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FACULTE DES SCIENCES AIN CHOCK
UNIVERSITE HASSAN II DE CASABLANCA

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ATLAS EXPERIMENT

The ATLAS Inner Detector trigger design and performance during Run 2 data taking from the 13 TeV LHC collisions

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The ATLAS Inner Detector (ID)

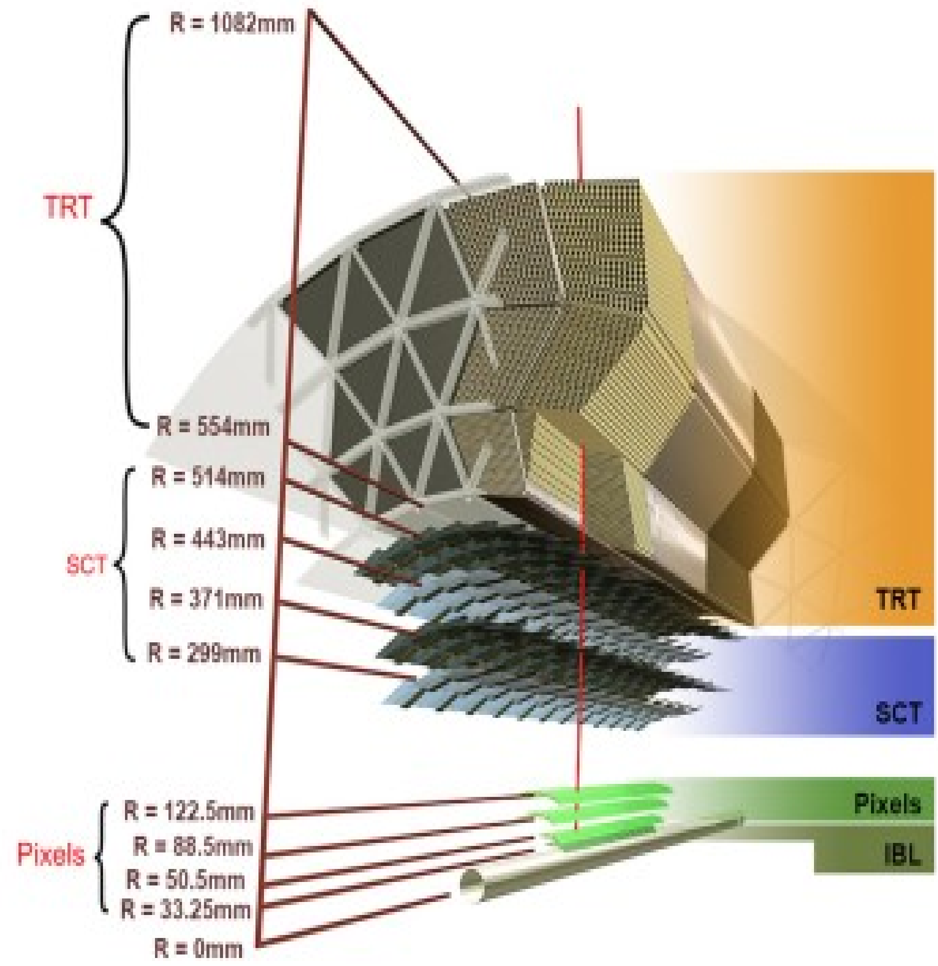
- **The ID is the ATLAS sub-detector dedicated to track and vertex reconstruction, It consists of 3 sub-systems:**
- **Pixel Detector – closest to the beamline and the Interaction Point (IP) :**

  → 3 layers of barrel and endcap silicon pixel modules

  → Insertable B layer (IBL) – 1 Barrel layer added for LHC Run 2
- **Semiconducting Tracker (SCT) :**

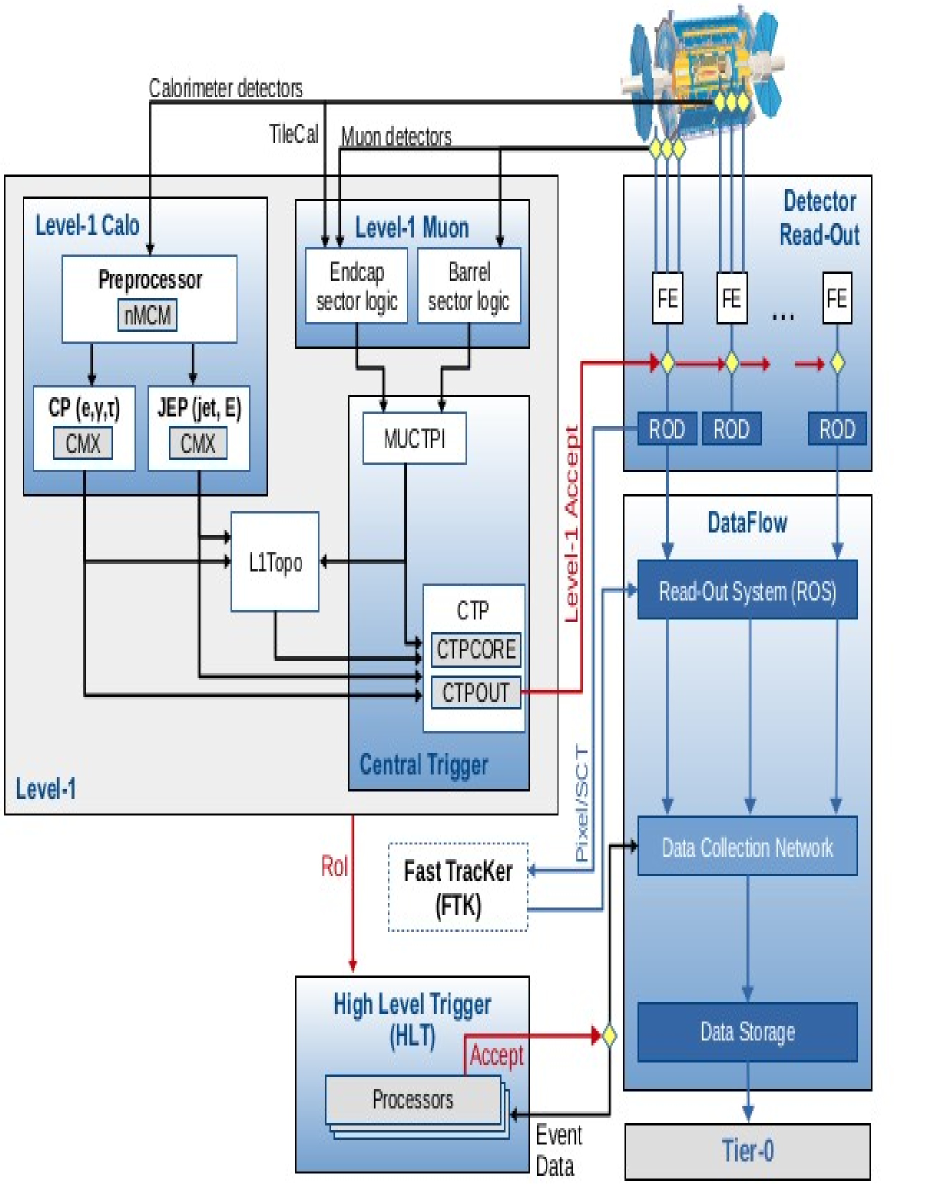
  → 4 barrel and 9 endcap layers of silicon microstrip modules
- **Transition Radiation Tracker (TRT) :**

  → Barrel and endcap modules of thin-walled drift tubes



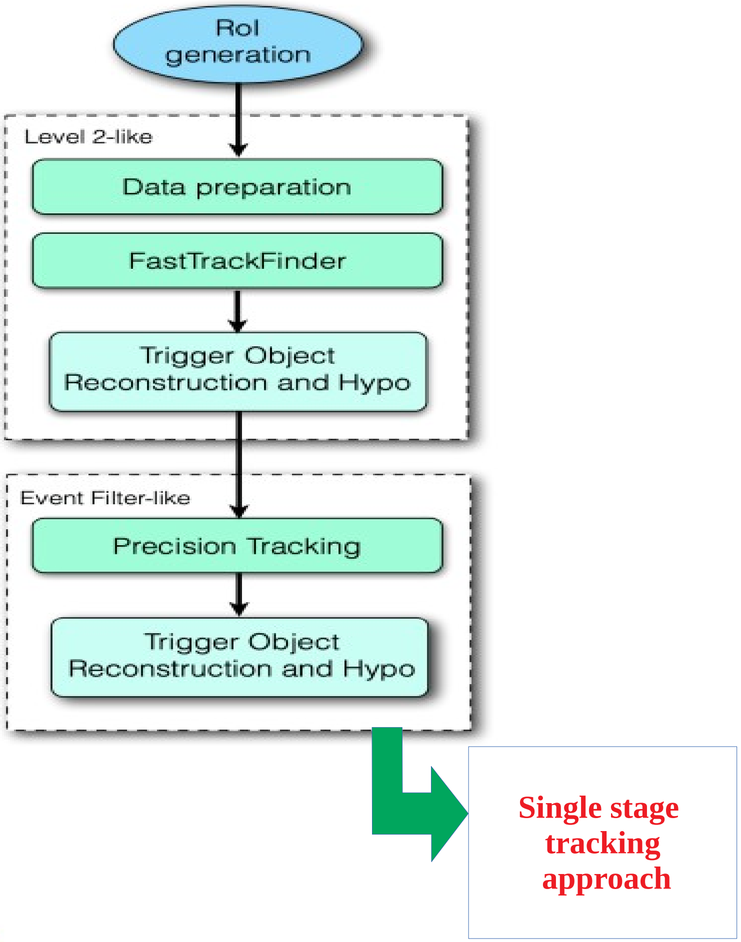
The ATLAS Trigger system design – Run 2

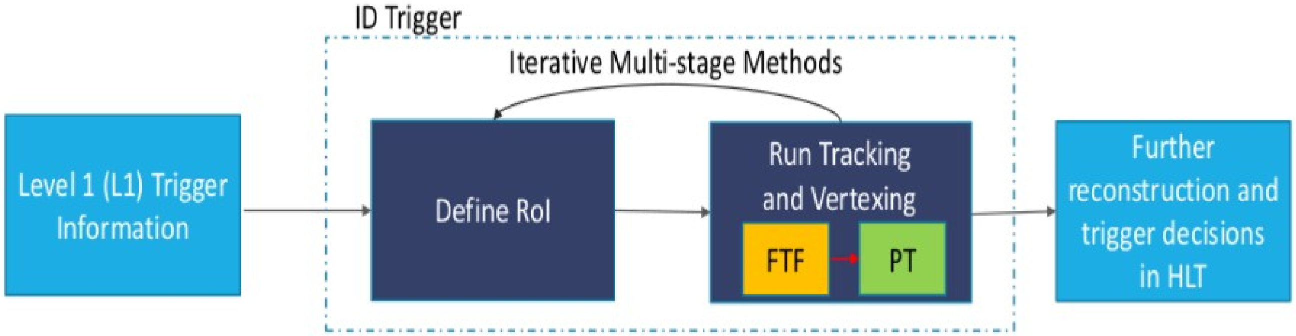
- **The ATLAS Trigger system – Run 2 consists of:**
- **Level-1 (L1):** hardware-based pipelined trigger using coarse granularity data from the calorimeter, and muon spectrometer to identify Regions of Interest (RoIs) → reduction to only 2-6% of the data volume to be processed by the HLT for each event
- **High Level Trigger (HLT):** software based; each L1 RoI used to seed full granularity reconstruction → first place ID information is available
- For Run 2, the previous two run 1 software stages (L2 and EF) were merged into a single High Level Trigger (HLT) stage → Dataflow simplification, no need to request data twice, common storage and data preparation



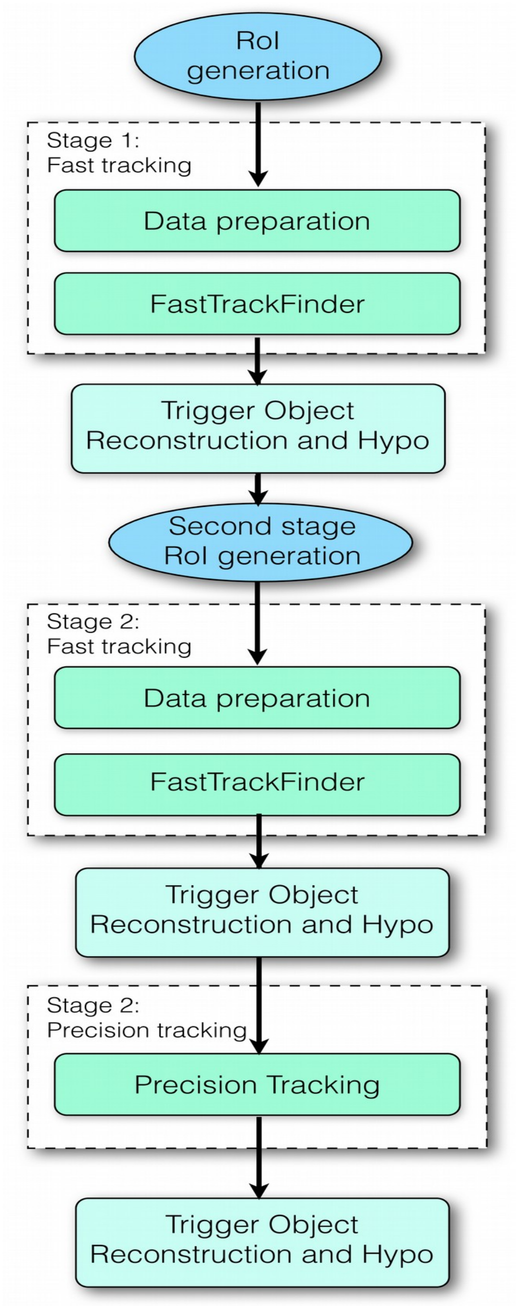
The ATLAS ID Trigger design – Run 2

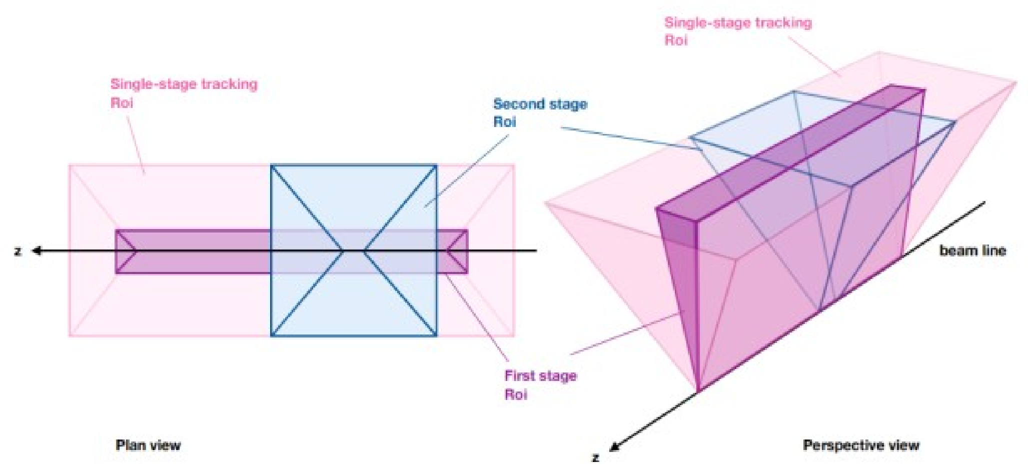
- The ID Trigger : is part of HLT system. It processes information from the ID to reconstruct tracks and vertices → customised for each physics signature – electron, muon, tau and b-jet candidates
- Various methods are used to ensure speed while keeping good performance
- Spatial Regions of Interest (RoIs) allow tracking and vertexing in reduced volumes
- Tracking is split into:
  - FastTrackFinder (FTF) algorithm that produces fast but low quality track
  - Precision Tracking (PT) algorithm which processes tracks and clusters from the first stage, and improves their quality while applying tighter requirements
- The single stage tracking approach as used in Run 1 is the baseline strategy
- Added for LHC Run 2, Multi-stage RoI methods define multiple RoIs in sequence to allow for reduced RoI volumes, tailored for different stages of tracking and vertexing





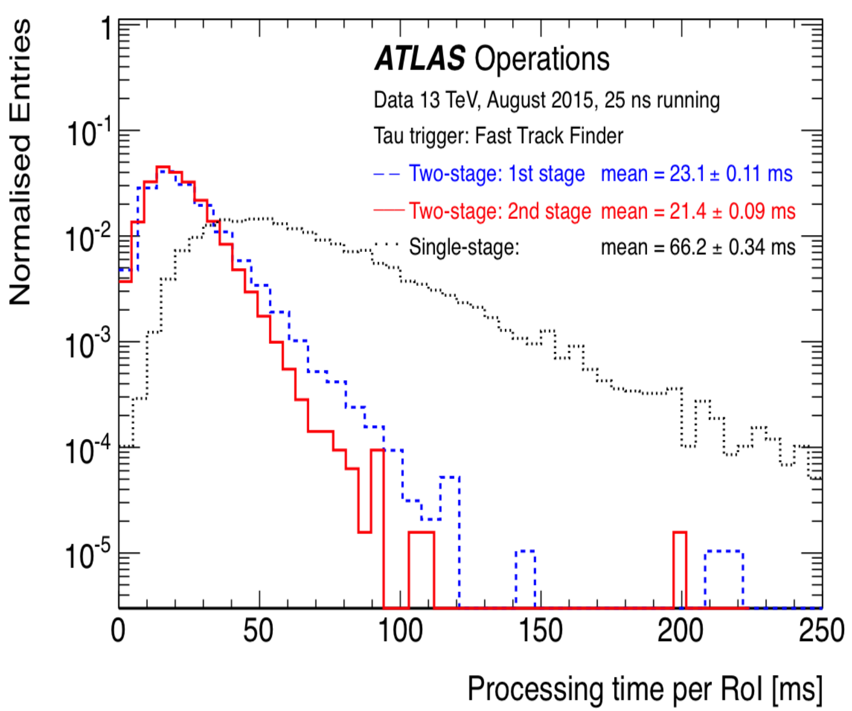
The ATLAS ID Trigger design – Run 2

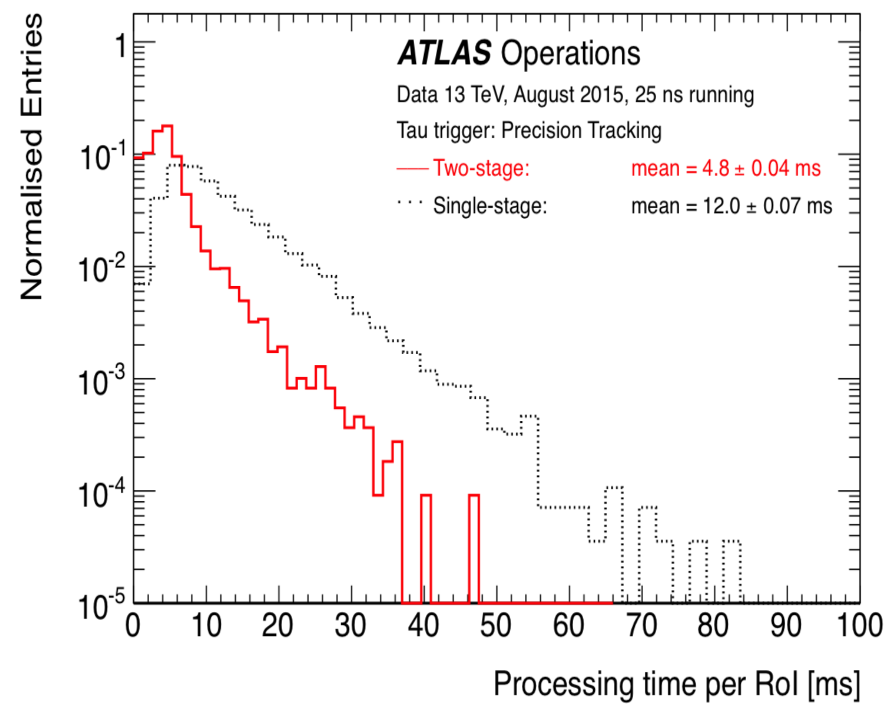




- **RoI sizes can be reduced by using multiple RoIs in sequence, reducing latency of track finding**
- **Two-stage tracking approach:**
  → Performs initial FTF tracking in RoI with large range along beamline, but narrow width in φ and pseudorapidity η
  → Determines track or vertex of interest
  → Seeds second RoI around this position, with narrower range along beamline, but widened in φ and pseudorapidity η
  → Performs FTF in second RoI, followed by Precision Tracking
- **Employed in jet and hadronic-decay tau triggers, where z-position of the primary vertex is not known from L1 information**

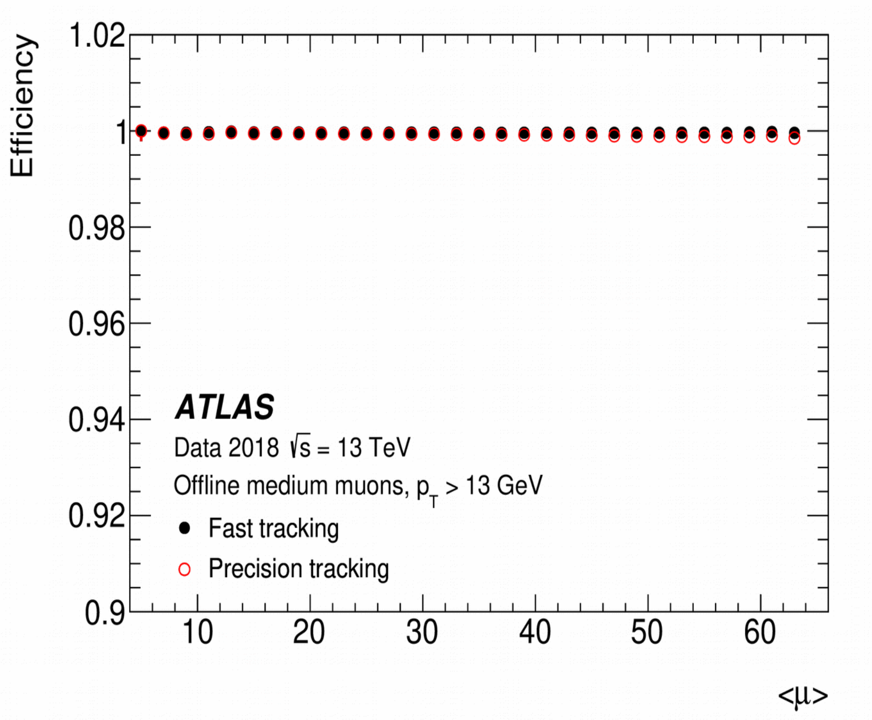
The ATLAS ID Trigger – Run 2 : timing performance

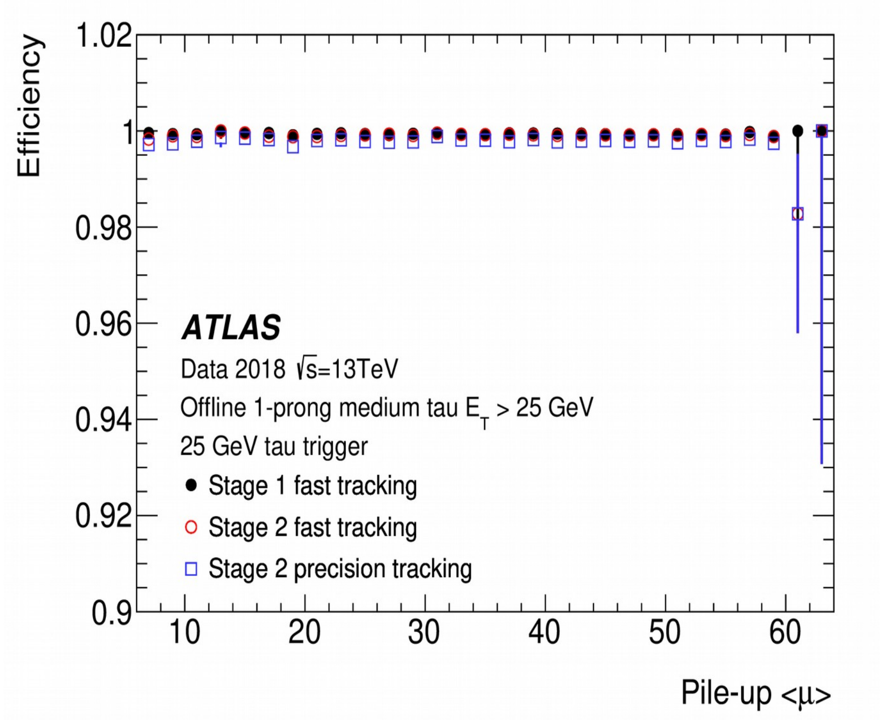




- **Processing times per RoI for the FastTrackFinder (left) and Precision Tracking (right) algorithms for the tau trigger.The mean number of interactions per bunch-crossing (pile-up) was <μ> ~ 14.**
- **The data were taken during 13 TeV LHC collisions in August 2015 with a 25 ns bunch spacing.**
- **The single stage tracking approach as used in Run 1 is shown by the black dotted line.**
- **The two-stage tracking approach used in Run 2 is shown by the solid red and dashed blue lines.**
- **Tau trigger average timing reduced by implementing multi-stage tracking.**

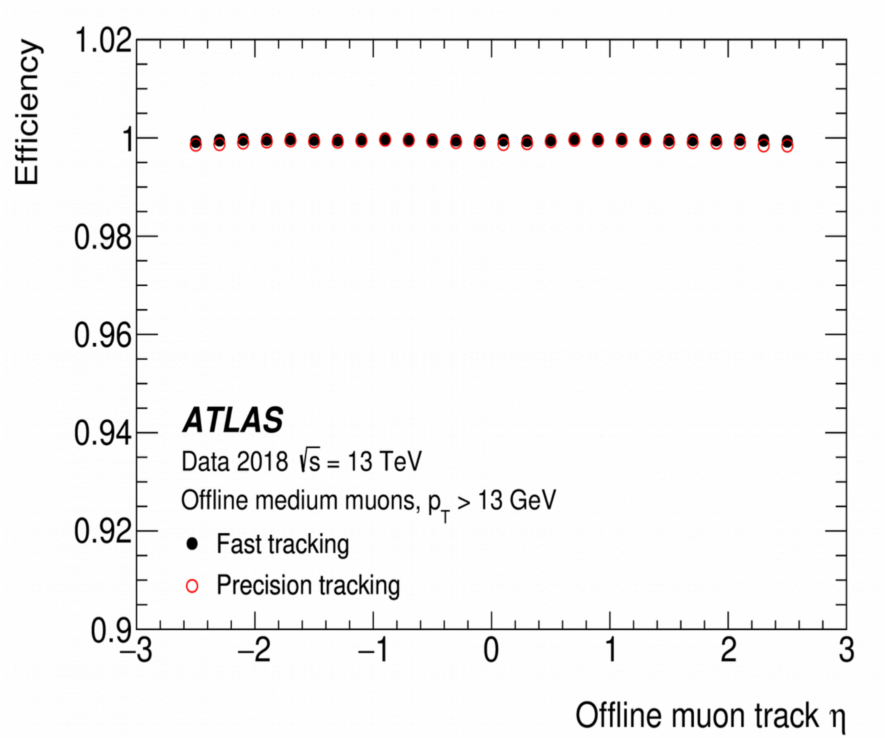
The ATLAS ID Trigger – Run 2 : pile-up performance

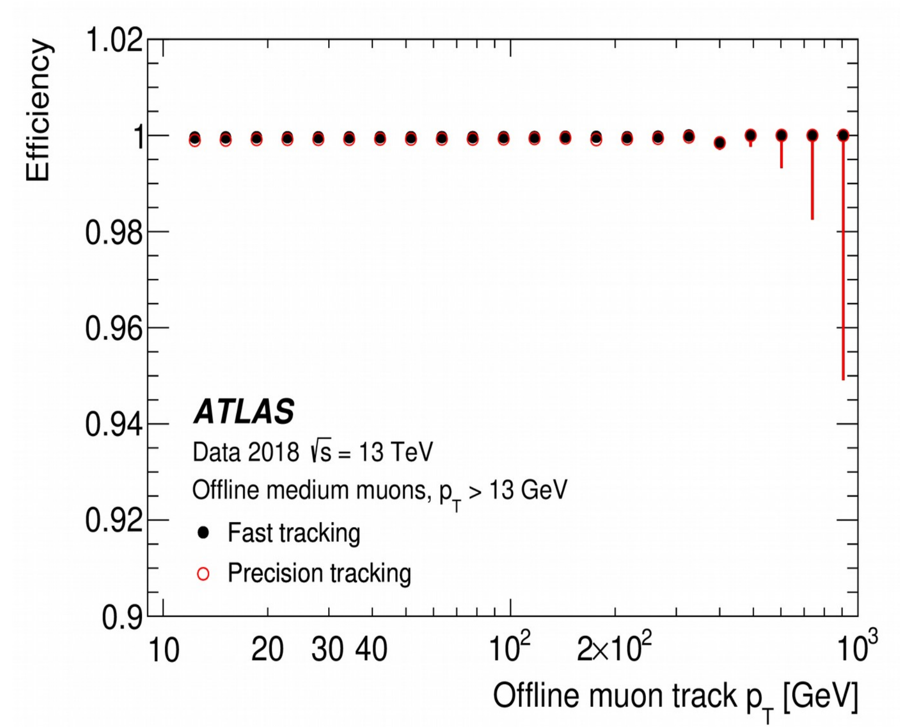




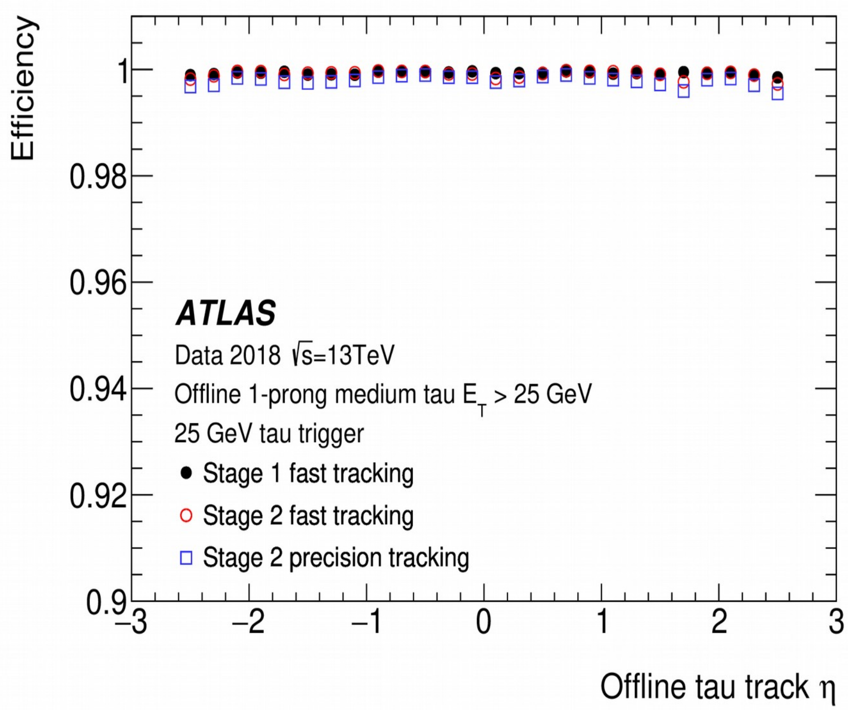
- **Efficiency of ID trigger track reconstruction for offline medium quality muons with $p_T > 13$ GeV (left) and offline medium quality 1-prong tau candidates with $E_T > 25$ GeV (right) as a function of the mean number of interaction per bunch-crossing (pile-up) <μ> . Statistical, Bayesian uncertainties are shown.**
- **The data were taken during 13 TeV LHC collisions in 2018.**
- **The single stage tracking approach is used for the muon signature.**
- **The two-stage tracking approach is used for the tau signature.**
- **Efficiency close to 100% and flat with increasing pile-up for both signatures.**

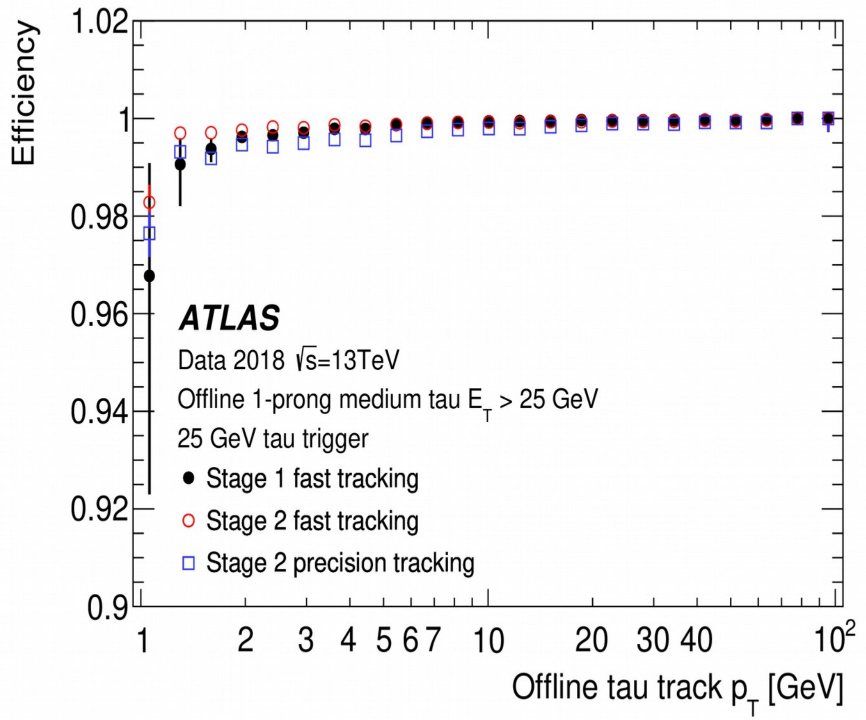
The ATLAS ID Trigger – Run 2 : muon performance





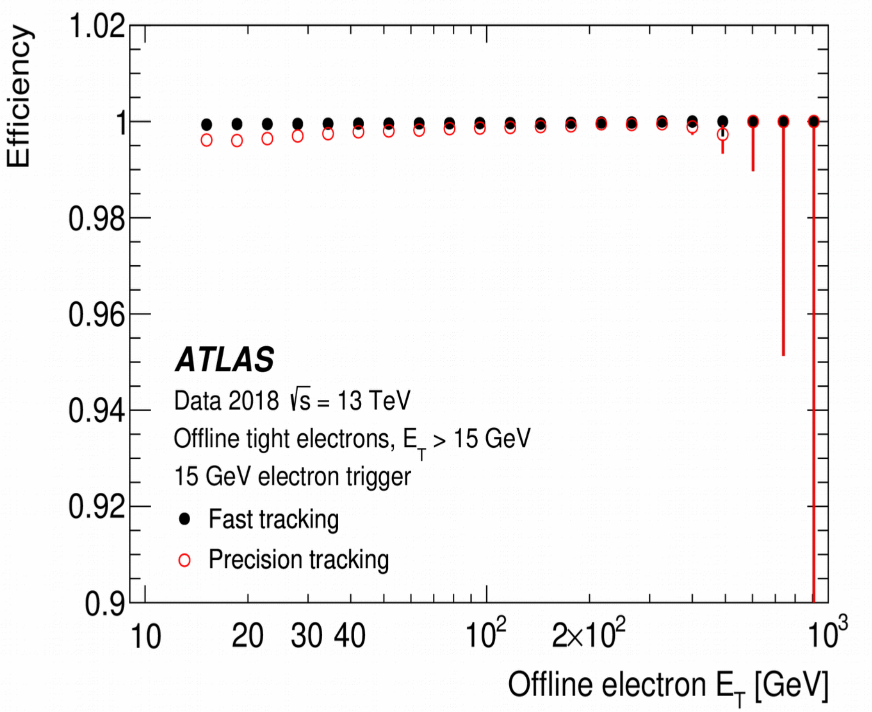
- **Efficiency of ID trigger track reconstruction for offline medium quality muons with p_T > 13 GeV as a function of pseudo-rapidity η (left) and transverse momentum, p_T (right). Statistical, Bayesian uncertainties are shown.**
- **The single stage approach is used here.**
- **The data used here correspond to the full 2018 integrated luminosity.**
- **Efficiencies are approximately ~100%.**

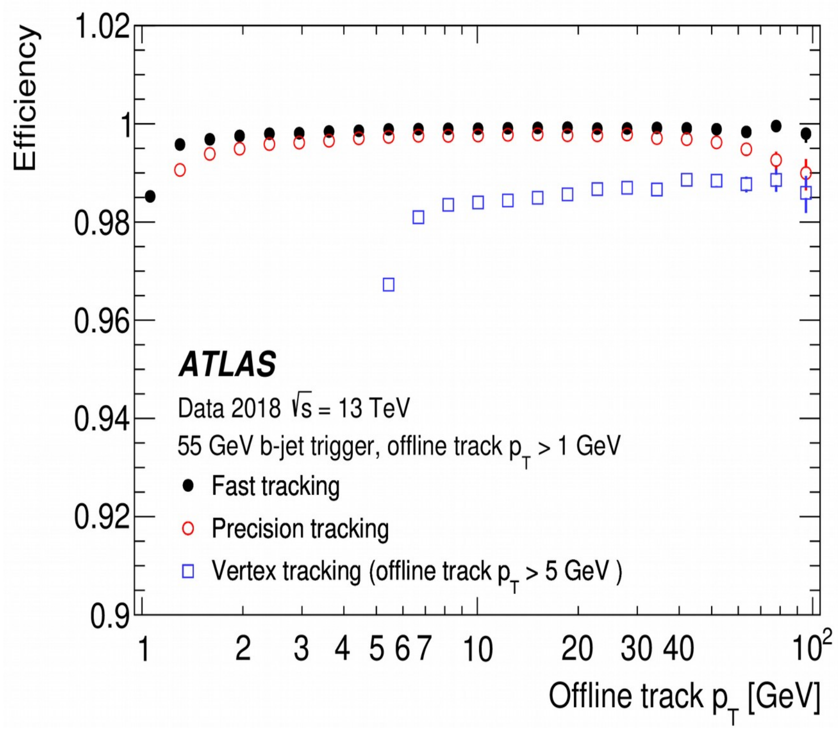




- **Efficiency of ID trigger track reconstruction for offline medium quality 1-prong tau candidates with E_T > 25 GeV as a function of pseudo-rapidity η (left) and transverse momentum, p_T (right). Statistical, Bayesian uncertainties are shown.**
- **The two-stage tracking approach is used here.**
- **The efficiency is evaluated with a 25 GeV tau trigger.**
- **Both efficiencies close to 100%.**

The ATLAS ID Trigger – Run 2 : electron and b-jet performance





- **Efficiency of ID trigger track reconstruction for tracks from offline tight quality electron candidates as a function of the offline electron transverse energy (ET) with E_T > 15 GeV (left) and for tracks from offline b-jet candidates as function of offline track p_T (right). Statistical, Bayesian uncertainties are shown.**

- **For the b-jet triggers, the ID reconstruction runs in two stages :**

- **The first stage runs a fast vertex tracking stage for tracks in η and φ around the jet axis for each jet but extended along the interaction region at the beamline, and with a higher transverse momentum (p_T> 5 GeV).**

- **The second stage runs the FTF algorithm in a wider region about the jets but with a tight selection about the z position of the vertex identified in the first stage, followed by the PT algorithm.**

- **Efficiency is excellent using FTF and PT algorithms and is evaluated with a 15 GeV electron trigger for electrons and 55 GeV b-jet trigger with offline track p_T > 1 GeV for b-jet candidates.**

Conclusion and outlook

- **The LHC delivered record high instantaneous luminosity and pile-up Levels during 2018 data taking. The ATLAS Inner Detector tracking trigger has performed well under these extreme conditions due to improvements made during the 2013-2015 Shutdown.**
- **The multiple RoIs methods in sequence reduced latency of track finding.**
- **The performance of the tracking for muons, taus, electrons and b-jets has been shown to be excellent with efficiencies close to 100% and flat with increasing pile-up.**
- **For Run 3, the trigger is being redesigned to cope with future running conditions, to maintain or improve upon the superb performance from Run 2.**
- **These developments include multi-threaded trigger reconstruction.**

Backup

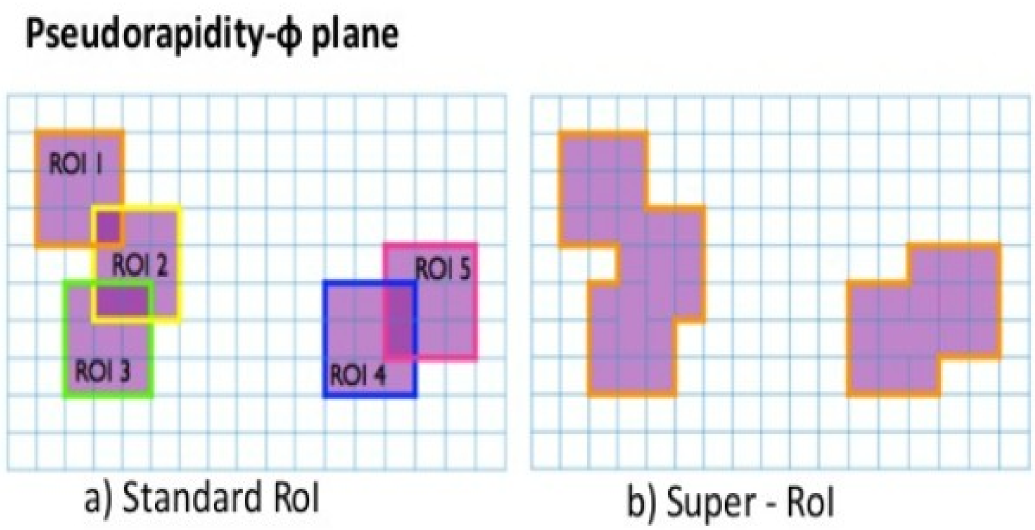
Super-RoI

- **Added for LHC Run 2, RoI overlap can be avoided by combining RoIs :**
- **Super RoI:**

→ Defines RoIs with large range along beamline, but narrow width in φ and pseudorapidity, and combine into a single region

→ Performs tracking and vertexing over the combined region

→ Avoids multiple processing and double counting of tracks that could occur when using multiple RoIs



Super-RoI

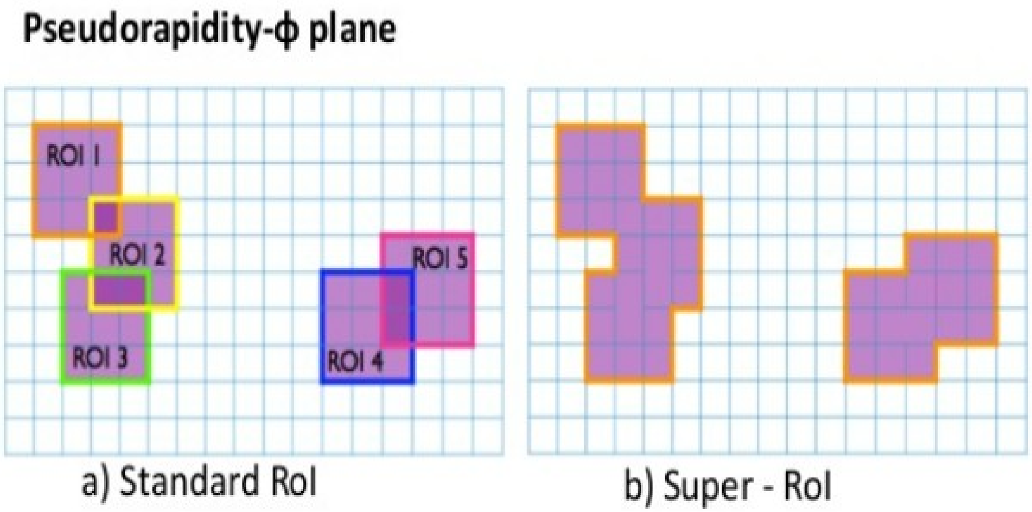
- **Employed in b-jets triggers, along with two-stage tracking :**

  → **Performs initial FTF tracking in Super RoI defined around jets passing L1 trigger**

  → **Performs primary vertex reconstruction using Super RoI track collection**

  → **Defines individual secondary RoIs around jets, originating from the primary vertex**

  → **Performs FTF in secondary RoIs, followed by Precision Tracking, and secondary vertexing needed for b-hadron tagging**



Full-Scan approach

- **In order to reconstruct all tracks from some signatures,e.g. taus, b-jets and cosmics, we use :**

- **Full-Scan approach :**

  → large RoIs covering huge or total volume of ID were required leading to high processing times for the trigger tracking in these cases.

Reference

- **https://link.springer.com/article/10.1140/epjc/s10052-021-09920-0**