Performance of the ATLAS Inner Detector Trigger algorithms in pp collisions at 7TeV

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Outline

- Introduction
 - the ATLAS Inner Detector and Trigger
 - the Inner Detector Trigger track reconstruction
- Inner Detector trigger performance
 - efficiencies (as a function of pileup)
 - track quality
 - determination of beamspot in the trigger
 - reconstruction timing as a function of pileup

ATLAS Inner Detector

The Pixel, SemiConductor Tracker (SCT) & Transition Radiation Tracker (TRT)

- high precision tracking and vertexing

TRT:

barrel and 2
endcaps of transition
radiation tubes,
~35 hits/track

SCT:

4 layers+2x9 discs
80 μm strips, back-to back
modules, 40mrad stereo angle

Pixels:

3 layers + 2x3 endcap discs
of pixels 50x400 μm
(majority)

The ATLAS Trigger

- Event selection in 3 levels
 - Hardware L1 (primary inputs muon & calo)
 - 2 software levels (L2 and Event Filter - EF) running on farms of commodity PCs
- forms a flexible, efficient and highly rejective trigger system
 - from 40MHz interaction rate to ~200 events/s on tape
- reconstruction in “Regions of Interest”
 - Rol identified by previous trigger level

- Track reconstruction in the Inner Detector
 - in L2 and EF

Tracking algorithms in the trigger

- a significant component of the signature identification and selection power of the High Level Trigger (HLT=L2+EF)
 - used in muon, electron, tau, b-jet, B physics selection and also for the determination of the beamspot in the online environment
- L2 custom algorithms to provide fast reconstruction in the 40ms budget
 - 2 tracking software packages
 - histogramming approach
 - combinatorial approach
 - large speed up comes from the identification of the primary interaction and reconstructing only tracks from track seeds compatible with it.
- EF - most of the reconstruction software shared with the offline (combinatorial)
 - longer time allowed for reconstruction (~4s)
 - adapted to run in the regions of interest RoI
 - configuration to deal with limited knowledge of detector calibration, when multiple implementations of certain reconstruction task exist the faster option chosen

Running conditions & luminosity

- The LHC operation in 2011
 - a very successful data taking (over 3 fb^{-1} so far)
- instantaneous luminosity increased significantly
 - number of bunches, bunch spacing
 - bunch current $\rightarrow$ multiple interactions
- increasingly demanding environment for the track reconstruction
 - the mean number of interactions (BCID average) has doubled until September

Pileup in a picture

- an example $Z \rightarrow \mu\mu$ event on top of 10 pileup interactions
- identification of primary interaction is an important constraint for reconstruction which reduces the number of track candidates and may speed up the trigger reconstruction considerably
- reconstruction settings need to be tightened as the levels of pileup increase

Evaluating the performance

- with respect to the offline reconstruction (in the following electron and muon)
 - efficiency and track parameters should be close to the offline
- special monitoring triggers for unbiased estimation
 - done for each signature and important trigger thresholds
 - different signal, reconstruction settings and in L2 it may be also a different algorithm (histogramming or combinatorial)
- common track selection in the plots
 - a track associated with a reconstructed offline object
 - ($|\eta| < 2.5$, $N_{\text{pixel hits}} > 0$, $N_{\text{SCT clusters}} > 5$, $|z_{\text{offlineVertex}}| < 200\text{mm}$, with respect to the offline vertex: $|a_0| < 1.5\text{mm}$, $|\Delta z \sin\theta| < 1.5\text{ mm}$)

Trigger Tracking performance with muons

- L2 and EF ID tracking reconstruction efficiency wrt offline muon tracks that are located inside monitoring (unbiased) triggers with a threshold 20GeV in transverse momentum
 - very high efficiency for both trigger levels
 - over 99% in the L2, 100% in the EF
- a similar plot from last year's data
 - stability of the performance in time

Track quality

- Residuals of the inverse of the track transverse momentum between ID trigger track and a matching offline ID track.
- The trigger reconstruction provides tracks with a quality close to the offline
- Small differences between trigger and offline track parameters are expected as a consequence of a simplified material model and different pattern recognition algorithms in case of L2 and partial access to calibration for both trigger levels

Tracking efficiency as a function of pileup

- Muon tracking efficiency as a function of number of offline vertices reconstructed in the event.
- Robust behaviour with increasing pileup.
 - A small inefficiency in L2 related to misidentification of the primary interaction and it is being addressed in algorithm tuning for higher pileup

Trigger tracking performance - electrons

- Tracking efficiency wrt offline electron candidates as a function of p_T
 - monitoring trigger with a transverse energy threshold 22GeV
- Efficiency to find a hit on the EF ID track in the innermost layer of the pixel detector when a hit is expected and found by the offline reconstruction. A high efficiency is important for signatures which perform rejection on the basis of a non-existent hit in the innermost pixel layer (e.g. tighter electron selection).

Whether an innermost layer hit is expected depends on the knowledge of the detector status which can be largely deduced from data and is further refined by the conditions information for the offline.

Online Beamspot measurement

- L2 track and vertex reconstruction used for online determination of the beam spot
 - the actual value distributed to the online farm and used for optimal performance of b-tagging
 - monitoring of the LHC operation

CPU consumption

- Tracking is the most CPU intensive application in the HLT
- sensitive to the increasing number of interactions
- the trend monitored in data taking
- predictions when the farm capacity will saturate w/o optimizations
 - tightening the reconstruction settings
 - algorithm optimizations

Reconstruction in RoI

Reconstruction in full detector

Summary

- Inner Detector Tracking is an essential component of the HLT event selection of ATLAS
- it provides track reconstruction with a very high efficiency and a very good track quality close to the offline tracking
- the performance is stable in the challenging conditions of increasing number of interactions
 - adjustments and further developments to provide optimal performance in terms of physics and also technical aspects (execution time)
- more challenges on the way towards the design luminosity