Performance of the ATLAS inner detector trigger algorithms in p-p collisions at $\sqrt{s} = 900$ GeV and $\sqrt{s} = 7$ TeV

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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 2 T 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 the calorimeters and the muon spectrometer, and defines one or more regions of interest (RoIs), geometrical regions of the detector, identified by η and ϕ coordinates, containing interesting physics objects. L2 and the EF (globally called high level trigger, HLT) are software based and can access information from all subdetectors, including the inner detector. 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 τ 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 the 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. the reconstructed offline primary vertex).

The data used in the following for these performance studies are taken from LHC stable beam collisions with 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. At this stage, there was not enough statistics of collected tracks from an RoI-based trigger. Therefore, during 900 GeV collisions the HLT algorithms worked in *full scan* 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.

Comparisons between the 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.

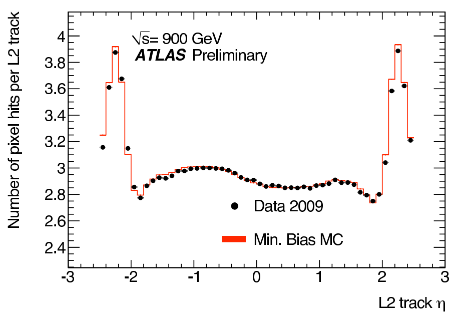

Figure 1: Average number of pixel hits per L2 track (data and MC).

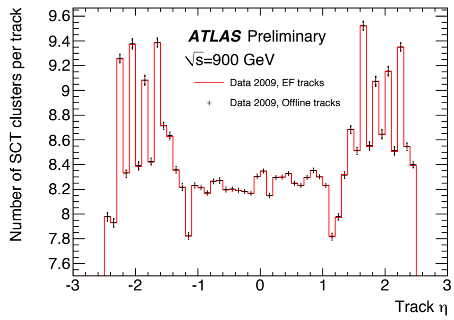

Figure 2: Average number of SCT hits per EF track (data and offline).

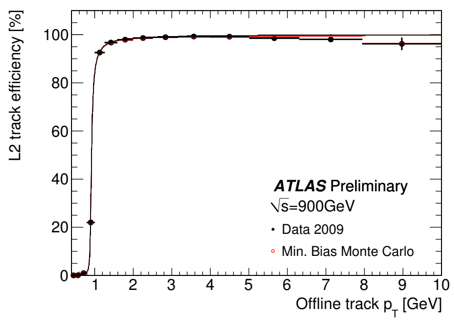

Figure 3: L2 tracking efficiency vs p_T w.r.t. offline (data and MC).

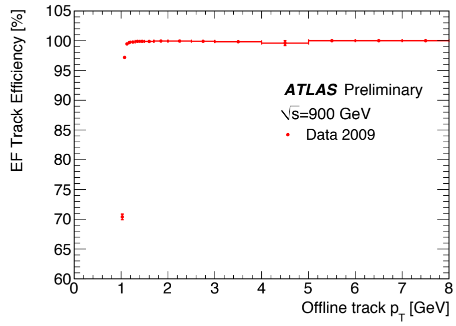

Figure 4: EF tracking efficiency vs p_T w.r.t. offline (data).

Figure 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 agreement at the same level. Figure 3 and Fig. 4 prove very good tracking efficiency w.r.t. offline. Figure 3 shows also excellent agreement between data and MC performance. More detailed results about 900 GeV tracking performance can be found in [2].

For the previously discussed reasons, collision data taken at $\sqrt{s} = 7$ TeV, with increased luminosity, represent the first opportunity to test the performance of RoI-based selections with real data.

In the following, the tracking efficiencies for muon and jet selections are presented. The track reconstruction for muons and jets starts from different RoIs ($\Delta\eta$, $\Delta\phi = 0.2$ and $\Delta\eta$,

$\Delta\phi = 0.4$, respectively). For muons, the reconstructed tracks are then matched to the muon spectrometer, while for jets a precise estimate of the track parameters at the perigee is crucial to identify tracks coming from secondary vertices for jet flavour tagging purposes.

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

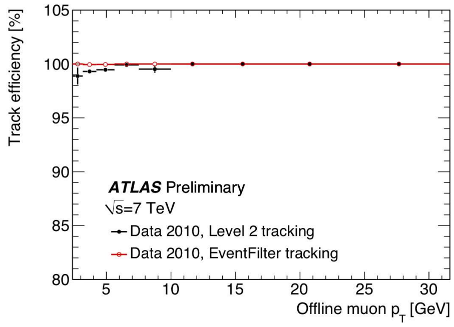

Figure 5: L2 and EF muon tracking efficiency vs p_T w.r.t. offline.

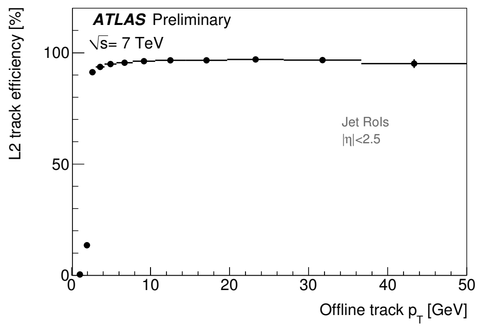

Figure 6: L2 jet tracking efficiency vs p_T w.r.t. offline.

As already mentioned, L2 tracking is used in the online determination of the beam spot, i.e. the transverse position of the 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 for an estimation of the beam spot mean position using the transverse distribution of online reconstructed primary vertices. Online primary vertices are obtained by fitting together all the L2 tracks reconstructed in full scan mode.

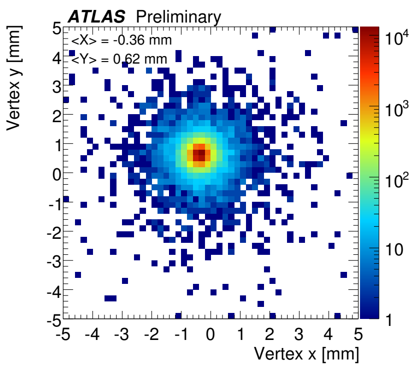

Figure 7: xy-distribution of the online L2 vertices.

Figure 7 shows the xy-distribution of online primary vertices 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 measurements.

ATLAS HLT algorithms have been successfully run online at the LHC since December 2009, at a centre-of-mass energy of 900 GeV and 7 TeV: it was shown that performance studies w.r.t offline tracks and MC simulations are 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 position of the LHC luminous region.

References

[1] ATLAS Collaboration, "The ATLAS Experiment at the CERN Large Hadron Collider," JINST 3 (2008) S08003.

[2] ATLAS Collaboration, "Performance of the ATLAS Inner Detector Trigger algorithms in p-p collisions at $\sqrt{s} = 900$ GeV," ATLAS-CONF-2010-014 (2010).