ATLAS high-level calorimeter trigger algorithms performance with first LHC *pp* collisions

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DOI: http://dx.doi.org/10.3204/DESY-PROC-2010-01/jez

After the commissioning phase with beams at SPS injection energy (450 GeV), the LHC [1] recently started the physics program with 7 TeV collisions. Consequently, the ATLAS detector [2] also entered its operation phase recording these collisions.

The task of the ATLAS trigger is to select 200 events out of 40 millions every second. It starts with the hardware-based trigger, the Level 1 (L1), which finds Regions of Interest (RoI's) using coarse information from the fast muon chamber or calorimeter. These RoI's are used as starting points for the two software based trigger levels: the Level 2 (L2), which operates only in the RoI's but uses full detector granularity, and the Event Filter (EF), which can explore the whole detector using full granularity information. The L2 and the EF are altogether referred to as the High Level Trigger (HLT) system. The L1 output rate is roughly 75 kHz with a latency of 2.5 μs. At L2, the output rate is decreased to 3 kHz with 40 ms latency and finally the EF output is 200 Hz and the time budget is roughly 4 s per event.

All trigger algorithms share a common data preparation step, optimized for fast processing. During the initial data taking period while the nominal luminosity is not attained, the trigger system accepts most of the incoming events and the bulk of the selection is performed only by the L1. The HLT is functional, but its decision is used for event rejection only when the maximum recording rate is reached. The trigger menus are composed of several signature subtriggers specialized in selecting different event types. Those using calorimeter data are presented in this paper.

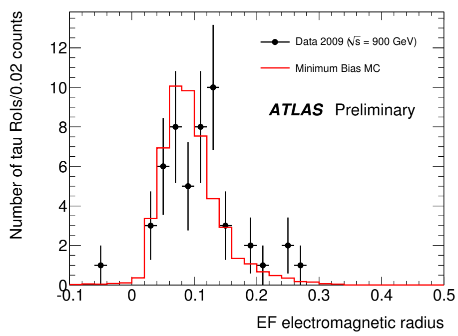

Figure 1: Candidate τ jet EM radius distribution at EF. Dots are 2009 collision data, solid line is MC expectation.

For example, the τ trigger is designed to select hadronic decays of the τ lepton, characterized by the presence of 1 or 3 $\pi^{\pm}$ accompanied by a ν and possibly π^0's. At L1, the τ trigger uses the electromagnetic (EM) and hadronic calorimeter to find transverse energy (E_T) deposits which pass the threshold (lowest is 5 GeV). At L2, selection criteria are applied using tracking and calorimeter based information. This takes advantage of calorimeter cluster confinement and low track multiplicity to discriminate τ's from the multi-jet background. Exploiting the same characteristics, the EF uses different selection criteria for single-prong (1 $\pi^{\pm}$) and multi-prong (3 $\pi^{\pm}$) decays in more refined algorithms which are almost identical to the offline reconstruction algorithms.

The distributions of the important observables obtained from data during 2009 have been compared with the non-diffractive minimum bias Monte Carlo and show reasonable agreement given the limited statistics. Fig. 1 presents a measure of the shower lateral size in the EM calorimeter (EM radius) calculated by the EF as the energy-weighted average cell distance from the cluster barycenter (obtained after weighting the position of each cell by its energy). It is an important discriminating variable because τ jets are more confined than QCD jets. Note that in all figures the MC has been normalized by the number of entries in data sample.

The ATLAS jet trigger is based on the selection of high hadronic E_T depositions. If a L1 jet candidate passes a given E_T threshold (lowest is 5 GeV), the L2 jet trigger continues by requesting calorimeter data around the L1 jet RoI position and runs an iterative cone algorithm with fixed radius. The EF jet algorithm is based on the offline reconstruction algorithm using calorimeter towers projecting towards the collision centre.

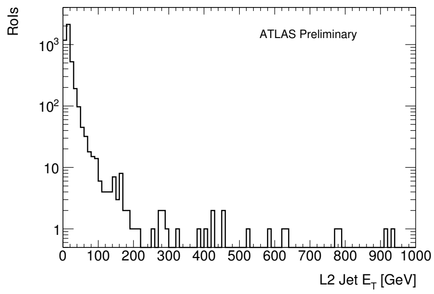

Figure 2: Transverse energy of jets measured at L2 in 900 GeV collisions.

The most important variable for the jet trigger is the transverse energy. The E_T measured in both the EM and the hadronic calorimeter is added up to obtain the jet trigger E_T. The distribution of the jet E_T obtained at L2 is presented in Fig. 2. Some clearly unphysical jets (with more than half the beam energy) are related to the detector noise. Jet clean-up procedures are being established by the collaboration to deal with such issues.

The aim of the e/γ trigger is to select events with electrons or photons in the final state. At L1, a threshold is set on minimal E_T deposit in the electromagnetic calorimeter (the lowest was 3 GeV in the commissioning period). At L2, fast algorithms for calorimeter reconstruction are run and fast tracking is used to reconstruct electron L2 objects. Already at this level it is possible to use the fine granularity of the first layer of the EM calorimeter to distinguish between primary and secondary γ's coming from π^0. At the EF, reconstruction algorithms very similar to those used offline are applied.

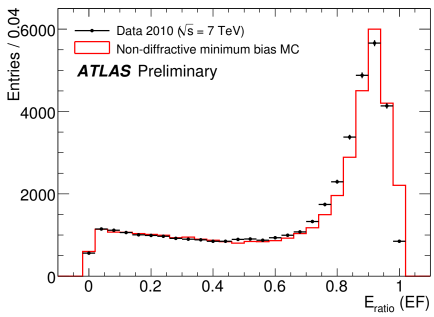

Figure 3: Distribution of photon E_{ratio} at EF. Dots are 7 TeV collision data, solid line is MC expectation.

Nice agreement with Monte Carlo expectation is observed with both 900 GeV and 7 TeV collisions. An important e/γ shower shape variable is called E_{ratio}, which is the fractional difference between the first and second highest energetic cell in the first calorimeter layer (Fig. 3 shows its distribution). For single γ's it peaks around 1, while for γ pairs from π^0 decays it is close to 0.

The ATLAS detector can be triggered also by events with considerable missing E_T or with a large amount of total E_T deposited in the calorimeters. That could play a crucial role in new physics discoveries such as dark matter candidates. The vector (missing E_T) and scalar (total E_T) sum of E_T are computed at L1 from all calorimeter elements. At L2, missing E_T is computed by adding the vector and scalar sums of all reconstructed muon momenta to the calorimetric measurement done at L1. Note that L2 is presently not configured to access L2 energy measurements due to strong network restrictions to read-out the whole detector at the full L2 input rate. At the EF, the total E_T and missing E_T are again recalculated with more precise input from the whole detector. Like for the other calorimeter triggers, no significant deviation from the MC expectation was observed in collision data. Figure 4 presents the comparison of minimum bias Monte Carlo and missing E_T measured at the EF from 7 TeV collisions. More details about the missing E_T trigger performance can be found in [3].

In order to guarantee the quality of the information provided at the trigger level, automatic monitoring is performed with respect to the information obtained offline. One of the most important tests is the comparison of energy of the clusters produced by the EF to the clusters produced by the offline code. Those checks verify that the cell and cluster calculations are compatible at both levels despite the different choice of algorithms or parameters.

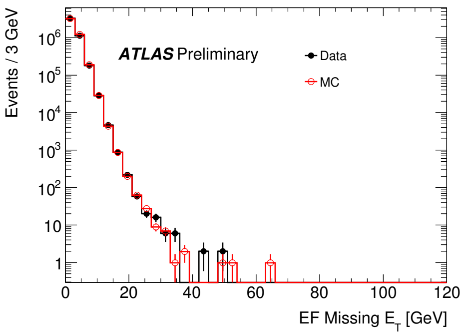

Figure 4: Distribution of missing E_T at EF. Dots are 7 TeV collision data, solid line is MC expectation.

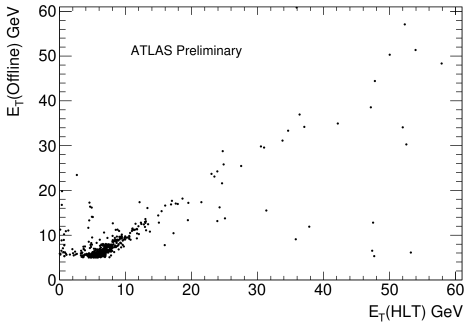

Figure 5: Correlation of the EF and offline E_T obtained from 900 GeV data.

The correlation of the E_T of e/γ clusters calculated at the EF and during offline reconstruction is presented on Fig. 5. Note that several off-diagonal candidates with low offline E_T and high EF E_T would not pass offline quality cuts which are used to declare the EM cluster to be an electron or photon candidate. More analyses are ongoing to produce even more HLT/offline compatible results.

The studies presented in this paper demonstrated that calorimeter HLT algorithms are under control. Key observables behave comparable to MC studies and ongoing comparison with offline performance shows no important bias caused by those algorithms. Furthermore, time requirements were evaluated to be within the required operational constraints and all algorithms proved their robustness during the many hours long LHC runs. A comprehensive summary of the calorimeter HLT performance as well as further references can be found in [4].

Recently, many of the algorithms (especially from e/γ and τ triggers) were switched to perform active selection of events during runs with higher luminosity.

References

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[3] G. Aad *et al.* [ATLAS Collaboration], ATLAS-CONF-2010-026.

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