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BSM Searches with 2010 data at the ATLAS experiment

Diphotons with large missing transverse energy.

Heavy long-lived charged particles using the muon spectrometer.

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On behalf of the **ATLAS collaboration**
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Overview

- ATLAS has a wide program for searches for BSM physics.
- I will present **new** results, based on the the full 2010 dataset (36 pb^{-1}), for two such searches:
  - Non-resonant diphotons with large transverse missing energy (E_T^{miss}).
  - Heavy long-lived charged particles using the muon spectrometer (MS).
- In both cases, ATLAS sets world's best limits.

Motivation for searches with diphotons and large missing transverse energy

GGM (arXiv:0801.3278 [hep-ph])

- If SUSY exists, it must be a broken symmetry due to the high sparticle masses.
- Gauge mediation models are favored methods of transmitting SUSY breaking to the MSSM (do not introduce flavour-changing effects).
- General Gauge Mediation (GGM) is the generalisation of these models.

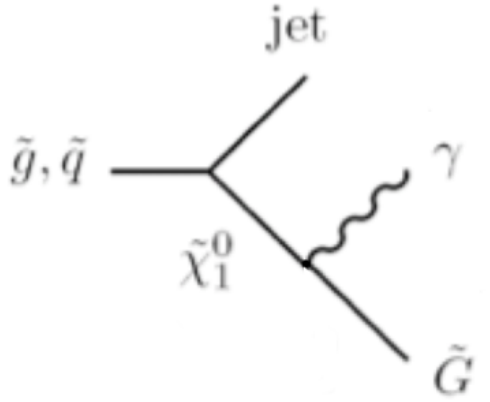
UED (arXiv:hep-ph/0012100)

- Universal Extra Dimensions (UED) theories allow all SM particles to propagate in extra dimensions.
- Particles can then have Kaluza-Klein (KK) excitations; the lightest KK particle (LKP) is γ^*.
- The LKP can decay into a graviton and photon.

Experimental signature

- Expect pair production of SUSY or KK particles; these will decay eventually to a pair of photons and gravitons/gravitinos.
- So expect two photons and significant E_T^{miss}, a nice experimental signature.

Possible GGM decay chain (one side of event)

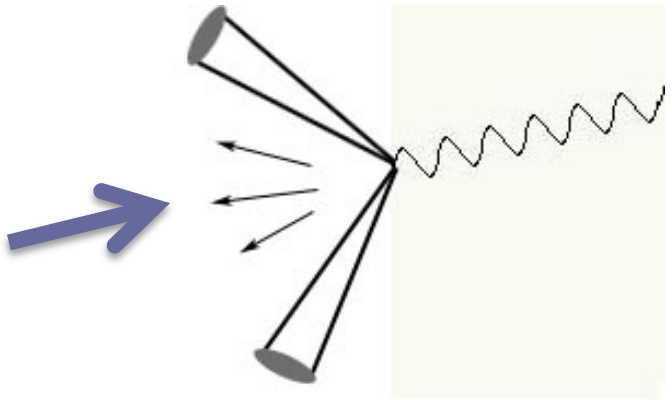


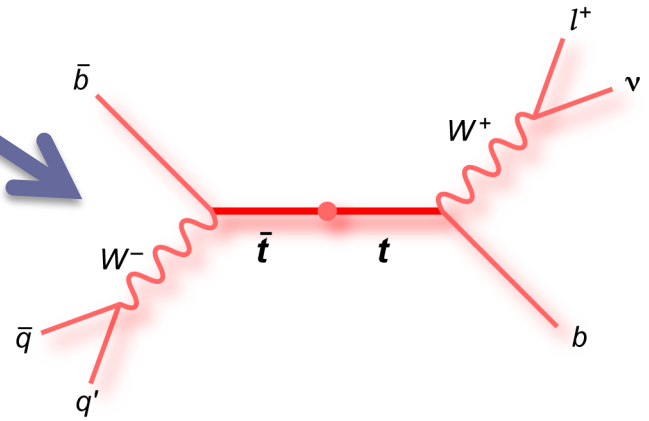
Analysis technique

- Trigger:
  - First 0.5 pb^{-1}: single EM cluster with $E_T > 14$ GeV.
  - After: two loose photon candidates with $E_T > 15$ GeV.
- Vertex requirement:
  - At least one primary vertex. Five or more associated tracks.
- Leptons:
  - Veto on electrons and muons with $E_T > 20$ GeV.
- Photons:
  - 'Tight' photons with $E_T > 30, 20$ GeV.
- Signal region:
  - $E_T^{miss} > 125$ GeV.

Background estimation

- Sources of background separated into two types:
  - Instrumental background: $\gamma\gamma$, γ + jet and multijet (fake $E_{\mathrm{T}}^{\mathrm{miss}}$, fake and real photons).
  - $W + X$ and tt background (real $E_{\mathrm{T}}^{\mathrm{miss}}$, fake and real photons).
- In both cases, we need to measure the $E_{\mathrm{T}}^{\mathrm{miss}}$ distribution of events of this type.

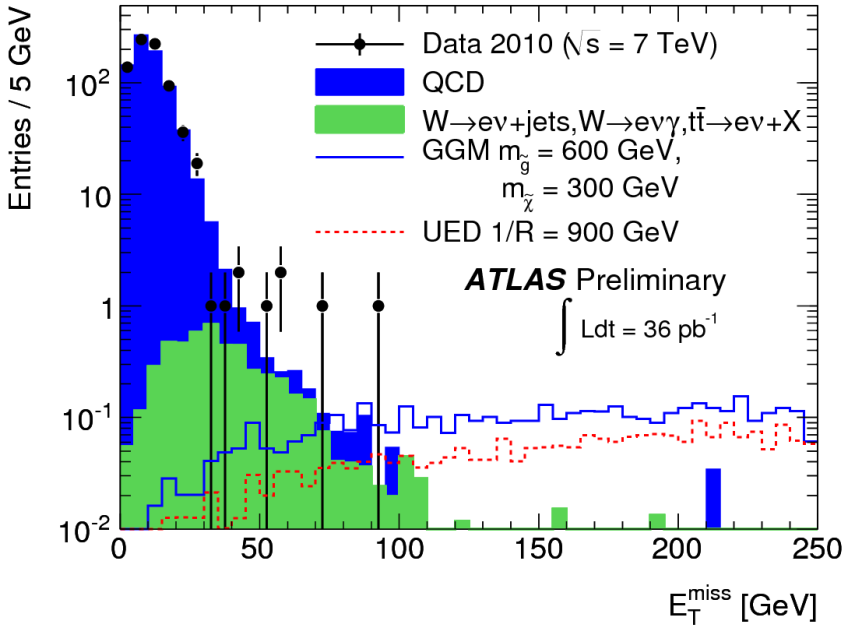




Instrumental Background

- Use two control samples:
  - QCD_{γ}. A QCD dominated sample where one or more of the photons has looser selection.
  - *Z -> ee*. To model the response of events with two genuine EM objects.

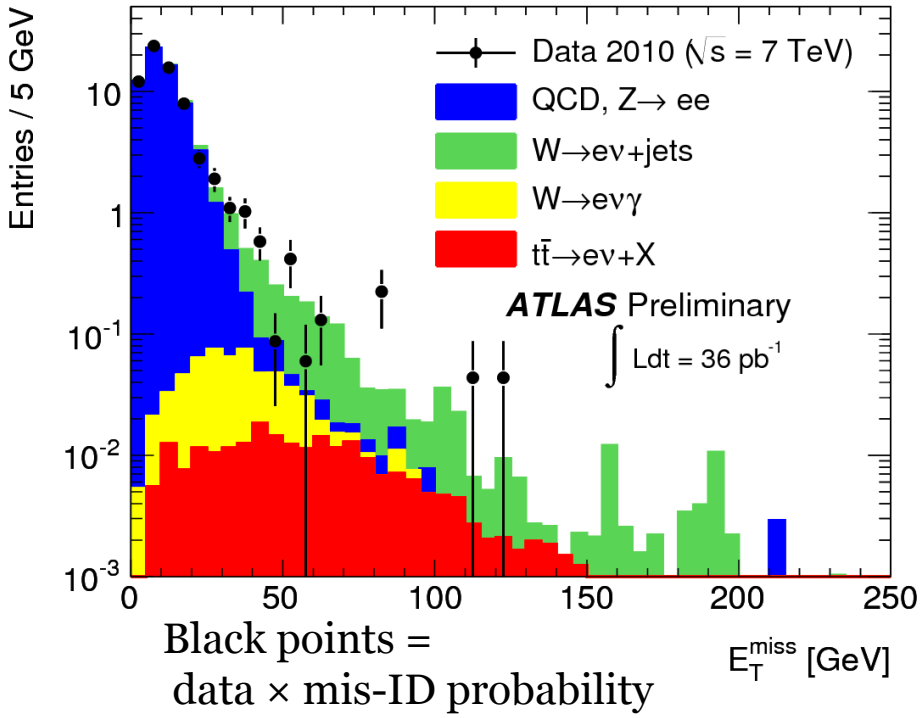
- QCD_{γ} used as composite instrumental background.
- *Z -> ee* used to assess systematic uncertainty.
- The distributions are normalised to the data with $E_T^{miss} < 20$ GeV.



W + *X* and *tt* background

- Take *e*-γ control sample and scale by probability that *e* is misidentified as γ.
- Subtract normalised (with $E_T^{miss} < 20$ GeV) QCD_γ spectrum.
- Limited statistics so use complimentary techniques:

1. Loosen photon requirement.
2. MC events passed through same analysis. Normalise to data with $E_T^{miss} > 40$ GeV.



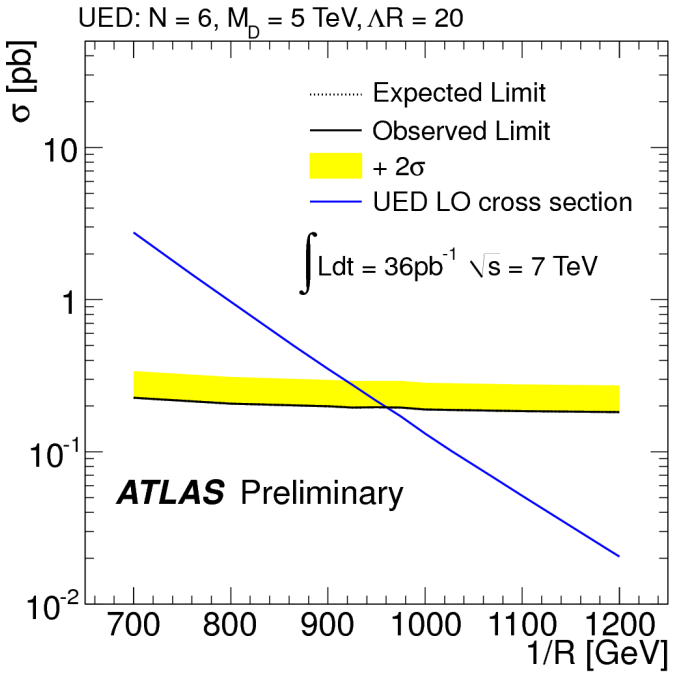
Results

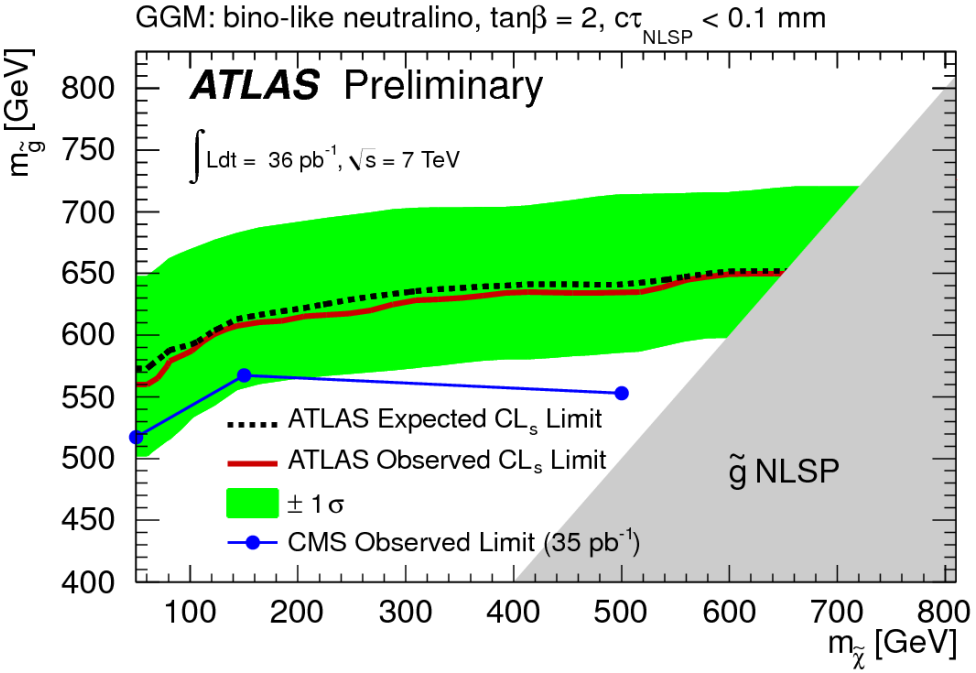
Process	Expected number of signal events	Uncertainty
All backgrounds	0.13	± 0.05
GGM	4.66	± 0.14 (stat), 1.21 (sys)
UED	5.35	± 0.11 (stat), 0.26 (sys)

- Uncertainties accounted for:
  - Luminosity, signal efficiency, theoretical uncertainty and trigger efficiency.
  - γ identification and reconstruction efficiency.
  - Material composition of the detector.
  - Pileup effects and MC stats.
  - E_T^{miss} reconstruction.

Interpretation of results

- No excess found ☹, so set limits using the CLs method.
- Model-independent 95% upper limit of 3.0 events in signal region.
- Set limits on production cross-sections in UED and GGM models.



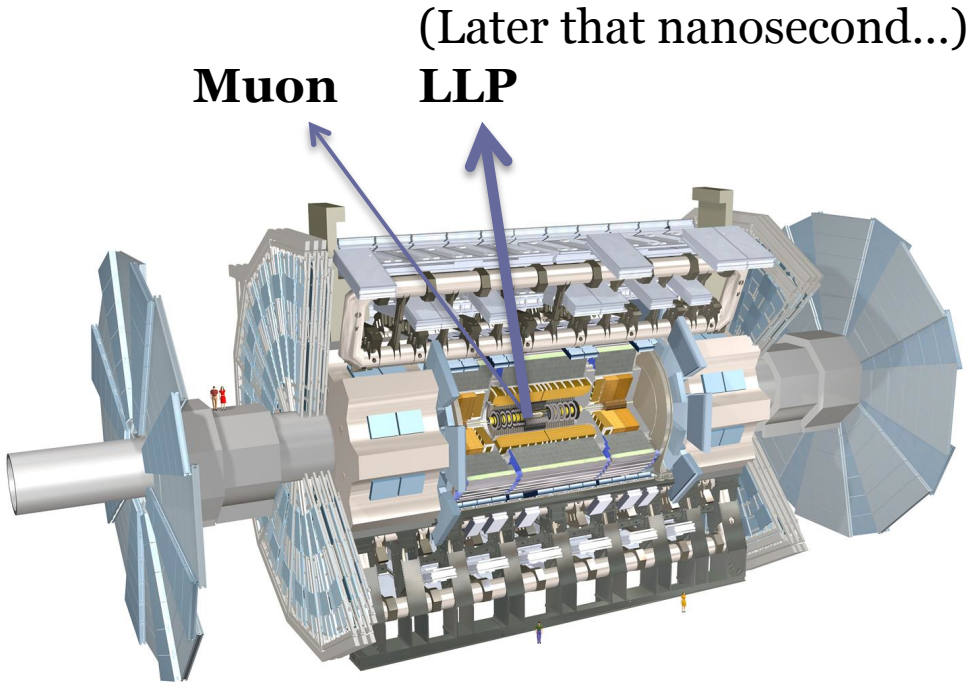


Motivation for searches for heavy long-lived charged particles

- Heavy long-lived particles (LLPs) predicted in a range of BSM theories, including SUSY.
- These particles may travel significantly slower than c; can measure mass from β and p.
- This analysis concentrates on searches for:
  - Long-lived sleptons interpreted in the Gauge Mediated SUSY Breaking (GMSB) framework with the stau particle as the LLP (sensitive to **colour neutral** LLPs).
  - *R*-hadrons interpreted in Split SUSY model with the gluino as the LLP (sensitive to **coloured** LLPs).
- These analyses rely on the particles reaching the Muon Spectrometer (MS). For searches using the pixel and tile subdetectors, see SUSY 2010 overview talk by Troels Petersen.

Analysis technique

- LLPs behave like slow muons in the detector.
  - Standard segment fitting in the Monitored Drift Tubes (MDTs) may not work so correct for this.
- Slepton search uses dedicated ID package utilising ID and MS information.
  - Calculate β from MS and tile calorimeter information and then refit track.
- *R*-hadron search only uses the MS:
  - Seed candidates from MS trigger hit* and find track.



* Therefore loss of efficiency at low β.

Analysis Technique

Common to both searches

- Hardware trigger using MS. Require good primary vertex candidate with more than 2 tracks.
- Cosmics rejected using tracking and primary vertex information.
- Pairs of candidates consistent with Z mass are rejected.
- β must be consistent within and between sub-detectors.
- LLP selection is $\beta < 0.95$.

Slepton searches

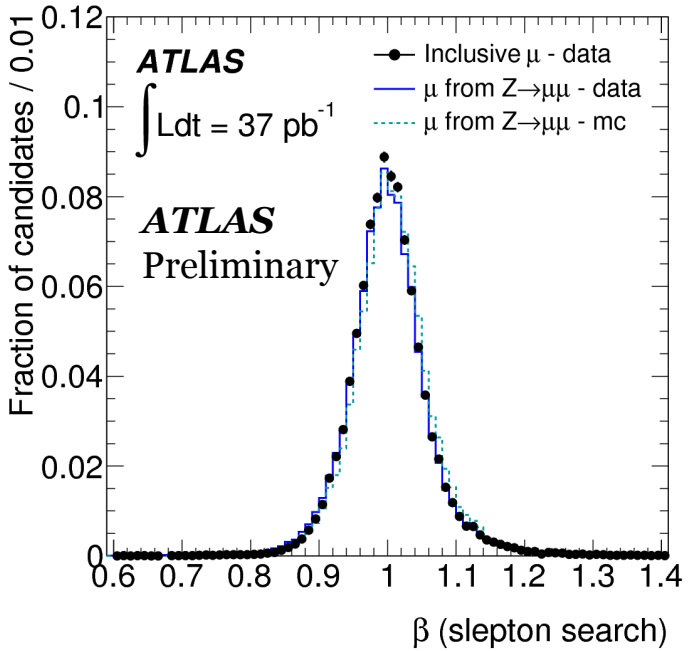
- Software trigger: ID track matched to MS track. $p_T > 13$ GeV.
- 2 candidates with $p_T > 40$ GeV, 1 passing LLP selection.

***R*-hadron searches**

- Software trigger: MS only, $p_T > 40$ GeV.
- One candidate with $p_T > 60$ GeV, passing LLP selection.

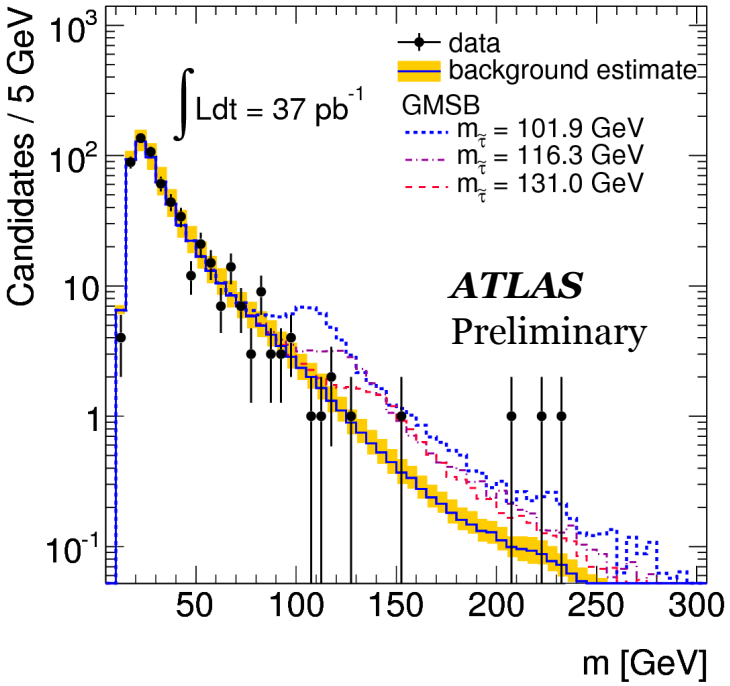
Background estimation

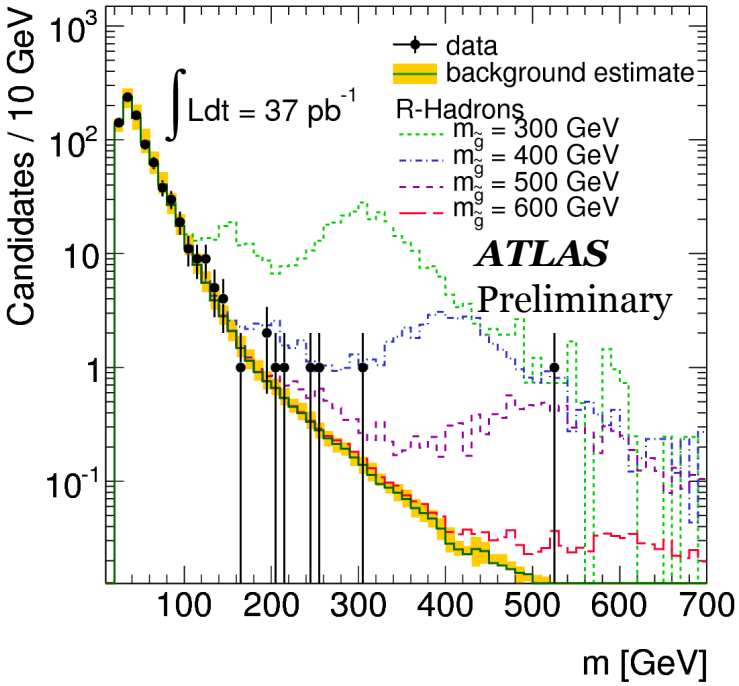
- Assumptions:
  - Signal / background before β cut is low.
  - β resolution independent of muon source and p_T.
  - Assumptions confirmed using data.
- Technique:
  - For each muon candidate, sample from β p.d.f. a number of times. If $\beta < 0.95$, calculate mass from the random β.
  - Different β distributions measured for different η ranges.



Results

- Sources of systematic uncertainty accounted for:
  - Luminosity, trigger efficiency and signal cross-section uncertainties.
  - Signal β resolution (through smearing of hit times with time calibration spread).
  - Data/MC differences in track reconstruction efficiency and momentum resolution.
  - Statistical uncertainty in background determination.

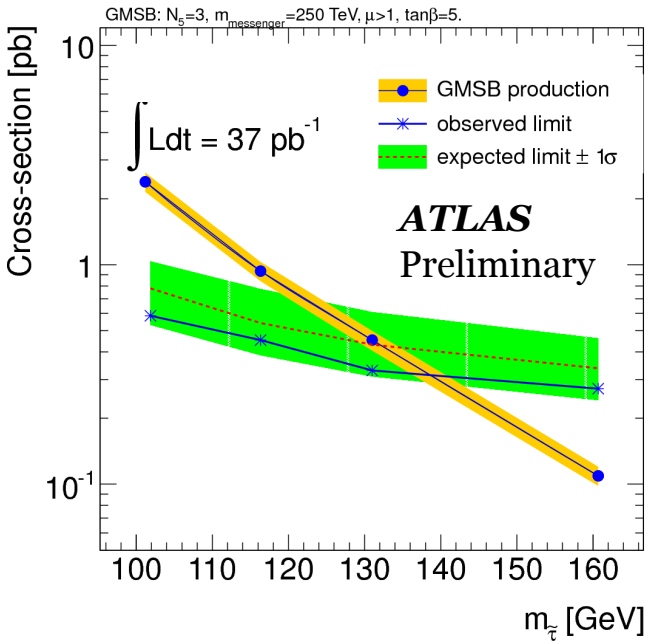




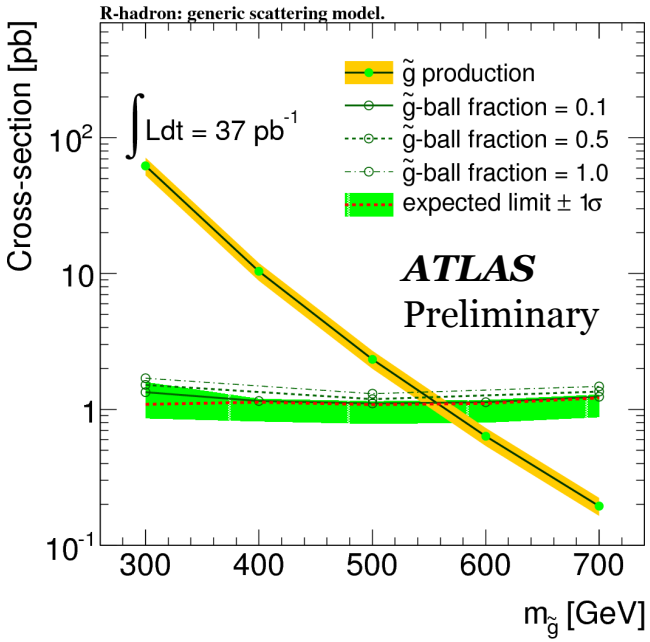
Interpretation

- No excess found so the CLs method is used to set limits.

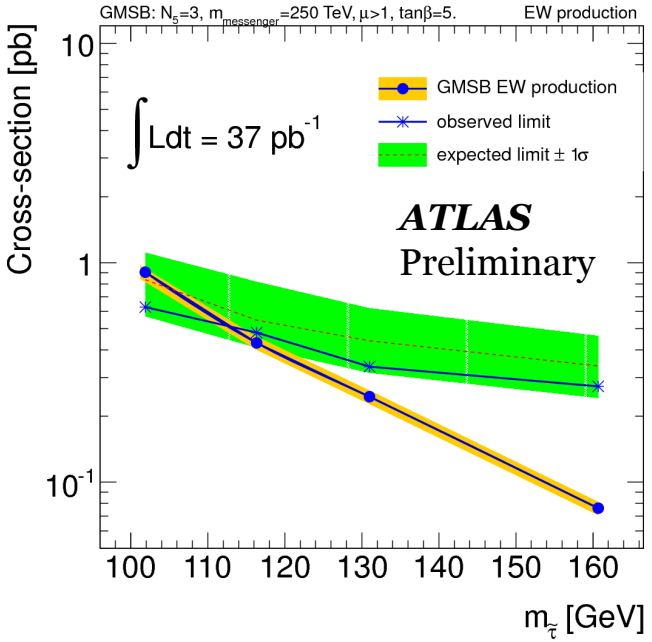
Slepton search as a function of stau mass in GMSB model.



R-hadron search as a function of gluino mass.



EW produced slepton search as a function of stau mass in GMSB model (less model-dependence)



Conclusions

- In searches for new physics in diphoton events with large E_T^{miss} and for LLPs using the MS, no excesses over the SM were found.
- 95% CL limits were set:

Process	Cross-section limit (pb)	Mass or compactification radius limit
Bino-like GGM model	$\sigma < 0.36 - 0.65$	$M > 560$ GeV
UED model with one extra dimension	$\sigma < 0.18 - 0.23$	$1/R < 961$ GeV
GMSB model with stau lepton as LLP	-	$M > 136$ GeV
GMSB model with EW produced sleptons	-	$M > 110$ GeV
Gluiono R-hadrons in generic interaction model	-	$M > 530 - 544$ GeV

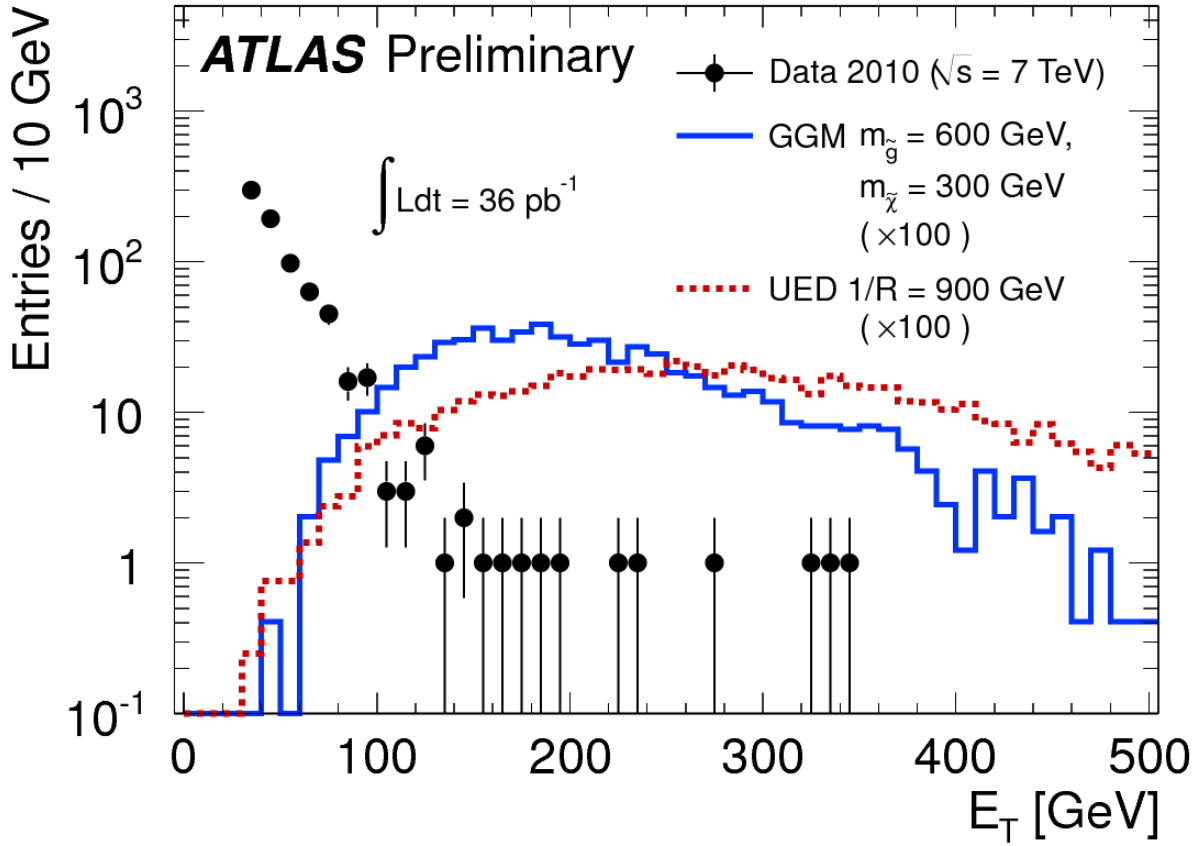
References and further info

- CLs method: A.L. Read, J. Phys. G: Nucl. Part. Phys. 28 (2002) 2693.
- ATLAS search for stable hadronising squarks and gluinos: http://cdsweb.cern.ch/record/1335111
- See SUSY 2010 overview talk by Troels Petersen for info on other 2010 SUSY searches.
- See talk by Michael Rammensee for search for SUSY using jets and $E_{\mathrm{T}}^{\mathrm{miss}}$ with 2011 data.

BACKUP SLIDES

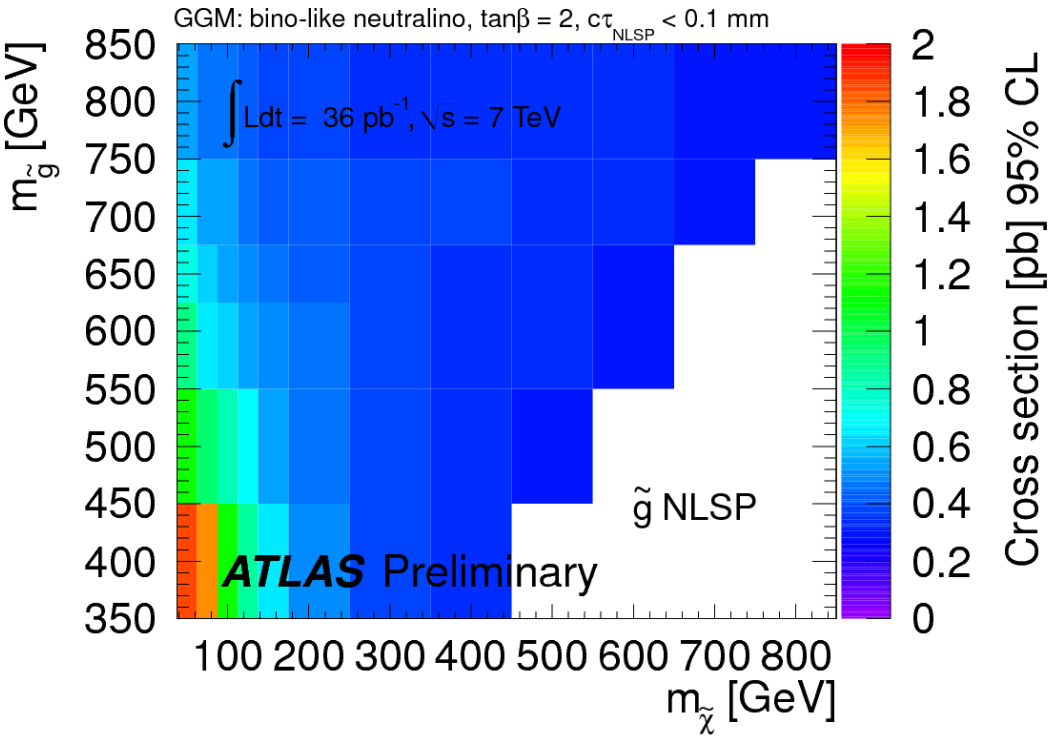
E_T spectrum of $\gamma\gamma$ candidates

- Before E_T^{miss} cut.



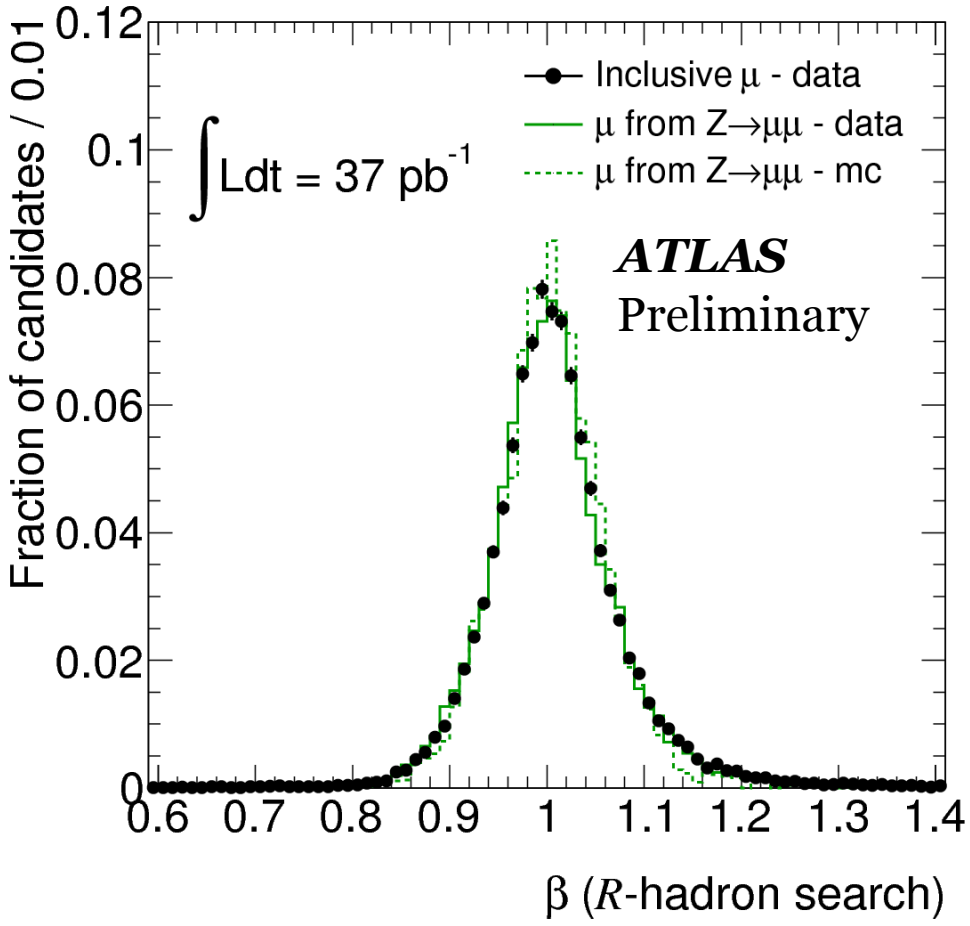
Cross-section limit on GGM from $\gamma\gamma$ + E_T^{miss} search

- 95% CLs limit.
- Bino-like GGM.



β distribution in R-hadron search

- All candidates.



β distributions for signals