THE UNIVERSITY of EDINBURGH
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A search for displaced τ production at the ATLAS experiment

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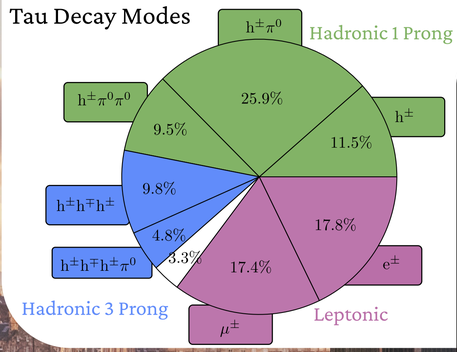
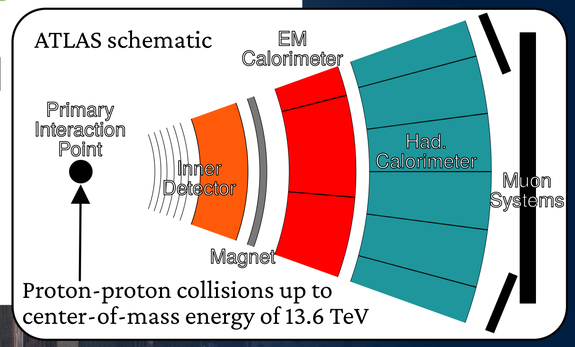
1 Taus at the ATLAS detector

- Large mass of 1.7 GeV and short mean lifetime of 2.9×10^{-13} seconds → decays within the ATLAS detector
- Measured by detecting the τ decay products in the various ATLAS subsystems
  - Inner Detecter (tracking), EM Calorimeter (electrons), Hadronic Calorimeter (Hadrons), Muon systems (muons)

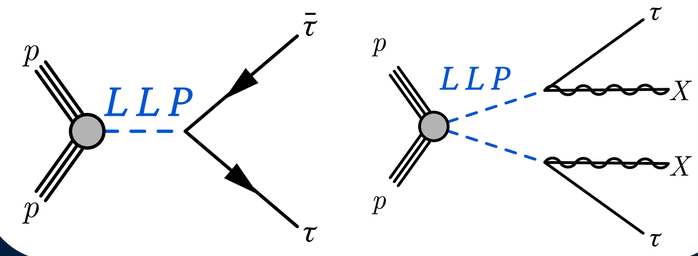




2 Displaced Taus

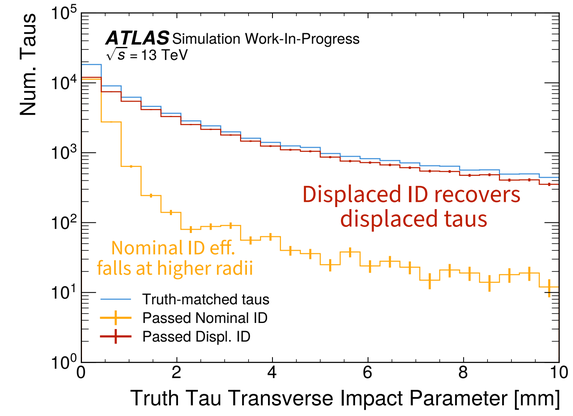
A displaced τ is a SM tau that is produced at a displaced vertex, away from the primary p-p interaction point.

- Could be produced by the decay of new ***long-lived particles (LLP)***
  - SUSY, Heavy Neutral Leptons, Hidden Valley Models or something new entirely!
- ATLAS could be sensitive to this signature with a ***dedicated identification algorithm*** and ***Large Radius Tracking***.



3 Displaced τ Identification

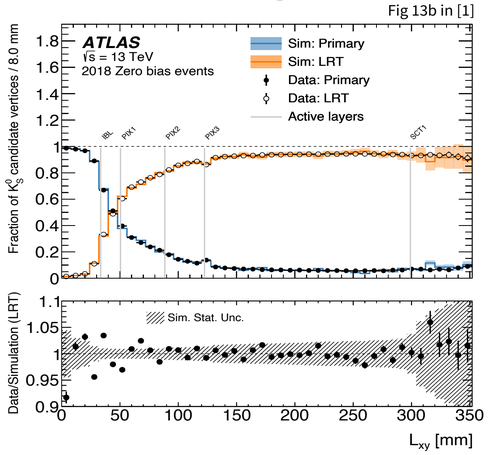
- Difficult to distinguish hadronically decaying displaced τ's from ***gluon- and quark-initiated jets***
- ATLAS's nominal τ identification (***tau ID***) algorithm was retrained on simulated displaced taus
- ***My Work***: Currently upgrading for Run 3

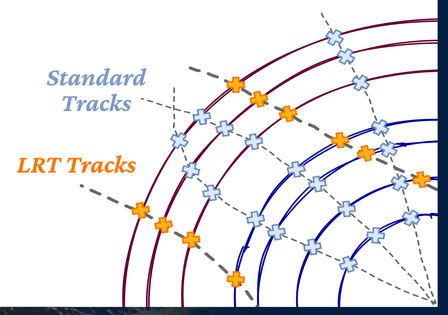


4 Large Radius Tracking

- ***Primary Tracking*** in the ATLAS Inner Detector
  - Tracks are reconstructed from hits in the ***Inner Detector***
  - Displacement of track is determined by longitudinal (z_0) and transverse (d_0) impact parameters
  - Performs poorly for highly displaced tracks
- ***Large Radius Tracking (LRT)*** [1]
  - Unassigned detector hits used to reconstruct tracks with high impact parameters
  - LRT tracks can have a $z_0 > 500$ mm and $d_0 > 300$ mm
  - Allows for searches for ***LLPs*** that decay within the ATLAS inner detector
    - Can be used in displaced τ reconstruction

Fig 13b in [1]





5 Analysis Overview

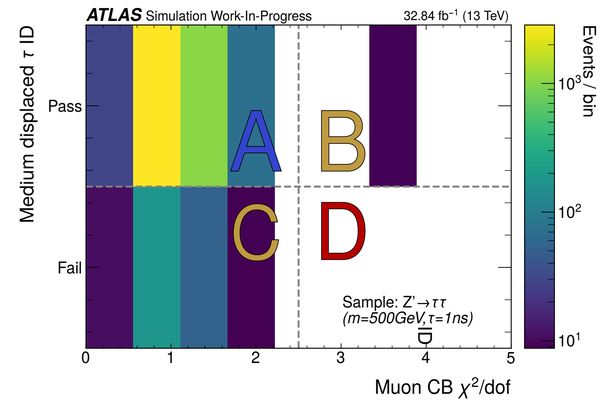
Analysis Aim: Model independent search for long-lived particles decaying to 2 τ's

- Run 2 Analysis with Run 3 planned in future
- Relevant final states:
  - ***[had-had]*** 2 displaced τ_{had}
  - ***[e-had]*** 1 displaced e + 1 displaced τ_{had}
  - ***[mu-had]*** 1 displaced μ + 1 displaced τ_{had}
- Simulated samples for benchmarking
  - ***Simplified Long-Lived Z'→ di-τ model***
  - Gauge-Mediated SUSY Stau Stau production
- Main background contributions from QCD jets
  - ***Data-driven*** bkg estimation methods
    - e-had and mu-had → ***ABCD method***

ABCD Method

- Define ABCD plane using 2 ***uncorrelated*** selections
- Isolate signal in the A region
- Estimate background in A

$$N_A^{\text{bkg}} = \frac{N_C}{N_D} \times N_B$$



Next Steps

Finalising background estimation

Upgrading displaced tau ID to a Graph Neural Network

[1] ATLAS Collaboration (2023) 'Performance of the reconstruction of large impact parameter tracks in the inner detector of ATLAS', The European Physical Journal C, 83(11), p. 1081.

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