Performance of the ATLAS Inner Detector Trigger Algorithms in p-p collisions at $\sqrt{s} = 900$ GeV and $\sqrt{s} = 7$ TeV

Andrea Ferretto Parodi for the ATLAS Collaboration

DESY, Notkestraße 85, 22607 Hamburg, Germany

DOI: will be assigned

The ATLAS Inner Detector trigger algorithms have been running online during data taking with proton-proton collisions at the Large Hadron Collider (LHC) in December 2009 and spring 2010 at the centre-of-mass energies of 900 GeV and 7 TeV.

The Inner Detector [1] is the ATLAS subdetector closest to the interaction point and provides precise tracking and momentum measurement of particles created in the collisions. It is composed of the Pixel Detector (silicon pixels), the SemiConductor Tracker (SCT) (silicon stereo strips) and the Transition Radiation Tracker (TRT) (straw drift tubes). The whole detector is immersed in a 2T solenoid magnetic field.

The ATLAS trigger [1], designed to reject uninteresting collision events in real time, performs the online event selection in three stages, called Level-1 (L1), Level-2 (L2) and Event Filter (EF). L1 is hardware based and has access to summary event informations from Calorimeters and Muon Spectrometer, and defines one or more Regions-of-Interests (RoIs), geometrical regions of the detector, identified by $\eta$ and $\phi$ coordinates, containing interesting physics objects. L2 and EF (globally called High Level Trigger, HLT), are software based and can access to informations from all the subdetectors, Inner Detector included. RoI based reconstruction reduces the data access (to $\sim 2\%$ of the entire event) and also the processing time by performing the reconstruction only in the region relevant for the trigger decision. Globally, the ATLAS trigger reduces the acquisition rate to about 200 Hz, down from a proton-proton bunch crossing rate of 40 MHz.

HLT tracking algorithms run on a farm of commercial CPUs, and their basic task is to reconstruct trajectories of charged particles, used for the definition of many trigger items (high $p_T$ leptons, tracks coming from $\tau$ decays, jets or $B$-hadrons decays) and for the determination of the online beam spot (more details in the following). L2 is based on fast custom algorithms, while EF is based on offline tools, adapted to take into account trigger requirements.

Performance of the HLT algorithms in terms of tracking efficiency is measured w.r.t. offline reconstructed tracks, requiring a one-to-one geometrical best matching ($\Delta R = \sqrt{\Delta \eta^2 + \Delta \phi^2}$) of a reconstructed online track with an offline one. For this kind of study only reconstructed tracks passing a set of selection criteria are considered: at least 1 pixel hit and 6 SCT clusters, $|\eta| < 2.5$, $|z_0| < 200$ mm, $|d_0| < 1.5$ mm (both impact parameters $z_0$ and $d_0$ are calculated w.r.t. reconstructed offline primary vertex).

The data used in the following for these performance studies are taken from LHC stable beam collisions and Inner Detector components and magnetic solenoid fully operational. In addition,
comparisons between data and non-diffractive minimum bias Monte Carlo (MC) simulated events are presented.

The RoI selection mode previously described is designed to work with higher energy physics objects, while data taken at $\sqrt{s} = 900$ GeV contain mostly soft events and there was no statistics to collect sufficient number of tracks form a RoI-based trigger. Therefore during 900 GeV collisions HLT algorithms worked in FullScan mode, retrieving data from the whole Inner Detector. This mode of operation is adopted for the beam spot determination and for online selection of $B$-physics decay channels.

Comparison between number of Si hits w.r.t. MC/offline and efficiency vs $p_T$ for 900 GeV collisions data are shown in Fig. 1-4 for both L2 and EF algorithms.

Fig. 1 and Fig. 2 show an excellent agreement between data and MC/offline; complementary plots of L2 SCT hits and EF pixel hits are not presented, but show an agreement at the same level.

Fig. 3 and Fig. 4 prove very good tracking efficiency w.r.t. offline. Fig. 3 shows also an excellent agreement between data and MC performance.

More detailed results about 900 GeV tracking performance can be found in [2].

For the reasons previously discussed, collision data taken at $\sqrt{s} = 7$ TeV, with increased luminosity, represent the first opportunity to test on real data the performance of RoI-based selections.
In the following, tracking efficiency for muon and jet selection are presented. Track reconstruction for muons and jets starts from different RoIs (respectively $\Delta \eta, \Delta \phi = 0.2$; $\Delta \eta, \Delta \phi = 0.4$). For muons, reconstructed tracks are then matched to Muon Spectrometer, while for jets a precise estimate of track parameters at the perigee is crucial to identify tracks coming from secondary vertices for jet flavour tagging purposes.

Fig. 5-6 show muon and jet tracking efficiency vs $p_T$ during collision data taking at $\sqrt{s} = 7$ TeV. In both selections HLT tracking algorithms show very good reconstruction efficiency.

Figure 5: L2 and EF muon tracking efficiency vs $p_T$ w.r.t. offline Figure 6: L2 jet tracking efficiency vs $p_T$ w.r.t. offline

As already mentioned, L2 tracking is used in the online determination of the beam spot, i.e. the transverse position of LHC luminous region, crucial for all the selections which require a precise estimate of the interaction point (jet flavour tagging, monitoring of beam profile). L2 algorithms allow an estimation of the beam spot mean position using the transverse distribution of online reconstructed primary vertexes. Online primary vertexes are obtained by fitting together all the L2 tracks reconstructed in FullScan mode.

Fig. 7 show the $xy$ distribution of online primary vertexes during collision data taking at $\sqrt{s} = 7$ TeV: beam spot mean position and width are extracted by a gaussian fit of this distribution. Excellent agreement has been observed w.r.t. offline beam spot measurement.

Figure 7: $xy$ distribution of the online L2 vertexes

ATLAS HLT algorithms have been successfully running online at the LHC since December 2009, at a centre-of-mass energy of 900 GeV and 7 TeV: performance studies w.r.t offline tracks and MC simulations are proven to be in excellent agreement. Moreover the performance of reconstructing tracks in the trigger system has been studied over time and changing beam conditions, producing very encouraging results. Furthermore L2 tracks have been used to determine online the LHC luminous region.

References