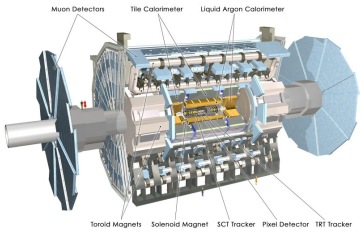
CHEP 2013 - Amsterdam, 14-18 October 2013

Performance and development plans for the Inner Detector trigger algorithms at ATLAS

We present a description of the algorithms and the performance of the ATLAS Inner Detector trigger for LHC Run 1, as well as prospects for a redesign of the tracking algorithms in Run 2. The Inner Detector trigger algorithms are vital for many trigger signatures at ATLAS. The performance of the algorithms for electrons is presented. The ATLAS trigger software will be restructured from two software levels into a single stage which poses a big challenge on the trigger algorithms in terms of execution time and maintaining the physics performance. Expected future improvements in the timing and efficiencies of the Inner Detector triggers are discussed, utilising the planned merging of the current two-stage software of the ATLAS trigger.

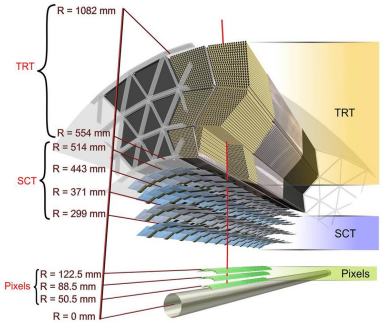
ATLAS Inner Detector and Trigger Architecture during LHC Run I (2010-2012)

The ATLAS Detector



- Large, general purpose detector at LHC
- Inner Detector for tracking complements electromagnetic and hadronic calorimeters and muon spectrometer

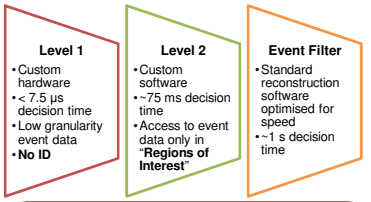
The Inner Detector (ID)



Comprises three sub-detectors which contribute in different ways to the track reconstruction:

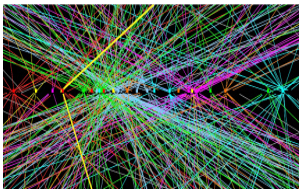
- **Pixel Detector** (3 endcap and barrel layers): Silicon pixels providing information for precise measurements of primary and secondary vertices and track parameters
- **SemiConductor Tracker (SCT)**: Silicon microstrip detector with 4 layers in barrel, 9 in endcap
- **Transition Radiation Tracker (TRT)**: layers of straw tubes used in electron identification and providing additional hits for tracking

Trigger architecture in Run 1



- Three level trigger system
- L1: hardware
- L2, EF: software
- Progressive reduction of output rate to 400 Hz

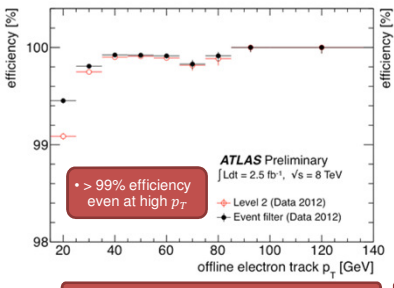
ATLAS Inner Detector Trigger in 2012



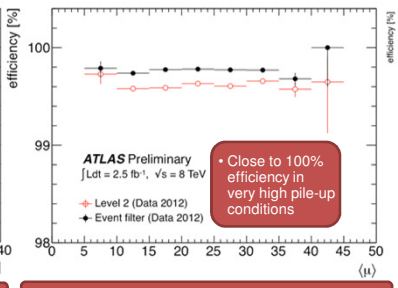
- A 2012 collision event with a Z→μμ candidate and 20 additional vertices
- Event is typical of 2012 running conditions
- High pile-up is difficult for tracking!
- In 2012 mean interactions per bunch crossing ⟨μ⟩=20.7

Measurement of electron efficiency in 2012 data

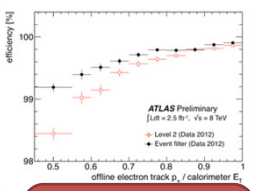
- Measure tracking performance in Z→ee events using a tag and probe method
- Select sample of Z candidate events
- **Tight trigger** for tag electron
- **Loose trigger** (no track information) for probe electron
- Match trigger track to good offline tracks in cone of ΔR=0.03



• 70 ≤ mass(Tag+Probe) ≤ 110 GeV



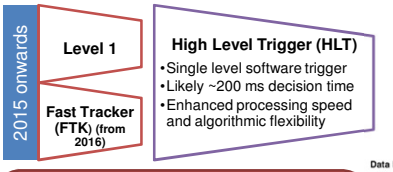
• No degradation at increasing ⟨μ⟩



- p_T/E_T : measure of energy loss due to **bremsstrahlung**
- Electron tracking > **98% efficient** even for candidates losing **50%** of energy in bremsstrahlung

ATLAS Inner Detector Trigger Upgrade

ATLAS Trigger Upgrade



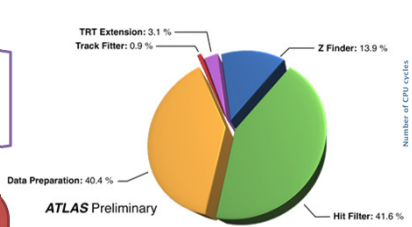
Two level trigger system

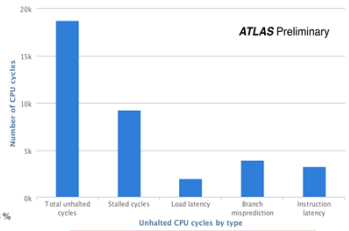
- **Upgraded** Level 1 calorimeter and muon triggers
- **New** hardware track trigger (FTK)
- Single stage HLT **reduces** data readout and preparation requirements
- Potential for **new flexibility** in algorithm design

ID Trigger Upgrade

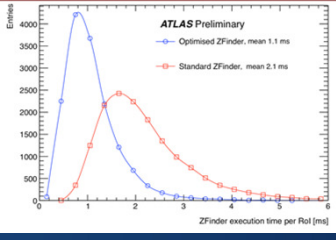
- Optimise and re-order Run I algorithms
- Exploit presence of hardware track trigger (Fast Tracker (FTK))
- Use new Pixel detector layer (IBL)
- Identify and exploit potential for parallelisation

Profiling of ID trigger algorithms





- `callgrind` used to profile percentage of time taken in different parts of the trigger tracking algorithms
- Detailed analysis of code performance then focused on most time-consuming functions



Detailed profiling results for Zfinder (primary vertex-finding) algorithm collected from

- Generic Optimization Data Analyzer (`GOoDA`)
- Linux `perf` monitoring tool

Low-level information about CPU cycle types found

- Investigating changes to loop ordering and program flow
- Reduce **stalled cycles**
- **Factor of 2** improvement in mean algorithm timing for vertex finding code (Zfinder) after optimisation to avoid **branch misprediction** (21% of all stalled cycles)

Other work currently underway

- Characterisation of Run I performance for muons, taus and b-jets
- Exploitation of new Pixel detector innermost layer (Insertable B-Layer/IBL)
- Parallelisation of ID trigger algorithms
- Improved recovery of tracks with high bremsstrahlung
- Development of FTK+HLT tracking

Conclusions

ATLAS Inner Detector trigger performed very well in LHC Run 1

- High efficiency in presence of pile up and bremsstrahlung

Much work underway to improve performance for Run 2

- Redesign to match upgraded ATLAS trigger and Inner Detector
- Software profiling and optimisation
- Parallelisation/vectorisation

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ATLAS EXPERIMENT