The design and performance of the ATLAS Inner Detector

Trigger in high pileup collisions at 13 TeV at the Large Hadron Collider

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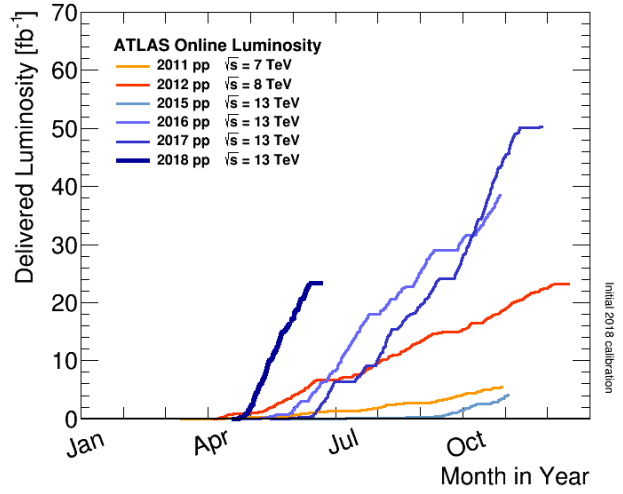
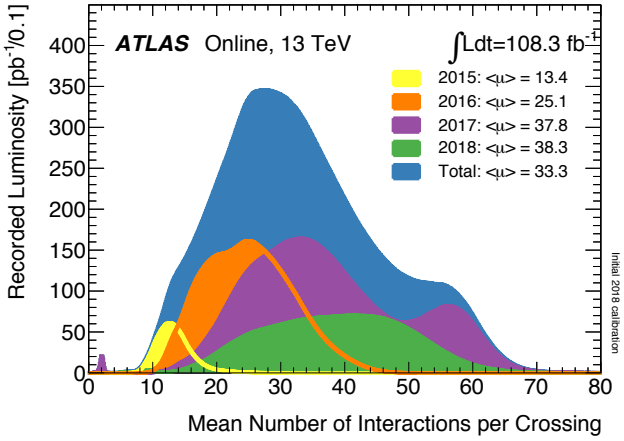
on behalf of the ATLAS Collaboration

Science & Technology Facilities Council

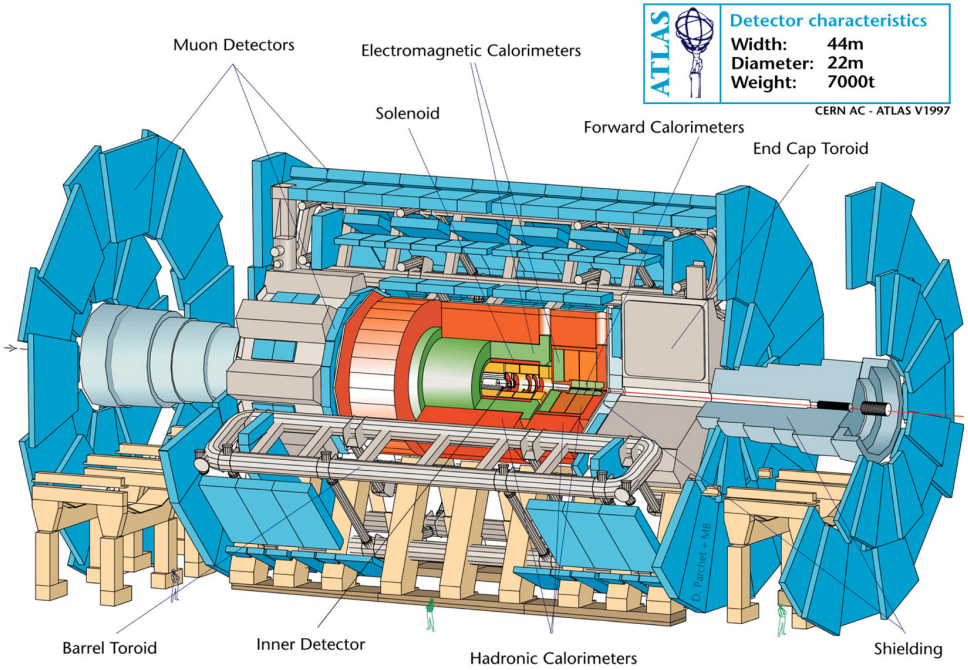
LHC & ATLAS

Increasing luminosity and pile-up





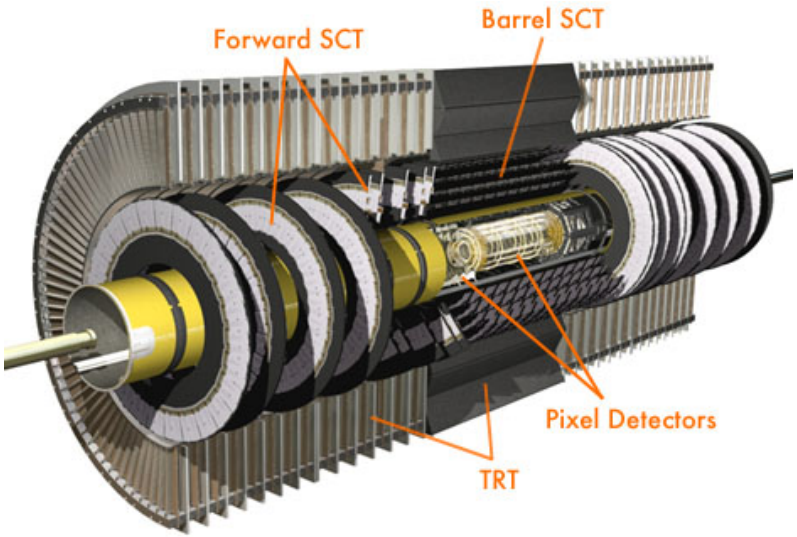
Multi-purpose LHC detector

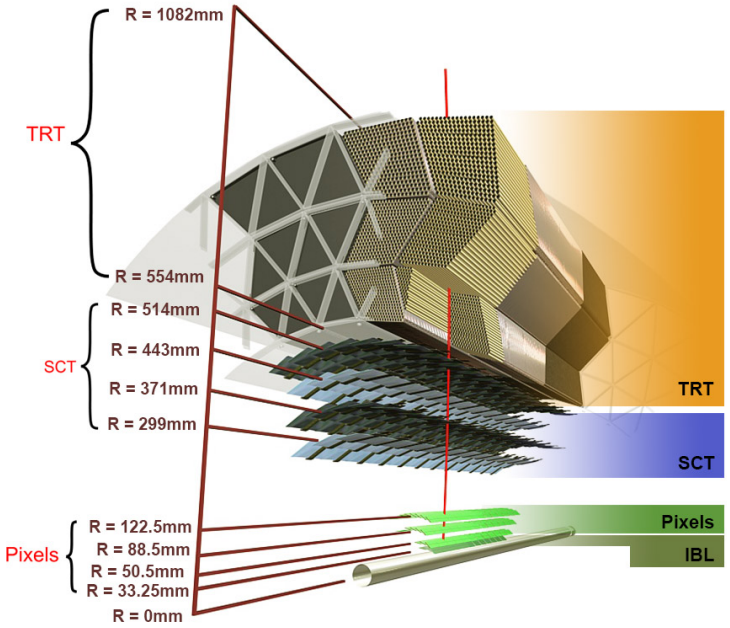


https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun2

ATLAS Inner Detector(ID)

- For track and vertex reconstruction
- 3 subsystems:
  - Pixels - 4 layers (inner layer added for Run 2, barrel only)
  - SemiConducting Tracker (SCT) –
    - 4 barrel and 9 endcap layers of silicon microstrip detectors
  - Transition Radiation Tracker
    - Gaseous straw tubes (average 36 hits per track)

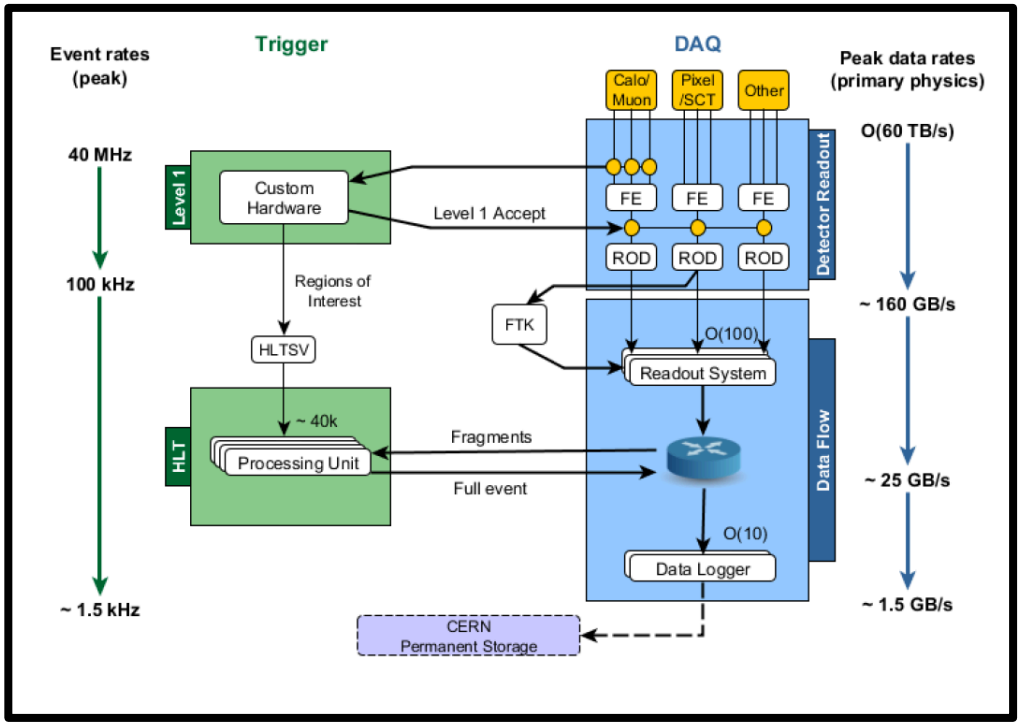




ATLAS Trigger System

- Two level system:
  - Level1 : hardware
    - 2.5µs, reduce rate to ~100 kHz
  - HLT : software based
    - ~200ms, reduce rate to ~ 1.5 kHz
- Region of Interest (RoI) based
- ID Trigger
  - Part of HLT
  - Fast online track and vertex finding
  - Essential for nearly all physics triggers
    - Online physics-object reconstruction with sufficient resolution to control rates.
  - CPU intensive, need to keep timing under control
- FTK
  - New hardware based tracking
  - Currently being commissioned

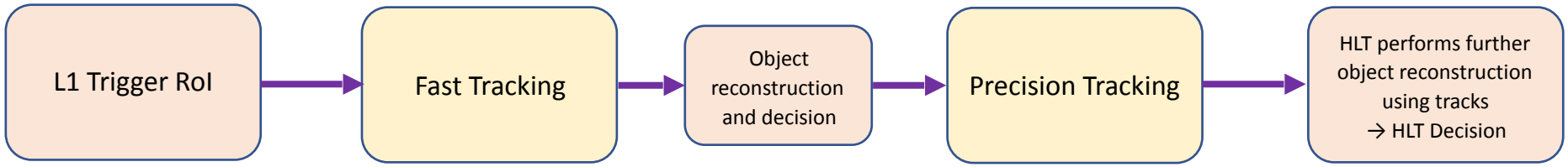
ATLAS Online System



See talk of Alex Martyniuk (Wednesday 11.45am, Track 1)
"The ATLAS Trigger in 2017 - improvements, performance and challenges"

Tracking Algorithms

Typical trigger “chain”

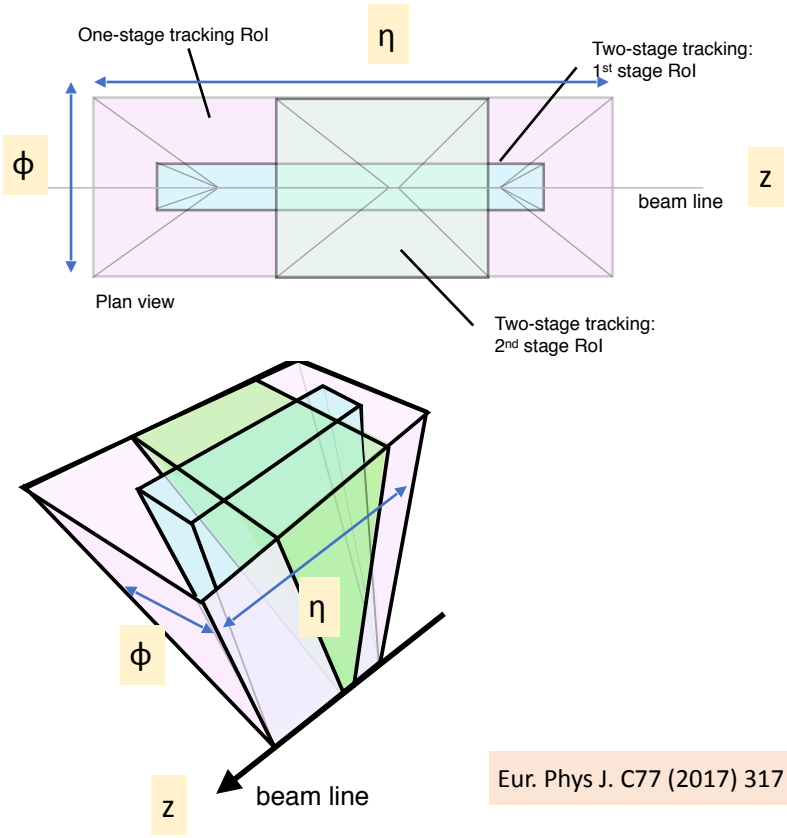


Tracking split into 2 parts – ensure speed while maintaining performance:

- Use Level-1 Regions of Interest (RoI) to restrict volume of detector for reconstruction
- Fast Tracking :
  - Fast custom pattern recognition plus initial Kalman filter track fit
- Precision Tracking :
  - Process tracks from first-stage, improve quality and apply tighter requirements

- For LHC Run 2 introduced “Multi-stage tracking” :
  - Multiple fast tracking stages: run in reduced volume RoI to improve RoI position before re-running in larger RoI.

Multi-stage tracking : 2-stage tracking



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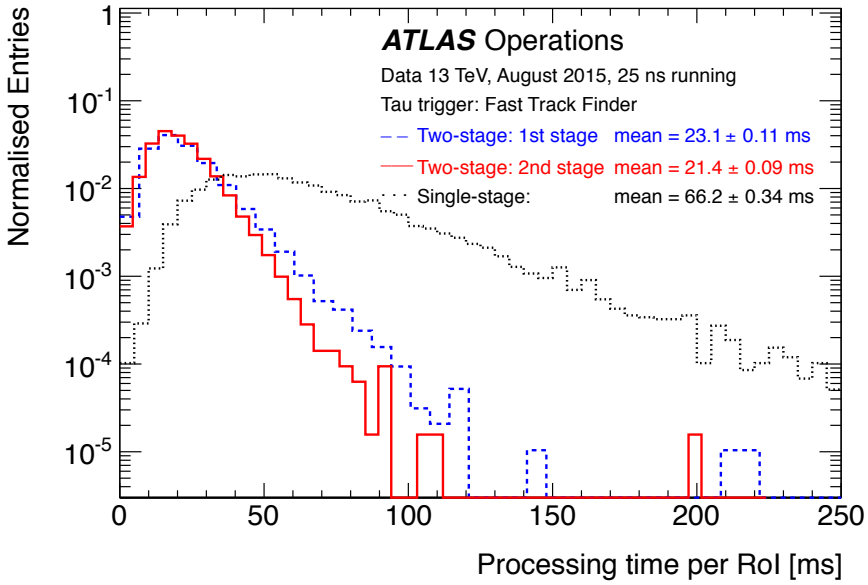
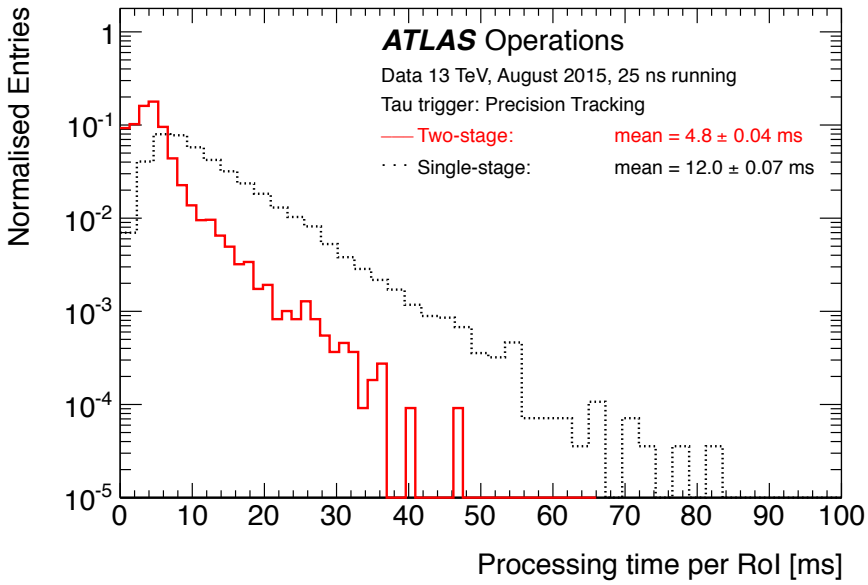
- 2-stage tracking used for jet and tau triggers
- Run 1 : Single stage RoI – large RoI (0.4x0.4)
- Run 2 : 2-stage tracking:
- Stage 1
  - Fast Tracking RoI with large range in z (|z|<225mm) but narrow in η and ϕ (0.1x0.1)
  - Determine track and vertex of interest
- Stage 2
  - Seed new RoI with narrow range in z (|z|<10mm) but wider in η and ϕ (0.4x0.4)
  - Fast Tracking and Precision Tracking run in second RoI

Multi-stage tracking : performance

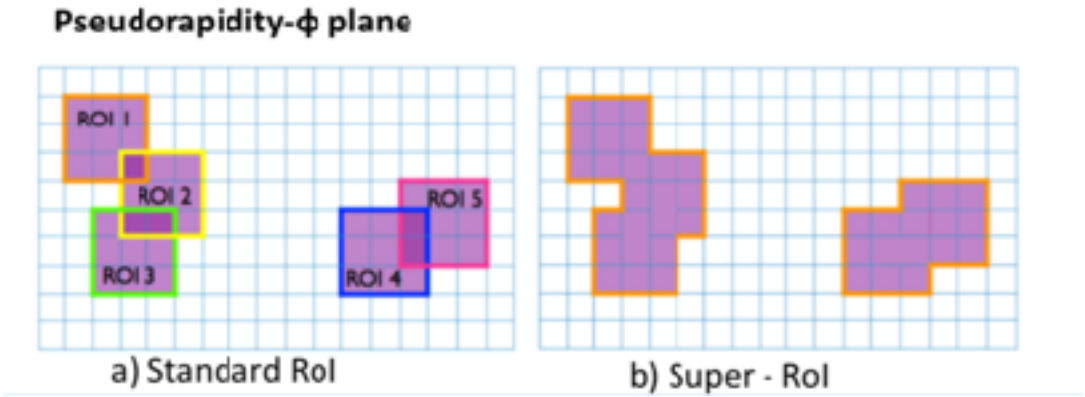
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HLTTrackingPublicResults





Multi-stage tracking : Super-RoI

- Avoid processing “overlap” areas twice by creating “Super-RoI”
- Super-RoI contains RoIs about each jet, large range along beamline but narrow width in η and ϕ
- Avoids reconstructing tracks multiple times in overlapping regions

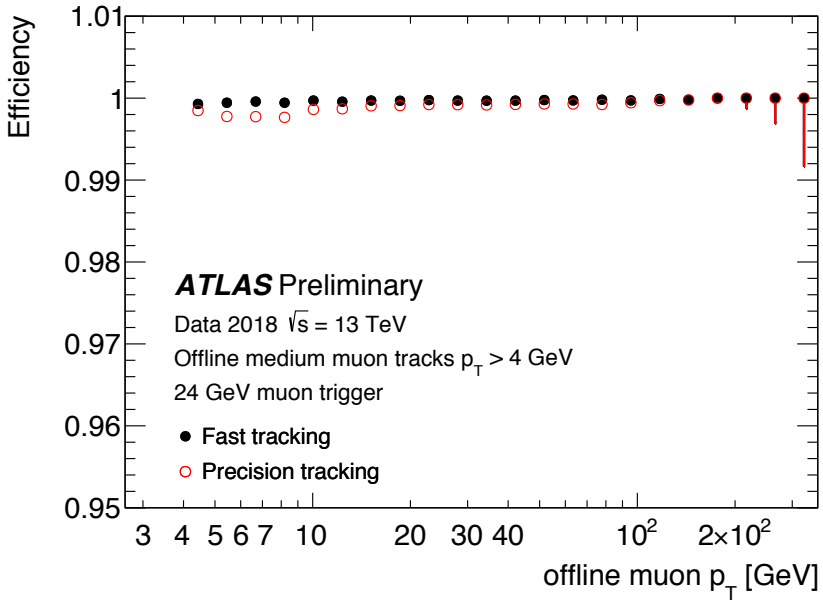


Used in bjet triggers:

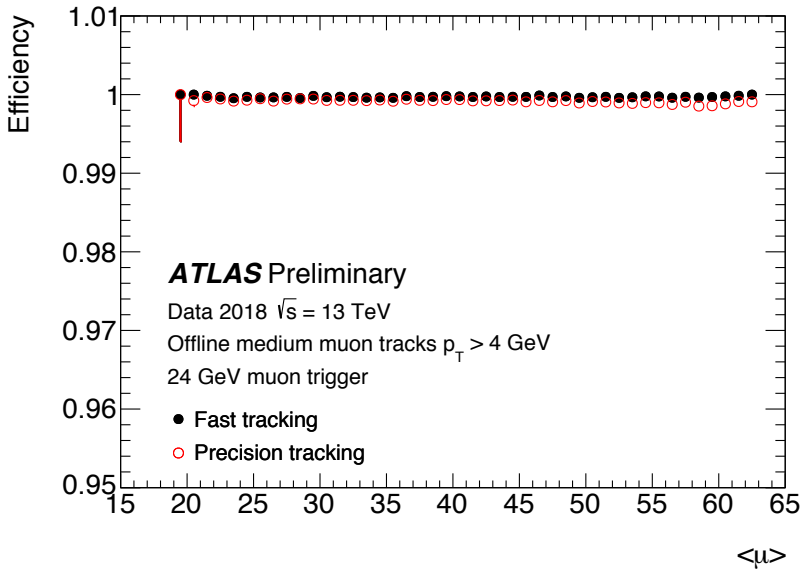
Find jets and combine to form SuperRoI → Fast Tracking in SuperRoI → Use tracks to find primary vertex → Define new Jet RoIs around L1 Jets, using primary vertex → Fast Tracking in new RoIs → Precision Tracking and secondary vertex finding

Performance : muon trigger

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HLTTrackingPublicResults



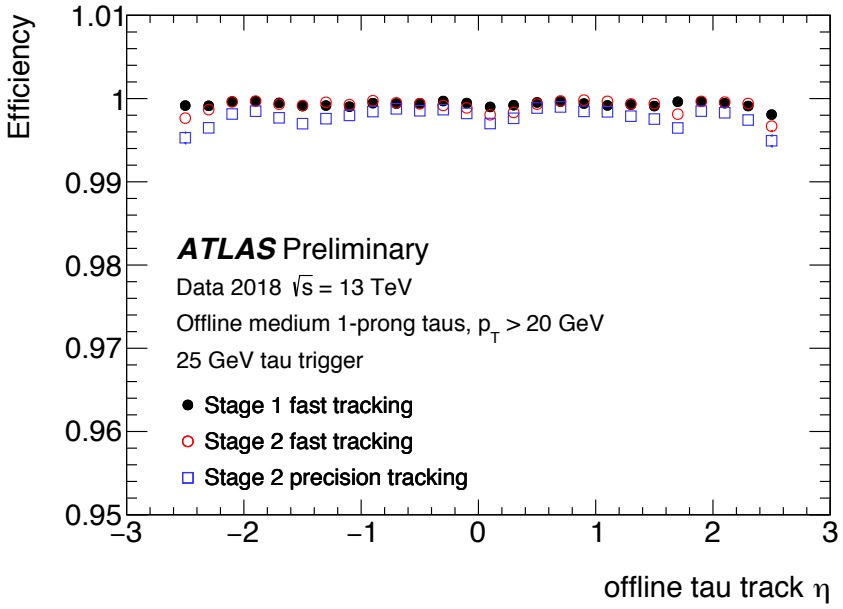
High efficiency >99%

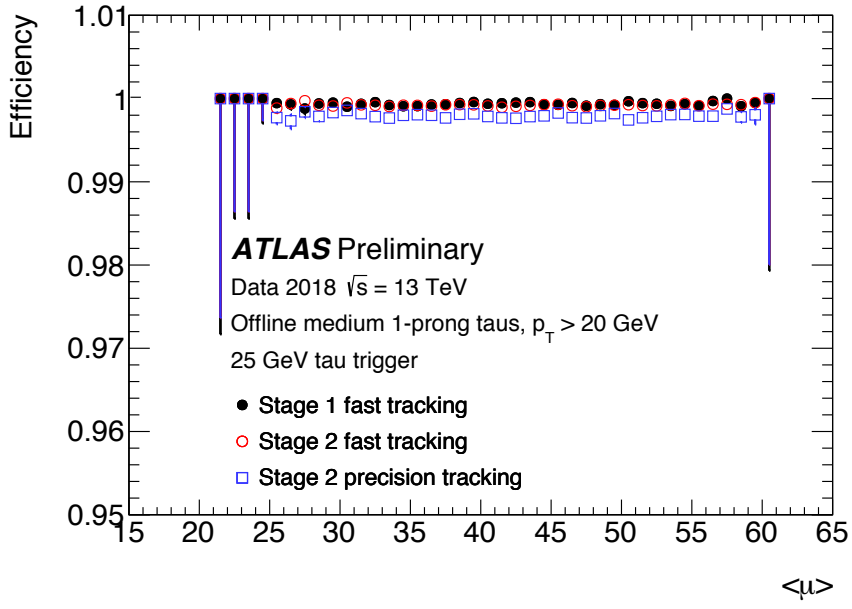


Efficiency stable even with high pile-up

Performance : tau trigger

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HLTTrackingPublicResults

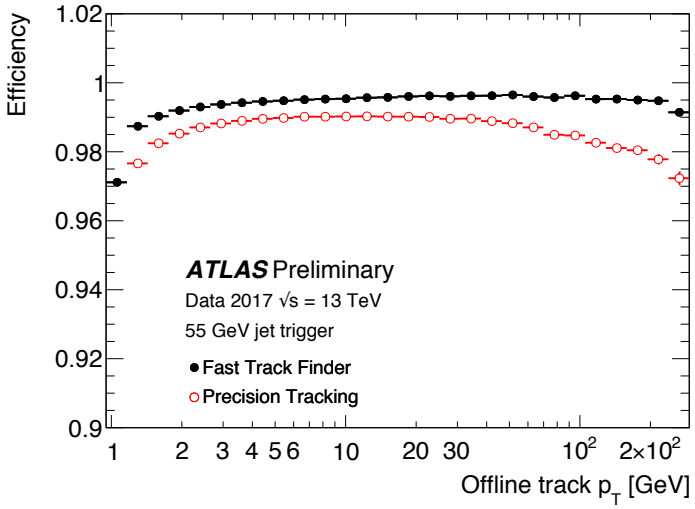


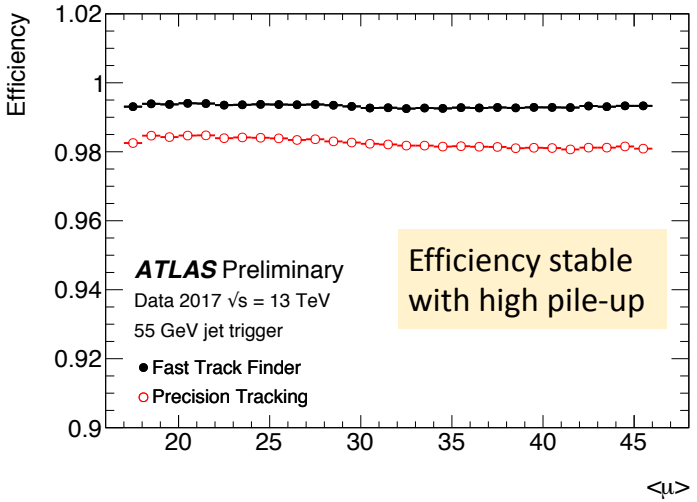


Efficiency stable even with high pile-up

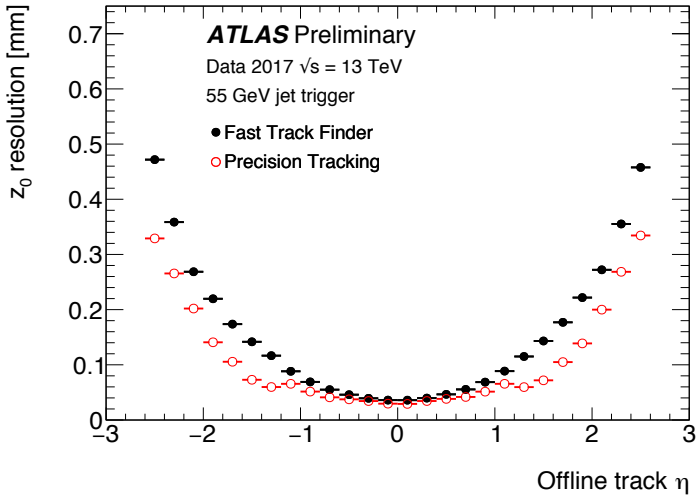
Performance : Bjet trigger

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HLTTrackingPublicResults

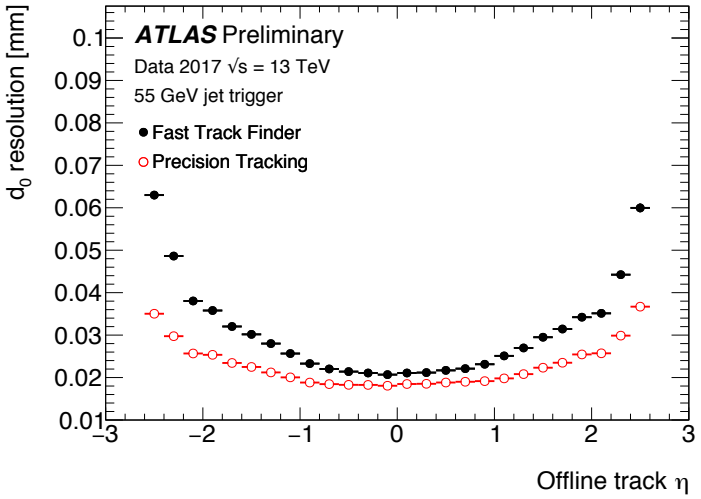




Efficiency stable with high pile-up



Good z0 and d0 resolutions



z0 - longitudinal impact parameter
d0 - transverse impact parameter

Summary

- Inner Detector trigger is essential for the operation of the ATLAS Trigger
- Upgraded to cope with increased luminosity and pileup in Run 2
  - Two stage reconstruction (Fast Tracking followed by Precision Tracking)
  - Multi-stage RoI methods
- Excellent tracking performance seen in 2017 and 2018 data
- Tracking performance insensitive to increased pileup seen in Run 2
- ID Trigger continues to provide the excellent performance needed to record important physics signatures within available time constraints

Backup

Performance : muon trigger