The ATLAS Fast TracKer

Architecture, Status & High-Level Data Quality Monitoring Framework

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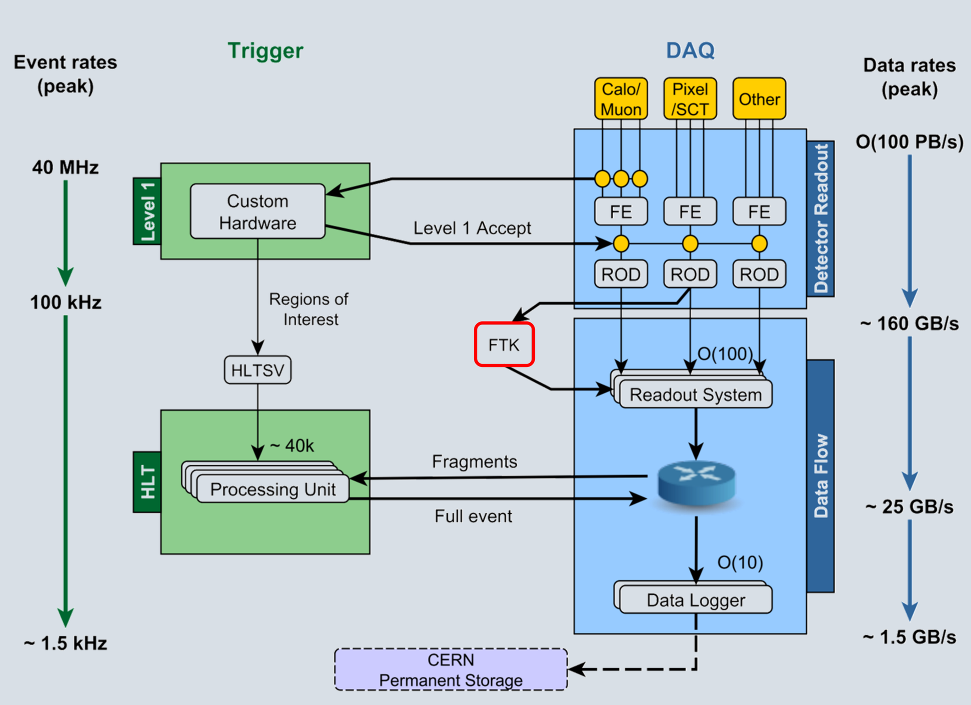
Overview

The Fast Tracker [1] (FTK) is a highly parallel processor dedicated to quickly and efficiently reconstructing tracks in the pixel and SCT detectors of the ATLAS [2] experiment at LHC. It is designed to identify charged particle tracks with transverse momentum above 1 GeV and reconstruct their parameters at an event rate of up to 100kHz. The average latency of the processing is below 100 microseconds at the expected collision intensities. This performance is achieved by using custom ASIC chips with associative memory for pattern matching, while modern FPGAs calculate the track parameters. In this presentation is described the architecture, the current status and a High-Level Data Quality Monitoring framework of the FTK system. This monitoring framework provides an online comparison of the FTK hardware output with the FTK functional simulation, which is run on the pixel and SCT detector data at a low rate, allowing the detection of non-expected outputs of the FTK system.

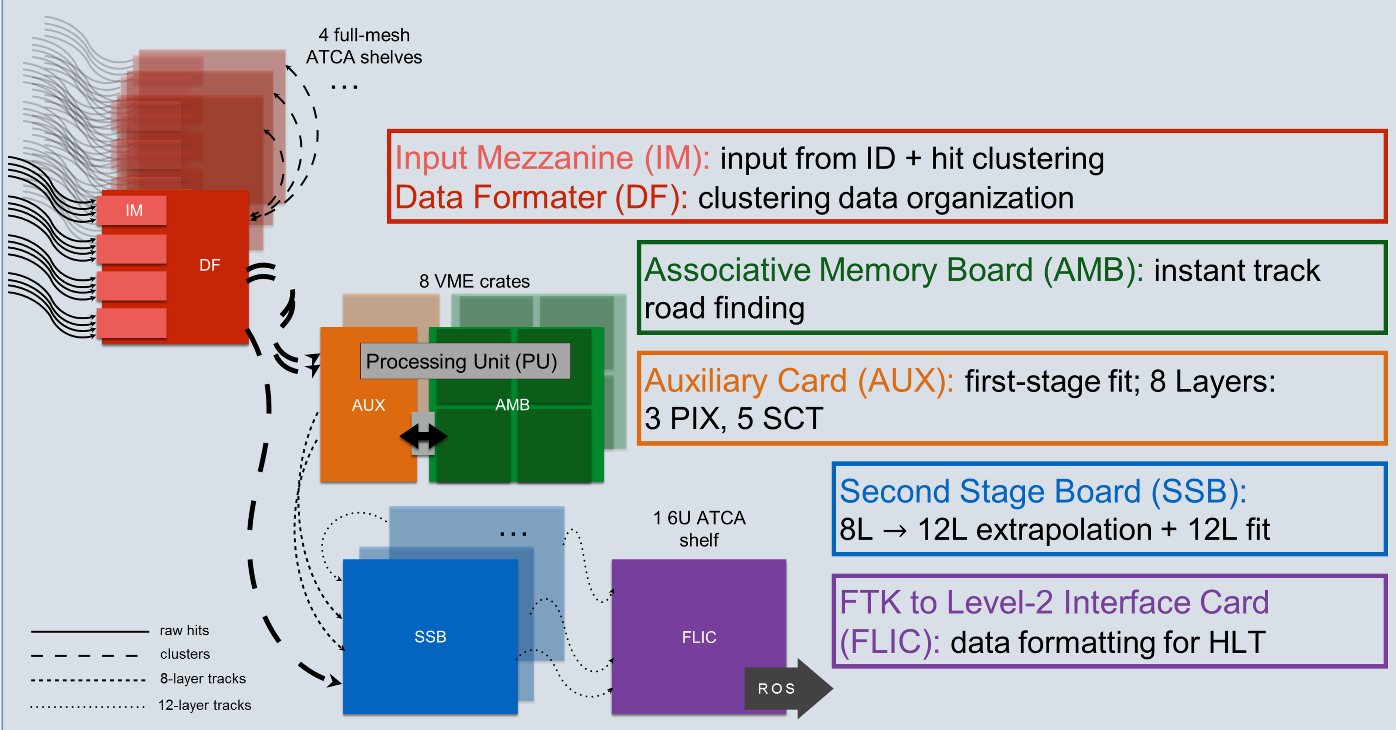
The FTK in the ATLAS TDAQ System



Following L1-accept signals (100kHz), FTK receives hits at full rate, as they are sent from the detector's RODs.

- Information from the 12 silicon layers of the ATLAS Inner Detector is used for the calculation of the track parameters.
- FTK reconstructs all tracks with $p_T > 1$ GeV and provides track information to High-Level Trigger (HLT) *before* the event processing

FTK Architecture



1. Incoming detector-data are clustered, organized according to detector region and sent to the corresponding Processing Unit (PU) in the FTK core system.

2. FTK core solves the huge combinatorics required by pattern recognition.

- Organized into **128 Processing Units** (PUs) which process the tracker data in parallel.
- Each PU executes in pipeline the two main FTK algorithms, the Pattern Matching (PM) in ASICs and the Track Fitting (TF) in FPGAs.

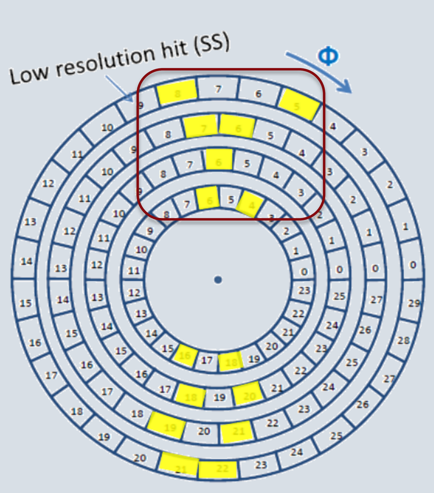
3. Final Fit extrapolates the 8–layers tracks to hits in the remaining 4 layers and performs a 12-layer track fit which removes even more fake tracks.

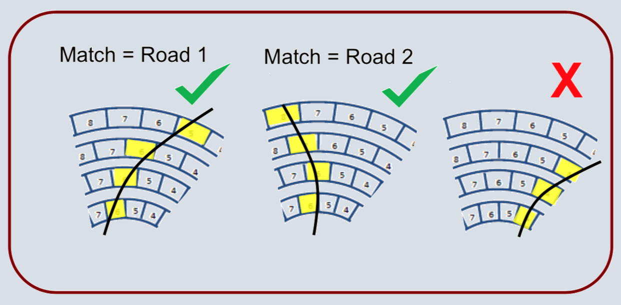
Pattern Matching in Dedicated Associative Memories

The pattern matching [3] is a core process of the FTK and takes place in ASICs called Associative Memory chips.

Each AM chip can contain up to 128k patterns. The memory size of the AM chip and the total number of patterns in the system affect the FTK performance accordingly.

In order to optimize the FTK performance, silicon hits are organized into coarse resolution hits called SuperStrips (SS).





The FTK contains a pattern bank of ~1 billion patterns covering the whole detector phase space, mapped into 64 $\eta - \varphi$ towers.

The FTK Infrastructure & Status

The FTK system is composed of 8 VME crates and 5 ATCA shelves, containing in total 450 boards, 8000 AM chips, 2000 FPGAs and thousands high-speed I/O links.

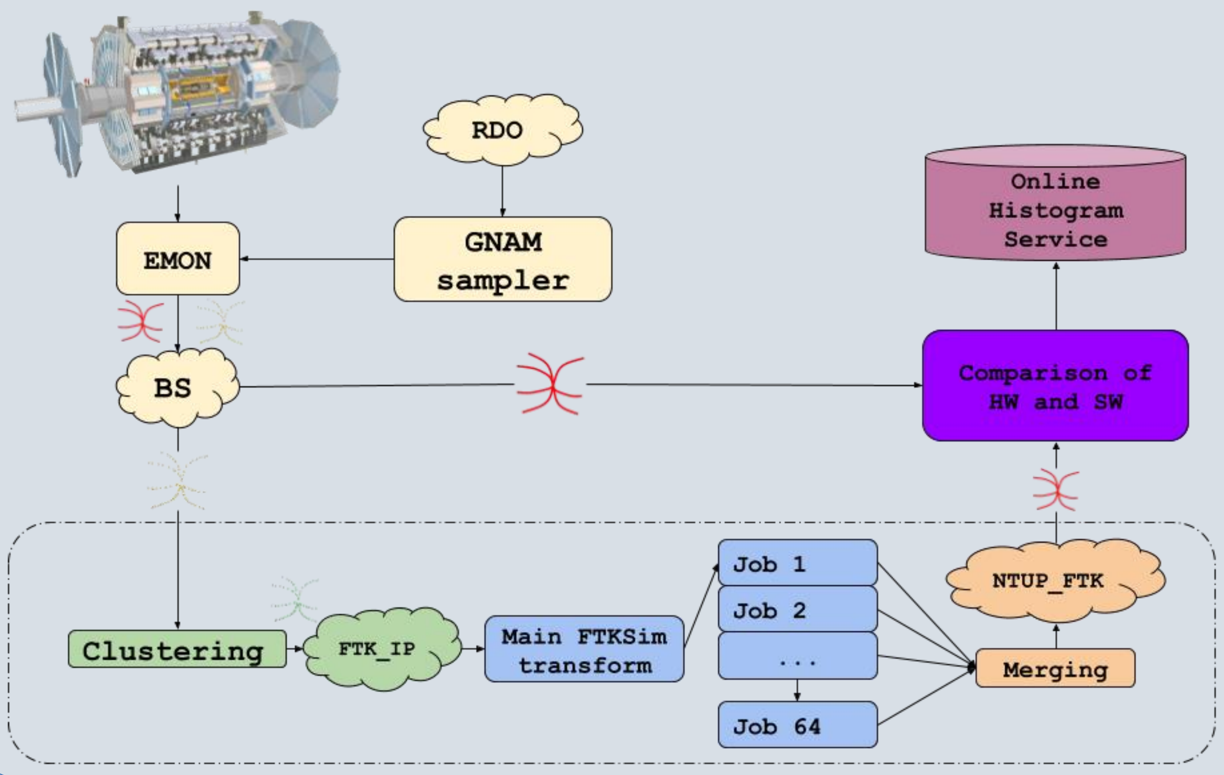
The FTK core is compact (4 racks of electronics) and the power usage is low (~50 kW) compared to a farm of thousands of commercial CPUs [4] required to perform an equivalent task.

FTK status in ATLAS

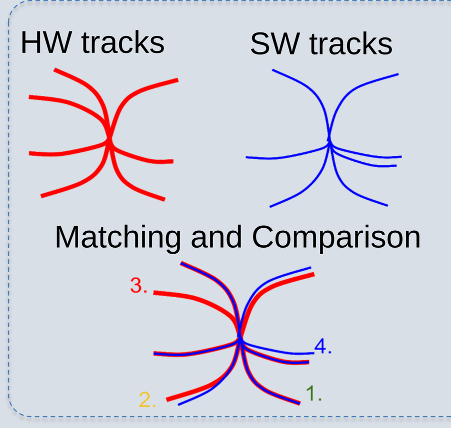
- IM/DF/FLIC : 100% installed.
- AUX/AMB : 100% installed / 100% at CERN
- SSB : 30% installed, more expected soon

The High-Level Data Quality Monitoring Framework

Monitoring the functionality of the FTK system by comparing the output of the hardware with the output of the FTK Simulation run on the same ID data.
Goal: Confirmation that FTK hardware works as expected (in real time)

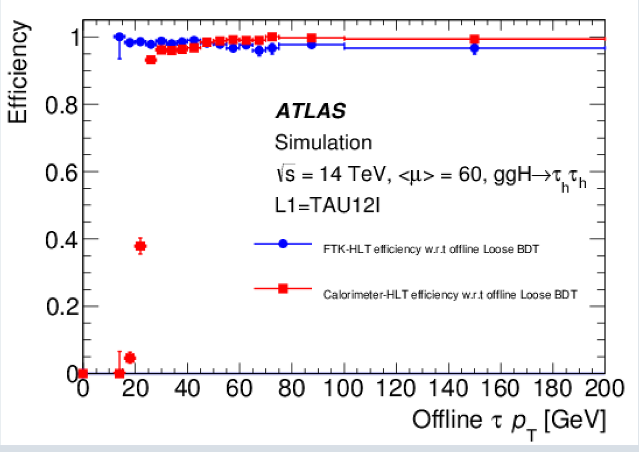


- A full event fragment (ID & FTK data) is sampled by the Data Collection Manager
- FTK Simulation [5] processes full event by following its basic algorithms:
  - Clustering – Data distribution – Pattern matching – Track fitting – Second-stage track fitting – Merging
  - Comparison of HW and SW events
  - Gets FTK simulated tracks (FTK SW)
  - Extracts real FTK tracks (FTK HW)
  - Compares track parameters
- Histograms published to Online Histogramming Service



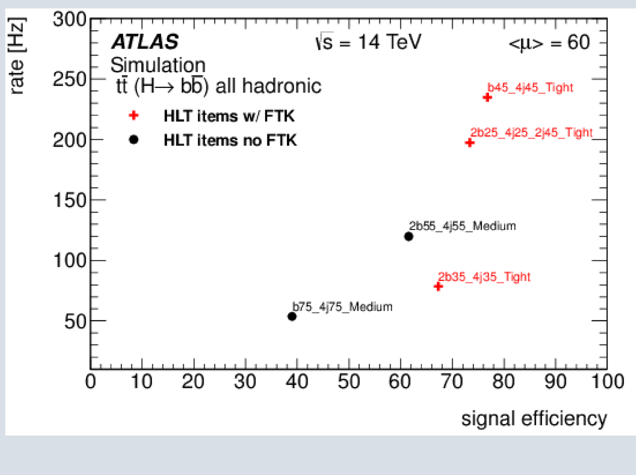
Four classes of histograms:
1. Matched HW/SW: tracks are the same
2. Matched HW/SW: tracks are (slightly) different
3. Tracks only in HW
4. Tracks only in SW

The FTK Performance



Tau identification efficiency as a function of the offline-tau p_T when applying the FTK selection (blue) and calorimeter clusters selection (red) at HLT. The efficiency is defined as the fraction of Level-1 tau matched to a true hadronic tau decay and to an offline tau identified with the offline loose Boosted Decision Tree (BDT). In both cases, the selections have be tuned to give the same background rejection factor of 2 per Level-1 tau candidate (with $p_T > 12$ GeV and calorimetric isolation of 4 GeV). [6]

Impact of the FTK b-tagging including the use of IBL and the refit of FTK tracks. Track finding with the FTK can be run with looser HLT jet thresholds without putting additional load on the HLT processors. The plot shows two working points from a draft run-2 menu along with some examples of re-optimized working points in which the b-tagging is run with lower jet thresholds. The output rates of the various trigger items are shown as a function of the event-level $t\bar{t}h\,(h -> bb)$ efficiency. All operating points assume the re-fitted FTK performance. [6]



References

1) ATLAS Collaboration., "The Fast Tracker (FTK) Technical Design Report" CERN-LHCC-2013-007 ; ATLAS-TDR-021; available online: https://cds.cern.ch/record/1552953
2) The ATLAS Collaboration, "The ATLAS Experiment at the CERN Large Hadron Collider," Journal of Instrumentation 3 S08003, 2008.
3) S. Citraro et al., "Highly Parallelized Pattern Matching Hardware for Fast Tracking at Hadron Colliders", submitted to IEEE Trans. on Nuclear Science, October 2015.
4) The CMS Collaboration, "Description and performance of track and primary-vertex reconstruction with the CMS tracker", Journal of Instrumentation 9 P10009, 2014.
5) J. Adelman et al., ATLAS FTK Challenge: Simulation of a Billion-fold Hardware Parallelism
6) ATLAS EXPERIMENT – Public Results: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/FTKPublicResults

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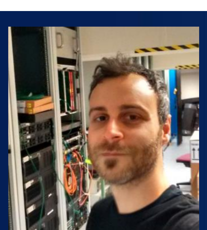

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