ATLAS Searches for Supersymmetry with Long-Lived Particles

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On behalf of ATLAS Collaboration

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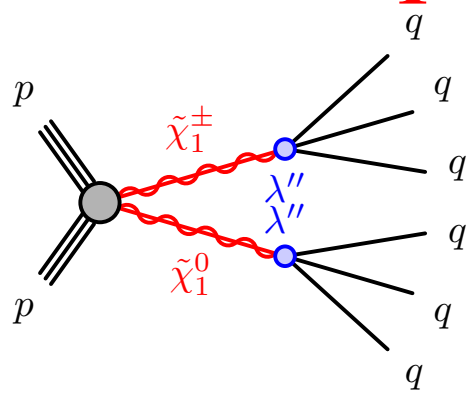
Outline

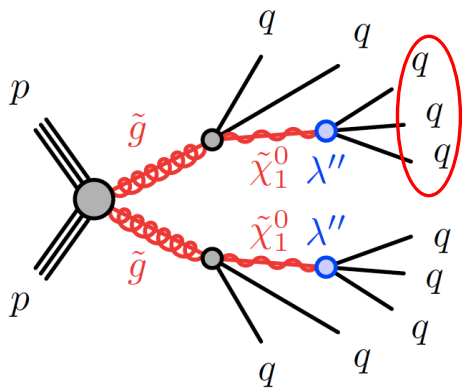
- Introduction
- Search for jets with displaced vertices
- Search for displaced photons from exotic Higgs decays
- Search for displaced photon/electron pair from Higgs/*Z* decays
- Search long-lived charged particles with large ionisation
- Summary

Introduction

- No evidence of supersymmetry in extensive searches by ATLAS and CMS
  ⇨ search for supersymmetry with long-lived particles
- ATLAS searches in *pp* collisions at $\sqrt{s}$ =13 TeV
- Integrated luminosity: 139 fb^{-1}

Search for Displaced Vertices plus Jets





Displaced

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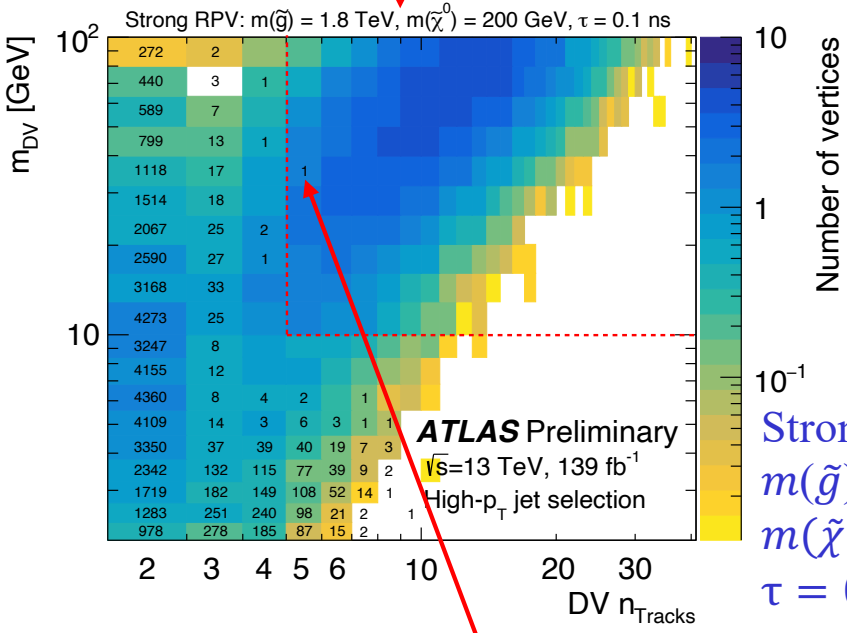
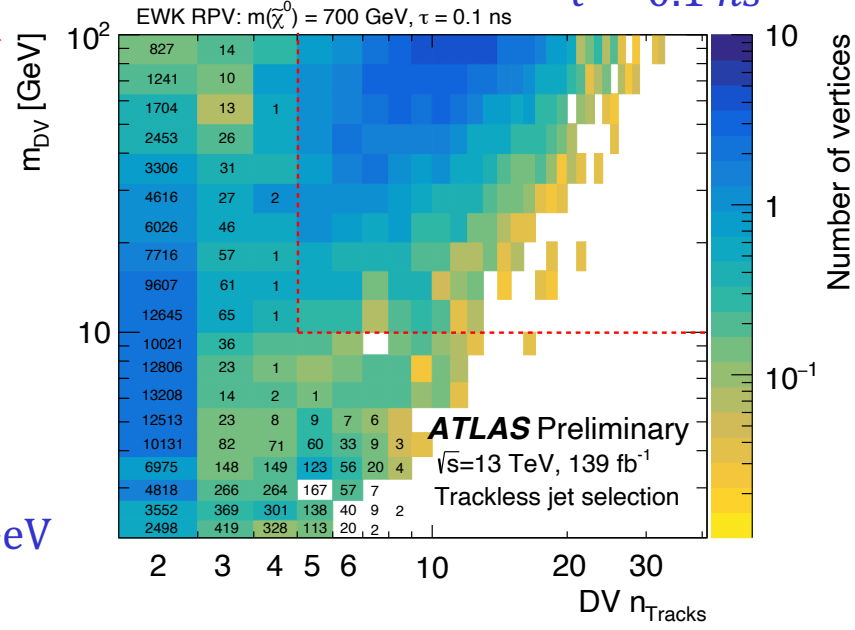
- search for long-lived massive particles in multijet events with displaced vertices (DV) in the inner detector
  $M_{DV} > 10$ GeV
- target small R-parity violating (RPV) coupling λ''
  - ⇨ long-lived SUSY particles
- no SM processes produce a high-mass DV
  - background: material interactions, random crossing of tracks, and merged vertices
  - background estimated from data
  - ⇨ nearly background free (~1 event/signal region)

Result

Signal Region	Observed	Expected	S^{95}_{obs}	S^{95}_{exp}	$\langle\sigma_{vis}\rangle^{95}_{obs}$ [fb]
High-p_T jet SR	1	$0.46^{+0.27}_{-0.30}$	4.5	$4.0^{+0.7}_{-1.4}$	0.032
Trackless jet SR	0	$0.83^{+0.51}_{-0.53}$	3.3	$4.4^{+0.6}_{-0.4}$	0.024

EWK RPV:
$m(\tilde{\chi}^0) = 700$ GeV
$\tau = 0.1\ ns$



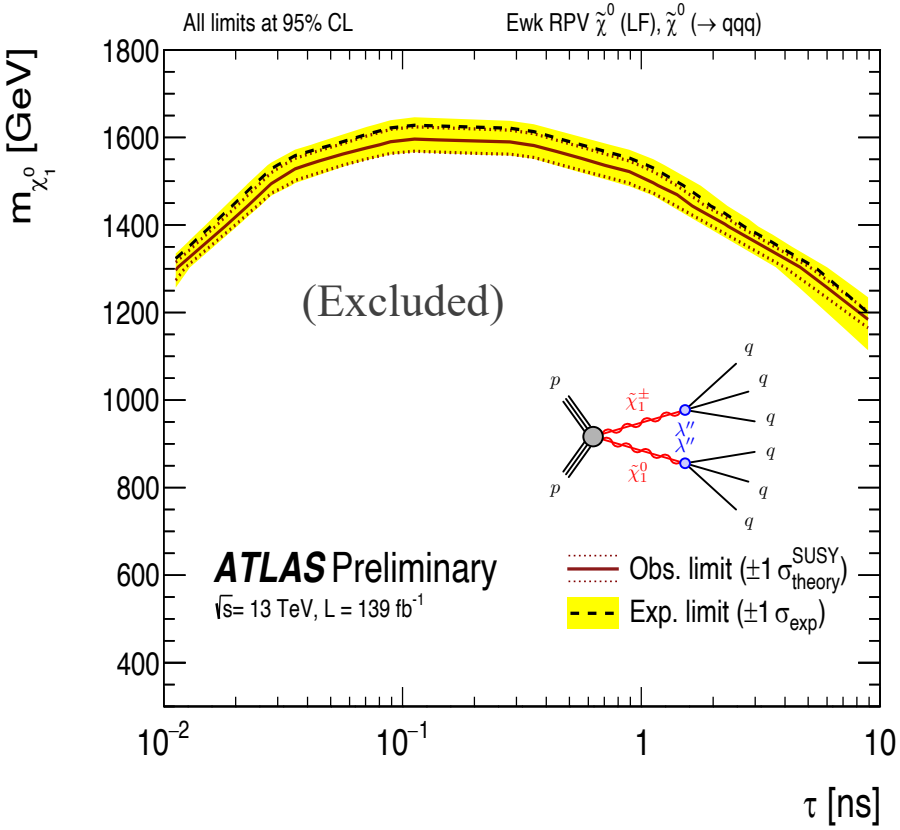


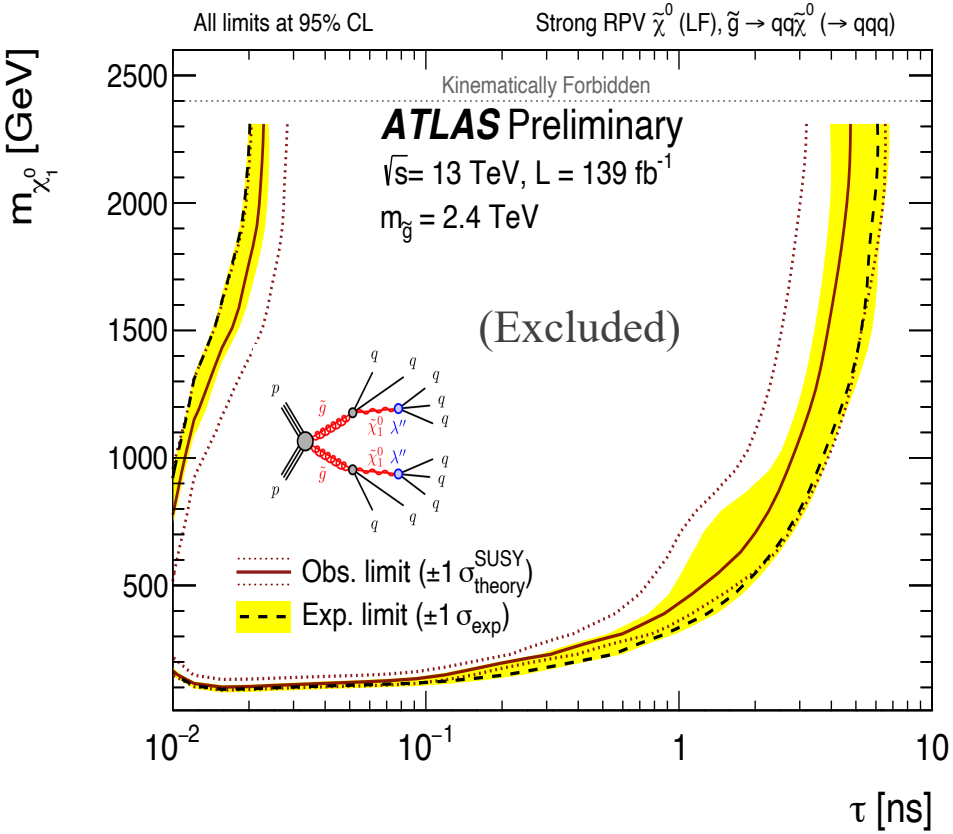
Strong RPV:
$m(\tilde{g}) = 1.8$ TeV
$m(\tilde{\chi}^0) = 200$ GeV
$\tau = 0.1\ ns$

$m_{DV} = 32.6$ GeV, $n_{Trk} = 5$ in event containing 7 jets with $p_T > 90$ GeV

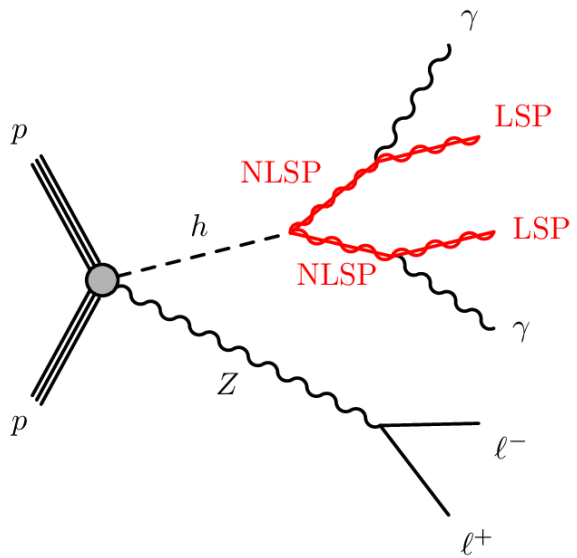
Limits on $\tilde{\chi}_1^0$

- Neutralinos with $m(\tilde{\chi}_1^0) < 1.5$ TeV are excluded for lifetimes between 0.03 and 1 ns





Search for Displaced Photons in Exotic Higgs Decays



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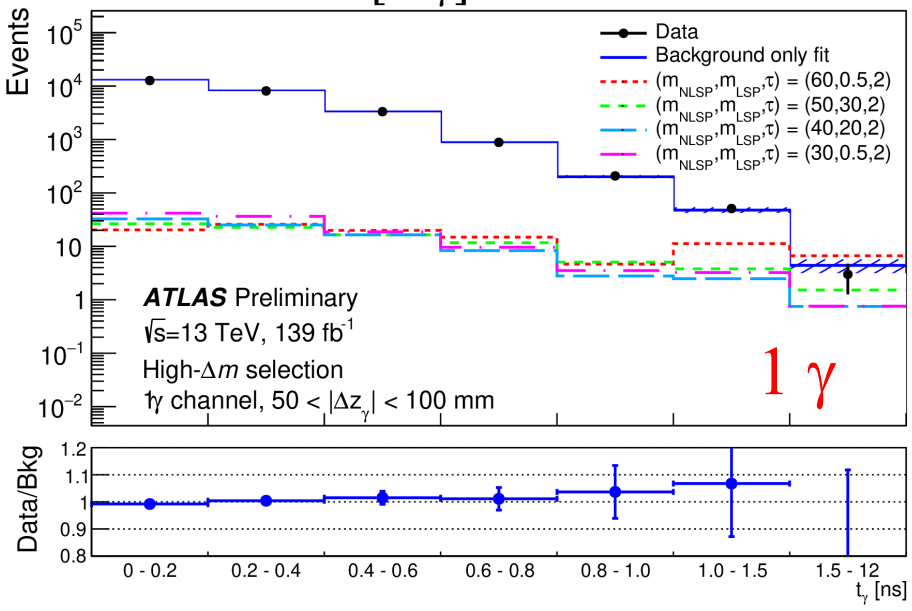
- fine segmentation of LAr EM calorimeter allows precise reconstruction of photon flight path
  - ⇨ select photons not produced at primary vertices
  - ◆ also precisely measure arrival time of photons
  - ◆ E_T^{miss} > 80 GeV for Δm = m(NLSP) – m (LSP) = 10 GeV
  - ◆ E_T^{miss} > 50 GeV for Δm = m(NLSP) – m (LSP) > 10 GeV
- select candidate photon with highest E_T

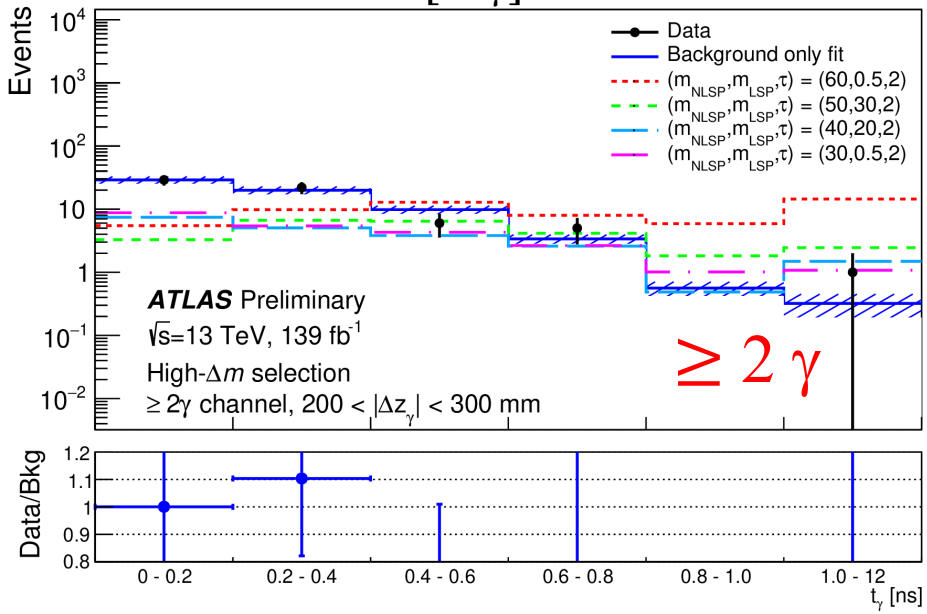
Signal Analysis for $\Delta m = m_{NLSP} - m_{LSP} > 10$ GeV

- analyze arrival time in five bins of z displacement (Δz_γ) from primary vertex
- background shapes estimated from data
  - ⇨ data consistent with background expectations

$50 < |\Delta z_\gamma| < 100\ mm$



$200 < |\Delta z_\gamma| < 300\ mm$



Signal Analysis for $\Delta m = m_{NLSP} - m_{LSP} = 10$ GeV

- analyze arrival time in five bins of z displacement (Δz_γ) from primary vertex
- background shapes estimated from data
  - ⇨ data consistent with background expectation

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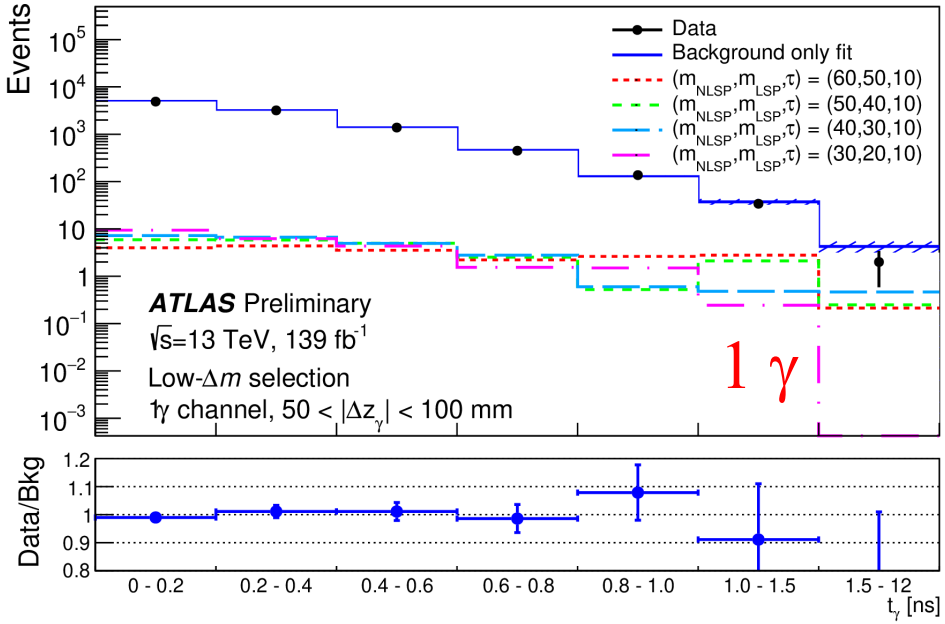
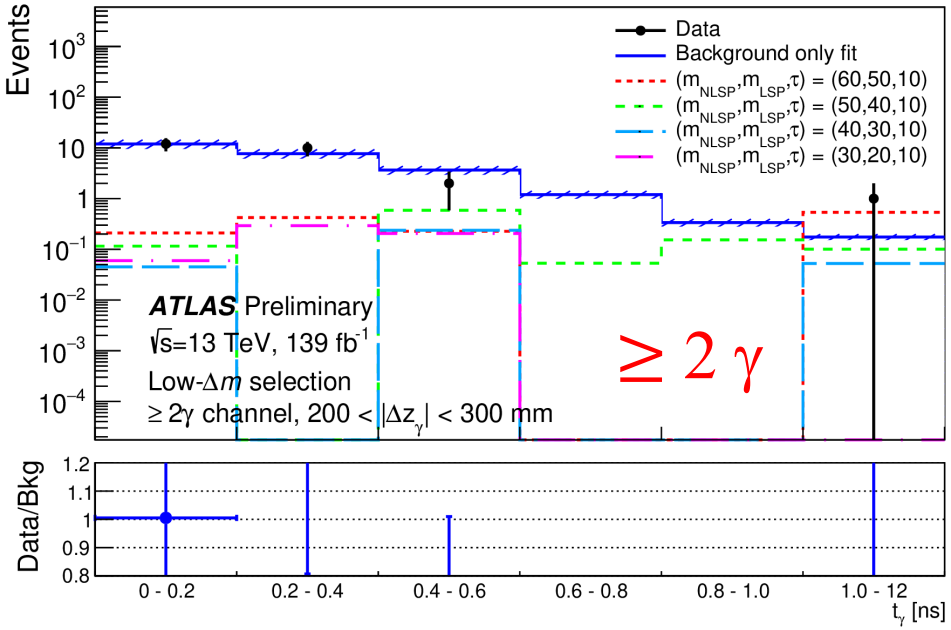
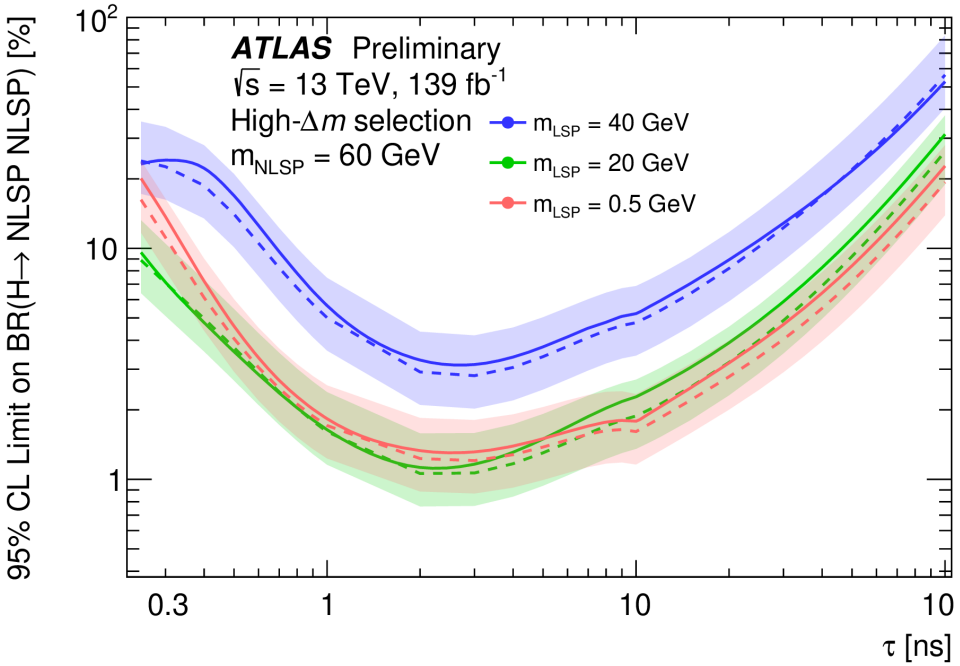


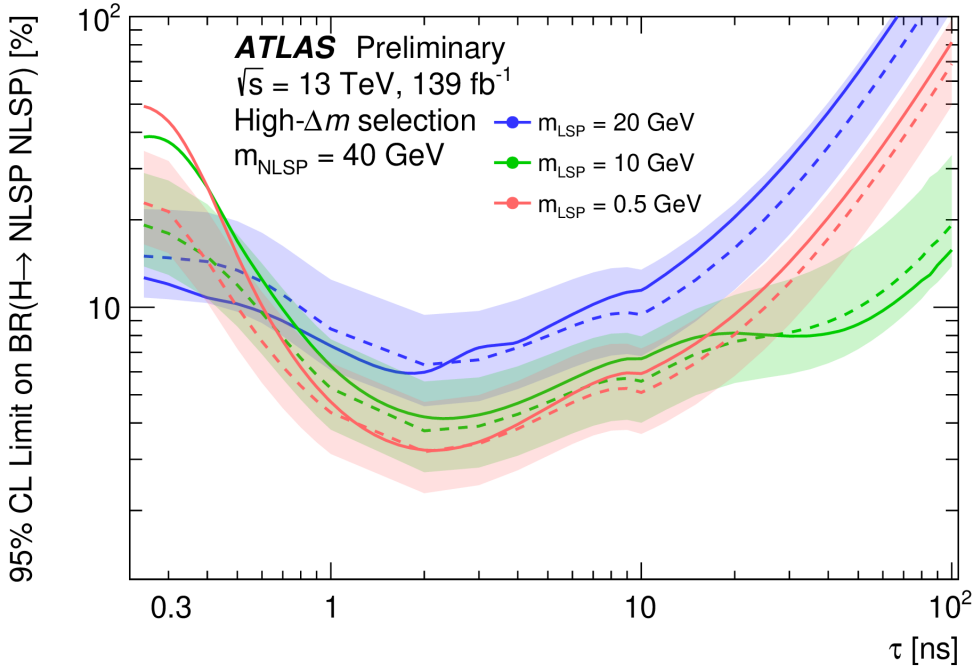
$200 < |\Delta z_\gamma| < 300\ mm$



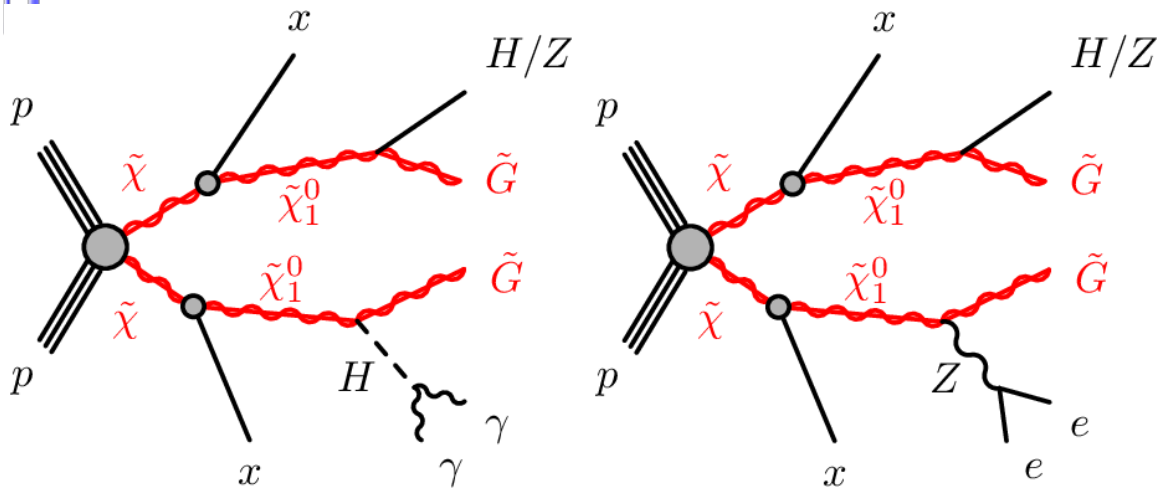
Limits on Exotic Higgs Decays

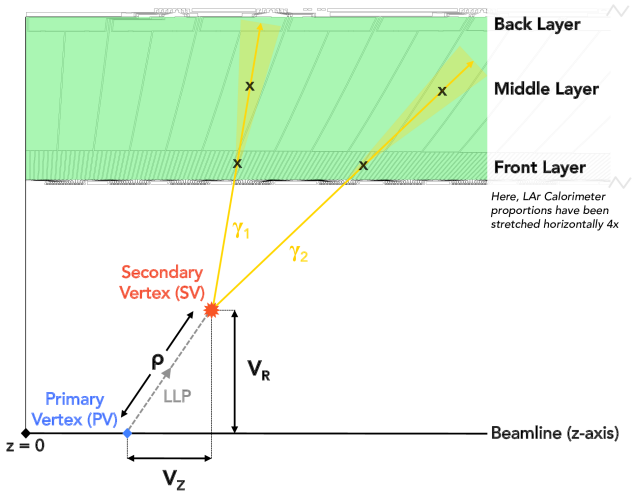
- set upper limit on BR(H→NLSP+NLSP) as a function of NLSP lifetime
  - limited sensitivity at low τ due to poor pointing resolution
  - limited sensitivity at high τ because decay is near edge of LAr
  - best sensitivity at $\tau \sim$1-10 ns with BR < a few percent





Search for γγ/ee from Displaced Higgs/Z Production





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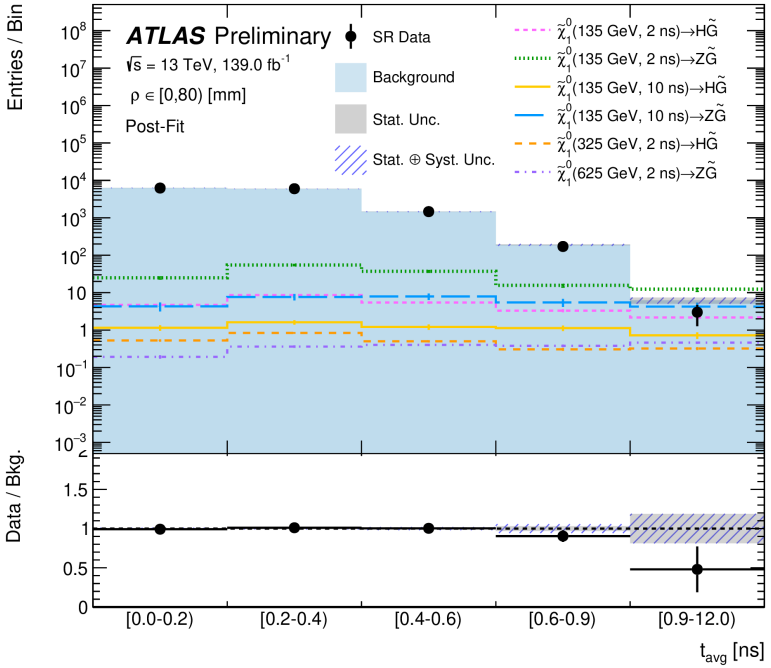
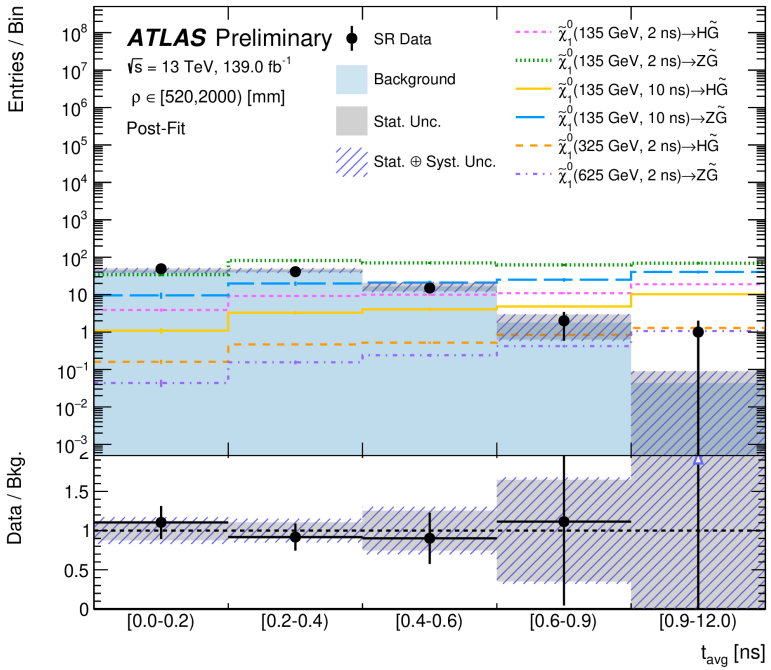
- again use fine segmentation of LAr EM calorimeter to precisely reconstruct EM shower flight path
  - ⇨ select γγ/ee not produced at primary vertex
  - ◆ also precisely measure arrival time of photons
  - ◆ $E_T^{miss} > 30$ GeV
  - ◆ analyze displacement (ρ) and arrival time to search for signal

Result

$0 < \rho < 80$ mm



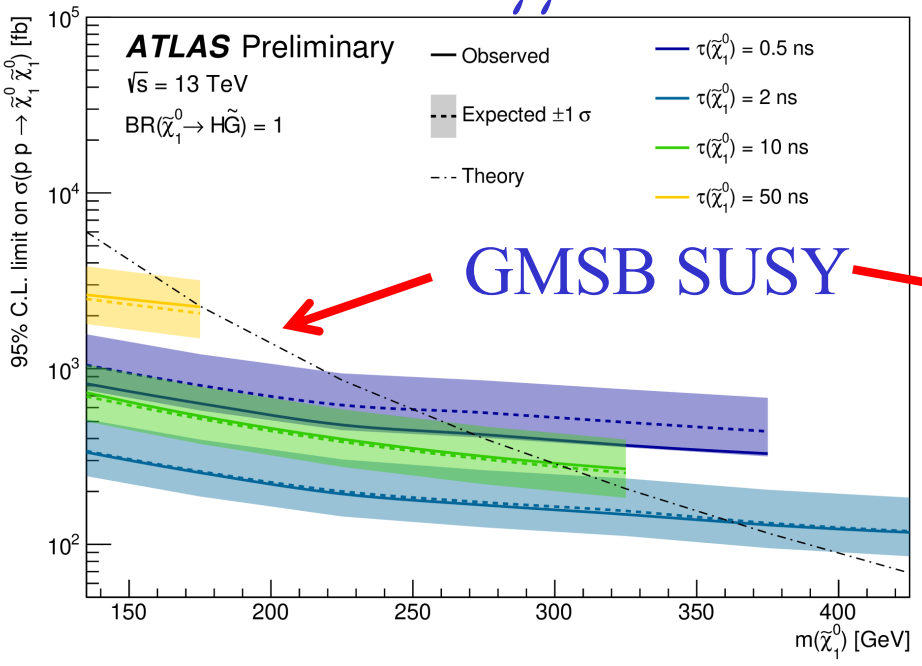
$520 < \rho < 2000$ mm



- analyze average arrival times in five displacement bins
  - arrival time distributions consistent with background expectations

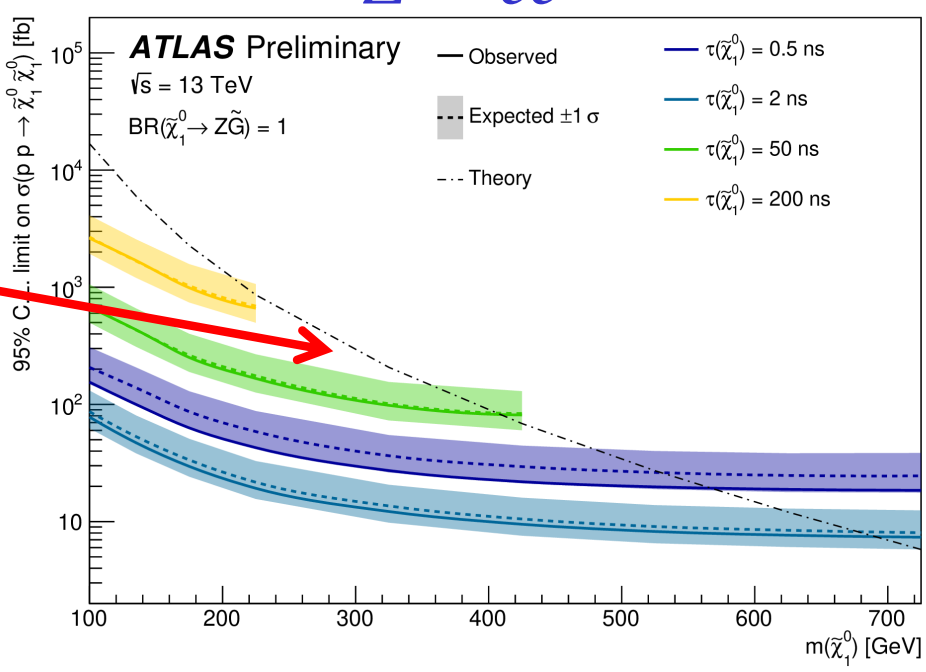
Limits on $\tilde{\chi}_1^0$

H → $\gamma\gamma$



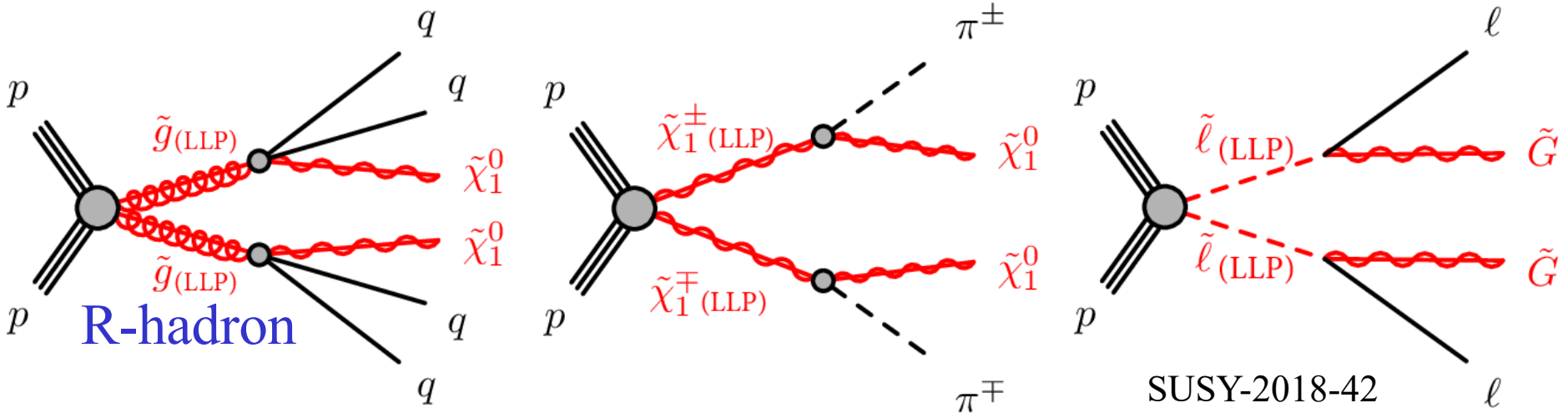
GMSB SUSY

Z → *ee*



- $m(\tilde{\chi}_1^0) > 369$ GeV @ $\tau = 2$ ns for B($\tilde{\chi}_1^0 \rightarrow H\tilde{G}$) = 100%
- $m(\tilde{\chi}_1^0) > 704$ GeV @ $\tau = 2$ ns for B($\tilde{\chi}_1^0 \rightarrow Z\tilde{G}$) = 100%
- higher sensitivity for $\tilde{\chi}_1^0 \rightarrow Z\tilde{G}$ because B(Z→ ee) > B($H \rightarrow \gamma\gamma$)

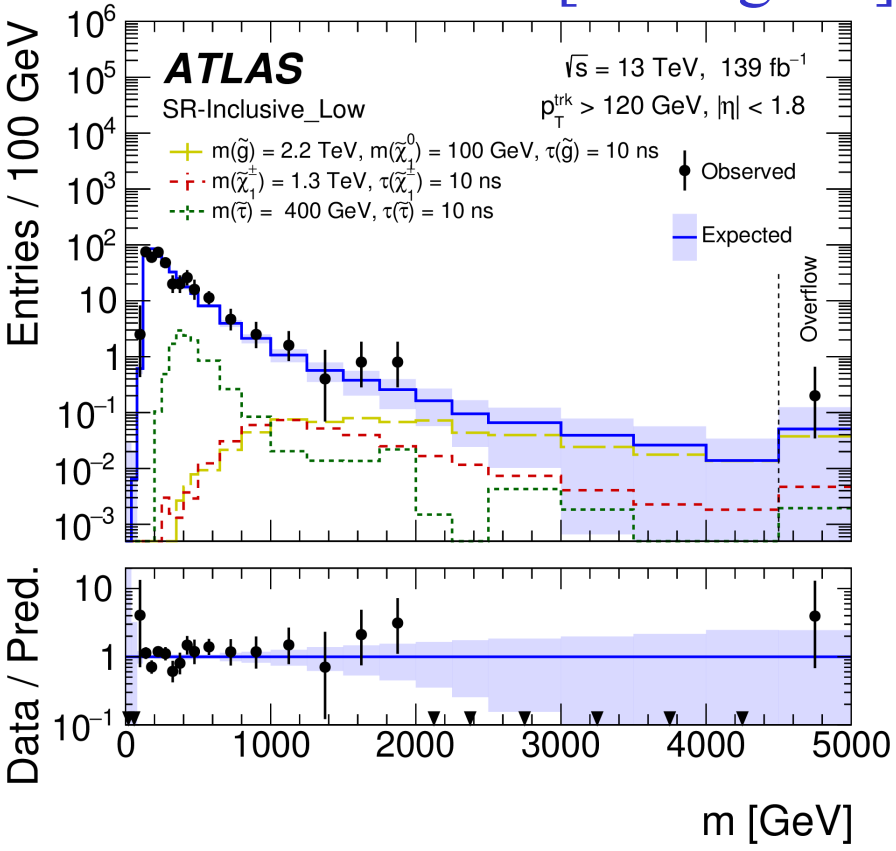
Search Long-Lived Charged Particles with Large Ionisation



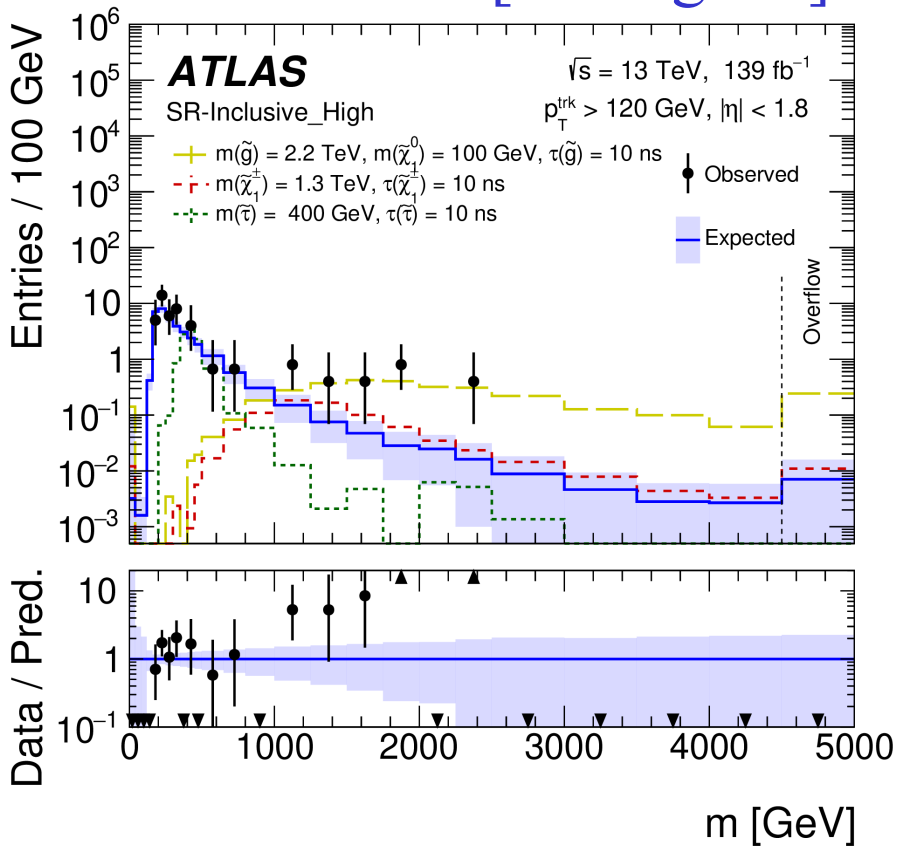
- Search for massive, charged, long-lived particles that move significantly slower than speed of light
  - high transverse momentum
  - anomalously large specific ionization loss, dE/dx
    - trajectory reconstructed in the inner tracking system
    - dE/dx measured in the pixel detector
      - mass extracted using Bethe-Bloch relation

Result

1.8 < dE/dx < 2.4 [MeV/g/cm]

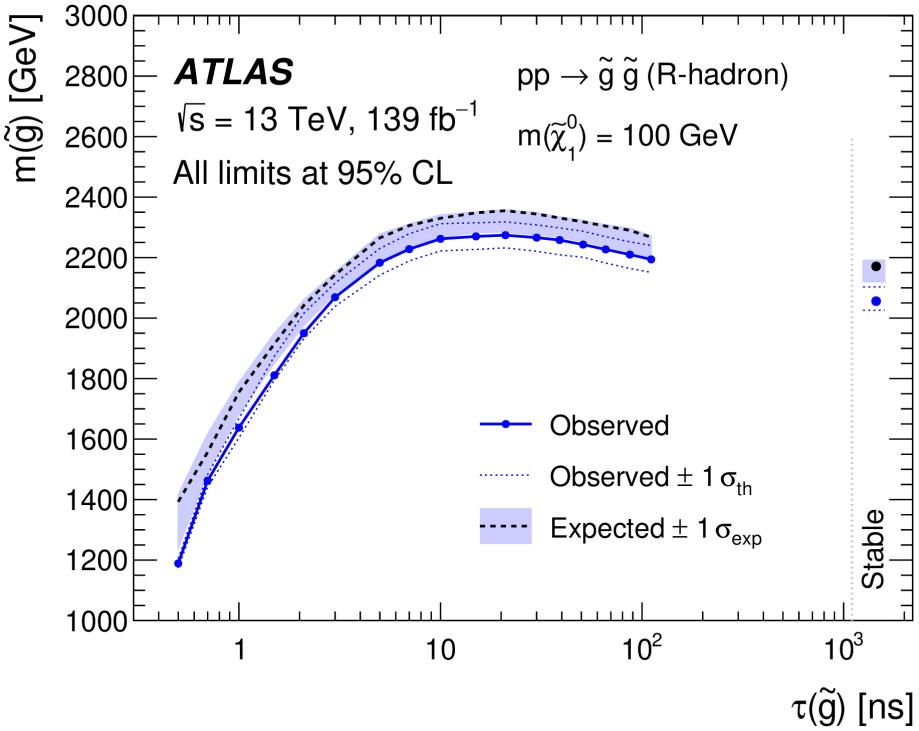


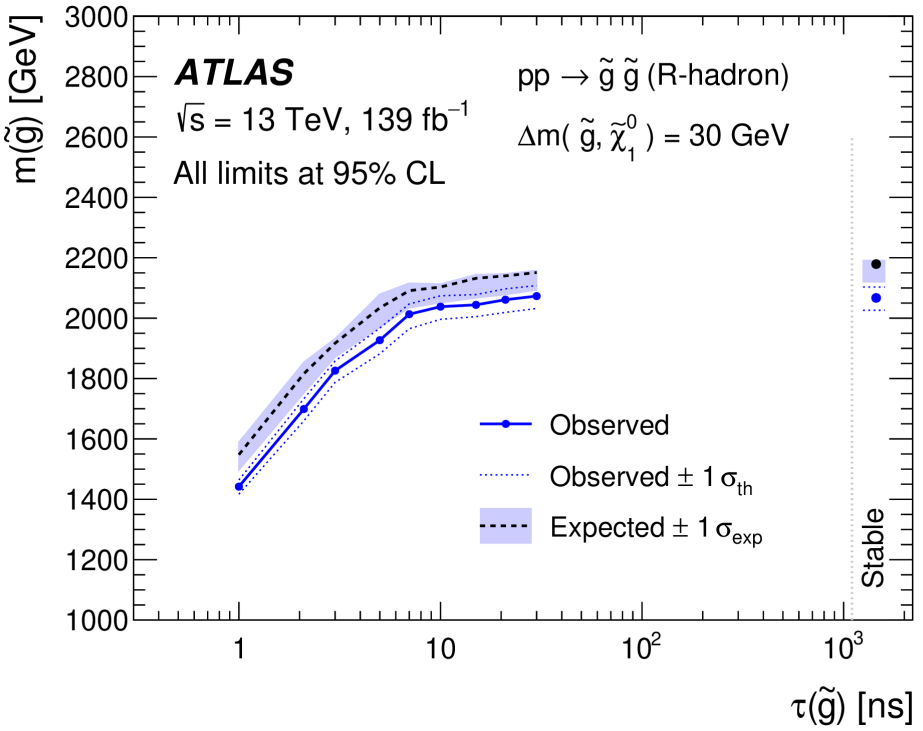
dE/dx > 2.4 [MeV/g/cm]



- observed mass distributions extracted from dE/dx measurements show some excess at high mass (3.6 σ local/3.3 σ global)
  - ToF study of excess events with calorimeter/muon system show β~1

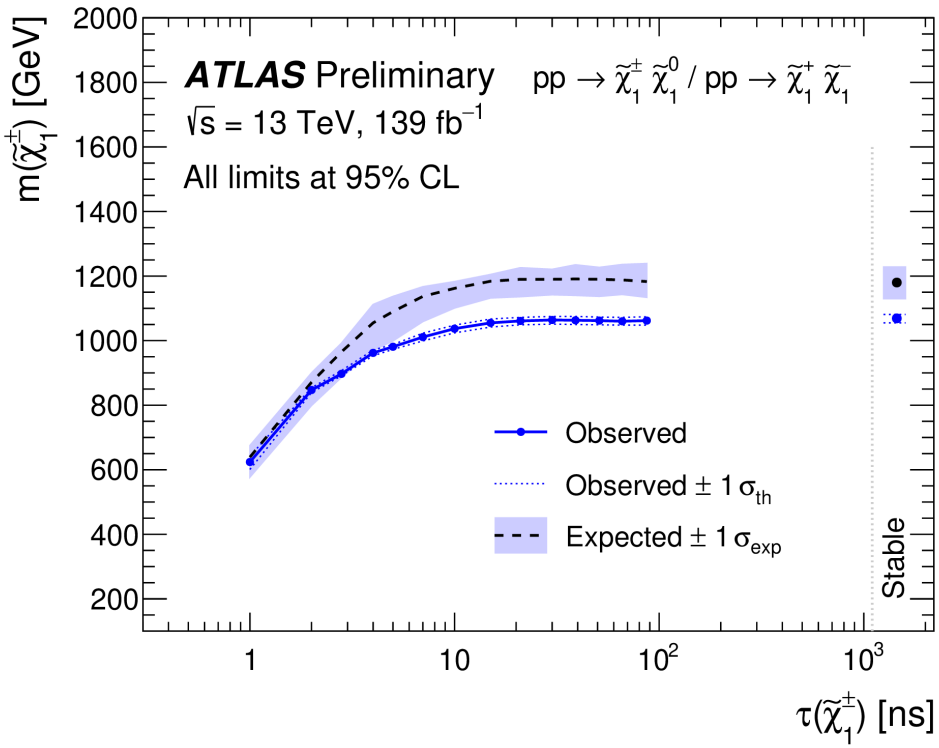
Limits on R-Hadron

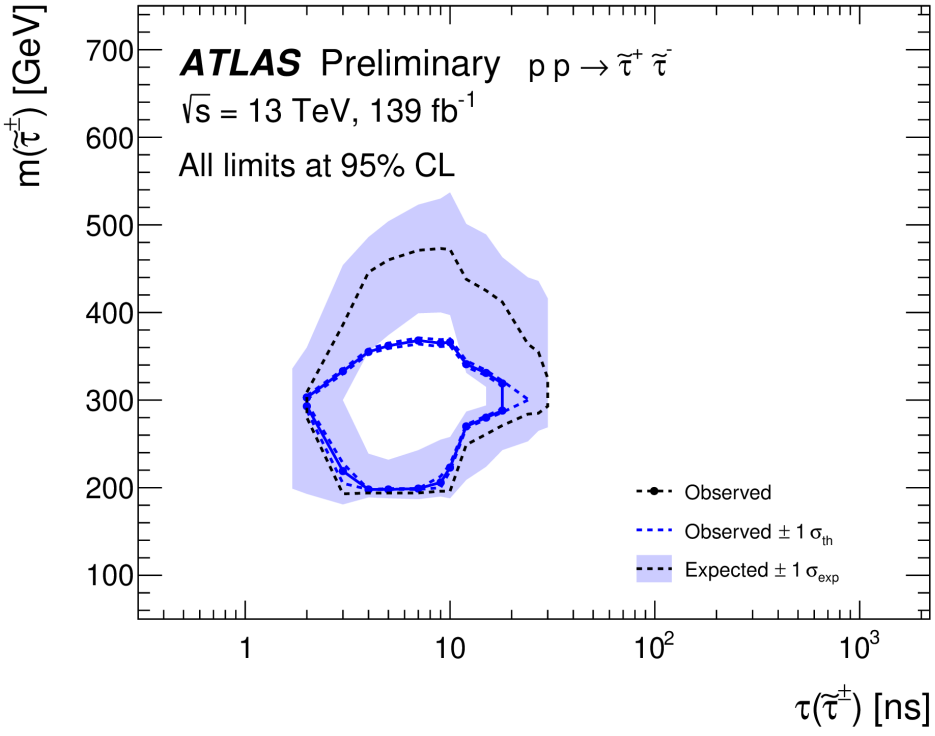




- most sensitive region: 10-30 ns
- Limits @ 95CL:
  - m > 2.27 TeV for $\tau = 20$ ns + $m(\tilde{\chi}_1^0) = 100$ GeV
  - m > 2.06 TeV for $\tau = 30$ ns + $\Delta m(\tilde{g}, \tilde{\chi}_1^0) = 30$ GeV

Limits on Chargino and Stau





- most sensitive region: 10-30 ns
- Limits @ 95CL:
  - chargino: m > 1.07 TeV for τ = 30 ns
  - stau: 200 < m < 360 GeV for τ = 10 ns

Summary

- ATLAS has greatly expanded the sensitivity to SUSY by searching for long-lived particles:
  - jets
  - photons/electrons
  - anomalously large specific ionization loss (dE/dx)
- No significant excess of events is observed
- Stay tuned for Run 3 with 3 times larger data sample