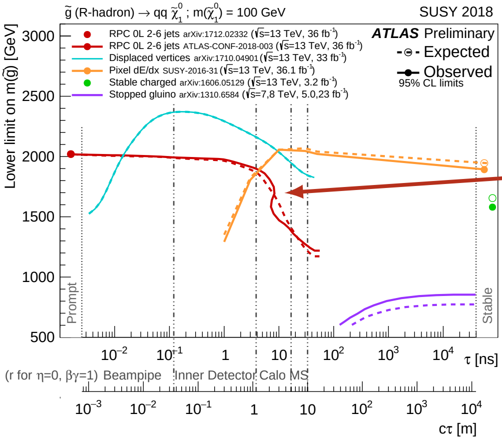
Searches for squarks and gluinos in signatures with long-lived particles with ATLAS

Dominik Krauss
on behalf of the ATLAS collaboration

Max Planck Institute for Physics

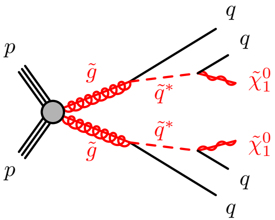
SUSY 2018 conference
July 25, 2018



Poster by Veronika Magerl

1. Tracks with large ionisation energy loss in the pixel detector [SUSY-2016-31]
2. Displaced vertices in the inner detector [SUSY-2016-08]

Split-Supersymmetry



- Long-lived gluino due to very heavy squarks
- Gluino hadronises with Standard Model partons to R-hadron
- Light-quark system of R-hadrons can change due to hadronic scattering

  $\rightarrow$ Electric charge not constant over time

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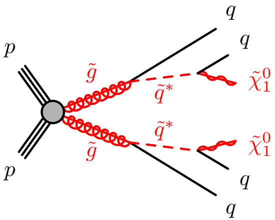

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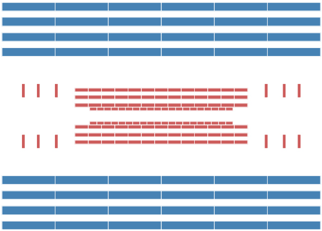
- Origin of E_T^{miss}:
  - Decay inside detector: $\tilde{\chi}_1^0$ not detected
  - Decay outside detector: R-hadron momentum often not fully reconstructed due to small energy deposits in calorimeters and late arrival at muon spectrometer

Measurement of R-hadrons in the inner detector



Silicon trackers in the barrel region, Pixel and SCT

- Charged R-hadron: **Large ionisation energy loss dE/dx**
  - dE/dx measured for each pixel cluster individually
  - Truncated mean using at least two clusters to avoid tail of Landau distribution

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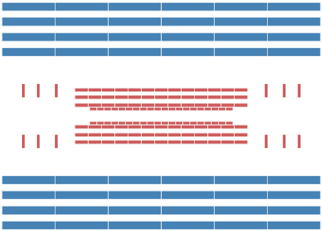


Silicon trackers in the barrel region, Pixel and SCT

- Charged R-hadron: **Large ionisation energy loss dE/dx**
  - dE/dx measured for each pixel cluster individually
  - Truncated mean using at least two clusters to avoid tail of Landau distribution
- Charged and neutral R-hadron: **Displaced vertex**
  - Requires additional large radius tracking to reconstruct tracks up to $|d_0| < 300\,\text{mm}$
  - Dedicated secondary-vertex algorithm

Pixel dE/dx search

- Signature: Isolated track with $p > 150\,\mathrm{GeV}$, $|\eta| < 2$ and $dE/dx > 1.8\,\mathrm{MeV\,g^{-1}\,cm^2}$
- Search for excesses in mass distribution of tracks
- $E_T^{miss} > 170\,\mathrm{GeV}$
- Two signal regions (SRs):

1) **Metastable**

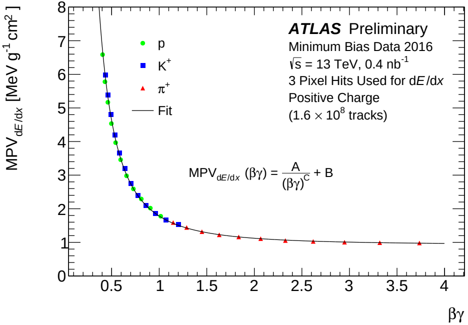
- Decay before muon spectrometer: $c\tau_{Lab}$(R-hadron) $\lessapprox 4\,\mathrm{m}$
- Muon veto

2) **Stable**

- Decay outside detector: $c\tau_{Lab}$(R-hadron) $\gtrapprox 12\,\mathrm{m}$
- Tighter isolation

Calibration of dE/dx

- Calibration of dE/dx based on p, K and π in minimum bias data
  1. Determine most probable value (MPV) of dE/dx binned in $\beta\gamma$ for each particle
  2. Low momentum correction for kaons and protons
  3. Fit MPV($\beta\gamma$) with Bethe-Bloch function independently for $q > 0$ and $q < 0$

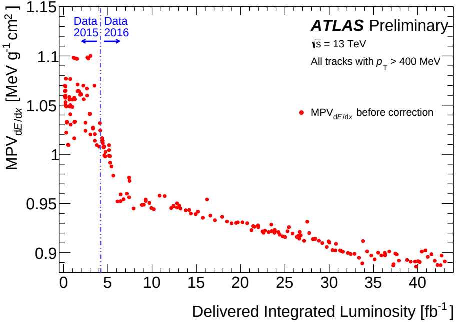


(average $\beta\gamma$ of R-hadrons: ≈ 0.8 @ 600 GeV and ≈ 0.4 @ 2.0 TeV)

- Measured dE/dx and momentum $\rightarrow$ mass of particle

Corrections of dE/dx on data and MC

1. [Data] Run dependent scale factor to account for changes in experimental conditions



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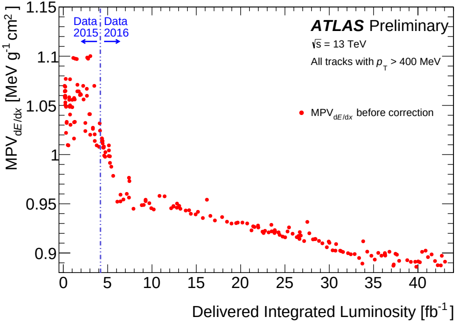

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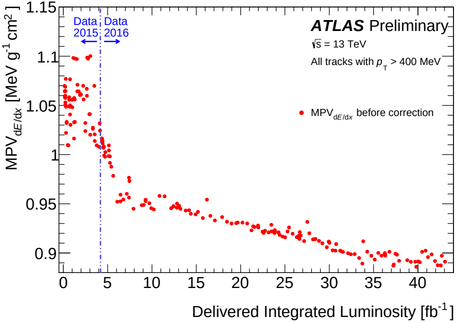

2. [Data,MC] Correct for η dependence of dE/dx to simplify background estimation
3. [MC] Scale factor of 0.886 to align simulation to data

Background estimation

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  1. CR with inverted dE/dx cut $\rightarrow$ p template
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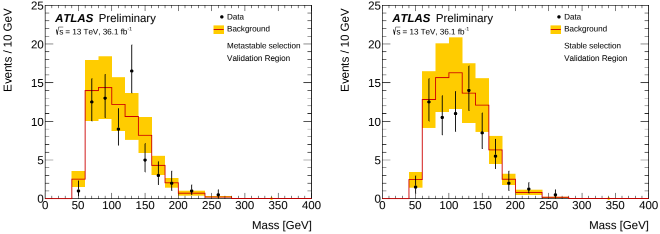
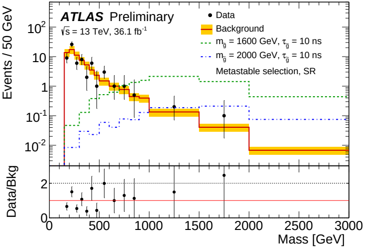
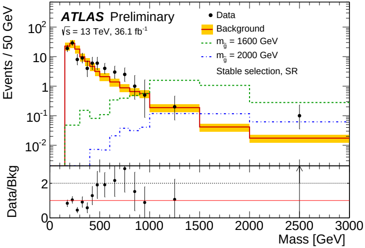
- Estimate validated using tracks with 50 GeV $< p <$ 150 GeV:





Metastable SR

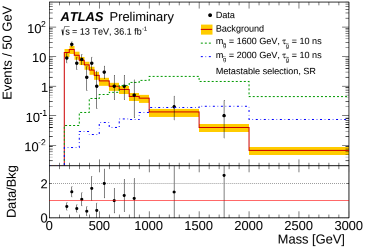


Stable SR

- SR yields:

SR	Prediction	Data
Metastable	$71 \pm 2 \pm 14$	72
Stable	$107 \pm 3 \pm 28$	107

- Largest local significance of 2.4σ in stable SR in bin designed for 600 GeV gluino



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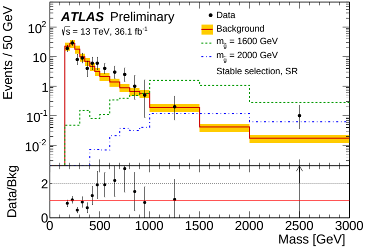

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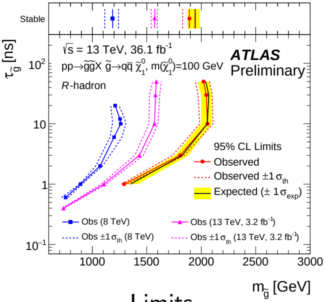

Limits

Search for displaced vertices

- Signature: Displaced vertex (DV) in the inner detector with high track multiplicity
- Sensitive to lifetimes of $\mathcal{O}(1\,\mathrm{ps})$ to $\mathcal{O}(10\,\mathrm{ns})$
- $E_T^{miss} > 250\,\mathrm{GeV}$

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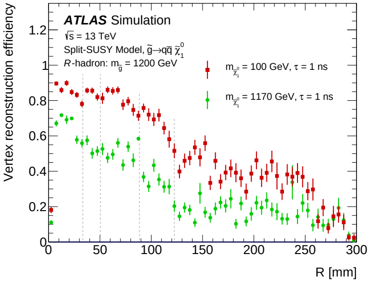
- Sensitive to lifetimes of $\mathcal{O}(1\,\text{ps})$ to $\mathcal{O}(10\,\text{ns})$
- $E_T^{miss} > 250\,\text{GeV}$
- Good vertex reconstruction efficiencies due to large radius tracking (LRT):



- LRT very time consuming → Events have to be preselected

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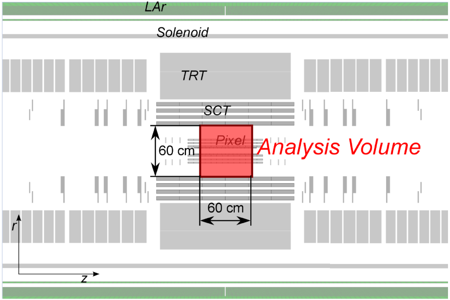

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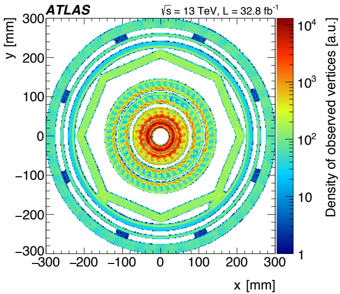
- DVs in material regions vetoed using 3D map



Estimation of dominant backgrounds

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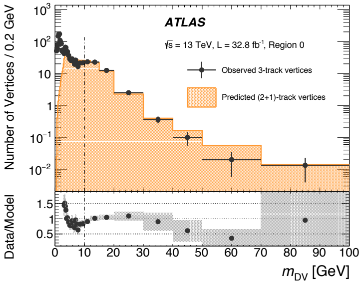
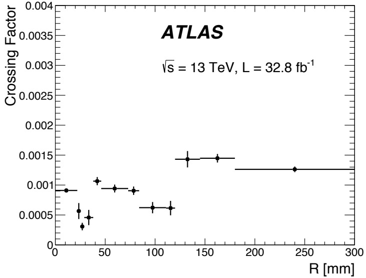
  - Normalisation (crossing factor) for n-track vertices derived from CR (3-track vertices)





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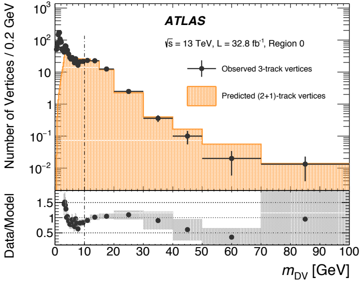
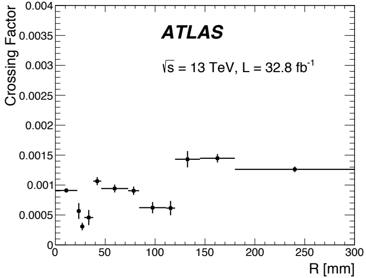
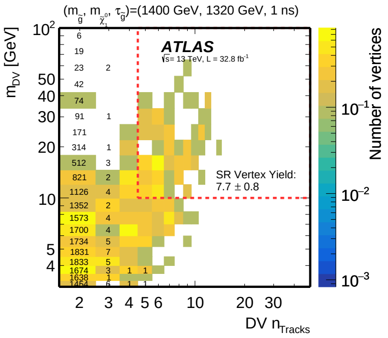


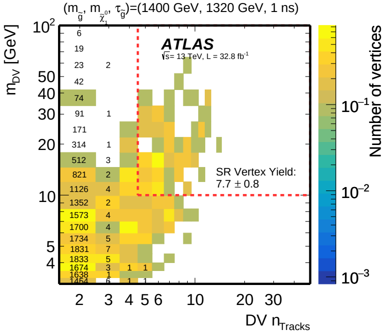


- Total background $= 0.02^{+0.02}_{-0.01}$ events



DVs in data

- No DV observed in signal region



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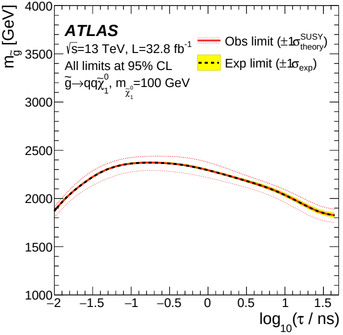

Limits for fixed LSP mass

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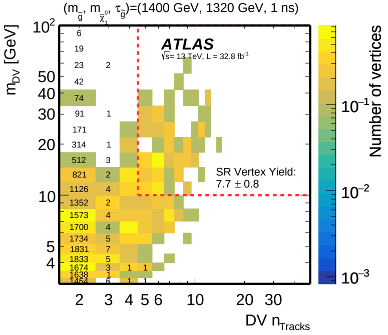
- $m(\tilde{\chi}^0_1) = 100\,\text{GeV}$: Best limit on $m(\tilde{g})$ from any LHC search



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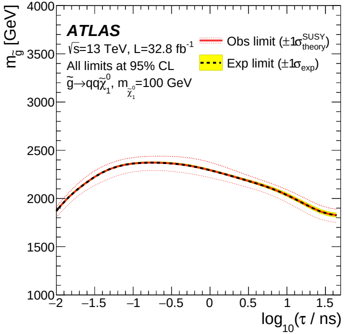

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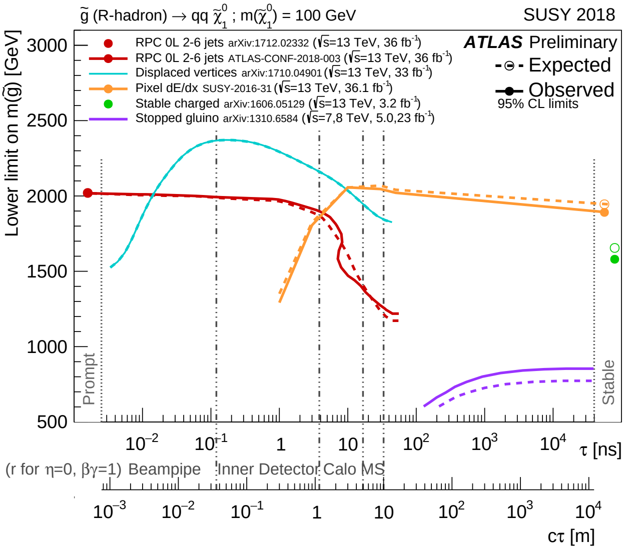
- Parametrised efficiencies available on HepData allowing reinterpretation of results

Summary


g̃ (R-hadron) → qq χ̃$_1^0$; m(χ̃$_1^0$) = 100 GeV
SUSY 2018
ATLAS Preliminary
Expected
Observed
95% CL limits
RPC 0L 2-6 jets arXiv:1712.02332 (√s=13 TeV, 36 fb^{-1})
RPC 0L 2-6 jets ATLAS-CONF-2018-003 (√s=13 TeV, 36 fb^{-1})
Displaced vertices arXiv:1710.04901 (√s=13 TeV, 33 fb^{-1})
Pixel dE/dx SUSY-2016-31 (√s=13 TeV, 36.1 fb^{-1})
Stable charged arXiv:1606.05129 (√s=13 TeV, 3.2 fb^{-1})
Stopped gluino arXiv:1310.6584 (√s=7,8 TeV, 5.0,23 fb^{-1})
Lower limit on m(g̃) [GeV]
Prompt
Stable
τ [ns]
(r for η=0, βγ=1) Beampipe
Inner Detector
Calo
MS
cτ [m]