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The Design and Performance of the ATLAS jet trigger

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Abstract. The ATLAS jet trigger, in combination with other triggers, provides an important ingredient to studies of Standard Model physics and searches for new physics at the LHC. The ATLAS jet trigger system has undergone substantial modifications over the past few years of LHC operations, as experience developed with triggering in a high luminosity and high event pileup environment. In particular, the region-of-interest (ROI) based strategy has been replaced by a full scan of the calorimeter data at the third trigger level, and by a full scan of the level-1 trigger input at level-2 for some specific trigger chains. Hadronic calibration and cleaning techniques are applied in order to provide improved performance and increased stability in high luminosity data taking conditions. In this presentation we describe the structure and performance of the jet trigger in recent data taking conditions.

1 Overview

The ATLAS [1] trigger performs a first online selection of interesting physics events from the large event rate produced at the LHC. Given the high frequency of collisions (up to 40 MHz) and large number of interactions per bunch crossing, the trigger system has to be highly flexible in order to provide unbiased efficiencies for a wide variety of physics analyses while providing a fast rejection of uninteresting events.

The ATLAS trigger [2] is organized in three levels: the first (L1) is hardware based, while the two software based (L2 and EF) form the High Level Trigger (HLT). The system is designed to work in a Region of Interest (RoI) based approach, where the second level trigger (L2) is limited to measuring signals in a narrow detector region around selected L1 objects. Only the last HLT level, the Event Filter (EF), has the potential to access the full event.

The three trigger levels bring the accept rate down from the 40 MHz collision rate to the final 200 Hz for offline storage, of which about 25% comes from jet signatures.

1.1 The jet trigger

The jet trigger is the primary means of selecting events with high transverse energy (E_T) jets. This is the first step for jet physics analyses, which contribute strongly to the main ATLAS physics goals (QCD, top, Higgs, etc..). Jets are identified at L1 using a sliding window algorithm based on towers formed from the energy sum of all layers of the calorimeter in the central region $|\eta| < 3.2$ (central jets) or in the forward region $3.2 < |\eta| < 5.0$ (forward jets). Identified L1 jets are then used to define the RoI,

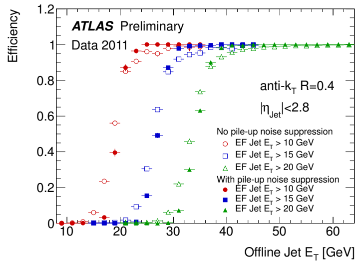

Figure 1. Efficiency of the EF inclusive jet trigger for three choices of threshold. The EF jet conditions were applied to random-triggered events. The efficiency is plotted as a function of the offline calibrated jet E_T for jets with central rapidities and in two different data-taking scenarios: before (empty markers) and after (full markers) pile-up noise suppression was applied to EF jets.

where a more sophisticated L2 jet finding is performed. If the event is accepted at L2, data are read at EF from the full calorimeter (full scan) and jets are reconstructed with the anti-*kt* algorithm [3], as in the offline reconstruction. Events are selected by requiring a minimum E_T and jet multiplicity. More complex discriminants (e.g. dijet mass) can also be used at HLT. A menu of jet signatures is defined, collecting all available configurations of the jet trigger.

2 Performance

The ATLAS jet trigger functioned efficiently during 2011 and 2012 data-taking and was used to collect a total integrated luminosity of about 25 fb^{-1} of proton-proton collision data. The increasing instantaneous luminosity (up to

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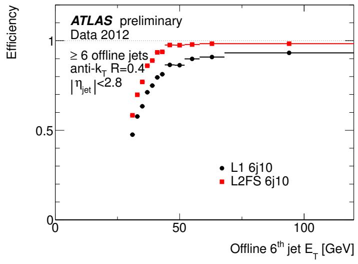

Figure 2. Efficiency for L1 and L2FS jets to satisfy a six jet trigger in events where at least six jets have been identified offline, in the central region of the detector. The efficiency is plotted as a function of the sixth offline jet E_T.

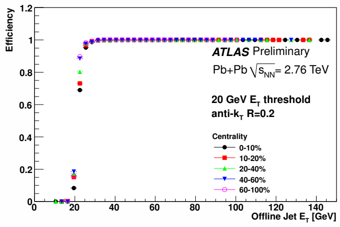

Figure 3. Efficiency of the primary HLT jet trigger used for the 2011 lead-lead run, for different centralities of collisions.

$8\times10^{33}\ cm^{-2}s^{-1}$) implied up to 35 interactions per bunch-crossing (pile-up), harshening the conditions for triggering. The performance was also affected by the granularity, resolution, calibration and algorithm used at the different levels. With the goal of providing well-understood high-efficiency triggers, efficiencies are evaluated in collected data. In addition, technical developments to cope with increasing pile-up were tested and implemented.

Pile-up and noise suppression

Starting from May 2011, noise suppression and pile-up correction were applied. Only calorimeter cells with energy depositions above a certain threshold (depending on pile-up conditions) are considered at HLT. This made it possible to keep trigger rates within the bandwidth as pile-up conditions harshened. Fig. 1 shows the jet selection efficiency of EF triggers with and without noise suppression. The overall 99% efficiency point improved by $\sim 5\ GeV$ by suppressing the pile-up noise.

Efficiency for multijet triggers

The RoI based procedure leads to efficiency losses in multi-jet events due to the geometrical differences between the square jets from the sliding window algorithm used at L1 and the pseudo-circular ones from anti-*kt* algorithm used in offline reconstruction. Therefore the possibility of using the anti-*kt* algorithm by performing a full scan with reduced granularity at L2 (L2FS) was introduced in 2012, with the aim of reducing the inefficiency. The improvement in efficiency for multijet triggers from using the full

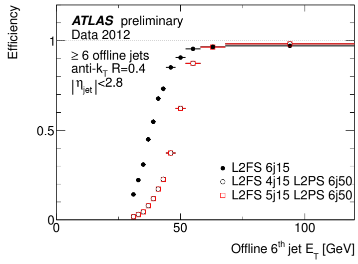

Figure 4. Efficiency for L2FS and L2PS jets to satisfy a six jet trigger in events where at least six jets have been identified offline.

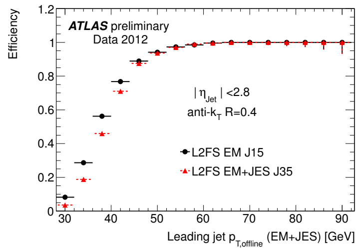

Figure 5. Efficiency for L2FS jets at electromagnetic (EM) calibration scale and hadronic (EM+JES) calibration scale.

scan is shown in Fig. 2. The gain in efficiency is achieved due to the use of the anti-*kt* algorithm and the removal of the RoI constraint.

Efficiency for jet triggers in heavy ion collisions

Jet triggers for heavy ion collisions were designed to recover the original jet energy without being affected by the large contributions from underlying events. An iterative baseline subtraction technique was implemented for this purpose. The jet trigger performance in lead-lead collisions is shown in Fig. 3; the sharp trigger efficiency turn-on is stable for all centrality scenarios, indicating that the jet trigger is not affected by the amount of energy from underlying events.

3 Developments

During 2012 data-taking a L2 partial scan (L2PS) was tested. L2PS jets are built by using the anti-*kt* algorithm on the calorimeter cells only from those regions of the detector in which significant jet activity was found by the L2 full scan. By exploiting the full granularity of the calorimeter cells, L2PS jets provide better energy resolution than L2FS jets, allowing for a more efficient rejection, as shown in Fig. 4.

An additional development tested during 2012 data-taking is the hadronic calibration of L2FS jets. Fig. 5 shows the efficiency for L2FS jets at hadronic calibration compared with L2FS jets at electromagnetic scale. A sharper turn-on is achieved with hadronic calibration allowing for more efficient rejection.

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