Search for Heavy, Long-Lived Particles Decaying to Lepton Pairs in *pp* Collisions at $\sqrt{s} = 13$ TeV with the ATLAS Detector

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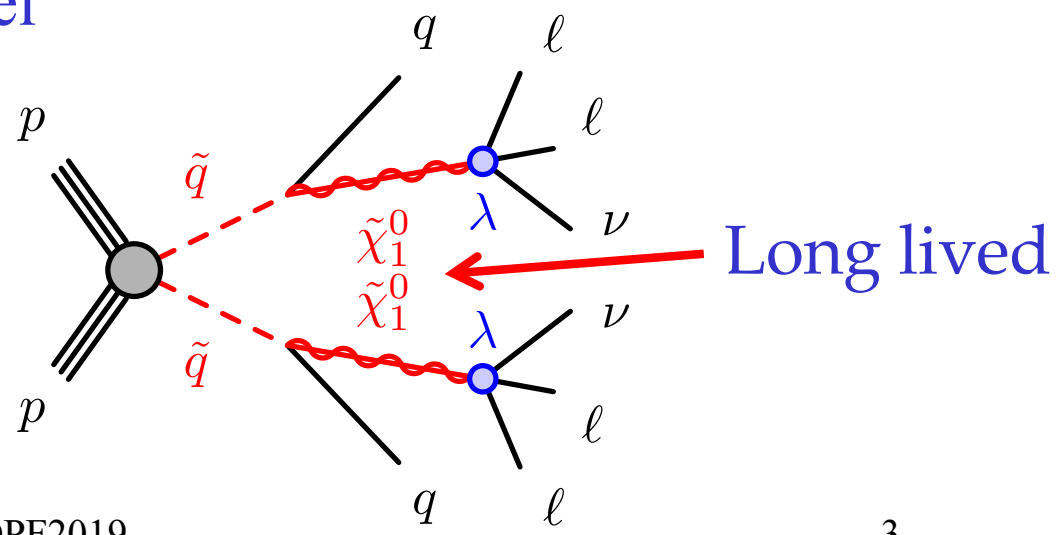
Outline

- Introduction
- Long-Lived Particles Reconstruction/Selection
- Background Estimates
- Systematic Uncertainties
- Summary

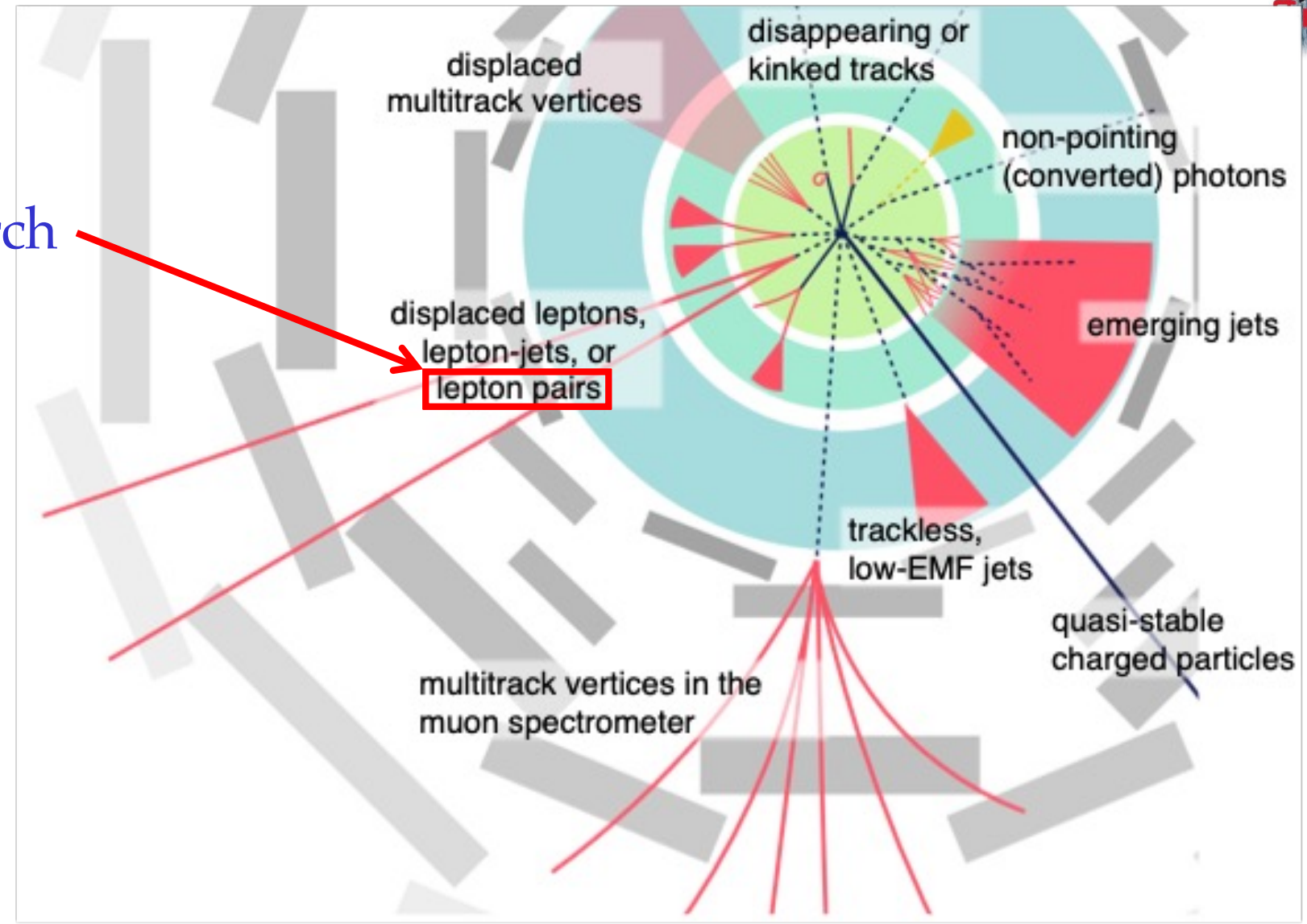
New Particle Search Signatures

- No new BSM particles at LHC so far
  - ⇨ searches for long-lived particles are of particular interest
- Two long-lived particles decaying into two leptons are searched for
  - $Z' \rightarrow ee + \mu\mu + e\mu$
    - cannot be singly produced via $q\bar{q}$ or else would have been observed as displaced jets
    - can be produced in pairs or from a decay
  - SUSY RPV simplified model



LLP Signatures

This search



Challenge in LLP Search

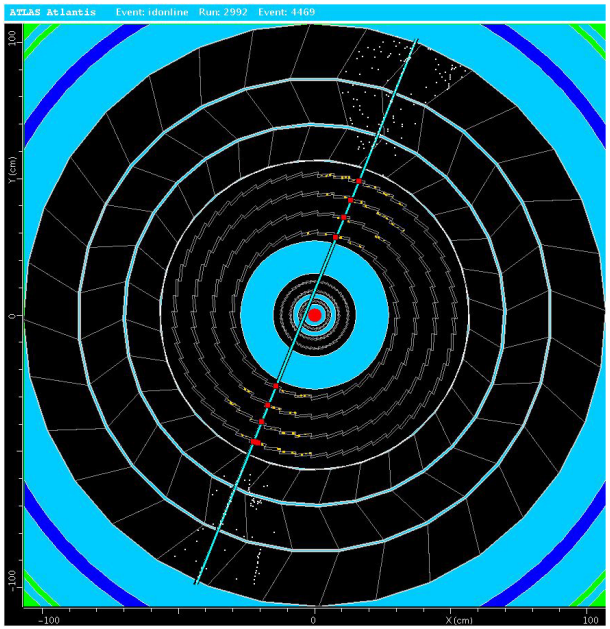
- Standard ATLAS trigger + track/vertex reconstruction are designed for particles originated near *pp* collision region
  - need special triggers without using inner tracker information
    - loose enough without producing too much data
    - use muon spectrum information only to select muons
    - use photon trigger only to select electrons
  - need to recover tracks not originated near *pp* collision region
    - use hits not used by the standard tracking
    - need special reprocessing: run large radius tracking program
    - $2 < |d_0| < 300$ mm
    - $|z_0| < 1500$ mm

Background

- no standard model process can produce heavy lepton pair with detached vertex
- two potential backgrounds
  - cosmic ray
  - two random leptons forming a detached vertex

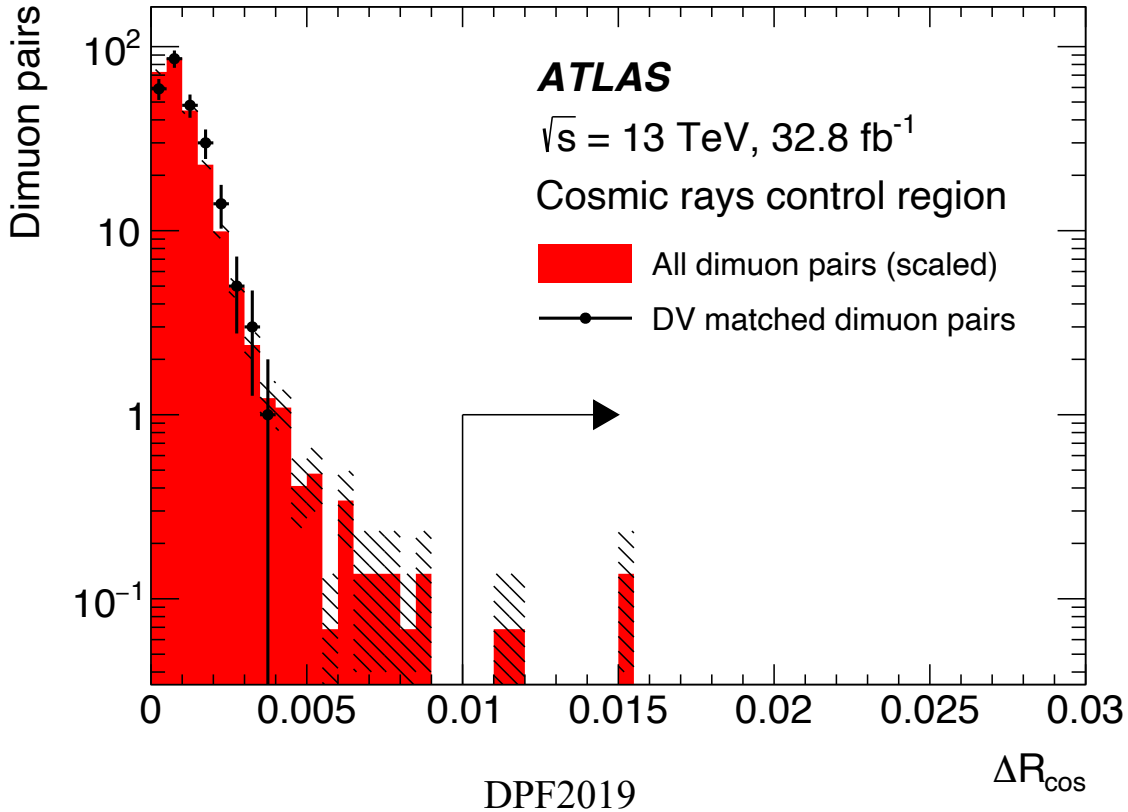
Cosmic Ray Veto

- one segment of cosmic ray could be reconstructed in opposite direction
  - ⇨ two opposite signed track forming a detached vertex
    - two tracks separated in ϕ by π
    - two tracks of opposite η
      - ⇨ CR veto: $\Delta R_{\cos} = \sqrt{(\Delta\phi - \pi)^2 + (\Sigma\eta)^2} < 0.01$



Cosmic Background Estimate

- use cosmic veto distribution to estimate background
- use distribution without vertex requirement to increase statistics in predicting number of cosmic events in signal region (> 0.01)
  - ⇨ 0.27 ± 0.14 ± 0.10 vertices



Random Crossing Background

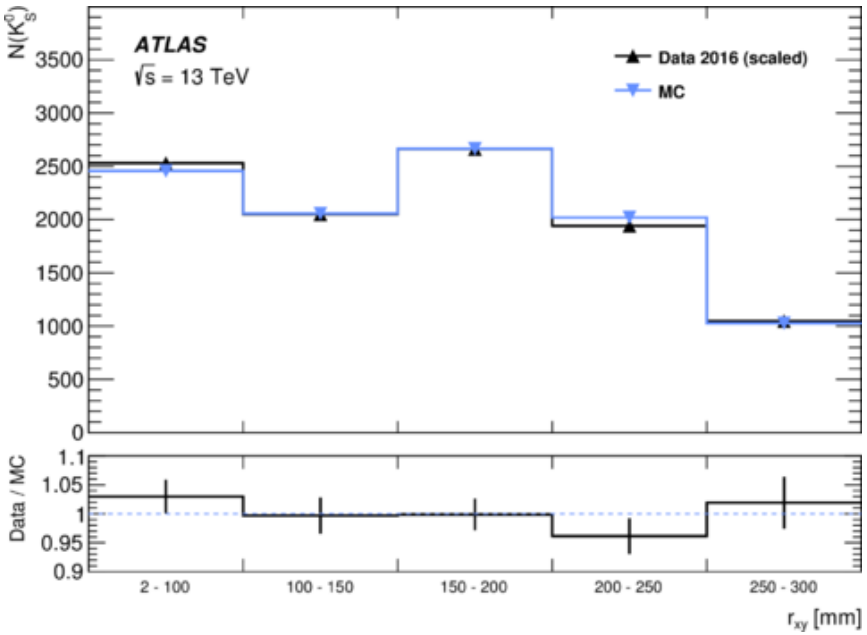
- estimated from data using two techniques
- no assumption on lepton origin or fake rate
  - event mixing
    - calculate probability for forming detached vertex using leptons from different events
    - multiple this by number of lepton pairs in data to yield number of vertices from random crossing
  - track flipping
    - randomly flip one track in a lepton pair with respect to beam spot
      - ⇨ try to reconstruct the vertex
    - number of successfully reconstructed vertex is then the estimated background
- both methods over estimate non-leptonic vertices (xx) by 20%

Summary of Background

- event mixing: 0.0024 vertices
- track flipping: 0.0039 vertices
  - difference of 63% is assigned as systematic uncertainty
  - ⇨ $0.0024 \pm 0.0005 \pm 0.0015$ vertices

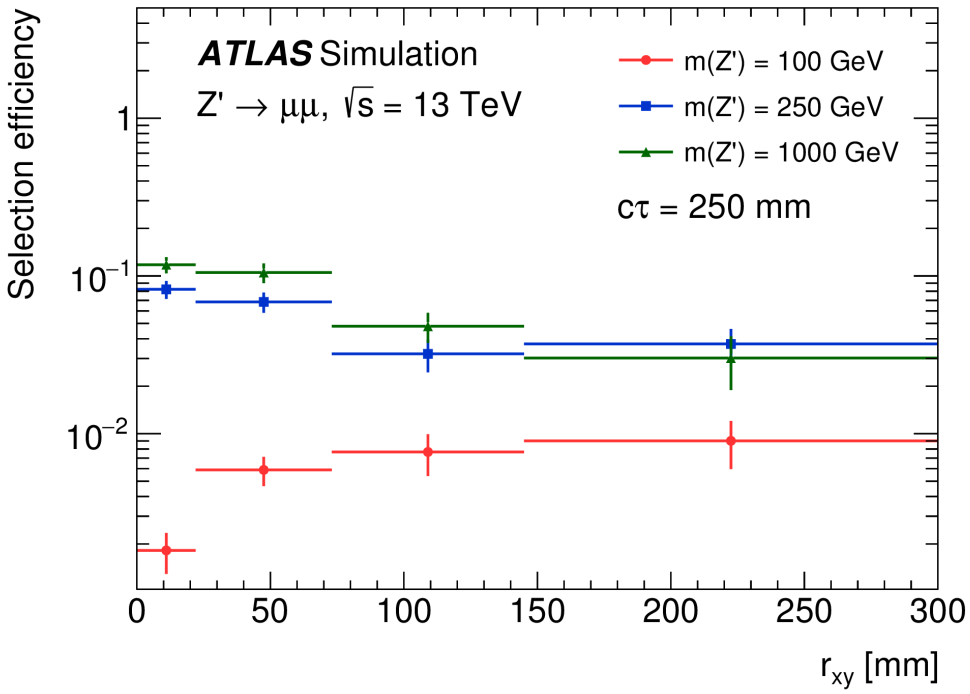
- cosmic ray: $0.27 \pm 0.14 \pm 0.10$ vertices

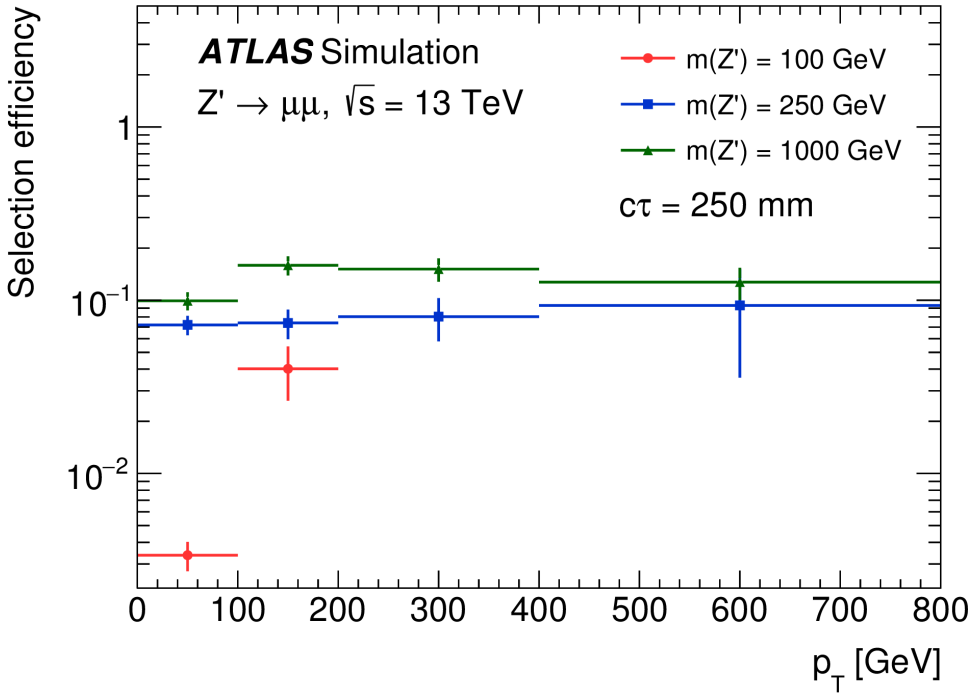
Systematic Uncertainty



- SUSY production cross section:
  - 8.7% for 700 GeV squark
  - 17.8% for 1600 GeV squark
- luminosity: 2.2%
- pile-up reweighting: ~10%
  - reweighted MC events to reproduce observed number of primary vertices
- trigger: few %
  - using Z boson with tag-and-probe technique
- tracking and vertexing efficiency for LLP: 10%
  - use $K_s \rightarrow \pi\pi$

Sensitivity for Z'

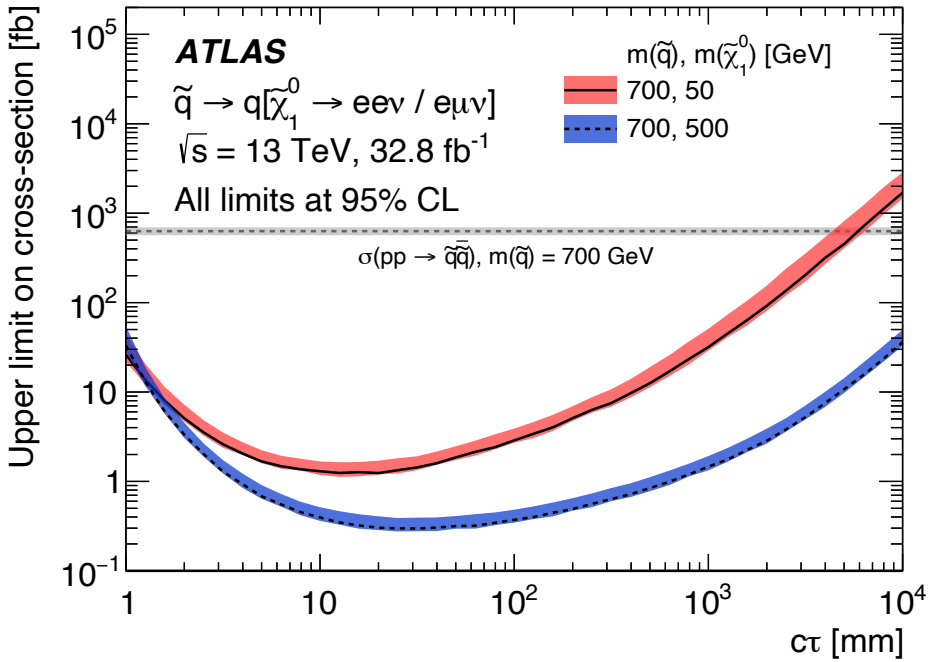


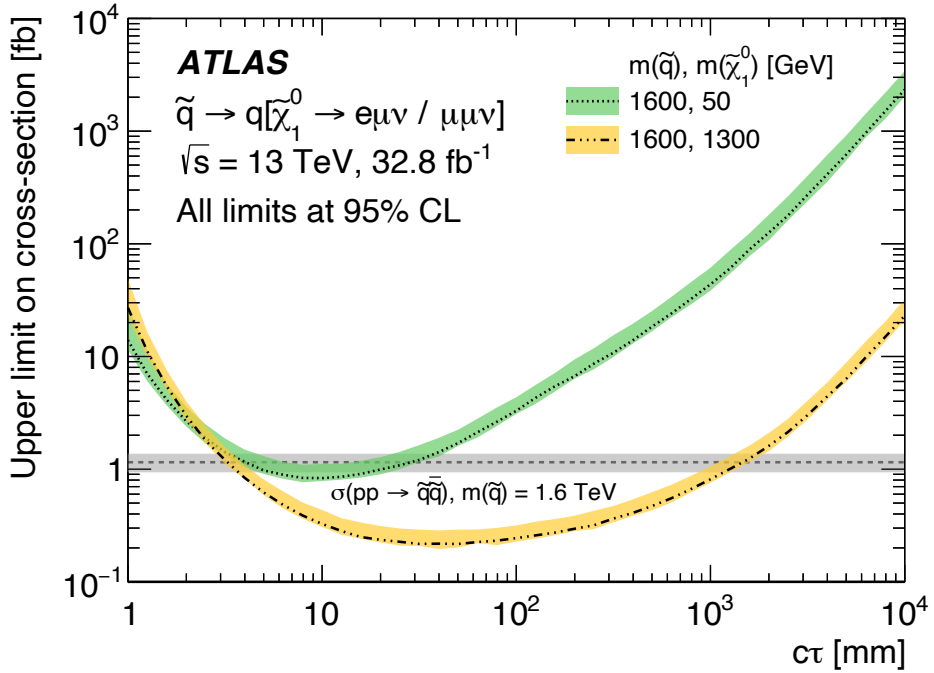


- efficiency ~10% to radius of 300 mm
- good sensitivity for Z' mass above 250 GeV
- present efficiency vs. radius and p_T
  for theorists to extract limits on their favorite models

Results on RPV SUSY

- two independent scenarios searched:
  - LSP decay is mediated by single dominant RPV coupling λ_{121} or λ_{122}
    - 700 GeV squark: exclude 50-500 GeV neutralino, $c\tau$ = 1 mm – 6 m
    - 1.6 TeV squark: exclude 1.3 TeV neutralino, $c\tau$ = 3 mm – 1 m





Summary

- Search for heavy, long-lived particles with two lepton final states in two search scenarios
  - $Z' \rightarrow ee + \mu\mu + e\mu$
  - SUSY RPV simplified model
  - no event was found in the data
  - exclude some neutralino masses and lifetimes