Search for New Physics through the Reconstruction of Challenging Signatures with the ATLAS detector

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Introduction

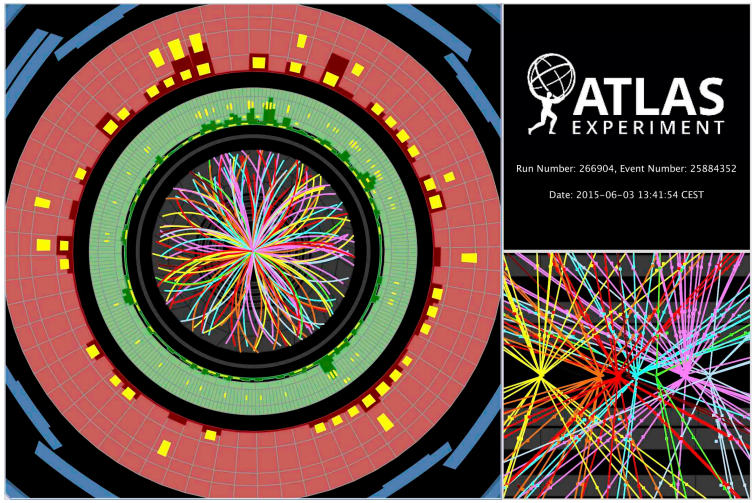
- No deviation of physics beyond the SM at LHC so far

- Increased emphasis in exploration of unusual final state signatures
  - elude the searches based on prompt signatures and stable particles!

- Unconventional signature arises from
  - Long Lived Particles (LLP)
  - particles with fractional or multiple value of the *e* charge
  - high mass (meta)stable charged particle

- Reconstruction and trigger needs to be adjusted
  - Face also degradations from pile-up conditions

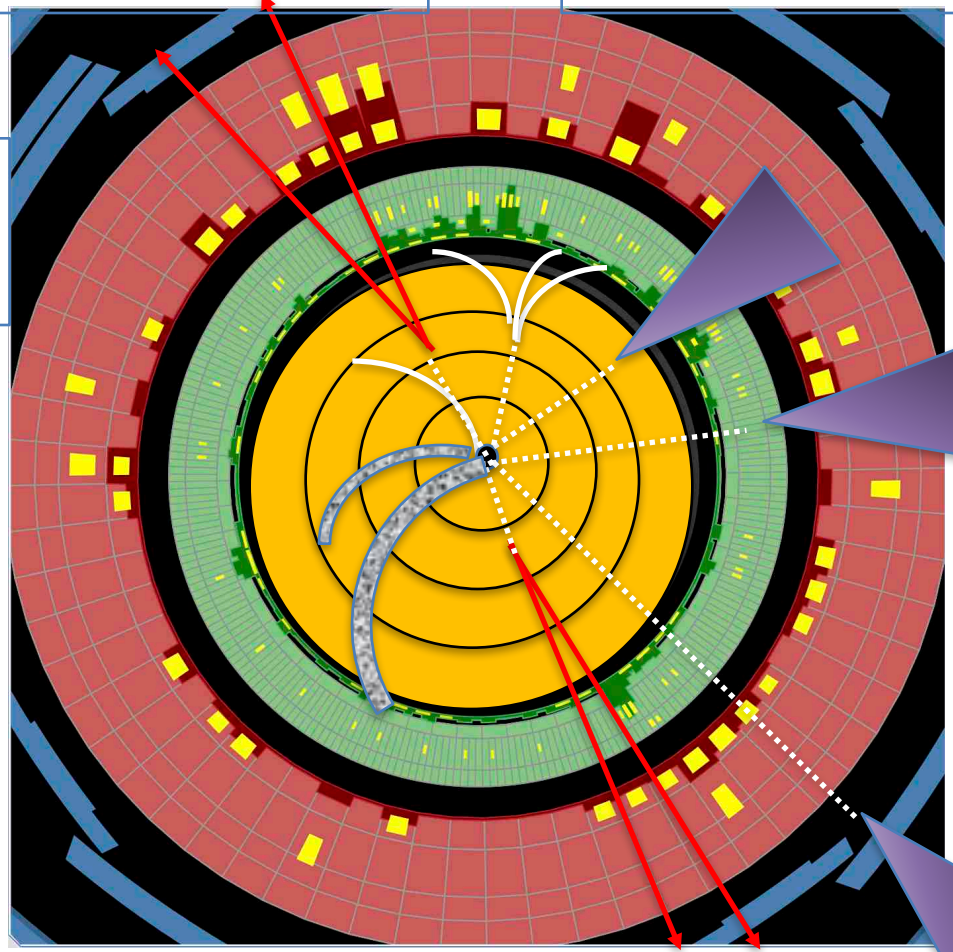
Run2 Event with pileup vertices



Challenging signatures

Displaced leptonic vertices 8 TeV, 20.3fb^{-1} Phys. Rev. D 92, 072004

Displaced vertices + MET, 13 TeV 32.8 fb^{-1} CERN-EP-2017-202



Disappearing tracks 13 TeV 36.1fb^{-1} JHEP06 022 (2018)

Displaced jets in the iD ATLAS, 8 TeV, 20.3 fb^{-1} PRD 92 012010 (2015)

(Meta-) Stable Charged LLPs with large ionization energy loss, 13 TeV, 3.2fb^{-1} Phys. Rev. D 93, 112015 (2016)

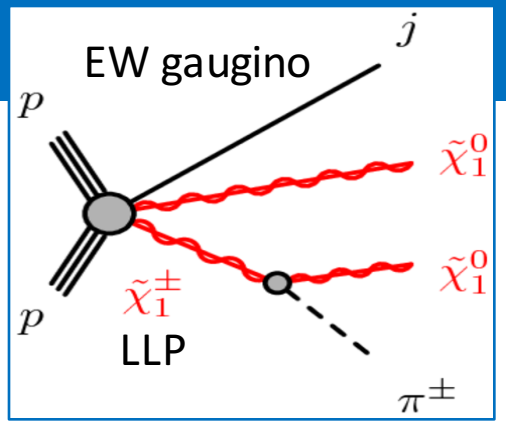
Displaced jets in the Calorimeter ATLAS, 13 TeV, 3.2fb^{-1} ATLAS-CONF-2016-103

Displaced jets in the MS 8TeV PRD 92, 012010 (2015)

Multi-charged highly ionizing LLP 8TeV PRD 93, 052009 (2016) Eur. Phys. J. C (2015) 75

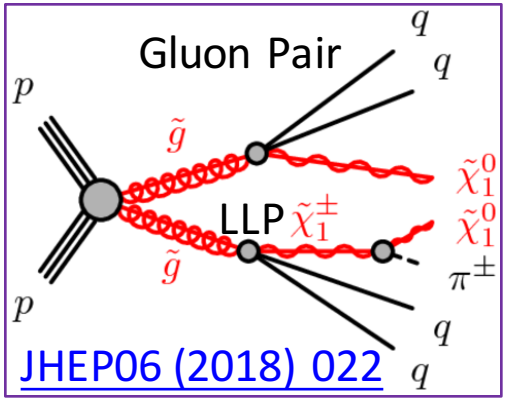
Displaced Lepton-jets 13 TeV, 3.2fb^{-1} ATLAS-CONF-2016-042

Disappearing Tracks



Motivation:

- Search for direct electroweak (EW) gaugino or gluino pair (GP) production with $m\chi^{\pm} - m\chi^0 \sim O(100\ MeV)$
  - $\chi^{\pm}$ is the LLP

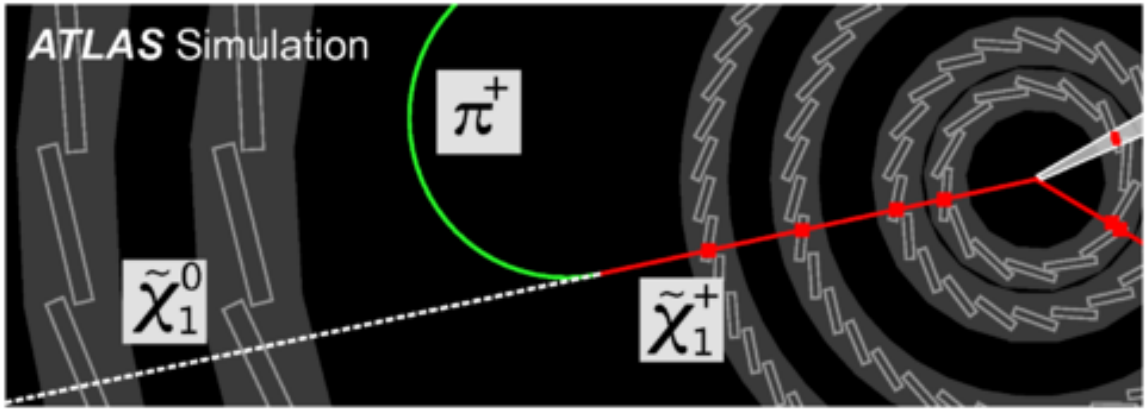


Signature:

- short tracks (tracklets) with hits only in inner most ID layers
- Low momentum pion track (~0.1 GeV) not reconstructed
- >=1jet with high p_T from ISR (EW) or by 4 jets (GP)

Selection:

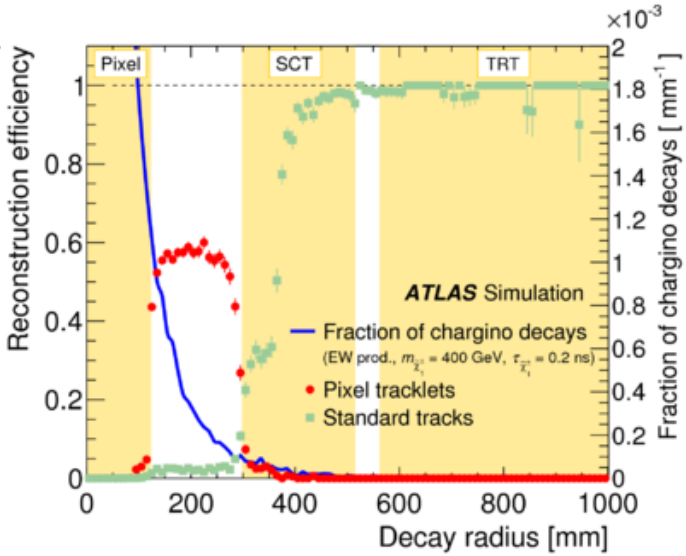
- high MET, ≥1 high p_T jet (ISR)
- high quality tracklet
- lepton veto



Search sensitive to LLP lifetime of 10ps to 10 ns

Disappearing Tracks: reconstruction challenge

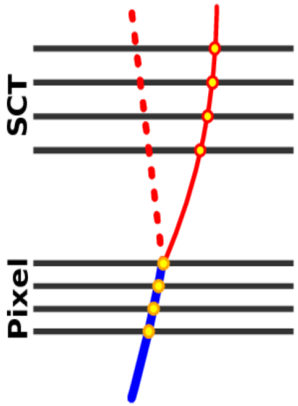
- Standard Tracks Reconstruction >= 7 silicon hits
- Pixel tracklets reconstruction:
  only hits not associated with standard tracks
  - ≥ 4 pixel hits, zero holes
  - Veto hits on SCT



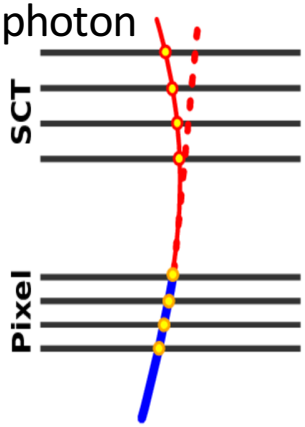
- Inclusion of IBL significantly improves sensitivity to short $\chi^{\pm}$ lifetimes
- Large increase in efficiency at decay radius < 300 mm

Background:
Main backgrounds from ttbar, W+jets with W→e/τ ν, where e/τ can fake tracklets

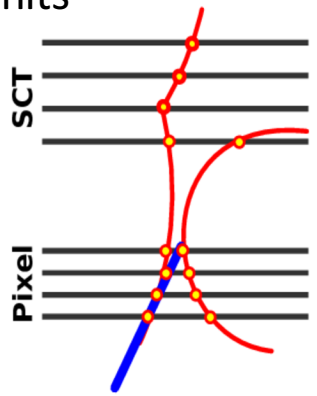
Hadron with hard scattering



Lepton emitting hard photon



Random combination of hits

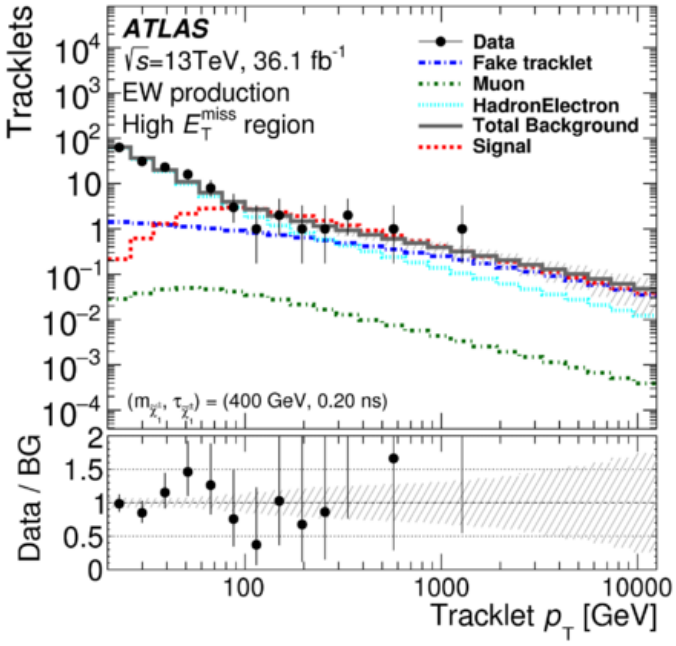


Disappearing Tracks: Results

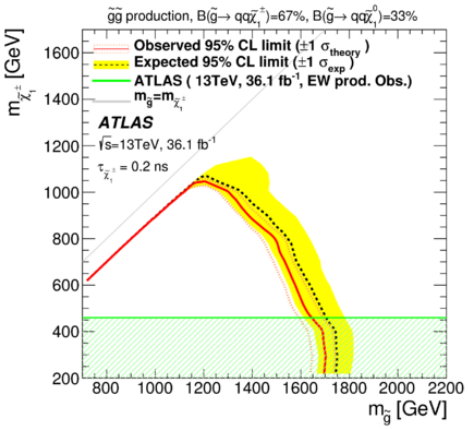
- Look for an excess of candidate events in the p_T distribution of pixel tracklets
- Templates for background components are estimated from data.

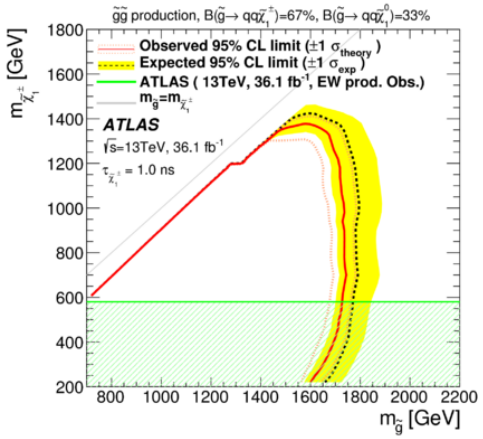
No excess found

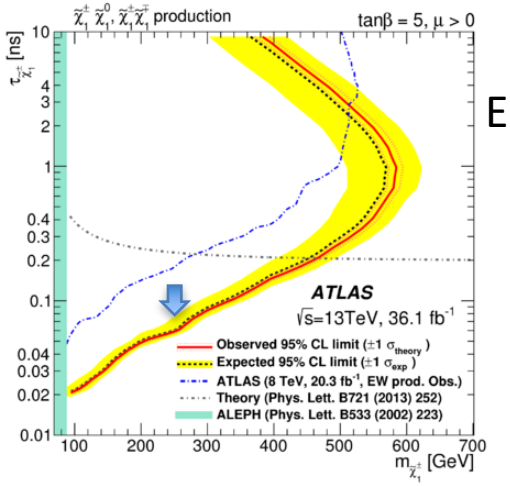
limits set for both strong and electroweak production



Strong production





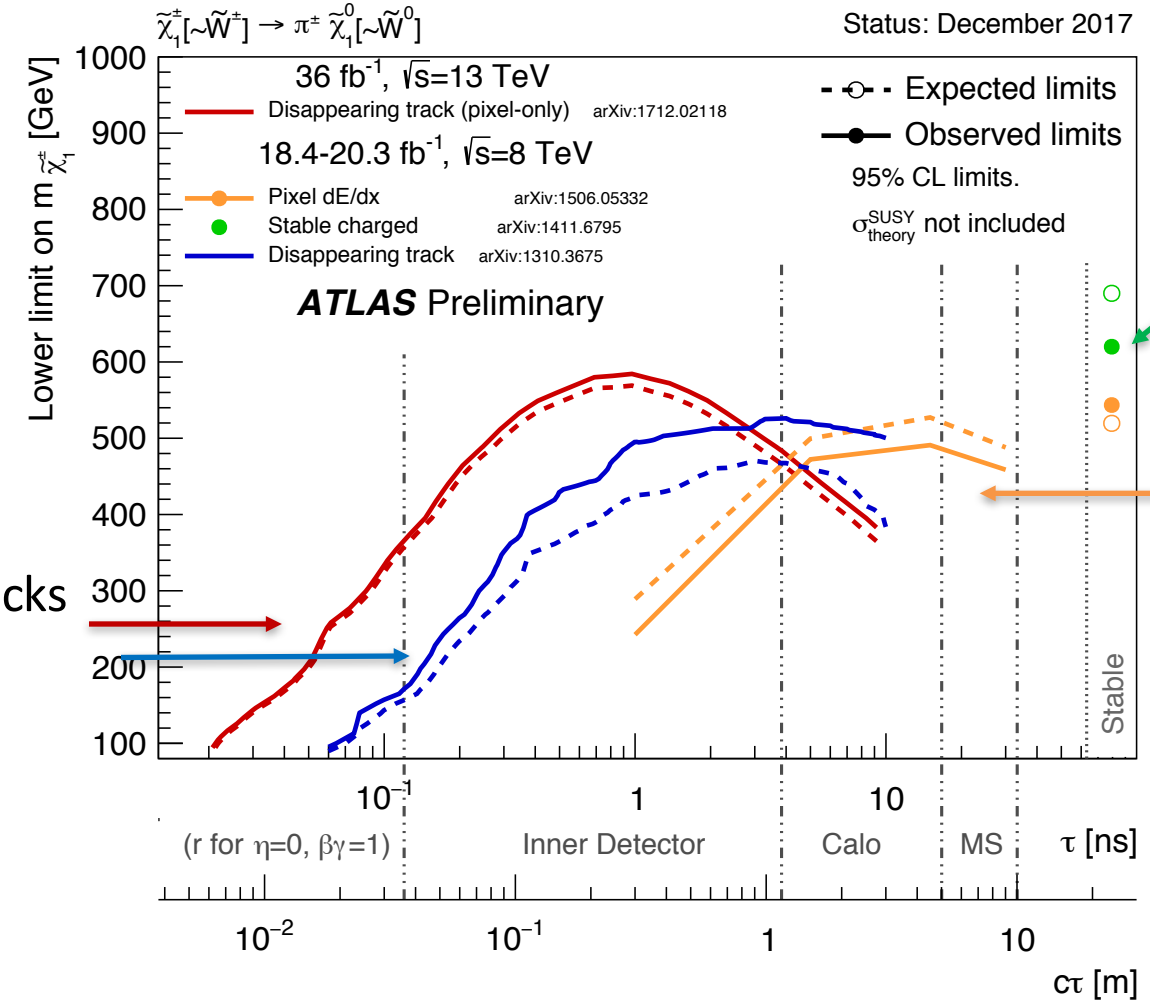


EWK

Extended limits to lower lifetimes

Summary Results for chargino LLP

Constraints on the chargino mass-vs-lifetime plane for an Anomaly Mediated Susy breaking model with tan(β)=5 and μ>0



pixel dE/dx & HCAL timing

pixel dE/dx

disappearing tracks in the ID at 13 an 8 TeV

Displaced Vertex

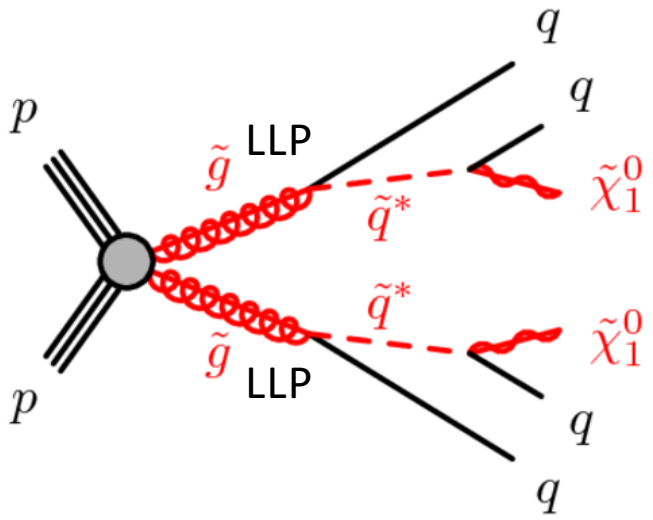
Motivation:

- Many BSM predicts LLPs with τ of 10^{-12} -10^{-9} s
- LLPs can decay in the ID away from the PV
  →displaced vertex

Signature:

- Neutral or charged LLP decaying in the Inner Detector (ID) leading to high-mass, multi-track displaced vertex

→*displaced vertex in the ID +*
Missing Transverse Energy (MET) from χ^0



Benchmark model:

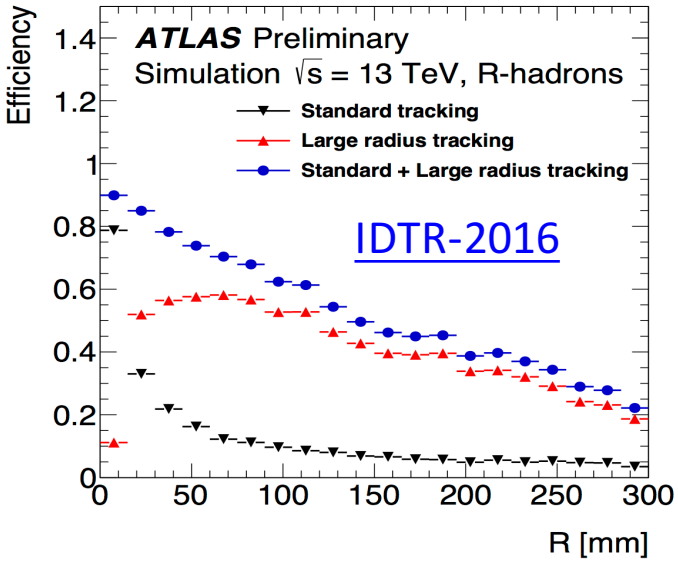
- simplified model inspired by Split SUSY
- $\tilde{g}$ kinematically accessible, $\tilde{q}$ not.
- $\tau\,\tilde{g}$ > 10 ps > hadronization scale
  →$\tilde{g}$ form a bound state *"R-hadron"* which is the LLP

Basic Selection:

- Trigger on MET
- Ntrk ≥ 5
- m_{DV}>10 GeV

CERN-EP-2017-202

Displaced Vertex: Reconstruction challenges

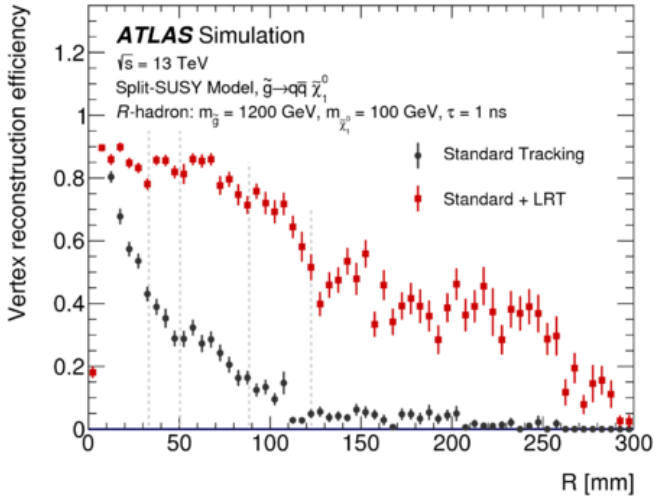


Standard ATLAS algorithms for tracking and vertexing have low efficiency for displaced vertices

Standard Tracking:

- tight requirements in number of silicon hits and impact parameter

  → not good for tracks form a displaced vertex



Large-Radius tracking (LRT)

- Relax requirements in number of silicon hits and impact parameter
- Re-run only with hits not associated with existing standard tracks

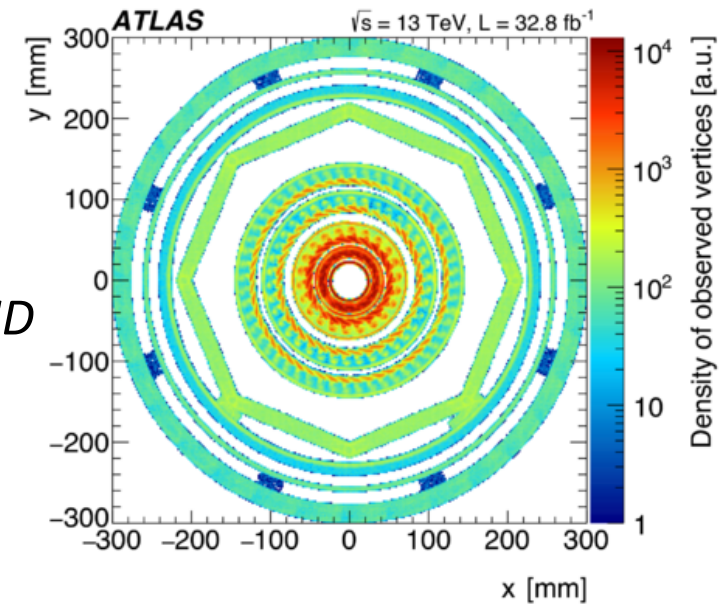
Secondary vertex

- Using standard tracks and LRT tracks
- form multi-track DVs
- increase the signal vertex reconstruction efficiency
- Analysis sensitive to decay length up to 300 mm

Displaced Vertex: Result

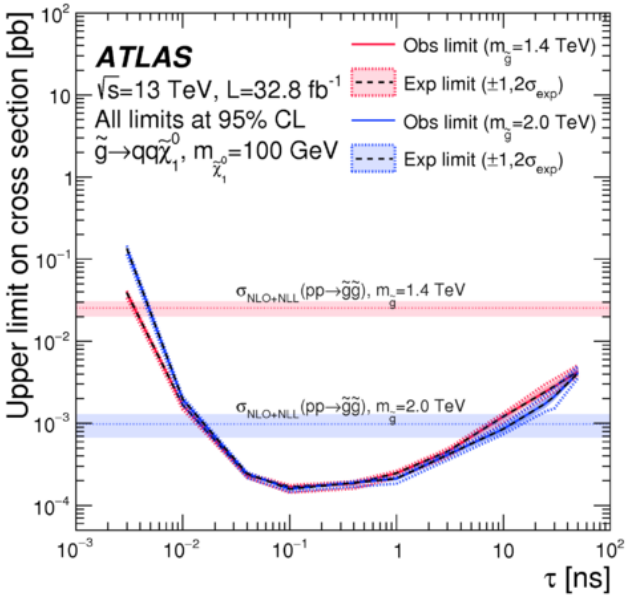
Backgrounds

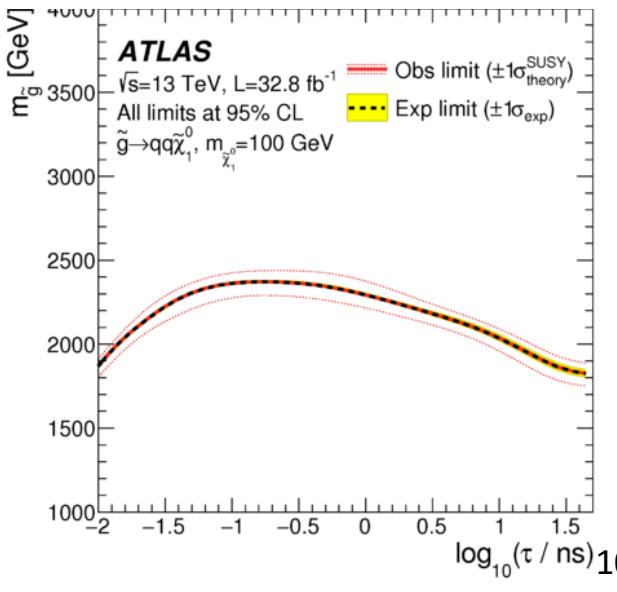
- SM negligible
- Other low background:
  - hadronic interactions
    veto vertices in dense material region of the ID
  - random track crossing
  - merged vertices
- uses data-driven methods



no excess is seen

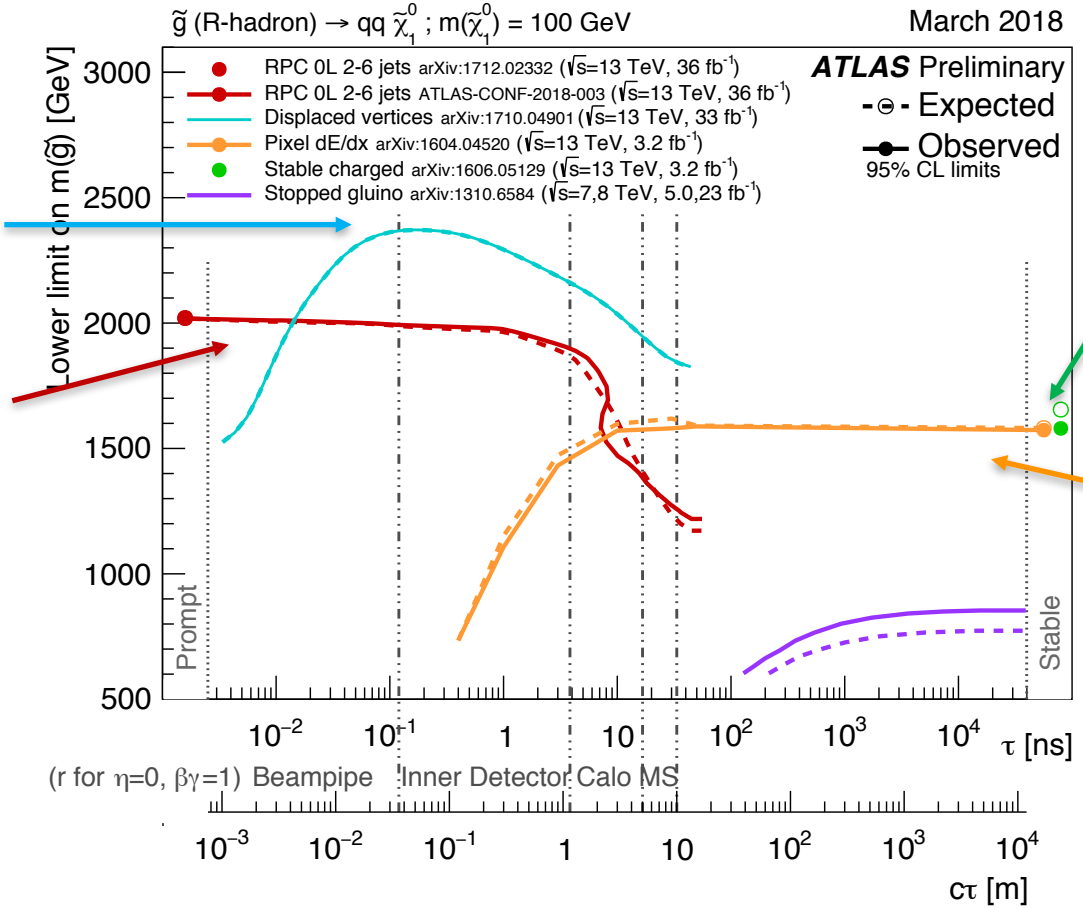
→limits set as function of neutralino τ, and in τ – gluino mass plane





Summary plot for R-hadrons LLPs

Constraints on the gluino mass-vs-lifetime plane for a split-supersymmetry model with the gluino R-hadron decaying into a gluon or light quarks and a neutralino with mass of 100 GeV.



DV+MET

reinterpreted prompt search

pixel dE/dx & HCAL timing

pixel dE/dx

stopped

(Meta)stable heavy charged particles

Motivation: Many BSMs predict massive *charged* LLP "R Hadrons" → *Low* β

Signature: High dE/dx in the Pixel system

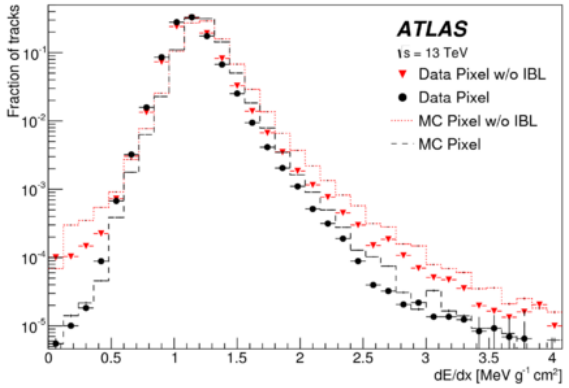
- Significant improvement due to additional Pixel layer IBL installed for Run2
- Mass from dE/dx and p

Benchmark: Gluino R-hadron, stable or meta-stable with $\tau \sim O(1\text{-}10)$ ns decay to $q\bar{q}\chi^0$

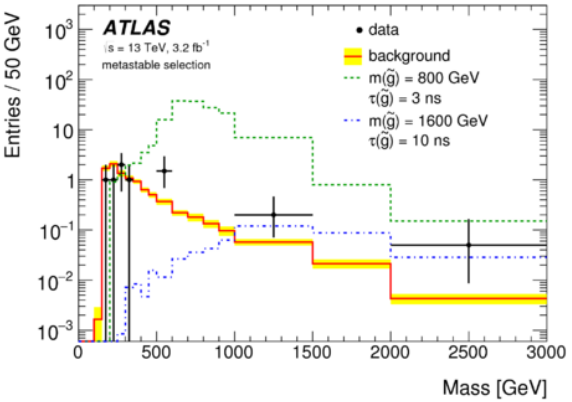
Background:

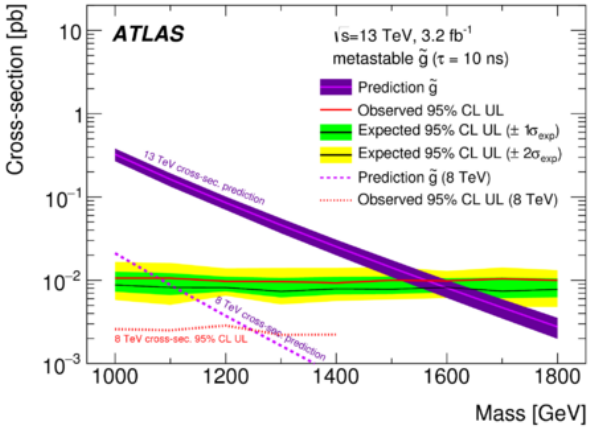
- Jets and leptons with high ionization
- Overlapping tracks

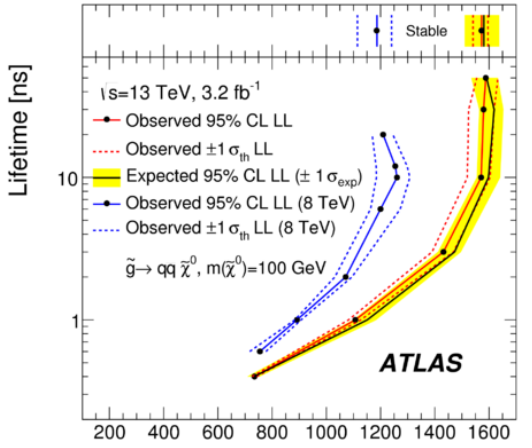
No excess found in mass distribution



Phys.Rev.D 93, 112015 (2016)



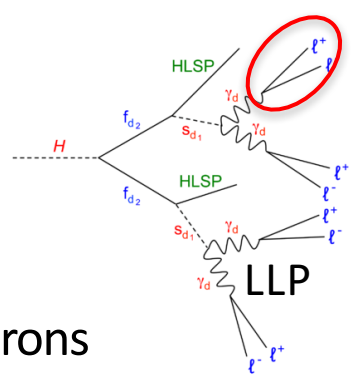


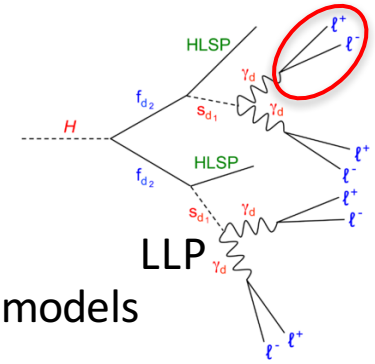


Neutral LLP decay in Displaced lepton jets

Motivation:

- Many BSM predicts a dark sector weakly coupled with the SM
  - Dark photons γ_d mixed with SM γ
- Long lived low mass γ_d decays in collimated pairs of leptons and/or light hadrons

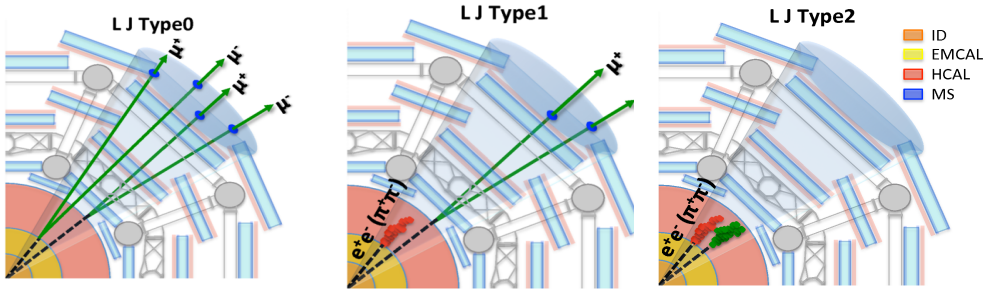




FRVZ models

Signature: *displaced* lepton jets (LJ) of leptons and/or light hadrons

Dedicated HLT narrow scan muon trigger

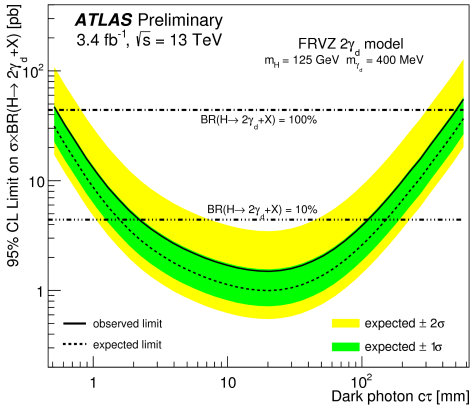


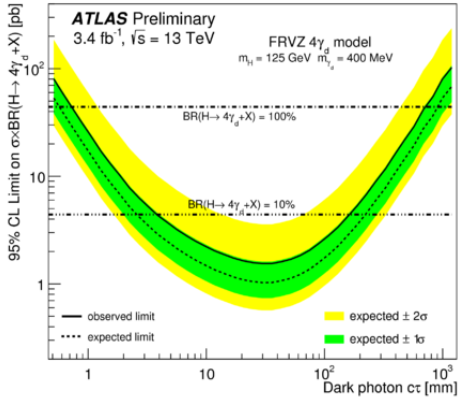
ATLAS-CONF-2016-042

Background: cosmic muons, QCD, non collision background

No excess found:

→ limits on γ_d life time for FRVZ benchmark mode

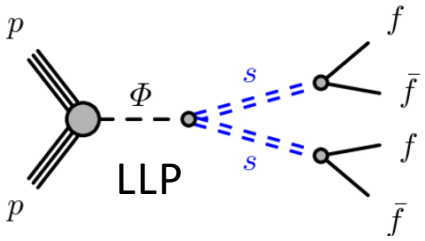




Neutral LLP decay in Hadronic Calorimeter

Motivation

Many BSMs predicts a dark sector weakly coupled with the SM through a heavy neutral boson Φ

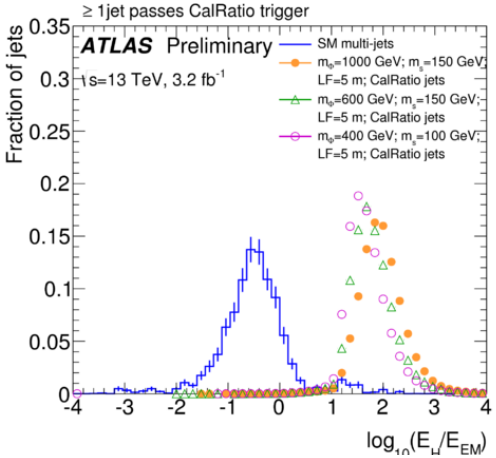


Benchmark Model

- $\Phi \rightarrow$ ss, s = long lived scalar
- s $\rightarrow$ ff, f is a SM quarks hadronizing in jet

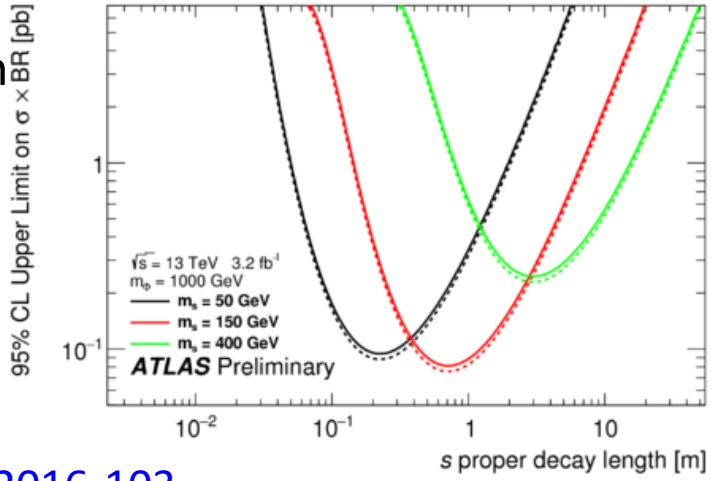
Signature:

- Only decays of the LLPs within the hadronic calorimeter
- two jets with unusual properties:
  high Ehad/Ecal, no tracks associated, small width



Dedicated cal-ratio trigger based on Ehad/Ecal

Background: Non-collision bkgd, QCD multijet



No excess found

ATLAS-CONF-2016-103

Conclusions

- Unconventional signatures are gaining in popularity due to missing New Physics in standard analysis, based on search on prompt particles

- ATLAS has a complete program to search for unconventional signature
  - Need ad hoc and challenging reconstruction and triggers
  - Many analysis working on improvements with the full 13 TeV dataset

- No discovery so far
  - but larger dataset in the next years will improve sensitivity to New Physics

Backup