Reconstruction and selection of physics objects in the ATLAS high level trigger

Rasmus Mackeprang for the ATLAS Collaboration

Discovery, center for particle physics,
Niels Bohr Institute, Blegdamsvej 17, 2100 København Ø, Denmark

DOI: http://dx.doi.org/10.3204/DESY-PROC-2010-01/258

We give an overview of the performance of the ATLAS trigger selections based on extensive online running during LHC collisions and describe the progress towards fully commissioning the individual triggers. Distributions of key selection variables are shown, calculated at the different trigger levels and compared with offline reconstruction. We include examples of triggering on Standard Model physics such as candidate W-boson decays. Comparisons between data and simulations are shown for important selection variables, already illustrating a good level of understanding of the detector and trigger performance. Finally, we give a brief overview of plans for the evolution of trigger selections.

1 The ATLAS trigger

The collision environment of the Large Hadron Collider (LHC) is expected to reach luminosities hitherto unprecedented for hadron colliders in the coming years. Among the experimental challenges facing the detectors installed is the fact that a bunch crossing rate of 40 MHz along with the high total cross section for proton proton collisions will give very high rates of events dominated by soft QCD. To ensure an efficient and unbiased reconstruction of TeV-scale physics, the ATLAS detector is equipped with a tree level trigger system described in detail in [1].

- Level 1 (L1) is a hardware-based trigger that takes decisions, based on calorimeter and muon spectrometer information, to bring down the rate from 40 MHz to below 75 kHz.
- Level 2 (L2) performs a partial reconstruction in the geometrical area (or *Region of Interest*, RoI) where the L1 trigger found candidate physical objects (electrons, jets, muons). Its task is to reduce the event rate to 3 kHz within an average time budget of 40 ms.
- The Event Filter (EF) Reads out the full detector and performs reconstruction with methods very close to those used in the offline reconstruction. The final output rate of the EF is approximately 200 Hz and the time budget is 4 s.

The L2 and EF trigger levels are collectively referred to as the high level trigger (HLT).

2 Performance of physics selections

A common trait for the L2 and EF trigger levels is that they utilize variables defined in the same way as in the offline reconstruction. A crucial point in understanding the trigger performance is thus the comparison of selection variables between the different HLT levels and the offline reconstruction.

An example is shown in Figure 1 for the muon trigger algorithms running on 7 TeV collision data. The muon reconstruction performs tracking both in the muon spectrometer and in the Inner Detector. Tracks are then matched and refitted. The transverse momentum referred to in the figure is thus the refitted transverse momentum of the combined muon track. The figure shows a clear linear correlation between the trigger and the offline reconstruction.

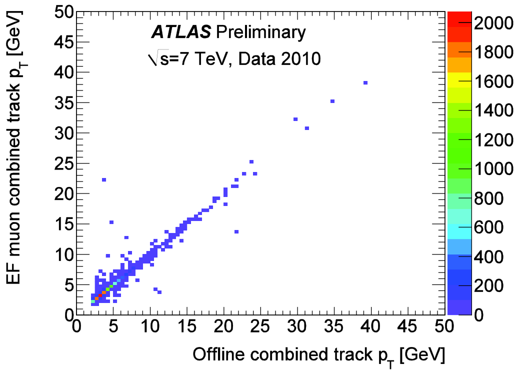


Figure 1: Reconstructed transverse muon momentum calculated in the EF vs the offline calculation.

Similar comparisons are carried out for all physics objects targeted by the ATLAS trigger. For details on these studies, we refer to references [2]. Studies in these notes are carried out for 900 GeV collisions, but the methods remain valid at other centre of mass energies. The performance of the trigger as such is detailed in [3]. In the following sections, we first present the evaluation of the e/γ trigger selections (Sec. 3). Then we present selected plots for various types of signatures (Sec. 4).

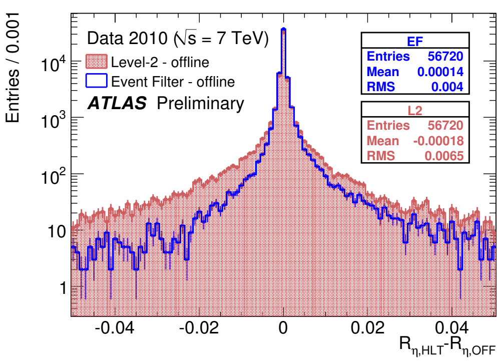
3 Electrons and photons

Electrons and photons (e/γ) are important objects to trigger on for many physics studies. Low-energy electrons allow us to study quarkonia, which can be used as standard candles. These are used for many analyses. Medium energy electrons give access to electroweak physics, while high energy electrons will be a good channel for many types of physics beyond the Standard Model. Photons ranging in energy from very low energies up to several hundreds GeV also serve a variety of calibration and signal purposes. For instance, $H \to \gamma\gamma$ is a central Higgs discovery channel in many scenarios.

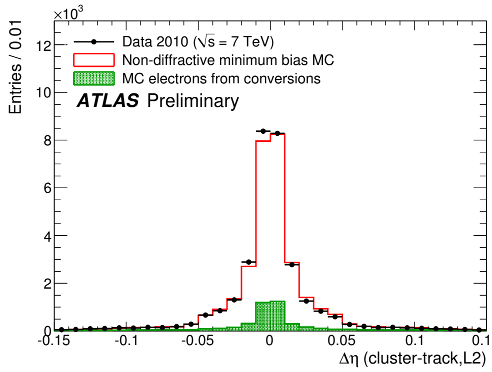
Both types of signatures seed off an L1 electromagnetic (EM) RoI. Clustering of EM calorimeter cells is then performed and cuts are applied on the shape of the shower in the calorimeter. Electron signatures furthermore perform tracking in the inner detector and match any tracks found to the EM cluster. All of this is done inside the cone defined by the RoI.

Key parameters in the e/γ selection are shown in Figure 2. The shower shape parameter R_η, shown in Figure 2(a), is calculated in the second layer of the EM calorimeter as the ratio of the energy deposited in a block of $\eta \times \phi = 3 \times 7$ calorimeter cells divided by the energy deposited in 7×7 cells centered around the shower position. A progressively better agreement with offline reconstruction is observed comparing L2 to EF, while Figure 2(b) shows good agreement between data and Monte Carlo in thread with other performance plots not shown in this paper.

On April the 5th 2010, the first W-candidate event was recorded in ATLAS, triggering an electron trigger with a transverse momentum threshold of 10 GeV. Agreement was good between trigger and offline reconstructed quantities and the event was seen to be consistent



(a) Comparison of R_η as calculated in the HLT and offline.



(b) Track/cluster matching in η at L2 compared to Monte Carlo.

Figure 2: Performance plots for e/γ trigger algorithms.

with a $W^+ \to e^+\nu_e$ decay. For details on the W/Z observation analysis, please see [4].

4 Jets and $\not{E}_T$

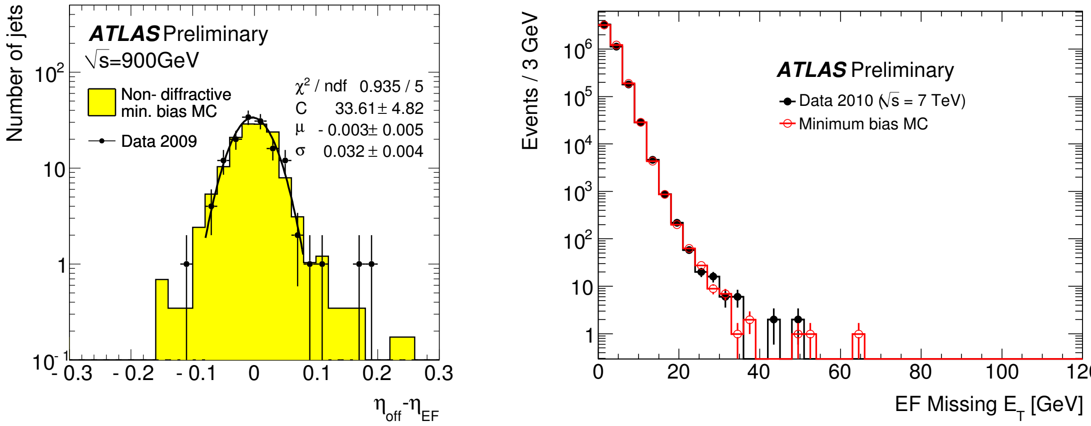
Giving a complete overview of all types of trigger signatures exceeds the scope of this paper. Here, however, it seems appropriate to show a few selected plots. Figure 3(a) shows the resolution of the EF jet algorithm relative to that of the offline reconstruction. It is worth noting that there is an apparent consistency in this plot despite the fact that different jet algorithms are employed. In the EF, a k_T algorithm is used, while the offline has migrated to being anti-k_T-based.

While the missing transverse energy is well described in the trigger with respect to the offline reconstruction, it is also a sensitive variable to the combined understanding of the detector. It is therefore good to see the agreement observed in Figure 3(b) between collision data and Monte Carlo.

5 Conclusion and outlook

The "trigger menus" (list of trigger signatures) of the first half of 2010 have been focused on the commissioning needs of the ATLAS detector. The triggering has been driven by L1 alone with the HLT running online *without* rejecting any events. This has allowed for a comprehensive validation of the combined trigger/DAQ software.

As the LHC increases luminosity, active HLT selection has been enabled for low-threshold signatures. The consistency demonstrated by the ATLAS trigger in reproduction of offline quantities as well as a generally good description of the data provided by the Monte Carlo has built confidence in the selections to the point where active rejection has been enabled for the HLT. The evolution from here is driven by physics requirements as luminosity increases beyond 10^{30} cm^{-2}s^{-1}. The planned evolution is shown in Table 1. The strategy for dealing with



(a) Spatial resolution in the EF with respect to offline and comparison with Monte Carlo.

(b) Data / Monte Carlo comparison of the missing E_T as calculated in the EF.

Figure 3: Performance plots for jets and $\not{E}_T$.

$\mathcal{L}(\mathrm{cm}^{-2}\mathrm{s}^{-1})$	10^{30}	10^{31}	10^{32}
Photons & Electrons	10 GeV γ	20 GeV γ	30 GeV γ (tight)
	10 GeV e	10 GeV e (medium)	15 GeV e (medium)
Taus	29 GeV τ	50 GeV τ	84 GeV τ
	12 GeV τ + 20 GeV $\not{E}_T$	12 GeV τ + 20 GeV $\not{E}_T$	16 GeV τ + 25 GeV $\not{E}_T$
Muons	10 GeV	10 GeV	13 GeV

Table 1: Evolution of primary trigger transverse momentum thresholds with luminosity. The electron, photon and tau triggers are using loose cuts where nothing else is noted. This distinction is not relevant for the muon signatures.

higher luminosities is comprised of three elements: Tightening cuts to increase purity, raising thresholds as commissioning needs diminish and applying prescales to bring down the rate. Many selections exist in "loose", "medium" and "tight" versions to facilitate this progression. Prescaling is generally not used on primary physics triggers.

References

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

[2] The ATLAS Collaboration, ATLAS-CONF-2010-013, ATLAS-CONF-2010-014, ATLAS-CONF-2010-021, ATLAS-CONF-2010-022, ATLAS-CONF-2010-026, ATLAS-CONF-2010-025, ATLAS-CONF-2010-028, ATLAS-CONF-2010-030.

[3] Iwona Grabowska-Bold,"Commissioning and performance of the ATLAS trigger with proton collisions at the LHC", in these proceedings.

[4] The ATLAS Collaboration, "Observation of $W \to \ell\nu$ and $Z \to \ell\ell$ production in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector," ATLAS-CONF-2010-044.