SEARCHES FOR SUSY LONG-LIVED PARTICLES WITH THE ATLAS DETECTOR

HBSM2013

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on behalf of the ATLAS collaboration

Outline

Searches for SUSY long-lived particles:

- Sleptons
- Stopped gluinos
- Non-pointing photons

Searches for heavy Long-Lived sleptons

Performed with 15.9 fb^{-1} ATLAS-CONF-2013-058

Outline

- Long-Lived sleptons – possible scenarios
- Expected signature & Analysis Strategy
- β estimation
- On-line selection
- Off-line selection
- Background estimation
- Results

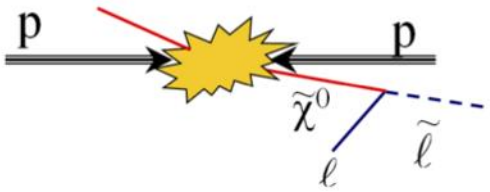
POSSIBLE SCENARIOS

LLP within the GMSB models

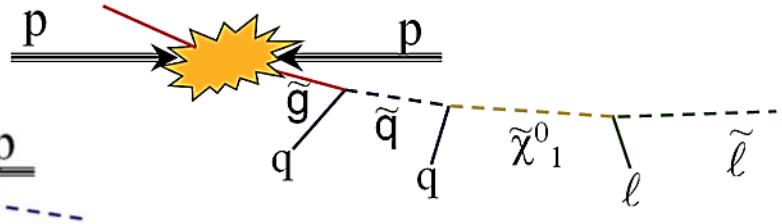
- The gravitino is the LSP
- Either the $\tilde{\tau}$ or the $\tilde{\chi}_1^0$ is the NLSP – we will consider the case of NLSP $\tilde{\tau}$
- In case of small coupling to the gravitino – the NLSP is long- lived
- Two LLPs per event are expected

Direct :

EW :



Strong :



- However, significant strong production is already excluded

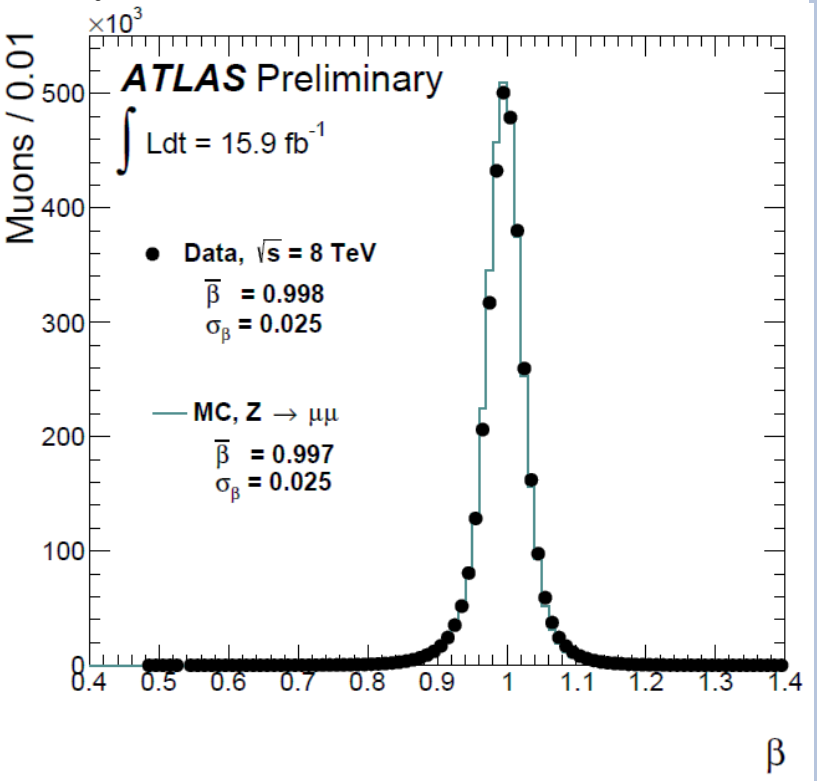
EXPECTED SIGNATURE & ANALYSIS STRATEGY

- Charged LLP expected to leave a signal throughout the detector
- Use track information to calculate the candidate mass: $\mathbf{m} = \frac{\boldsymbol{p}}{\boldsymbol{\beta\gamma}}$
  - p derived from the candidate track
  - ß calculated from the measured ToF
- Collision data from 2012 run, $\int Ldt = 15.9\ fb^{-1}$
- Simulated samples :
  - $Z \rightarrow \mu\mu$ for smearing the generated hit times according to data
  - GMSB simulated samples, with $SUSY\ breaking\ scale$: $80 \rightarrow 160\ TeV, \tan\beta : 5 \rightarrow 50$

β ESTIMATION

- β is estimated from the Calo, MDT and RPC
- For each tech: β is measured and weighted by it measurement errors:

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



- Consistency within each technology
- Consistency between technologies
- $\#(Tech) \geq 1$
- βγ is estimated from Pixel $\frac{dE}{dX}$ measureme
- Consistency between β, βγ
- Smeared the simulation hit times according to DATA
- Smearing checked with $Z \rightarrow \mu\mu$ and applied to signal samples

ON-LINE SELECTION

Event selection - Trigger:

- Single muon un-prescaled trigger chains with $p_T \geq 24GeV$
- Triggers only particles within collision BC - low ß particles might miss the collision BC
- Lower ß particles in the event are found when higher ß particle triggers
- Trigger efficiency is obtained from simulated events passing the trigger simulation (65% - 85% efficiency – production dependent)
- Systematic check with smeared hit times as in data

OFF-LINE SELECTION

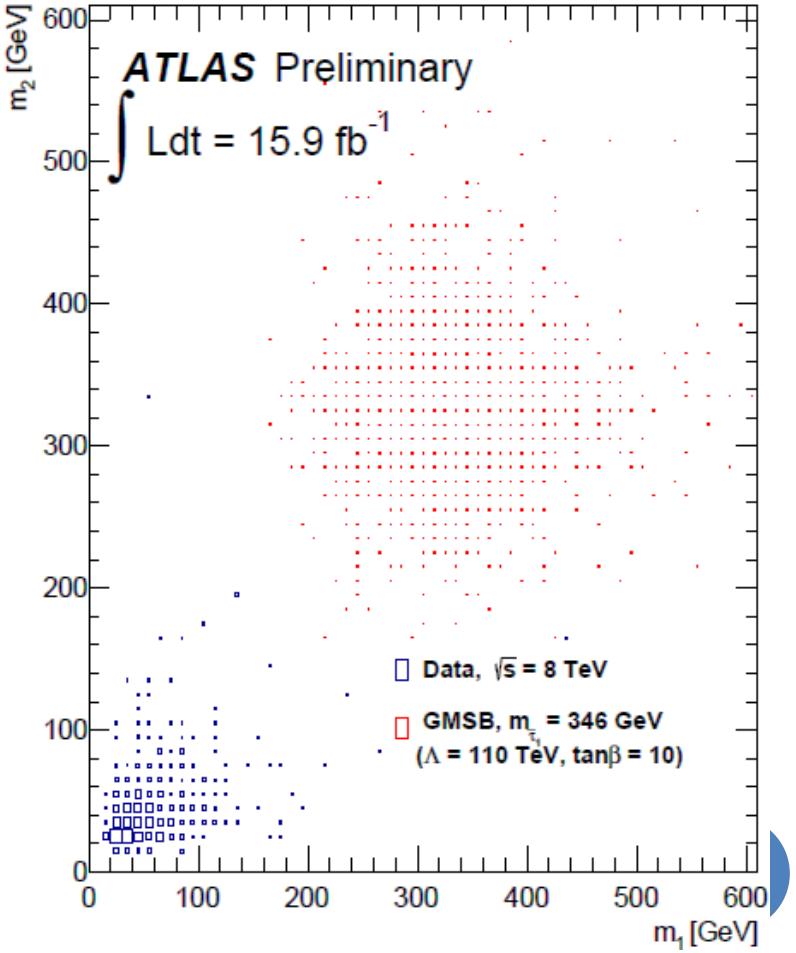
- Off-line selection of the events that passed the trigger chain - Good PV and Num $\mu's \geq 2$
- Candidates within each event are required to pass set of selection cuts:
  - eliminating cosmic, Z & beam halo
  - p consistency, p_T cut
  - $|\eta| \leq 2.5$
  - minimum DoF
  - β consistencies
  - β-βγ consistency

OFF-LINE SELECTION

- Two sets of selection criteria are applied:
  - Loose – select events where there are two LLP candidates – Signal Region.
  - Tight – events that passed the loose selection, however with only one candidate are required to pass tighter set of cuts – Control Region
- Final cut for slow-massive LLP: $0.2 \leq \beta \leq 0.95$
- Mass estimation $\mathbf{m} = \frac{\boldsymbol{p}}{\boldsymbol{\beta\gamma}}$
- Count all events above a mass cut (dependent on the stau mass in a model)

2 CANDIDATE AS SIGNAL-REGION

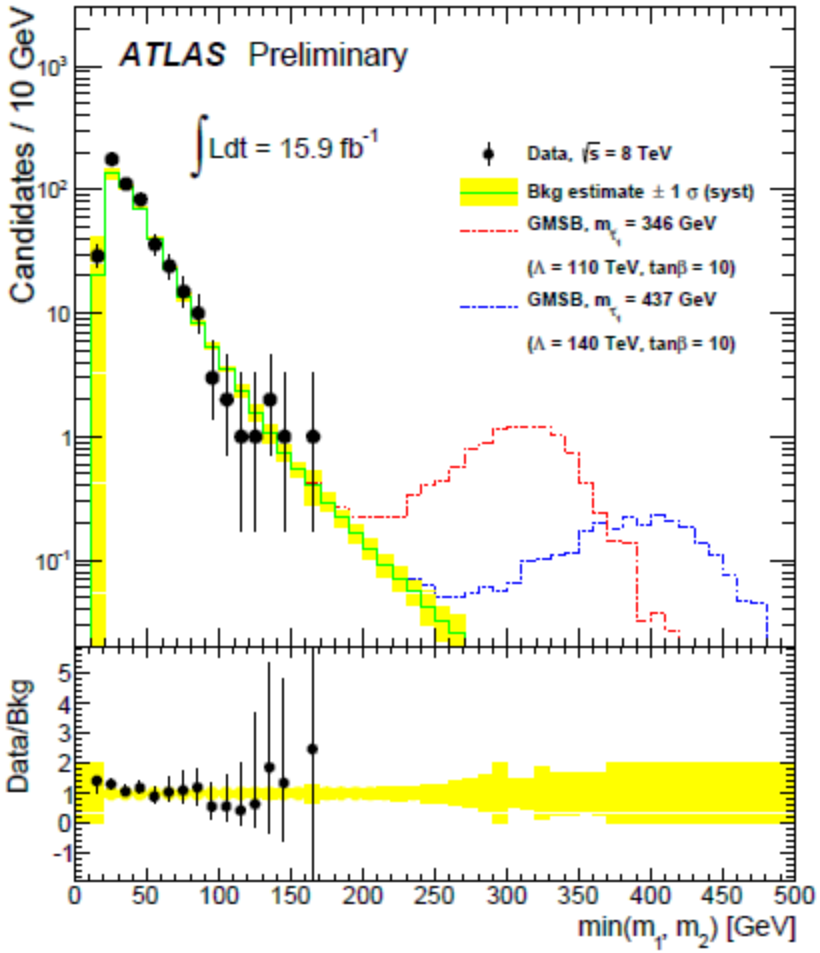
- Each signal event has two staus, with high efficiency of being selected.
- Very rarely would a non-GMSB event have two high p_T muons, both with β from the tail of the distribution and a large reconstruction mass.
- For the 2 candidate signal region - No evidence for new physics observed.



BACKGROUND ESTIMATION

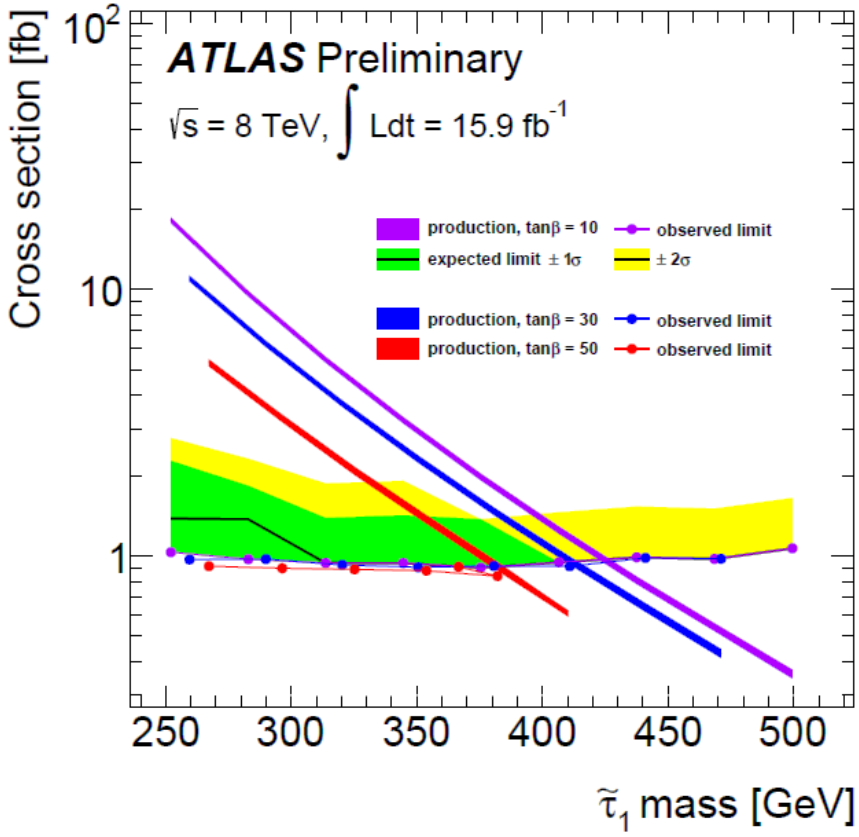
- SM relativistic particles have β~1
- LLP are massive and have β<1
- Mainly μ's with β from the tails of the distribution and high p_T
- β pdf (applying the same selection)

- Candidate with p is matched with random β from pdf
- Pass selection with random β



Repeated many times and weighted by the number of repetitions

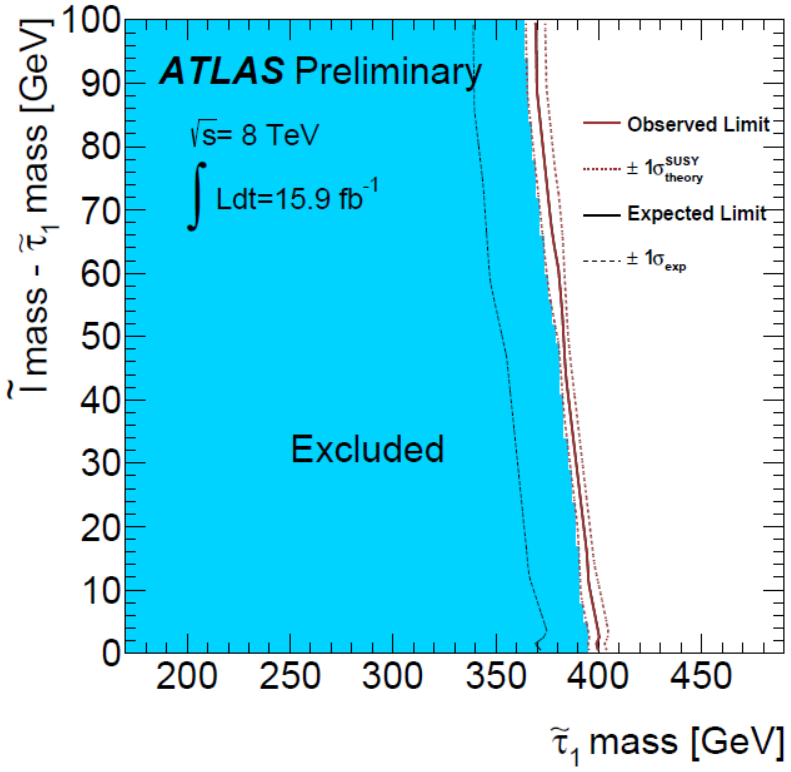
RESULTS



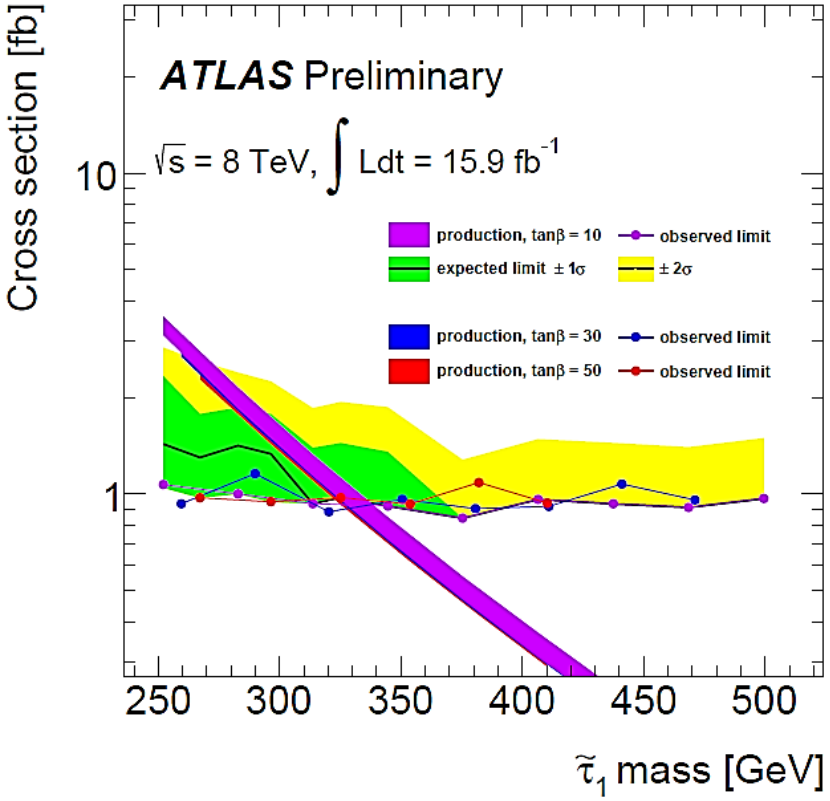
LL $\tilde{\tau}$ in GMSB models with:

$N_5 = 4\ M_{mess} = 250 GeV\ and\ sign(\mu) = 1$, are excluded at 95% CL up to $m_{\tilde{\tau}}$= 420,425,422,410,400,385 GeV for $\tan\beta = 5,10,20,30,40,50$ respectively

RESULTS

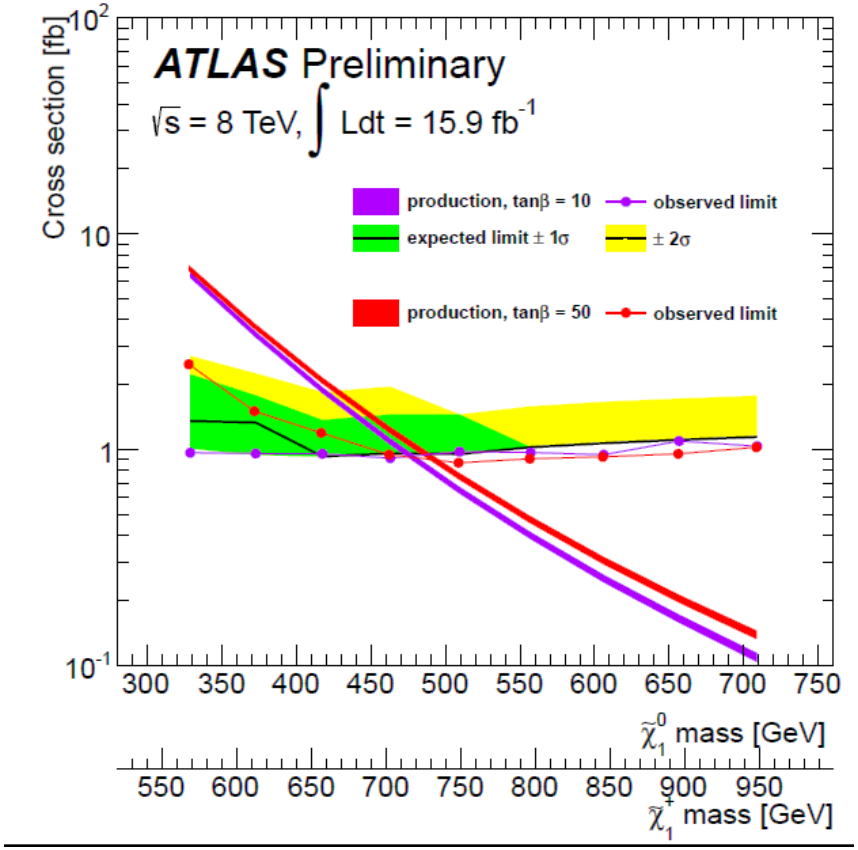


Slepton direct production is excluded at 95% CL up to $m_{\tilde{\tau}} = 365 \rightarrow 395$ GeV for models with $\Delta m_{slepton} = 0.75 \leftarrow 90 GeV$



Direct $\tilde{\tau}$ production, (when the mass splitting to the other sleptons is very large), $m_{\tilde{\tau}} < 327\ GeV$ are excluded if only $\tilde{\tau}_1$ is produced.

RESULTS



<u>EW production of $\tilde{\chi}$ decaying into $\tilde{\tau}$</u> - an in-direct exclusion at 95% CL on $m_{\tilde{\chi}^0} < 475 - 490\ GeV$ and $m_{\tilde{\chi}^\pm} - m_{\tilde{\chi}^0} < 210 - 260\ GeV$

Stopped Gluinos

Searches for long-lived Stopped gluino R-hadrons

Performed based with $5.3 + 22.9\ fb^{-1}$ ATLAS-CONF-2013-057

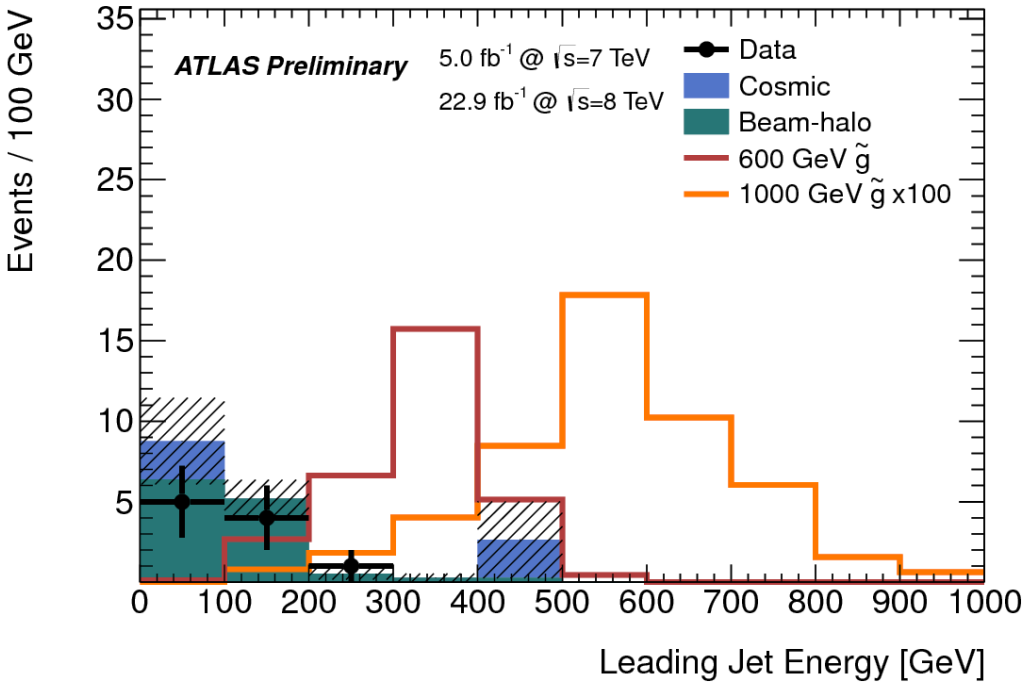
Split SUSY:

- The squarks are much heavier than the gluinos.
- Due to R-Parity conservation and color charge constraints - $\tilde{g}$ is long lived.
- The heavy $\tilde{g}$ will bound with colored SM particles to form R-hadron state.
- For very low ß the R-hadrons will stop at the calorimeter (due to ionization energy loss).
- Later will decay to either g, $q\bar{q}$ and $\tilde{\chi}^0$.
- Candidate decay events are triggered in the empty bunch-crossing of the LHC.

Searches for long-lived Stopped gluino R-hadrons

Performed based with $5.3 + 22.9\ fb^{-1}$ ATLAS-CONF-2013-057

- Selection is based on jet shape and MS activity – discriminate from bkg.



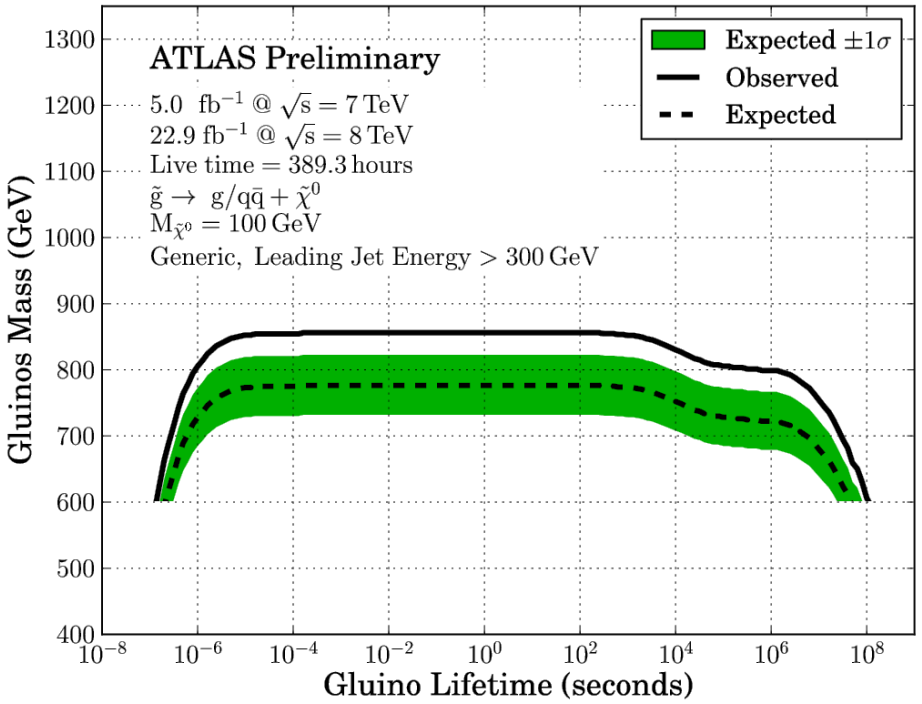
The event yields in the signal region for candidates with all cuts including the muon segment veto

- Good agreement between number of bkg. Events and observed number of events.
- No evidence for new physics.

Searches for long-lived Stopped gluino R-hadrons

Performed based with $5.3 + 22.9\ fb^{-1}$ ATLAS-CONF-2013-057

- Limits were set on the $\tilde{g}$ mass for different $\tilde{g}$ decay life-times and $\tilde{\chi}^0$ masses



- For $m_{\tilde{\chi}^0} = 100\ GeV$, an exclusion at 95% CL of $m_{\tilde{g}}$ <840 GeV for gluino life-time between 10μs and 1000 seconds.

Non-pointing photons

Searches for Non-Pointing Photons

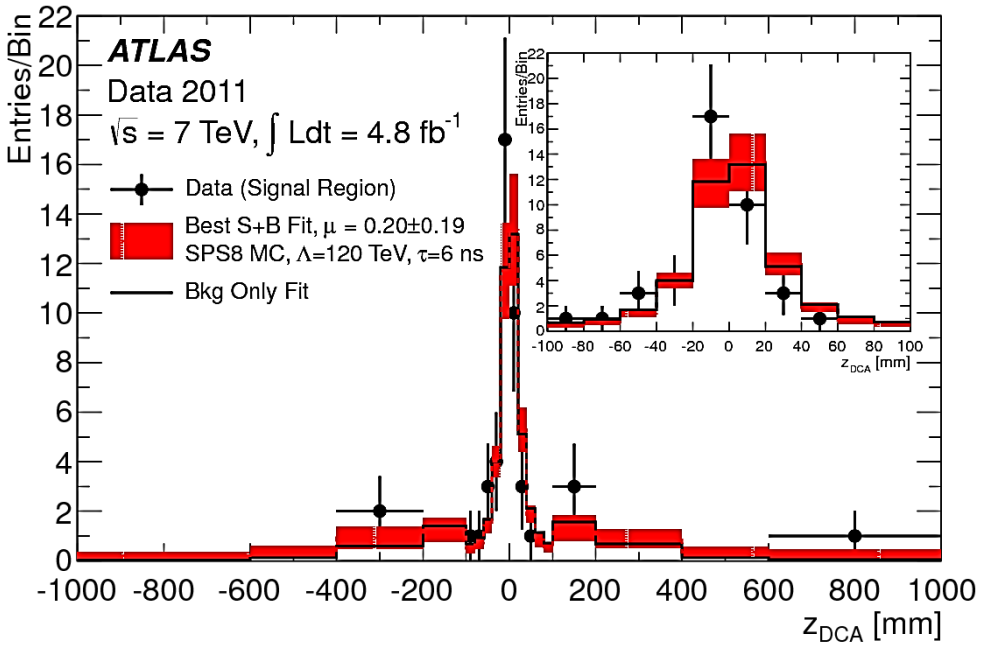
Performed with 4.8 fb^{-1} from pp collisions at $\sqrt{S} = 7\ TeV$ arXiv:1304.6310

- GMSB with $\tilde{\chi}_1^0$ as NLSP and $\tilde{G}$ as LSP.
- Dominant EW production of $\tilde{\chi}$'s.
- Dominant decay mode of $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$.
- If produced, the $\tilde{\chi}_1^0$ has a finite life-time and can travel some distance from its production point before decaying.
- When decaying, the final state will include a photon that does not point back to the PV and large MET from the $\tilde{G}$.
- This analysis relies on information from the Ecalo clusters (ToF and flight direction).

Searches for Non-Pointing Photons

Performed with 4.8 fb^{-1} from pp collisions at $\sqrt{S} = 7\ TeV$ arXiv:1304.6310

- Measure degree of non-pointing of the photon: $\Delta Z = Z_{DCA} - Z_{PV}$

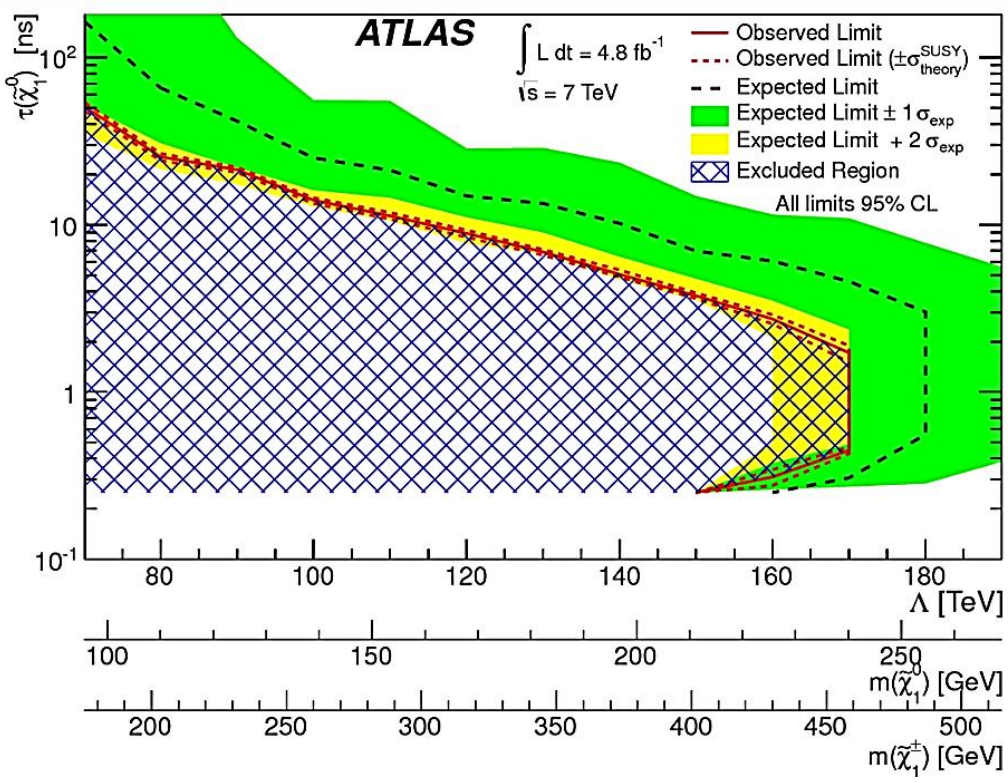


- The Z_{DCA} distribution for the events in the signal-region, background-only fit and background+signal fit for the case of Λ=120 TeV and τ= 6 nsec.
- No significant evidence for non-pointing photons is observed .

Searches for Non-Pointing Photons

Performed with 4.8 fb^{-1} from pp collisions at $\sqrt{S} = 7\ TeV$ arXiv:1304.6310

- The expected and observed limits in the plane of NLSP lifetime vs. Λ, and $\tilde{\chi}$' masses.



- 95% CL exclusion limits, on Λ = 70 TeV (160 TeV), for life-times τ = 0.25 (2.7 ns).

Summary

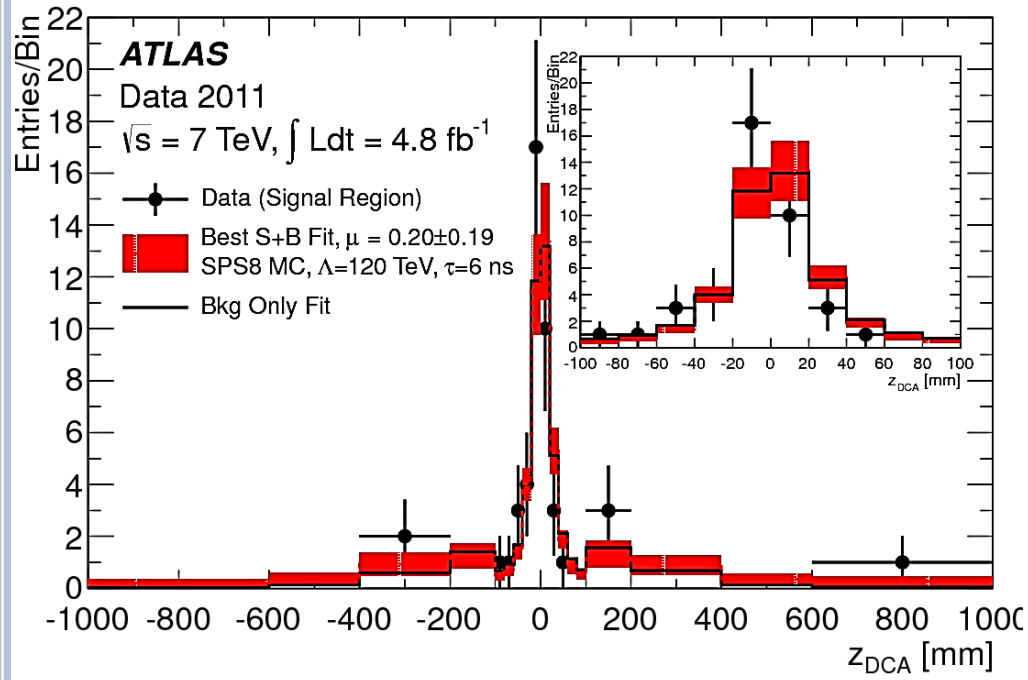
SUMMARY

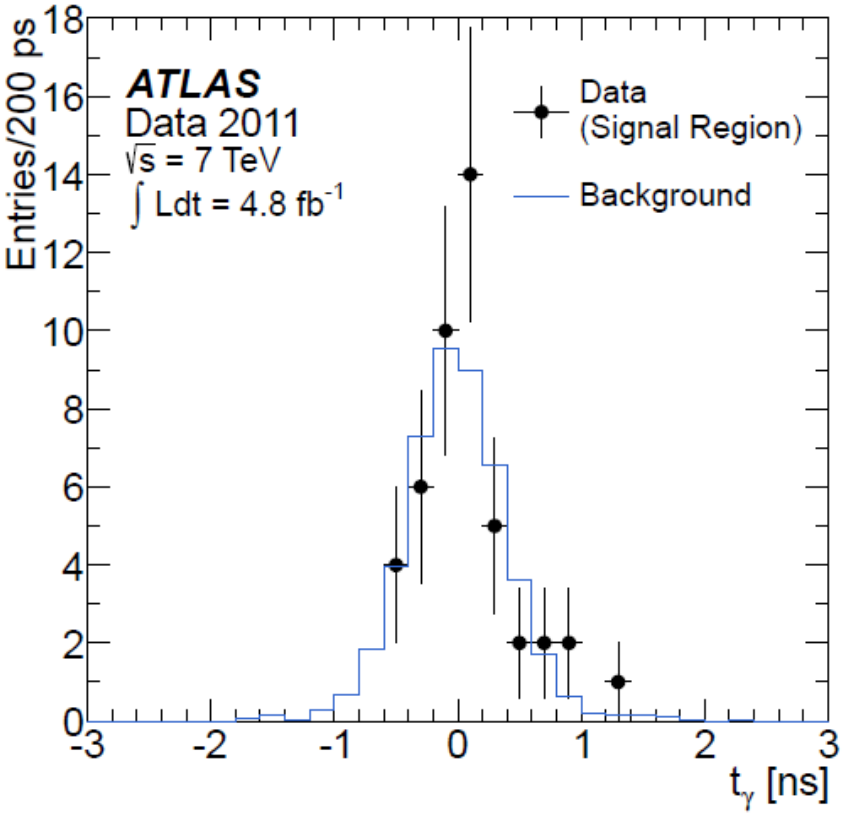
- Studies of LLP were done based on 2011 and 2012 data.
- No evidence for new physics was found so far.
- Exclusion limits were set on different parameters, for several scenarios, at 95% CL:
  - LL stau in GMSB: $m_{\tilde{\tau}}$<425-385 GeV as tanß: 5-50
  - LL directly produced sleptons: $m_{\tilde{\tau}}$<395 GeV for small $\Delta m_{slepton}$, and $m_{\tilde{\tau}}$< 365 GeV for $\Delta m_{slepton}$=90 GeV
  - LL direct stau: $m_{\tilde{\tau}}$< 327 GeV
  - Indirect limit on chargino and neutralino mass if they decay to LLP
  - LL Gluino - Exclude at 95% CL $m_{\tilde{g}}$ <840 GeV (for gluino life-time between 10μs and 1000 seconds, $m_{\tilde{\chi}^0} = 100\ GeV$)
  - LL Neutralino (Non-pointing photons): exclusion at 95% CL on Λ = 70 TeV (160 TeV), for life-times τ = 0.25 (2.7 ns) of the NLSP.

Back-Up

Searches for Non-Pointing Photons

Performed with 4.8 fb^{-1} from pp collisions at $\sqrt{S} = 7\ TeV$ arXiv:1304.6310





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