay outside the detector volume.
- In the framework of gauge-mediated SUSY breaking (GMSB) with the light stau ($\tilde{\tau}_1$) is the next to lightest supersymmetric particle (NLSP) and may be long lived:
  - ✓ GMSB events contain two $\tilde{\tau}_1$ (mostly right-handed in the considered GMSB points);
  - ✓ direct production dominates and allows to set model independent limits;
  - ✓ indirect limits set on $\tilde{\chi}_1^0$ and $\tilde{\chi}_1^{\pm}$ masses.

Analysis strategy

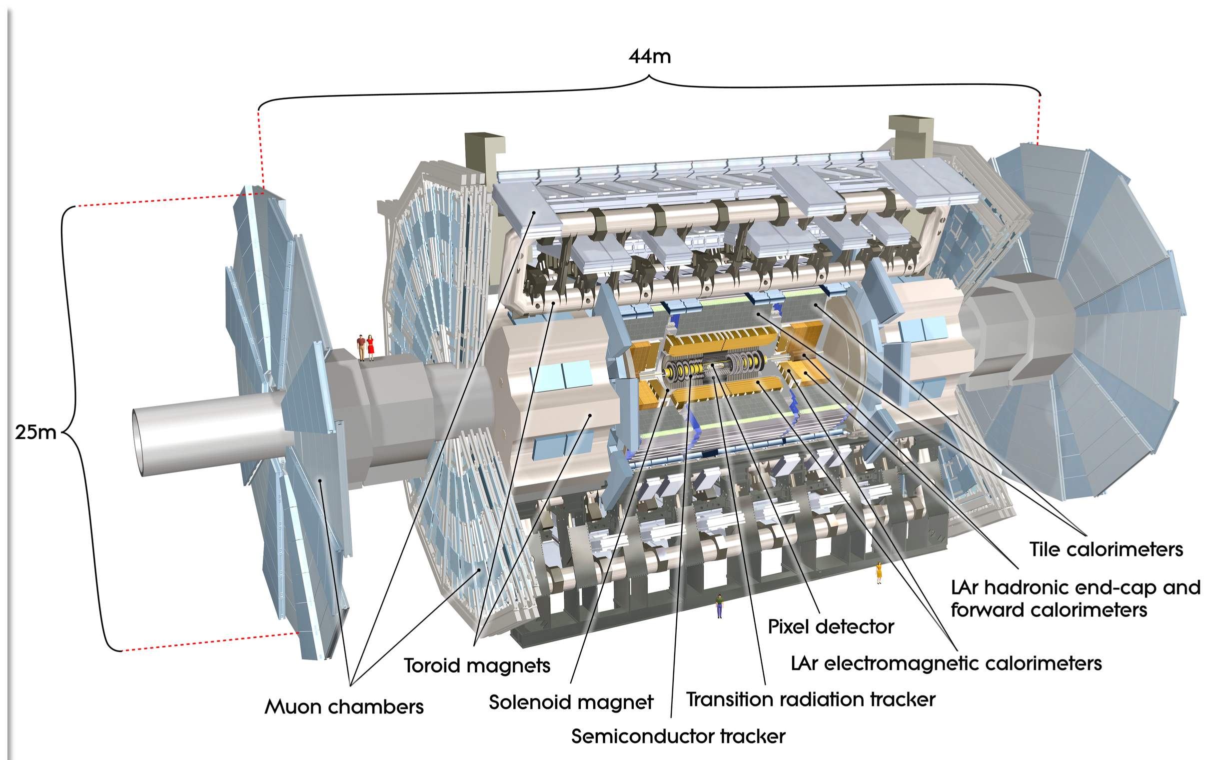
Heavy charged LLPs behave like heavy muons releasing energy by ionisation as they pass through the ATLAS detector:

- Select high momentum (p) particles having speed β<1, measure their mass through the relation:

$$m = \frac{p}{\beta\gamma}$$

From Time-Of-Flight (ToF) measurements in Muon Spectrometer (RPC + MDT) and Calorimeters → $\beta\gamma$; From track measurement → p

- Main background source (high-p muons with mis-measured β) estimated form data by repeated combination of the p of a candidate passing the selection with a random β extracted from muons β distribution;
- Signal efficiency evaluated from simulation, ToF distributions smeared according to data, smearing validated using $Z \to \mu^+\mu^-$ simulation.
- Data sample divided in two exclusive parts: two candidates, passing a loose selection (Signal Region) or if not, one candidate passing a tight selection (Control Region, used to assess systematic uncertainties).



Slepton search with the ATLAS detector

Inner Detector
- Silicon Pixel:
  - ✓Energy loss measurement (dE/dx) used as consistency test for β.

Calorimeters
- LAr + Tile:
  - ✓Timing resolution: σ_t~2 ns for an energy deposit of 1 GeV.

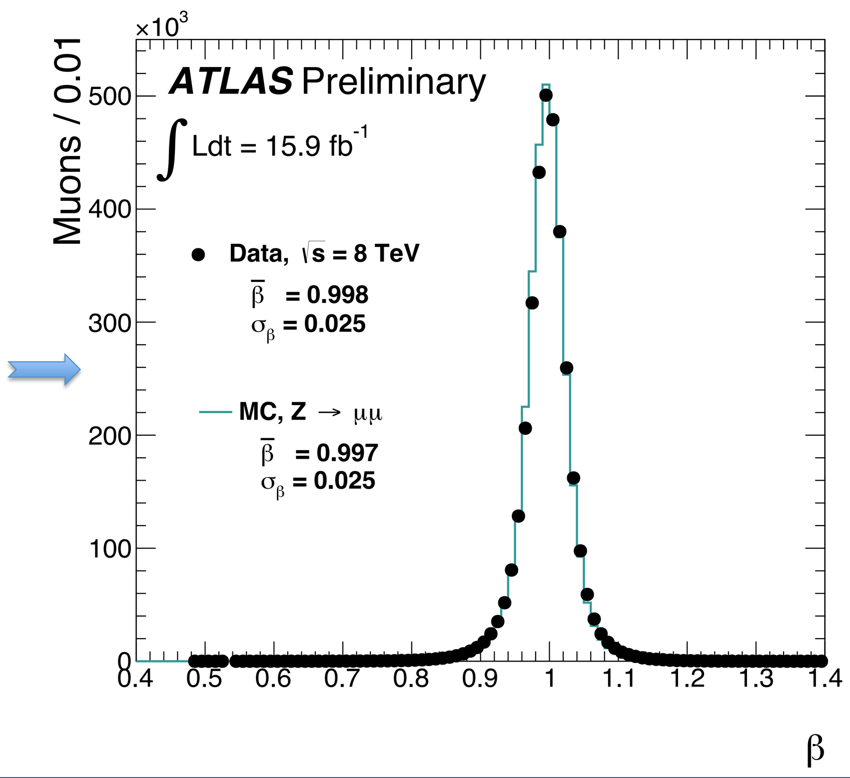
Muon Spectrometer
- Monitored Drift Tubes (MDT):
  - ✓Precision momentum measurement.
  - ✓σ_t ~0.8 ns.
  - ✓β obtained by a successive track re-fit.
- Resistive Plate Chambers (RPC):
  - ✓Intrinsic σ_t ~1 ns, digitised signal is sampled with a 3.12 ns granularity.
  - ✓β measurements averaged over different detector elements.

β calibration

- Dedicated calibration of timing crucial to this analysis.
- Time-of-Flight (ToF) is sensitive to relative offsets in time calibration between different detector elements.
  - In ideal case, energetic muons pass detector elements at t_0=0.
  - Means of t_0 distributions used to correct calibration by shifting the measured t_0.
  - Widths used as resolution of time measurement in β^{-1} average and to smear simulation accordingly.
- ToF to β:

$$\beta^{-1}_{\rm reco} = \frac{\sum_{i=0}^{N} \beta_i^{-1}/\sigma^2_{\beta_i^{-1}}}{\sum_{i=0}^{N} 1/\sigma^2_{\beta_i^{-1}}} \qquad \beta_i^{-1} = \frac{ToF_i}{d_i}$$

Measurements from different sub-detectors are combined in a weighted average for β

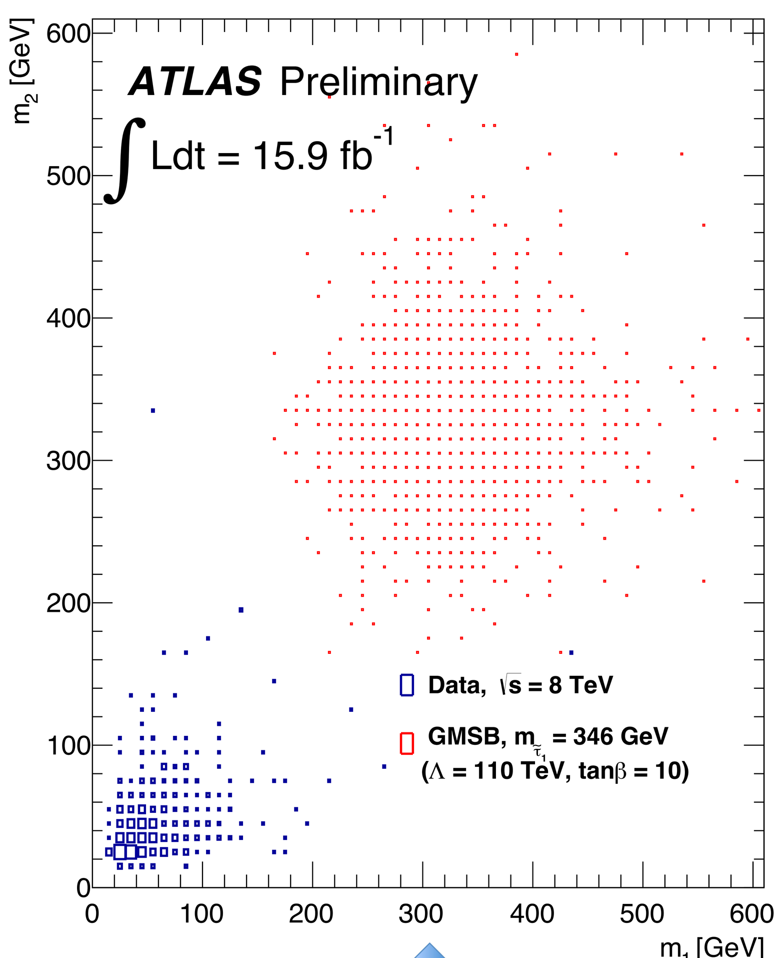


Event/candidate selection, systematic uncertainties

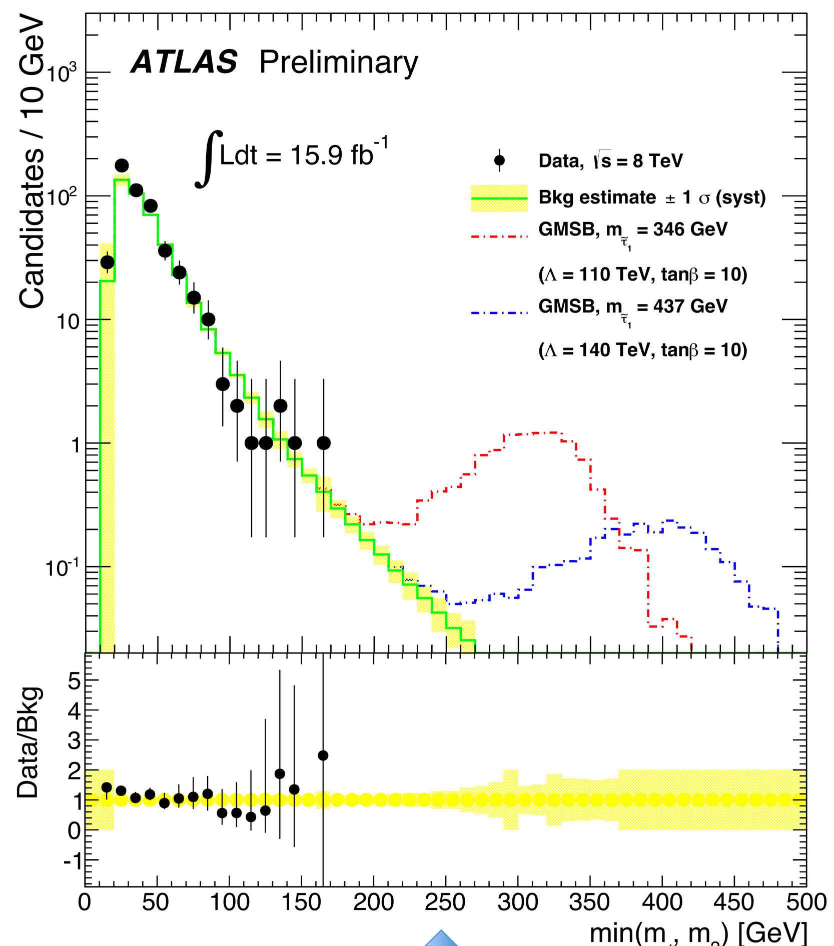
Event Selection:
- Functional detector, good primary vertex, cosmic muons veto.
- Single muon trigger

Signal Region (loose selection):	Control Region (tight selection):
• Two candidates • p_T >50 GeV • Z mass veto • β measurements consistency: - within same sub-detector - among two sub-detectors: 3σ - with βγ from Pixel: 5σ	• One candidate passing loose cuts • p_T>70 GeV • β measurements consistency: - among three sub-detectors: 2σ - with βγ from Pixel: 3σ

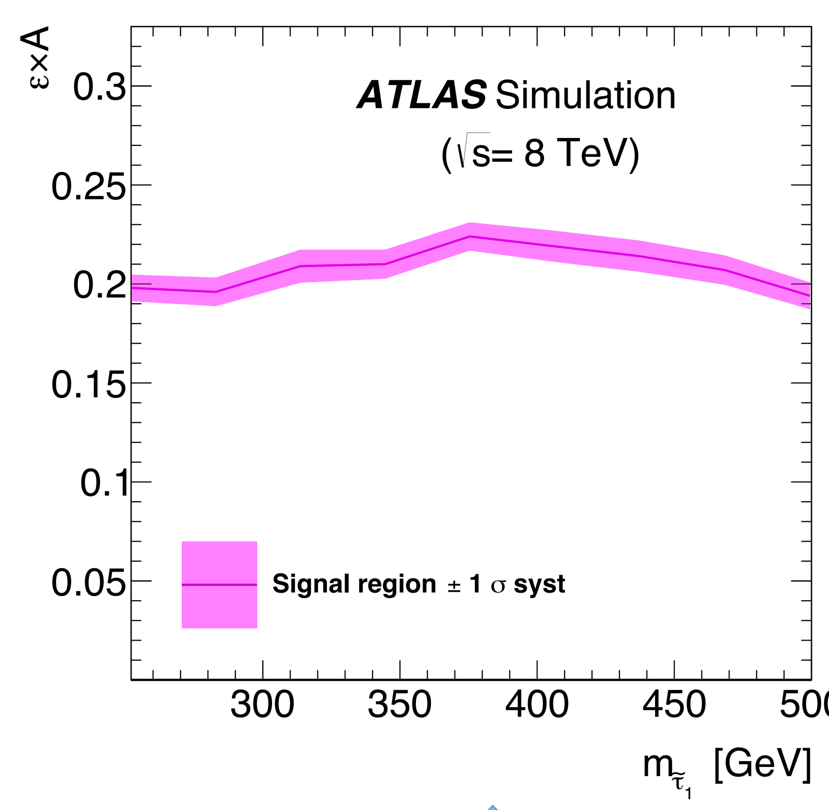
- 0.2< β (combined)<0.95
- Additional model dependent cut on candidate mass



Two-candidate signal region: observed data and expected signal in the m_1 - m_2 plane.



Two-candidate signal region: the lower of the two masses is plotted for observed data, background estimate and expected signal.



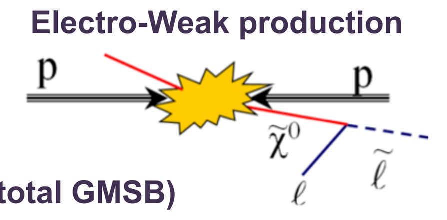
Efficiency times acceptance for directly produced slepton events in the two-candidate signal region as a function of the $\tilde{\tau}_1$ mass.

SYSTEMATIC UNCERTAINTIES	
Source	Uncert. (%)
Theoretical uncertainty on signal size	3.5
Total uncertainty on signal efficiency	3.8
Luminosity	2.8
Background estimate	8-21

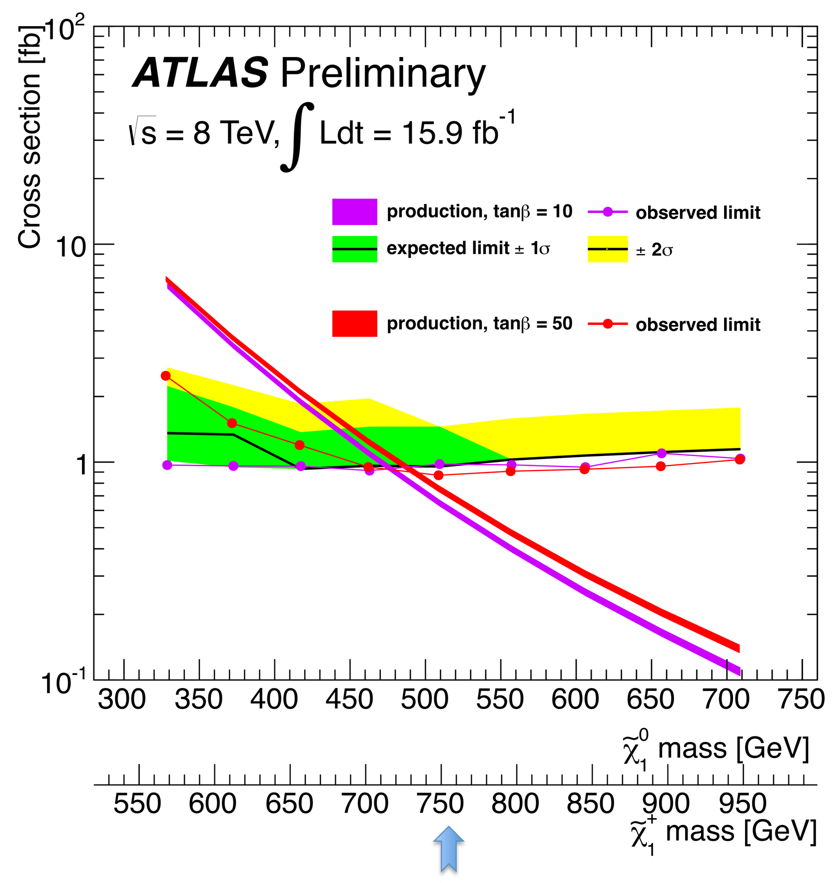
Results

- No indication of signal above the expected background is observed.
- Results are interpreted in the GMSB context where the lighter τ slepton ($\tilde{\tau}_1$) is the NLSP and is long-lived.
- Upper cross-section limits on model independent cross-sections for direct $\tilde{l}$ and $\tilde{\tau}_1$ production obtained at 95% CL.
- As an example, exclusion limits on directly produced $\tilde{\chi}_1^0$ and $\tilde{\chi}_1^{\pm}$, which afterwards decay directly or via heavier $\tilde{l}$ to $\tilde{\tau}_1$, are set for $\tilde{\chi}_1^0$ masses up to 475–490 GeV ($\tilde{\chi}_1^{\pm}$ masses 210–260 GeV higher).

Electro-Weak production



(21-36% of total GMSB)



Cross section limits on $\tilde{\chi}_1^0$ and $\tilde{\chi}_1^{\pm}$ production as a function of their masses when they decay to a long-lived $\tilde{\tau}_1$ for different tanβ values

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ATLAS EXPERIMENT