Performance and Improvements of the ATLAS Jet Trigger System

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Abstract

The ATLAS jet trigger is the primary means for selecting energetic jets produced in LHC collisions. The ATLAS trigger system has a three level structure, and was designed based on the concept of Regions Of Interest (RoI), wherein only areas of the detector around interesting objects identified at the first level are accessed at the higher levels. The first implementation of the ATLAS jet trigger was entirely RoI based. This was changed in 2011 with the addition of the possibility to access information from the full calorimeter at the Event Filter and similarly in 2012 for the second level. This change enhances the flexibility and versatility of the system as well as improving efficiencies in multi-jet events. This paper presents the performance of the jet trigger in 2011 and an overview of the new features available for 2012.

Key words: ATLAS, CERN, LHC, trigger, jet.

1. Overview

With the LHC colliding proton bunches every 50 ns and up to 40 proton-proton interactions per bunch crossing, the ATLAS [1] trigger system has to be highly flexible in order to maintain an unbiased efficiency for a wide variety of physics studies whilst providing a fast rejection of uninteresting events. The ATLAS jet trigger [2] is the primary means of selecting events with high transverse energy (E_T) jets and its good performance is fundamental in achieving the physics goals of ATLAS.

The ATLAS trigger system is divided into three levels, the first (Level-1 or L1) being hardware based, with a $2.5\,\mu s$ latency, and the following two (collectively called the High Level Trigger or HLT) being software based with larger processing times. This system was designed to work in a Region of Interest (RoI) based approach, wherein the second level trigger (L2) was limited to measuring signals in a narrow detector region around selected L1 objects and only the last HLT level, the Event Filter (EF), had the potential to access the full event.

The production of high energy quarks or gluons in LHC collisions are detected at ATLAS as collimated energy deposits in the calorimeter (jets). Such jets are identified at L1 using a sliding windows algorithm based on towers formed from the energy sum of all layers of the calorimeter over the full calorimeter coverage. Identified jets are then used to "seed" the more sophisticated L2 and EF jet finding in the surrounding RoIs. These are limited to finding one jet per RoI. This methodology can lead to efficiency losses in multi-jet events due to the differences in the jet finding definition used by the L1 trigger and that used in the offline reconstruction (and hence differences in the splitting and merging of near-by jets). A re-design of the jet trigger has happened in 2011, with the implementation of the ability to study the full calorimeter (full scan) at EF, and in 2012 with the further introduction of the option of a full scan at L2 (also referred to as L1.5). It is now also possible to run a variety of jet algorithms, both at L2 and at EF, and hence to reduce as much as possible the biases for physics studies.

2. Performance in 2011

The jet trigger functioned exceptionally well in 2011 and was used throughout data taking to collect events containing jets corresponding to integrated luminosities of $\sim 5\,\mathrm{fb}^{-1}$ of proton-proton and $\sim 160\,\mu\mathrm{b}^{-1}$ of lead-lead collision data. Figures 1 and 2 illustrate some examples of the performance of the new features implemented in 2011.

Figure 1 shows the jet selection efficiency of the EF trigger using the full calorimeter information to construct anti-k_T jets [3] across the entire calorimeter coverage (the same jet algorithm and coverage as is used in the majority of offline analyses). This trigger has an excellent efficiency relative to the offline jet finding. Events studied in this figure were preselected using a random trigger at L1/L2. The same system can also be used for events preselected by the normal L1/L2 jet trigger. The ability to be preceded by random L1/L2 trigger stages enables the collection of low E_T jets, which would not otherwise have been possible due to the poor L1 resolution in the low energy region. Figure 2 shows the EF performance in lead-lead collisions. These events were selected using the EF full scan system where jets produced in lead-lead heavy ion collisions were reconstructed using baseline subtraction techniques to recover the original jet energy without the large contributions expected from the underlying event. This technique enabled the maintenance of a sharp trigger efficiency "turn-on" even in events with several TeV of underlying event.

3. New features for 2012

A very complete and versatile set of triggers is now available for physics analyses, including the use of the anti-k_T jet

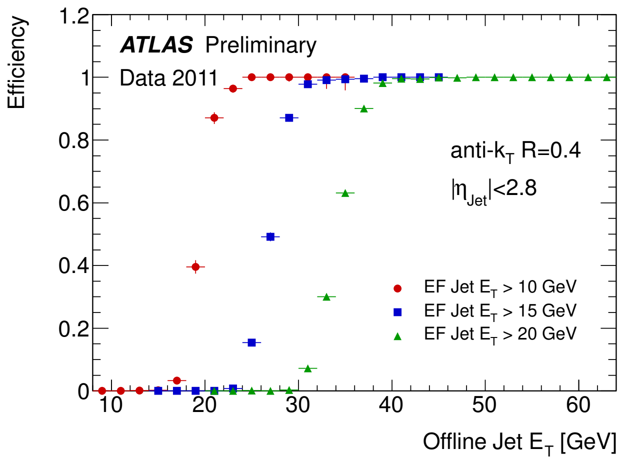

Figure 1: The efficiency for anti-k_T jets with distance parameter (R)=0.4 to satisfy the Event Filter (EF) inclusive jet trigger for three choices of threshold. The EF-jet conditions were applied to random-triggered events. The efficiency is plotted as a function of the offline calibrated jet E_T for jets with central rapidities. (Jet energies in the trigger are measured at the electromagnetic scale, whereas offline jet energies are shown at hadronic scale.) From [4].

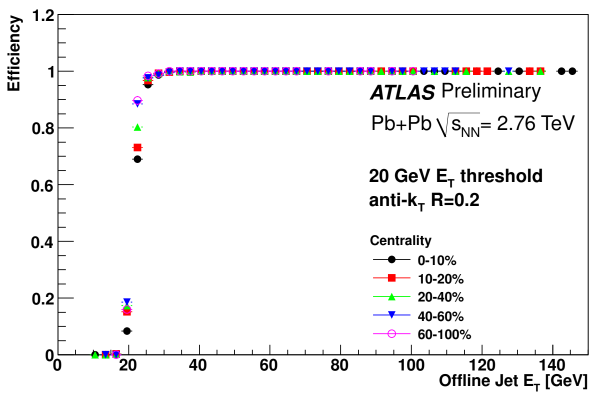

Figure 2: The efficiency of the primary HLT jet trigger used for the 2011 heavy ion run. The efficiency was evaluated using the data from the Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV corresponding to an integrated luminosity of 2.4 μb^{-1}. The HLT trigger algorithm is anti-k_T R=0.2 with a threshold of E_T=20 GeV. The HLT trigger algorithm is seeded by events with total transverse energy greater than 10 GeV identified by the Level 1 trigger. Efficiency is evaluated with respect to offline anti-k_T R=0.2 jets. Both the offline and HLT jets are at the electromagnetic scale. The efficiency is shown for different centralities of collisions, where centrality is characterised by the amount of energy in the forward calorimeters. From [4].

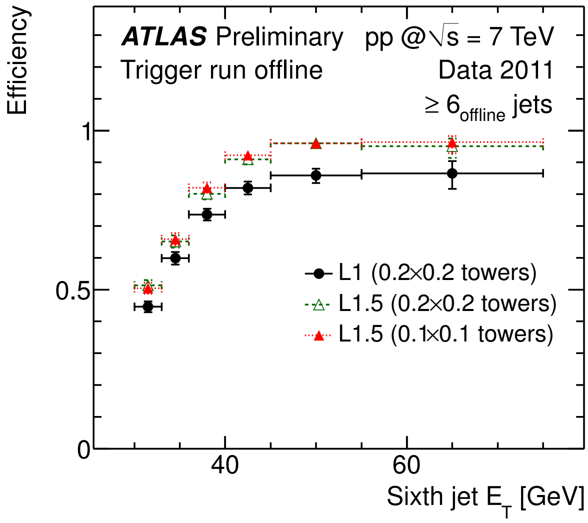

Figure 3: The efficiency for L1 (0.8x0.8 sliding window) and L1.5 (anti-k_T R=0.4) jets to satisfy a six jet trigger (trigger run offline) in events where at least six anti-k_T R=0.4 jets have been identified offline with $|\eta|$ <2.8, E_T >30 GeV (these events were pre-selected using a four jet trigger). The efficiency is plotted as a function of the sixth offline jet E_T. From [4].

algorithm, dedicated H_T ($\sum E_T$) and boosted heavy object triggers at L2. Each of these exploits the L1.5 system in ways that would not have been possible using the RoI mechanism. The use of anti-k_T enables the L2 jet finding to identify jets in the same way as the majority of physics analyses and hence reduces trigger biases. H_T is defined on an event-by-event basis and thus benefits from access to the entire event and the use of jet finding algorithms which are the same as those used offline. If a heavy unstable object is produced with substantial transverse momenta (boosted) then its decay products will become collimated and result in a wide energy deposit that is often not well contained in a single RoI. The removal of the RoI constrain allows the use of dedicated jet finding with large distance parameters. Figure 3 compares the efficiency for the L1 and L1.5 systems to identify 6 jets in events with at least 6 jets found by the offline jet finding (these events were preselected using a 4-jet trigger). It is evident that the use of L1.5 recovers efficiency lacking at L1. This gain in efficiency is achieved due to the use of the same algorithm as used for offline analysis (anti-k_T).

Further improvements to the jet trigger system, not discussed in detail here, allow the energies of identified jets to be better calibrated, and prevent temporary large increases in the trigger rates due to detector effects.

References

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