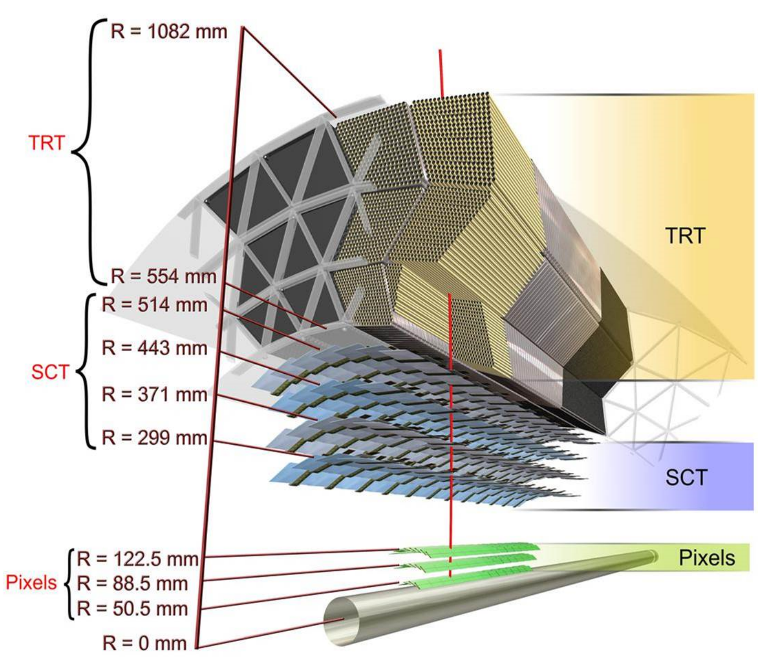
Stewart Martin-Haugh (STFC RAL), on behalf of the ATLAS Collaboration

Performance and Development Plans for the Inner Detector Trigger Algorithms at ATLAS

A description of the design and performance of the newly re-implemented tracking algorithms for the ATLAS trigger for LHC Run 2 is presented. LHC Run 2, beginning in 2015, is a challenging environment for track triggers due to the increased collision energy and pile-up. The High Level Trigger (HLT) has been restructured to run as a more flexible single stage process, rather than the two separate Level 2 and Event Filter stages used during Run 1. To make optimal use of this new scenario, a new tracking strategy has been implemented for Run 2. This new strategy will use a Fast Track Finder (FTF) algorithm to directly seed the subsequent Precision Tracking, and will result in improved track parameter resolution and significantly faster execution times than achieved during Run 1 and with better efficiency. The FTF algorithm is described. Timing measurements for the new electron and tau track triggers algorithms are presented. The profiling infrastructure, validation and commissioning strategies are also described.

ATLAS Inner Detector and Trigger Architecture

Atlas Inner Detector (ID)



Pixel Detector:
- Insertable b-layer (new for Run 2, not shown)
- Three layers of silicon pixels for precise tracking and vertexing

SemiConductor Tracker:
- Silicon microstrip detector with double layers at small stereo angle
- 4 double layers in barrel, 9 in endcap

Transition Radiation Tracker:
- Straw tubes used in electron identification and extra track hits

ATLAS Trigger in Run 1

Level 1 (L1)
- Custom hardware and firmware
- < 2.5 μs decision time
- 70 kHz output rate
- Low granularity event data
- Geometric Regions of Interest (RoIs) generated
- No ID

Level 2 (L2)
- Custom software
- ~75 ms decision time
- 5-6 kHz output rate
- Access to event data mainly in RoIs from L1

Event Filter (EF)
- Offline reconstruction software optimised for speed
- ~1 s decision time
- 700 Hz output rate

ATLAS Trigger in Run 2

L1
- Upgraded hardware and firmware
- < 2.5 μs decision time
- 100 kHz output rate
- New topological trigger (L1Topo) calculates angular and event-level quantities from hardware
- ID track preprocessor (FTK) from late 2015

High Level Trigger (HLT)
- Custom and offline reconstruction software
- ~200 ms decision time
- 1 kHz output rate
- Enhanced processing speed and algorithmic flexibility
- Single PC farm

ATLAS Inner Detector Trigger for Run 2

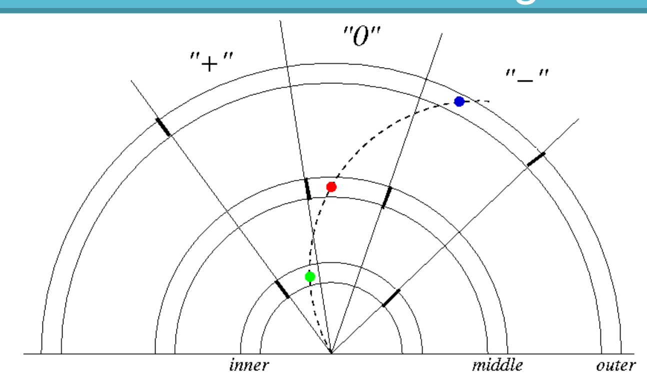
ID trigger algorithms in Run 1

1. L2 data preparation for L2 farm, L2 event data model (EDM)
2. L2 tracking – lower quality due to CPU constraints
3. Initial object hypothesis (required)
4. EF data preparation for EF farm, offline event data model (EDM)
5. EF tracking (offline-like) - seeded by detector hits
6. Final object hypothesis

ID trigger algorithms in Run 2

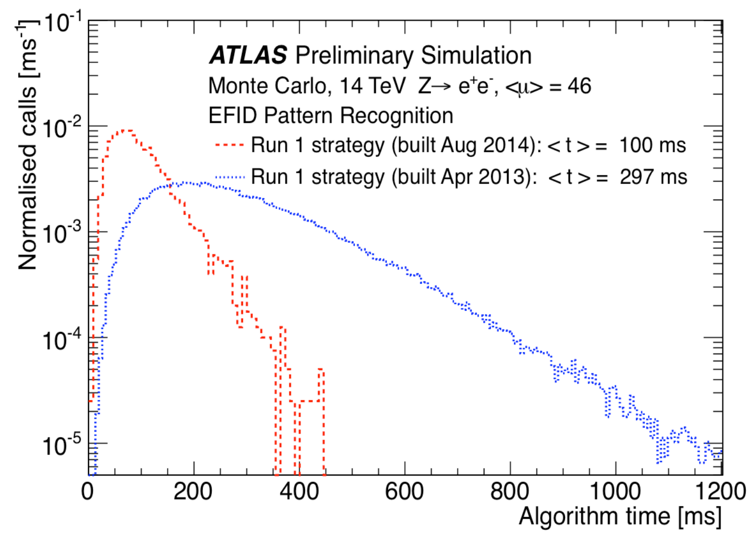
1. Data preparation for HLT farm, offline EDM
2. FastTrackFinder – initial good quality tracks
3. Optional object hypothesis - early rejection
4. Precision tracking (seeded by FastTrackFinder) – near offline-quality tracks
5. Final object hypothesis

The FastTrackFinder algorithm



- Combines features from two successful Run 1 algorithms
- Track seeding looks for triplets of spacepoints in radial and φ bins
- Estimate track seed parameters through conformal mapping
- Track seeds sent to offline-quality track finder, optimised for speed
- Fast Kalman filter track fit

Software upgrades



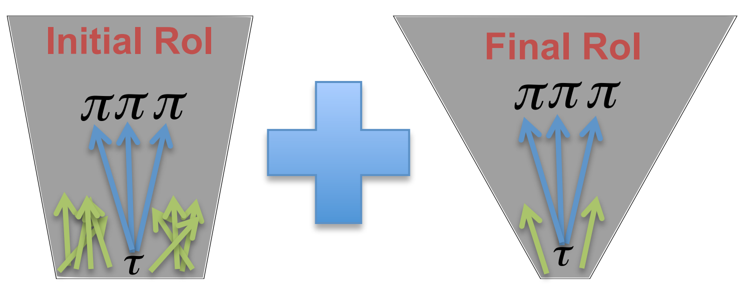
Significant software improvements
- Targeted software optimisation
- Use of Eigen, a fast linear algebra library
- Newer compiler, switch to 64 bit architecture

Significant speedup visible re-running Run 1 ID trigger code in new software release

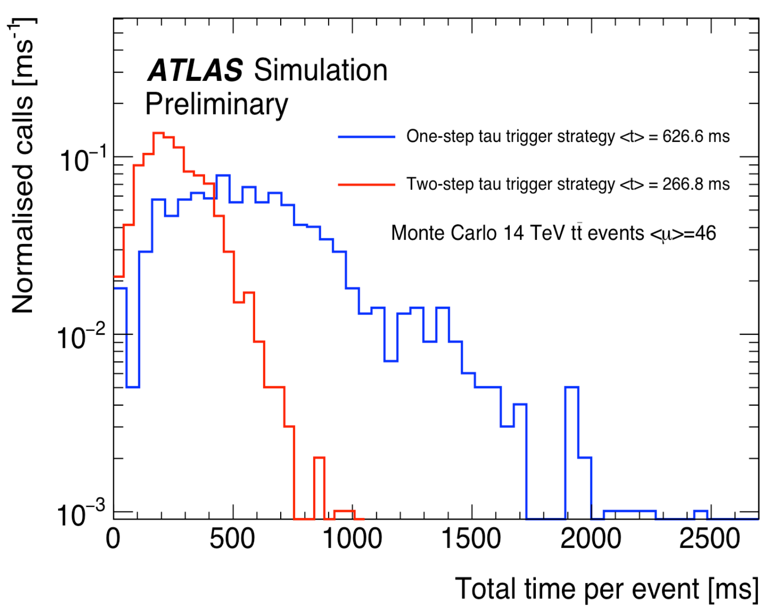
Two-step tracking

Two-step tracking strategy:
- Run tracking twice in different-sized Regions of Interest (RoIs)

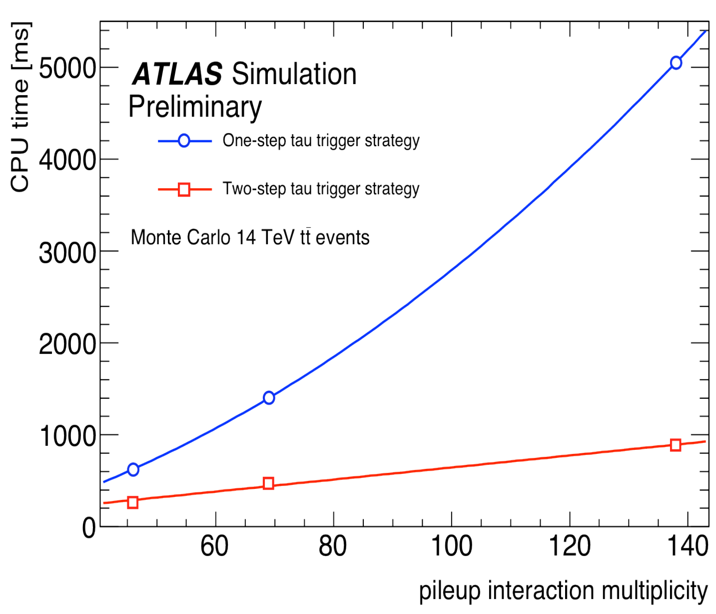
Various physics cases:
- Electron/muon isolation
- Tau core/isolation measurement
- B-jets – fast vertex finding and precision b-tagging



Two-step tracking for taus:
- Exploit physics of hadronic tau decays
- Reject events without a high-p_T lead track in η x φ = 0.1 x 0.1 RoI
- Find isolation cone tracks in 0.4 x 0.4 RoI within Δz = 10 mm of lead track
- First RoI constrained in η x φ
- Second RoI constrained in z



- Trigger processing times measured on 2.4 GHz Intel Xeon CPU
- Simulated $t\bar{t}$ sample with 46 additional pileup interactions
- Times for full trigger strategy shown, including ~37 ms for calorimetry
- Factor of two speedup from two-step tracking
- No significant loss of efficiency



- Smaller first RoI and z-constrained second RoI in z mitigates non-linear scaling of track seeding
- Implementations for other triggers (electron, muon, b-jet) undergoing testing
- Potentially interesting for High-Lumi LHC

Profiling and validation

Extensive validation programme
- Commissioning with cosmic rays
- Automated nightly tests on data and MC
- Static and dynamic analysis (Coverity, Valgrind, AddressSanitizer)

Profiling for technical performance
- GOoDA
- Callgrind
- CPU timing measurements

Conclusions

The Inner Detector Trigger has been extensively upgraded in preparation for Run 2.

Many improvements:
- Faster software
- New flexible two-step tracking strategy
- Smarter algorithms

Looking forward to first collisions!

ATLAS EXPERIMENT