Commissioning ATLAS Trigger

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The ATLAS experiment at the Large Hadron Collider (LHC) will face the challenge of efficiently selecting interesting candidate events in $pp$ collisions at 14 TeV centre-of-mass energy, whilst rejecting the enormous number of background events. Therefore it is equipped with a three level trigger system. The first level is is hardwa based and uses coarse granularity calorimeter information and fast readout muon chambers. The second and third level triggers, which are software based, will need to reduce the first level trigger output rate of $\sim 75$ kHz to $\sim 200$ Hz written out to mass storage. The progress in commissioning of this system will be reviewed in this paper.

1. The ATLAS trigger system

The Large Hadron Collider (LHC) at CERN, Geneva, is now starting operation. It will ultimately provide proton-proton collisions at a centre-of-mass energy of 14 TeV, a design luminosity of $10^{34}$ cm$^{-2}$ s$^{-1}$ and a bunch-crossing rate of 40 MHz. The ATLAS collaboration has built a general purpose experiment for the LHC which is described in [1][2]. The trigger and data acquisition (T/DAQ) system must work in the challenging environment of $\sim 10^9$ interactions per second and the large number ($\sim 10^8$) of readout channels of the ATLAS detector. The initial data stream of 1PB/s must be reduced to the $\sim 300$ MB/s which can be sustained to mass storage, while efficiently retaining a maximum acceptance of physics signatures for offline analysis. To achieve this, ATLAS has designed a three-level trigger system (see Fig. 1) [3].

The first level trigger (LVL1) is implemented in custom electronics (mainly ASICs and FPGAs). Its decision is based on relatively coarse data from two subsystems, the calorimeters and dedicated muon trigger stations. Events are selected based on inclusive high-$p_t$ objects (muons, electromagnetic/tau/hadronic clusters, jet clusters) plus global event features (missing and scalar transverse energy sums) There are a number of programmable trigger thresholds for each of these. During the LVL1 latency of 2.5 $\mu$s the data of all sub-detectors are kept in pipeline memories. For accepted events, the geometrical location of the objects, Regions of Interest (RoIs), are sent to the second level trigger (LVL2) and the data are then transferred from the pipeline memories to the Read-Out Buffers (ROBs). The LVL1 trigger reduces the event rate from the initial 40 MHz to about 75 kHz.

The High-Level-Trigger (HLT) is a software-based trigger, running on farms built from commodity computing and network technology. It is subdivided into LVL2 and the Event Filter (EF). LVL2 has a nominal average processing time of $\sim 40$ ms and should reduce the output rate to around 2 kHz. The EF can take around 4 s and should further reduce the rate to $\sim 200$ Hz. Both levels have access to the full granularity of all the detector data and follow the principle of further refining the signatures identified at LVL1. LVL2 must retrieve event fragments from the ROBs via Ethernet. To reduce the data transfer to a few percent, it uses only data in RoIs identified by LVL1. LVL2 algorithms are highly optimized for speed. If LVL2 accepts an event, all the fragments from the ROBs are combined and sent to one EF processor for further consideration. The EF further refines the classification of LVL2, using the extra time to run more complex algorithms, often based on the same tool set as offline reconstruction. It also benefits from more detailed calibration and alignment than used at LVL2. The processing at the EF is based mainly on the RoIs however the full detector information can be accessed and this capability is used, for example, in triggers involving missing transverse energy.
2. The trigger menu

The overall configuration of the trigger is called a menu. It is composed of building blocks, called trigger chains, which can be considered as the units of selection in that the event is accepted if at least one trigger chain is passed. Examples of trigger chains are the identification $25 \text{ GeV}$ electrons or $6 \text{ GeV}$ muons etc. This modular structure greatly simplifies the configuration of the trigger and allows for great flexibility as specific chains can be added or removed to the menu easily. The rate can be also controlled chain-wise by the use of prescaling - this means that a given chain is only run for a specified fraction of events chosen randomly, effectively reducing the rate for that chain by the prescale factor.

Such decomposition of the whole trigger selection into chains facilitates the tuning of the trigger selection to adapt to the beam and detector conditions as well as to the overall ATLAS experimental program.

Work on the menu is divided into working groups based around the ATLAS sub-detectors and the event-features of interest for trigger selection $e/\gamma$, $\tau$, jets, $\mu$, missing-ET, $b$-jet, B-physics [4]. These groups perform detailed performance optimizations, an example plot showing the efficiencies for single trigger chain are shown in Fig. 2

This work of the individual working groups is integrated into a set of trigger menus adapted to different phases of the experiment. The main consideration for these menus is to provide a full coverage of the physics programme within the limitations of the maximum rate-to-tape which DAQ system can sustain and the offline limitations for data processing and storage.

The rates for a given menu is studied by running the trigger selection on a sample of “minimum bias” events (these are events selected with the loosest possible trigger requirements and which, therefore, represent the main trigger background). About $70mb^{-1}$ of such events were generated and fed through the L1 trigger simulation and HLT processing. The composition of rates from some groups of chains is shown on the Fig. 3 [4].

The rates for menus designed for a luminosity of $10^{31} cm^{-1}s^{-1}$ can be determined in this way. However, for higher luminosity menus the minimum bias events are enriched by samples with an understood bias such as di-jets in order to obtain sufficient statistics for the higher $p_t$ thresholds used in these menus.
So far, the trigger has been commissioned with simulated data. When the first LHC beam is available, this will be used to “time-in” the detector (adjust for the signal propagation delays within the various detector and trigger components). A simple trigger menu will be used for this with more progressively more complex selections being introduced later. The sequence of menus used for commissioning of the trigger will be as follows; initially including only L1 in the selection, the HLT will be either excluded or included in a mode where it does not perform any selection. The L1 triggers will be set in coincidence with the signal from near beam detectors. Once a coarse timing has been achieved the low $p_T$ items from low luminosity menu can be added to the menu and the HLT can be added in the mode when the selection decision is evaluated but nevertheless all events are recorded. With the increasing luminosity the timing can be fine-tuned and the HLT selection turned on gradually. When moving to higher luminosities the rate will need to be controlled by tighter selections based on mid-$p_T$ items, disabling or highly prescaling the low-$p_T$ thresholds and introducing new high-$p_T$ chains. As an alternative to removing or prescaling low -$p_T$ items, these items can be required to have a higher multiplicity or new signatures can be formed from the combination of one or more simple selection items. It should be noted that more complex selections will be required at the nominal LHC luminosity where the rate of Standard-Model signatures will become impossible to record.
4. Integration with the Data Acquisition System

In addition to the offline menu performance studies, the HLT algorithms are taken to the final L2 and EF farms and used with simulated data preloaded to the detector readout system. In addition data taking periods are envisaged with detectors set to readout comics ray signals and with the trigger enabled. These tests help to understand the collective behaviors as well as the long term trends of the system, such as those shown in Fig. 4. Work is focussed around two types of online tests; the so called milestones runs using cosmic ray data from the real detectors and technical runs where simulated data is downloaded to the front-end. After each software release a series of technical runs are performed and software fixes applied. The resulting certified releases are used for cosmic rays data taking. So far a number of cycles of this kind have been performed.

5. Addendum

At the time of writing this report the trigger is involved in data taking with cosmic rays. The main purpose is detector commissioning. The trigger is being used mainly to provide a streaming functionality. This means that the trigger is used to split the raw data into a number of streams for recording. The streaming decision is taken at the first level trigger and then preserved by both higher levels. In addition to this, there is an active HLT selection performed based on tracking algorithms in order to enrich selected streams with the tracks useful for alignment of the ATLAS trackers. A part of the initial physics menu has also been deployed for testing purpose.

References

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