Tracking and flavour tagging selection in the ATLAS High Level Trigger

Milène Calvetti (*)
On behalf of the ATLAS Collaboration

(*) Università di Pisa ed INFN sezione di Pisa

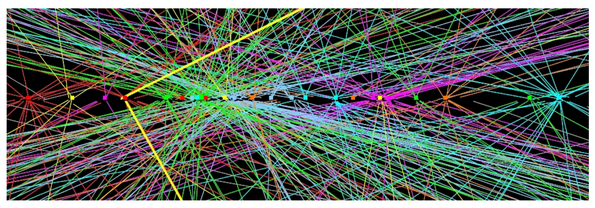
LHC Run 2 challenges

Center of mass energy:
8 TeV → 13 TeV
Bunch separation:
50 ns → 25 ns
Interactions per bunch crossing: ~ 20 → ~ 55

ATLAS strategies

Trigger improvements:

1) New pixel detector layer (insertable B-layer)
2) High performance inner detector tracking software
3) Improved algorithms on specific physics objects
4) Fast TracKer system installation



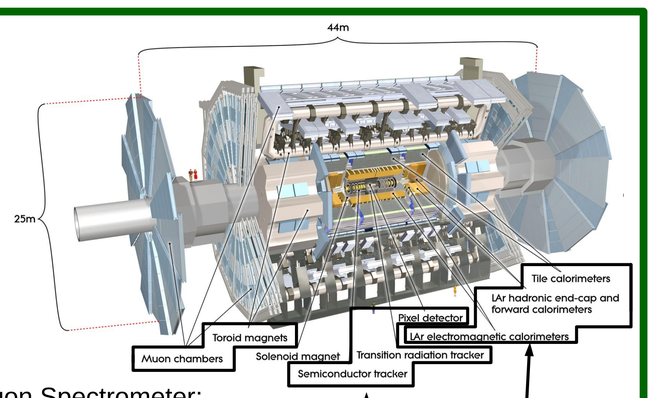
25 reconstructed vertexes

ATLAS trigger

~40 MHz Bunch crossing rate

~100 kHz **Hardware-based Level 1** (L1) trigger: receives input from the calorimeter and the muon systems.

~1 kHz **Software-based High Level Trigger** (HLT): the HLT receives **Region-of-Interest** (RoI) information from L1. RoI information can cause the HLT to request finer-granularity calorimeter information, precision measurements from the muon spectrometer and **tracking information** from the ID.

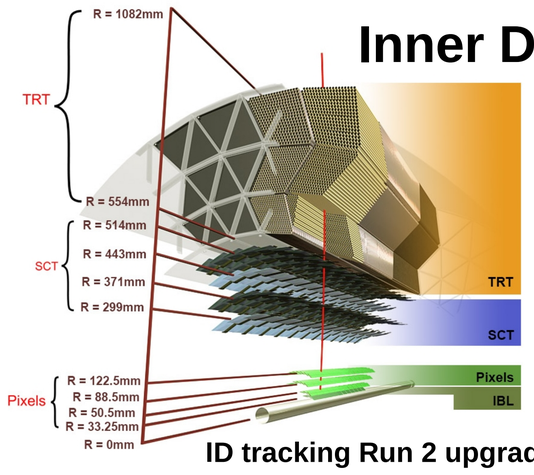


Muon Spectrometer: measures muon momentum

Inner Detector (ID): track reconstruction of charged particles

Calorimeter System: hadronic and electromagnetic energy measurements

Inner Detector trigger



ID tracking Run 2 upgrades

Inner Detector (ID) structure

ID provides track reconstruction employing:
- A four layer **Pixel** detector, including new insertable B-layer (**IBL**), which was installed for Run 2. Provides excellent tracking and vertex reconstruction.
- A silicon microstrip detector (**SCT**)
- A transition radiation tracker (**TRT**)

- ID trigger redesigned to cope with the larger number of interactions per bunch crossing
- ID tracking now includes IBL information
- System ready to include the new Fast TracKing (FTK) system

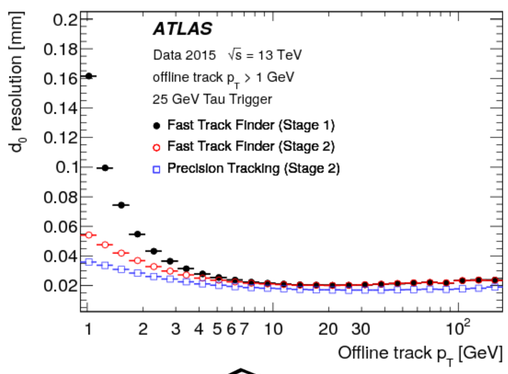
The tracking is generically performed in two distinct steps:
1) **Fast Tracking** - custom trigger pattern recognition
2) **Precision tracking** - modified offline track fitting

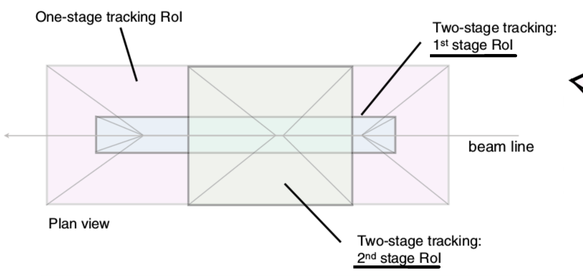
For electrons and muons the ID tracking algorithms are typically executed within the **RoI**s identified by L1. For b-jets and taus two-stage tracking is used with an additional initial fast tracking stage.

Two stage tracking

1) Leading track identified within the long but narrow **first-stage RoI**
2) Both fast tracking and precision tracking executed on the **second stage RoI**, built around the position of the leading track

Advantage: latency of processing the 1st and 2nd stage RoI is less than for a large single region.



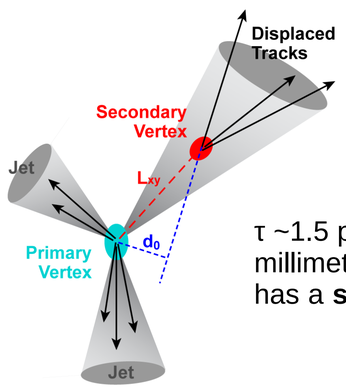


b-jet trigger

Bottom-quark-initiated jet (b-jet) trigger: Identify b-jets in real time

Goals:
- Optimise the rejection of light jets, while retaining a high efficiency on b-jets
- Maintaining affordable trigger rates without raising jet energy thresholds.

Tracks and their corresponding vertexes must be reconstructed and analysed for each jet above the desired threshold, regardless of the pile-up conditions.



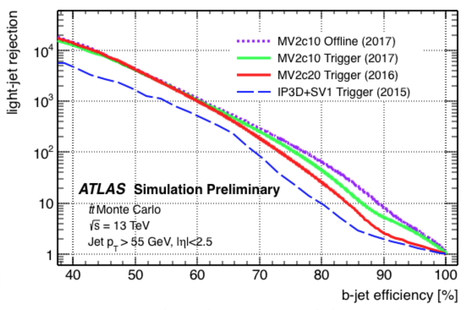
b-hadrons properties

τ ~1.5 ps: travels several millimeters → the decay has a **secondary vertex**

Relatively **high mass** (~ 5 GeV), (higher than the mass of light-quark-jets). b-jets have a larger fraction of energy carried by tracks and large track multiplicity.

Improvements

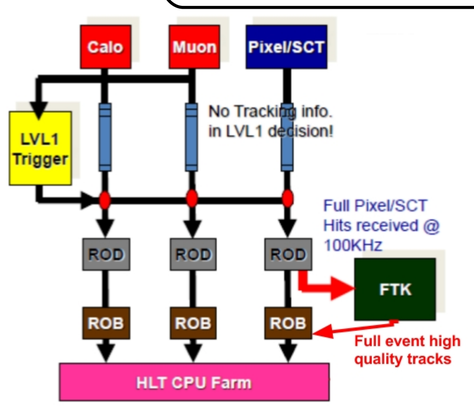
- b-jet identification relies on track and vertex reconstruction: the improved performance of the ID has directly benefited the b-jet trigger.
- Adaptation of offline b-tagging algorithms for use in the trigger. The BDT multivariate MV2 algorithm uses inputs from the following algorithms:
  - IP3D: exploits the longitudinal and transverse **impact parameters**
  - SV1: exploits properties of the **secondary vertex** such as the **invariant mass** of tracks associated to the vertex, the fraction of jet energy associated to the secondary vertex and the number of two-track vertices.
  - JetFitter: exploits the **topological structure** inside the jet.



Expected performance of the MV2 algorithm in 2017 compared to the algorithm used in 2016 and 2015 and to offline tagging

Fast TracKer (FTK)

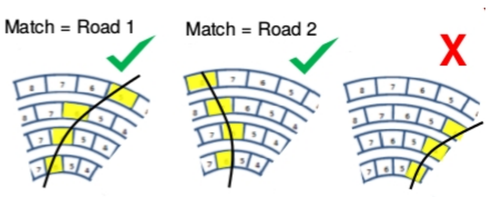
The new Fast TracKer (FTK) system:
designed to deliver full event track reconstruction for all tracks with transverse momentum above 1 GeV (≠ ID tracking, run on RoI).



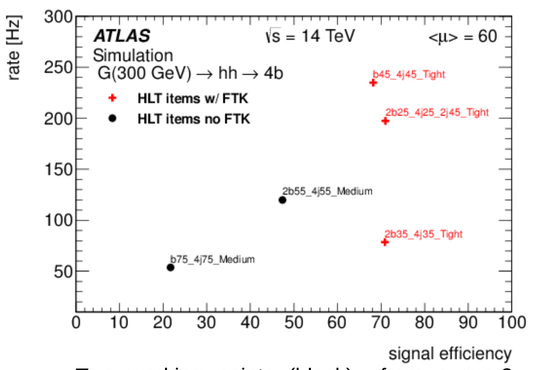
- Receives data from the Pixel and SCT detectors for all events accepted by the Level 1 trigger
- Will allow the use of tracks at much higher event rates in the HLT
- Implemented to required performance level using a combination of dedicated ASIC hardware based on associative memories and high performance Field Programmable Gate Arrays
- Improves the identification of b-jets, τ leptons and missing transverse momentum.
- **Under commissioning**

How does FTK work

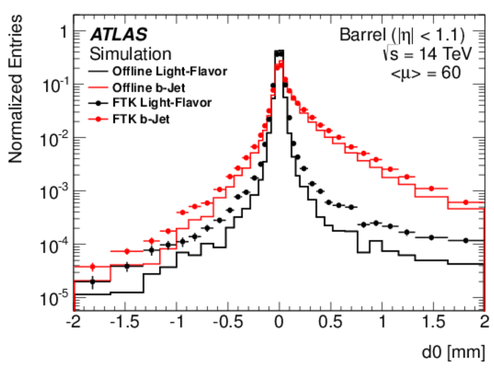
1) Cluster the Pixel and SCT hits into coarse resolution hits → reduce the amount of data
2) The detector is divided in 64 ηxφ towers and the inputs from the towers are processed in parallel
3) Coarse hits are simultaneously compared to many pre-stored track patterns simultaneously (Roads)
4) The fine resolution hits are retrieved for all the Roads and a track fit is performed.



With FTK track finding can be run with looser HLT jet thresholds



Two working points (black) from a run-2 menu along with 3 examples of re-optimized working points in which the b-tagging is run with lower jet thresholds.



The distribution of the transverse impact parameter for the offline tracks compared to the FTK tracks.

REFERENCES:

[1] The ATLAS collaboration. "Performance of the ATLAS trigger system in 2015" *Eur.Phys.J.* C77 (2017) no.5, 317
[2] Annovi, A. and others, "Design of a hardware track finder (Fast TracKer) for the ATLAS trigger" *JINST* (2014) no. 9, C01045