Event Filter Tracking for the Upgrade of the ATLAS Trigger and Data Acquisition System (TDAQ)

Sudha Ahuja on behalf of the ATLAS Collaboration

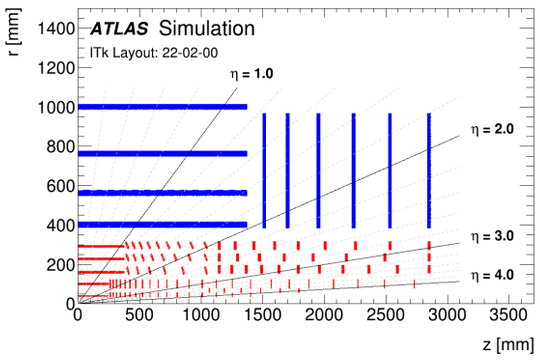
High Luminosity LHC (HL-LHC) & TDAQ

HL-LHC expected to start at ten times higher design luminosity & deliver around 4000 fb^{-1} data within ten years:

- ✦Challenging environment with high radiation doses & particle production rate.
- ✦Upgrade foreseen for the LHC machine & several detector components (including the ATLAS TDAQ system) to cope with high pileup conditions & maintain Run 2/Run 3 performance.
- ✦Prospect to observe/measure rare processes is the main driver of the upgrade.

HL-LHC ATLAS trigger system will take advantage of the upgrades, including the planned ***Inner Tracking Detector (ITk)***.

- ✦ITk layout has undergone major revision simplifying the detector layout, optimising tracking performance & minimising CPU required for reconstruction.
- ✦Tracking information is a key ingredient to control the high L0 rate. A novel approach for ITk track reconstruction [4] for high pileup (PU) events has also been developed.



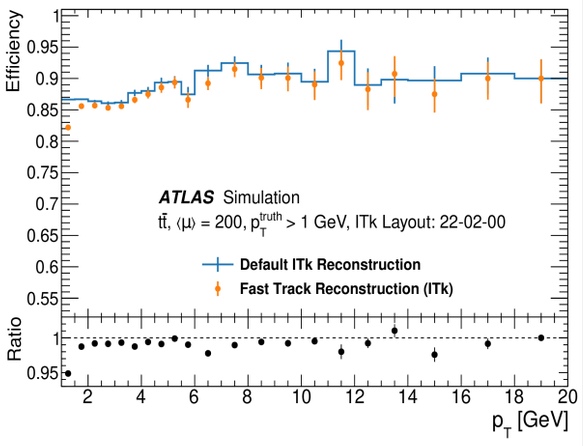
Amendment to Phase II TDAQ TDR for Tracking Trigger:

- ✦Due to the recent advances in track reconstruction software (SW) and commercial accelerator technology, assumptions behind TDAQ Phase II TDR [2] were in need of revision.
- ✦ATLAS decided to commit to a commercial solution for EF tracking at HL-LHC.

Fast Tracking CPU based Demonstrator (I)

A fully functional ITk fast trigger reconstruction has been developed [4]:

- ✦Selection cuts tuned to significantly reduce the reconstruction time by speeding up the Seed Finding & improving the purity of the output seed collection.
- ✦Additional fakes and duplicate track candidates from the output track collection are removed in the Silicon Track Finding (SiTF) itself. No Ambiguity Resolution step involved here.
- ✦For the track parameter estimation the fast Kalman Filter track fit is used directly.
- ✦CPU performance of the prototype fast ITk track reconstruction shows that it is approximately six times faster .



"This demonstrator meets the EF tracking requirements in the studied phase space with CPU requirements that are compatible with the available power and space at ATLAS Point-1."

GPU based Demonstrator (III) [2]

Was studied using current Inner Detector (PU = 46), and with now outdated GPU's. Compute intensive data preparation and track seeding step were implemented in CUDA modules & a minimum version of detector geometry was developed for the GPU.

- ✦Measurements indicate it would cost approximately the same to increase the farm throughput by adding GPUs or CPUs.

"This demonstrator shows that the tracking SW can be successfully adapted to other architectures in order to perform a full cost/benefit evaluation with current & future GPUs".

Event Filter Tracking (EF Tracking)

EF Track reconstruction chain consists of: [a] Input ITk Data Preparation, [b] Track Seeding & Pattern Recognition (PR), followed by final Stage [c] Track Extension, Fitting, and Ambiguity Resolution.

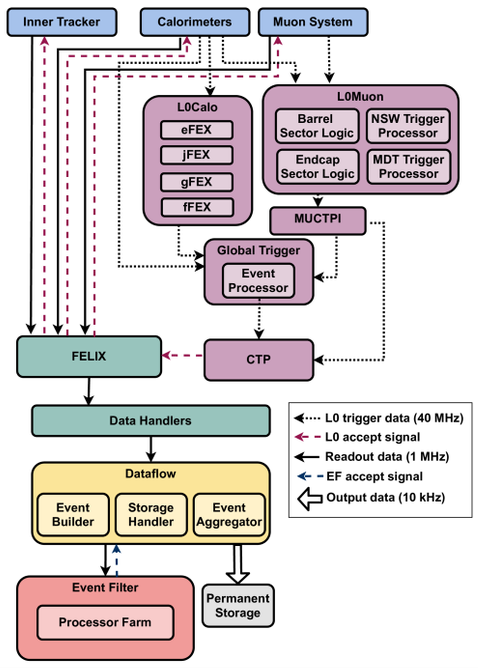
- ✦Offline ITk material/geometry made available by Acts SW framework [3].
- ✦Ability to do Large Radius Tracking (LRT) triggers for new physics searches for LLP's, focusing on tracks with high impact parameters.

EF Tracking requirements: Robust against PU, Capable of reconstructing vertices & tracks as needed for PU suppression, Overall tracking efficiency be close to offline efficiency. Tracking done in two stages for all tracks within ITk coverage, $|\eta| < 4.0$:

- ✦*Regional Tracking* [1 MHz] performed in Regions of Interest (RoIs) for all charged tracks with $p_T > 2$ GeV, and for an initial rejection.
- ✦*Full scan tracking* [150 kHz] for charged tracks with $p_T > 1$ GeV.

The proposed EF system design is a flexible, heterogeneous commercial system consisting of CPU cores and possibly accelerators, to perform the EF reconstruction including the compute intensive ITk track reconstruction chain.

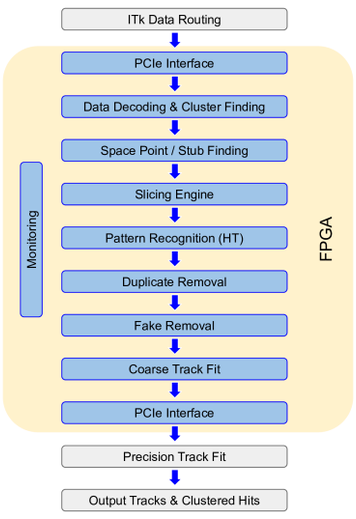
- ✦Heterogeneous approach gives flexibility to select the best commercial hardware (HW) together with optimal algorithmic approaches & also benefit from emerging commercial technologies, to provide high quality EF Tracking.



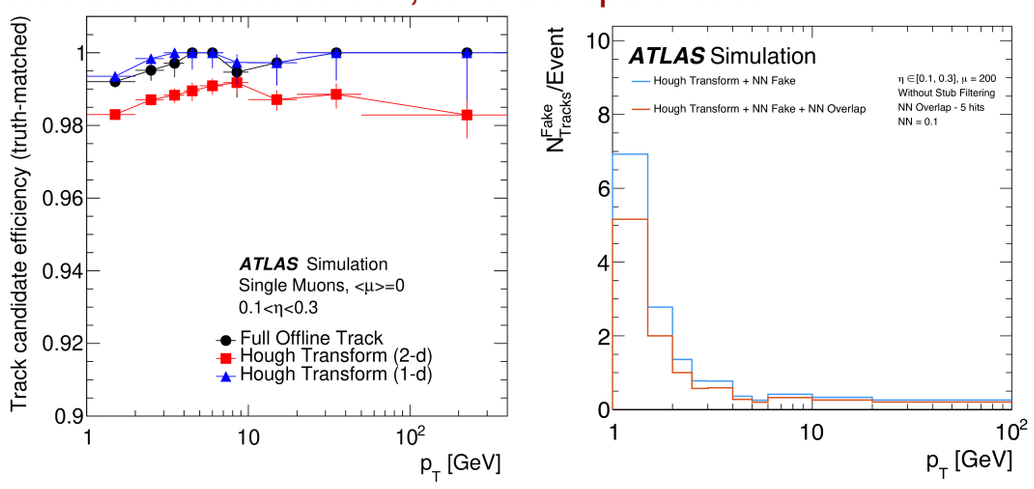
FPGA based Demonstrator (II)

Prototype Firmware (FW) workflow involved:

- ✦Lightweight CPU based SW sends input to a FPGA, which implements all functionalities up to an initial track fit. FPGA output (track candidates and their associated hit clusters), are passed to a precision Kalman filter [4] for a final precision fit.
- ✦Hough Transform option is considered for the most resource-intensive PR stage.



Precise determination of the boundary, between functionality performed in HW versus SW, is to be optimised.



"This demonstrator includes PR FW for a baseline Hough transform with FW estimates shown to fit within the target FPGA, SW aspects that take advantage of novel developments in fast tracking SW for ATLAS, & reduced power consumption."

References: EF Tracking TDR Addendum (ATLAS-TDR-029-ADD-1) [1]
Technical Design Report for the Phase II Upgrade of the ATLAS TDAQ System [2]
A Common Tracking Software Project [3]
Fast Track Reconstruction for the LHC [4]

ATLAS EXPERIMENT

ROYAL HOLLOWAY UNIVERSITY OF LONDON