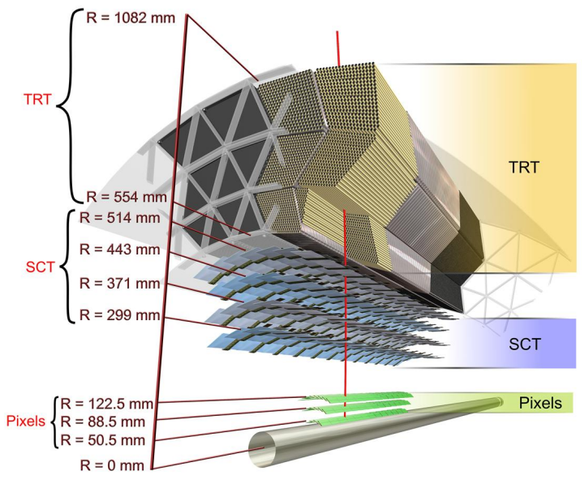
LHCC Poster Session - CERN, 4th of March 2015

Performance and development for the Inner Detector Trigger algorithms at ATLAS

A redesign of the tracking algorithms for the ATLAS trigger for Run 2 starting in spring 2015 is in progress. The ATLAS HLT software has been restructured to run as a more flexible single stage HLT, instead of two separate stages (Level 2 and Event Filter) as in Run 1. The new tracking strategy employed for Run 2 will use a Fast Track Finder (FTF) algorithm to seed subsequent Precision Tracking, and will result in improved track parameter resolution and faster execution times than achieved during Run 1. The performance of the new algorithms has been evaluated to identify those aspects where code optimisation would be most beneficial. The performance and timing of the algorithms for electron and muon reconstruction in the trigger are presented. The profiling infrastructure, constructed to provide prompt feedback from the optimisation, is described, including the methods used to monitor the relative performance improvements as the code evolves.

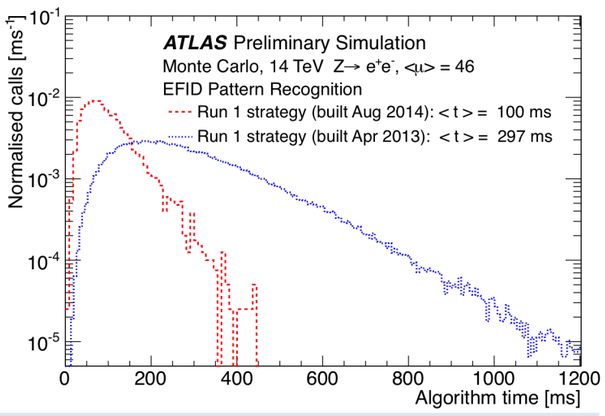
ATLAS - Inner Detector



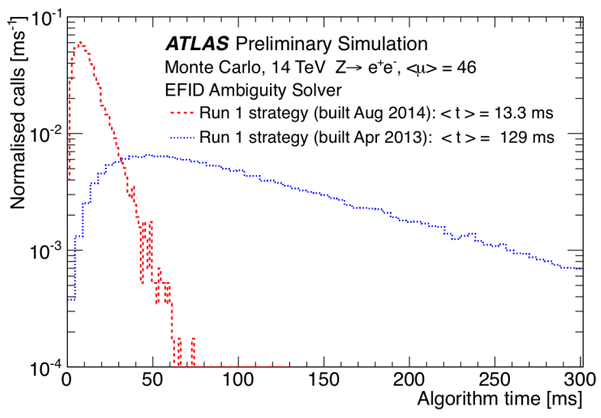
ATLAS – a general purpose detector for particle physics at the LHC at CERN.

- **Inner Detector** – a set of three complementary detectors at the center of the ATLAS detector designed for high precision tracking of particles in a 2 T axial magnetic field.
- **Pixel Detector** – high-resolution, Si-pixels, 3 barrel layers, 3 disks of endcaps.
- **Semiconductor Tracker** (SCT) – 4 barrel layers, 9 disks in each endcap, Si-microstrips.
- **Transition Radiation Tracker** (TRT) – outermost, 40000 Xe-gas detector straws.
- **Insertable B-layer** (IBL) – an additional pixel barrel layer inside the Pixel Detector (Run 2). The closest to the interaction point. Better reconstruction of tracks and primary and secondary vertices [1].

ATLAS code optimisation



- The code for the EF pattern recognition is three times faster than in Run 1 as a result of the optimisation.
- The timing optimisation will be essential to deal with the high pileup expectations for Run 2.
- For the Fast Track Finder, the profiling tool Callgrind is being used to determine the most often called, or computationally expensive parts of the code for optimisation.
- Even small and simple changes in the code can lead to significant reduction of the execution time of the algorithm. For instance, the precalculation of a constant variable before a *for*-cycle or avoiding precalculation of a variable, if there is a possibility the variable will not be used.
- Other optimization techniques to avoid branch misprediction/cache misses discussed in [5].



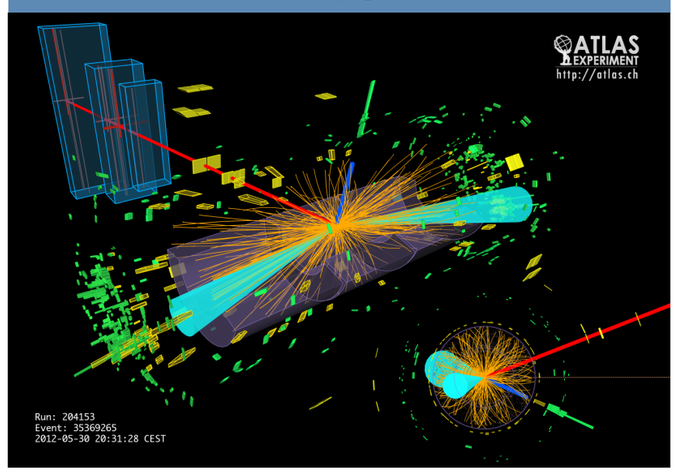
Run 1 vs Run 2 Trigger Architecture

Run 1 L1	Run 1 L2	Run 1 EF	Run 2 L1	Run 2 HLT
70 kHz	6.5 kHz	1 kHz	100 kHz	1 kHz
<2.5 μs	~75 ms	~1 s	<2.5 μs	~250 ms
pipelined ASIC	7000 cores	7000 cores	L1Topo upgraded CTP	Merge L2 + EF Fast Tracker (FTK) 20000 cores

- **Level 1** (L1) – pipelined hardware stage with ASICs, processes the information from the calorimeter and muon spectrometer to determine Regions of Interest (RoI) for further processing in the trigger.
- **High Level Trigger** (HLT) – consists of Level 2 and the Event Filter which are software triggers running on processor farms.
- **Level 2** (L2) – processes data at the full detector granularity within the RoIs from L1, performs calorimeter reconstruction and the earliest available Fast Tracking, and track-cluster matching.
- **Event Filter** (EF) – can run on the data from the full detector, runs accelerated versions of the offline reconstruction for final event selection, runs the Precision Tracking.

- For Run 2, the L1 stage will include a new Topological Processor [2] and an upgraded FPGA based Central Trigger Processor (CTP).
- Both **HLT stages have been merged** in to a single HLT stage to run on single CPU nodes. This simplifies the dataflow, with no need for network communication between the levels. Data for L2-accepted events **do not need to be requested twice**, repetition of reconstruction steps at each level can be avoided **reducing processing time** [3].
- Fast Tracker (FTK) is a new hardware stage to run after the L1, but before the HLT to reconstruct tracks with massively **parallel processing** [4].

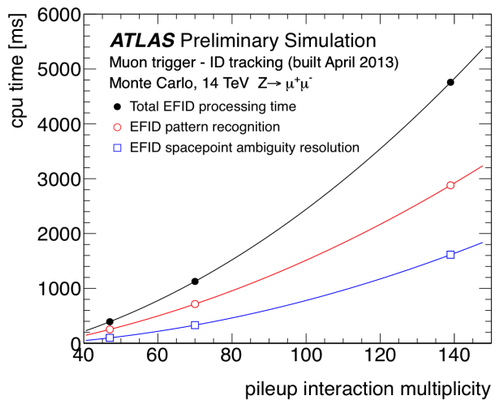
LHC upgrade



Machine parameter	Run 1	Run 2	Unit
Centre of mass energy	7	13	TeV
Luminosity	$7 \cdot 10^{33}$	$2 \cdot 10^{34}$	$cm^{-2}s^{-1}$
Bunch separation	50	25	ns
L1 input	20	40	MHz
Average pileup	21	~55	events / crossing

- The **upgraded LHC** will allow the measurement of the properties and branching ratios of the **Higgs boson**, and improved measurement of many Standard Model physics processes, and searches for **physics beyond the Standard Model** etc.

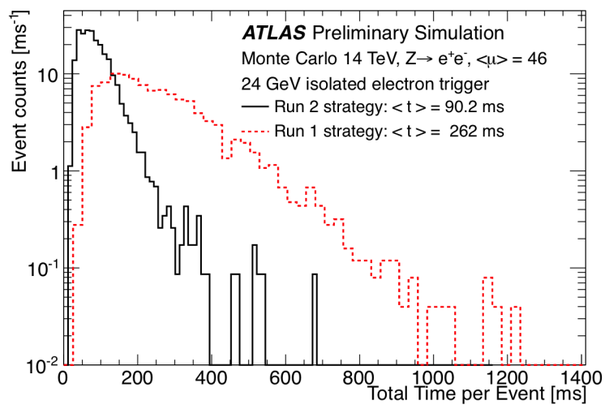
Pileup dependency

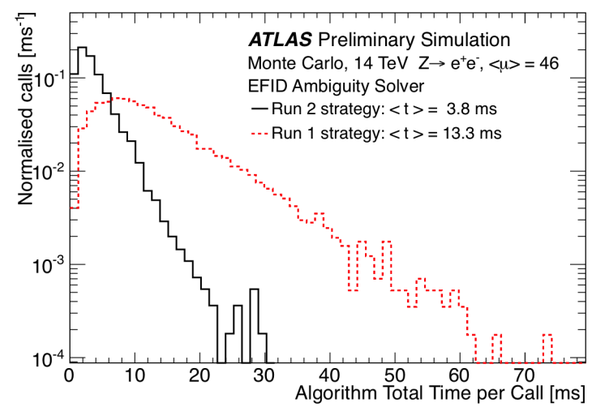


- With increasing pileup, the algorithms used in Run 1 do not scale linearly with the occupancy and will quickly become too costly to run in the HLT.
- The most costly stages in the EF precision tracking are the EF pattern recognition, and the Ambiguity Solver which resolves ambiguities between near by and crossing tracks.
- These long processing times have lead to optimisation of the tracking code for the Precision Tracking, and a redesign of the trigger tracking strategy to be used for Run 2.

Run 1 vs Run 2 Strategy

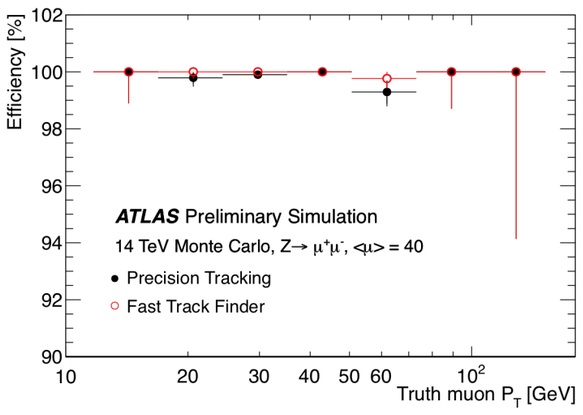
- In Run 2, the general approach of running a fast tracking stage followed by a more time consuming precision tracking stage as used in Run 1 will still be followed [5].
- During Run 1, the EF had to run the pattern recognition anew, even after the L2 tracking. With the optimised code this stage still takes around 100 ms. With the new single node HLT, this stage can be omitted, and instead use the pattern recognition from the Fast Tracking stage.
- The Precision Tracking stage for Run 2 will consist of the track fit and the resolution of ambiguities between close or crossing tracks (Ambiguity Solver).
- The FTK will also become available to seed the Precision Tracking in the future.
- The tracking has been modified to include the insertable B-layer.

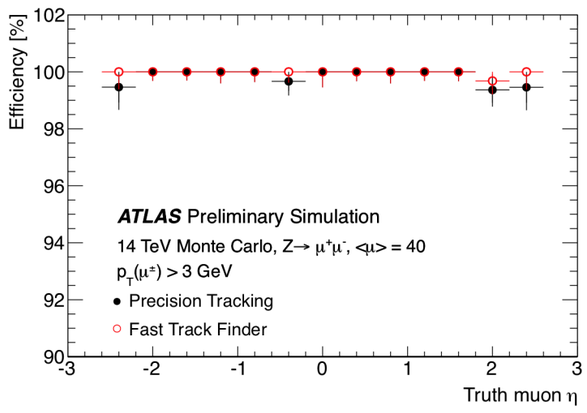




- **The Run 2 strategy is almost three times faster than the Run 1 strategy.**

Muon efficiency in Run 2





- The Fast Track Finder seed the Precision Tracking which performs additional rejection of fake tracks using the Ambiguity Solver algorithm, and refits the track.
- The efficiency is above 99 %, the ATLAS ID trigger performance has been preserved. The apparent small loss of the efficiency for the Precision Tracking at high eta is due to rejecting very poorly reconstructed, mismeasured, or split tracks which result from the looser requirements of the Fast Tracking which is optimised for efficiency rather than purity.
- Simulated data contain hits from the IBL.

Summary

- To deal with the significantly larger rates and occupancy in Run 2, the ATLAS Tracking Trigger code has been redesigned and significantly improved.
- Routine validation and testing frameworks are being used.
- Further detailed optimisation and profiling is underway.
- The IBL has been successfully installed.
- The first cosmics were detected by the IBL in July 2014. Since February 2015, cosmics with the Silicon detectors and the new tracking strategy are being taken.
- The new tracking is well on course for readiness as soon as data taking starts in May 2015.
- The presented plots are available in [6].

[1] Atlas Collaboration, CERN-LHCC-2010-013 ; ATLAS-TDR-19, CERN 2010
[2] Atlas Collaboration, ATL-DAQ-PROC-2012-041, CERN 2012
[3] Atlas Collaboration, CERN-LHCC-2013-018 ATLAS-TDR-023, CERN 2013
[4] Atlas Collaboration, CERN-LHCC-2013-007 ATLAS-TDR-021, CERN 2013
[5] Atlas Collaboration, ATL-DAQ-PUB-2013-002, CERN 2013
[6] Atlas Collaboration, ATL-COM-DAQ-2014-088, CERN 2014

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