Results from the first p+p runs of the ALICE High Level Trigger at LHC

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Abstract.
The High Level Trigger for the ALICE experiment at LHC is a powerful, sophisticated tool aimed at compressing the raw data volume and issuing selective triggers for events with desirable physics content. At its current state it integrates information from all major ALICE detectors, i.e. the inner tracking system, the time projection chamber, the electromagnetic calorimeters, the transition radiation detector and the muon spectrometer performing real-time event reconstruction.

The steam engine behind HLT is a high performance computing cluster of several hundred nodes. It has to reduce the data rate from 25 GB/s to 1.25 GB/s for fitting the DAQ mass storage bandwidth. The cluster is served by a full GigaBit Ethernet network, in addition to an InfiniBand backbone network. To cope with the great challenge of Pb+Pb collisions in autumn 2010, its performance capabilities are being enhanced with the addition of new nodes. Towards the same end the first GPU co-processors are in place.

During the first period of data taking with p+p collisions the HLT was extensively used to reconstruct, analyze and display data from the various participating detectors. Among other tasks it contributed to the monitoring of the detector performance, selected events for their calibration and efficiency studies, and estimated primary and secondary vertices from p+p collisions identifying V^0 topologies. The experience gained during these first months of online operation will be presented.

1. Introduction to the ALICE High Level Trigger
The ALICE detector is a dedicated experiment at the Large Hadron Collider with the main objective to study heavy ion collisions at new unprecedented beam energies [1]. Before being able to draw conclusions about the state of matter under such conditions, it is essential to collect data from p+p collisions, which not only serve as baseline for understanding the heavy ion data but also stand as a new interesting field of research at the energy of 3.5 TeV per proton beam.

The computational challenge posed by an experiment as diverse as ALICE becomes immediately apparent, as the HLT input data rate can reach 25 GBytes/s. In order to match the permanent data storage capabilities, it is important to reduce this value by an order of magnitude without compromising the physics content of the recorded data. The tool to achieve this goal is the ALICE HLT [1]. It comes after a sequence of three hardware implemented triggers L0, L1, L2, which initiate the readout based on coincidence signals from trigger detectors, in combination with the results of signal shape analysis of some of the tracking devices. Every single event that passes the first three trigger levels is reconstructed within the HLT, the Event Summary Data (ESD) is produced and a trigger decision is issued based on the physics content.
of the event. In case of a negative decision the event is rejected. The possibility exists that the trigger decision is ignored by the data acquisition (DAQ) to allow for efficiency studies of trigger algorithms on real data. Moreover, the format of the HLT ESD is identical to the one produced during the offline reconstruction providing the possibility for comparison with the more elaborate offline reconstruction algorithms.

Since the HLT integrates several ALICE detectors, it can serve as the means to reconstruct, analyze, calibrate and monitor their data during a physics run. In 2010 all major detectors participated in the online system, i.e. the Inner Tracking System (ITS), the Time Projection Chamber (TPC), the Transition Radiation Detector (TRD), the PHOton Spectrometer (PHOS), the ElectroMagnetic CALorimeter (EMCAL) and the muon tracking and trigger chambers (DIMUON). The main focus of this article though is the performance of two of the central barrel detectors during the proton collisions of 2010, namely the TPC in combination with the ITS. The low interaction rate ALICE deliberately operated with gave the HLT the opportunity to focus on performance optimization and improvement of output quality without the need to reduce the amount of data to be stored.

2. Aspects of the HLT Operation

The main data flow scheme of HLT (see figure 1) includes the general reconstruction steps followed for every detector, i.e. raw data processing, cluster finding, track finding and fitting. After the tracklets have been calculated for every detector, they can be combined into longer tracks with updated and more accurate parameters, in order to improve efficiency and momentum resolution, as well as to reduce fake contributions. The TPC tracklets, ITS and PHOS clusters are combined, the ESD is created and the primary and secondary vertices are calculated. The ESD serves as input to the trigger algorithms, however, without excluding the option that some of the latter could directly work on raw tracks before the ESD format has been applied. An example of a reconstructed p+p event with HLT data is shown in figure 2.

![Figure 1. General data flow scheme within the HLT framework. Tracklets and clusters from subdetectors like TPC, ITS and PHOS are combined into longer tracks with updated parameters.](image1)

![Figure 2. Example of a p+p event displayed with HLT. The TPC clusters and tracks that were found appear inside the volume of the TPC in the centre of the picture.](image2)
Since HLT has access to all intermediate reconstruction and analysis steps, it is an ideal tool for monitoring the detector performance using not only information at the raw level but all the way to physics quantities, like momentum, pseudorapidity and track multiplicity. In addition to this, it becomes apparent that all the means are in place for calculating calibration parameters online. The TRD detector is such an example, as it performs gain, time offset and drift velocity calibration in HLT. Figure 3 depicts the latter calibration parameters produced within HLT and with two offline methods. The agreement among them is reasonable and qualifies the HLT calibration results as appropriate to be used for the offline reconstruction of the TRD data. Including all reconstruction, analysis, calibration and histograming components necessary to perform the afore-mentioned tasks, the chain performance for the minimum bias p+p collisions reached 1.5 kHz, 50% higher than the original HLT design value.

The HLT functioned reliably and participated in almost all p+p runs with very few technical failures, comprising only 2-3% of the total run duration, as depicted in figure 4. The reasons for these failures have been identified and solutions are being implemented. Moreover, a hardware update of the computing cluster in terms of additional nodes, as well as the installation of an InfiniBand backbone network have prepared HLT for the Pb+Pb challenge.

3. The HLT Performance
The main tracking device of ALICE is a large TPC [1, 2]. Online data reconstruction of a gaseous detector poses a lot of challenges, as there are several calibration corrections that could influence the position of the clusters, thus having a direct impact on the tracking procedure. At the moment there is no online calibration process running for the TPC in HLT; instead the calibration conditions database of the TPC is constantly updated with the offline values produced by the respective analysis [3]. An example of the calibration influence on the quality of the HLT data can be seen in figure 5. A problematic calibration makes the transverse distance...
of the tracks from the primary vertex broader. A better understanding of the calibration and its application brings the HLT data quality comparable to the offline analysis results.

![Figure 5. Distance of closest approach on the transverse plane for HLT (black: early runs, blue: late runs) and offline data (red). The HLT and offline track distributions have become comparable. No cuts have been applied in this figure.](image)

Aside from track properties, the event properties need to be considered as well, in order to study the differences of the vertex finders. Such an example is figure 6, which depicts the number of events with reconstructed primary vertices for HLT and offline as a function of tracks participating in the vertex finding procedure (per event). The HLT vertex "efficiency" with respect to offline is close to 1 over a large range of the distribution. Possible improvements could be considered for events with low number of participants, depending on the significance of these events when it comes to trigger algorithms.

An additional difference between the HLT and offline vertex finders becomes obvious in figure 7, which shows the RMS distribution of the primary vertex X coordinate as a function of the number of participants. The discrepancies appearing at the low side of the spectrum are attributed to the fact that the offline analysis first calculates the beam position in X and Y and uses the result for finding the vertex position in Z, a method yielding more accurate results. This is yet to be implemented in HLT, which instead uses a 3-dimensional fit of the X,Y and Z parameters at the moment.

![Figure 6. Number of HLT (black) and offline (red) events with reconstructed primary vertices as a function of number of participants.](image)

![Figure 7. Comparison of the HLT (black) and offline (red) RMS distributions of the primary vertex X position as a function of number of participants.](image)

The quality assessment of the HLT data is essential for the evaluation of the trigger algorithms that will become operational in 2011. The trigger framework is in place and its mechanics have
been tested with p+p and Pb+Pb data with the application of a central barrel multiplicity trigger. The configuration of a trigger menu that will fulfill the expectations of ALICE in 2011 is the primary goal of the HLT system. To this end, several physics triggers are being considered and their evaluation study is either finished or on its way.

4. Summary and Outlook
During the first LHC proton collisions in 2010 the ALICE HLT successfully participated in the majority of the runs reconstructing all events and producing online ESDs, whose quality are comparable to the offline ones. The HLT was extensively used to monitor the detector performance, calibrate, calculate primary and secondary vertices, reaching performance rates up to 1.5 kHz, 50% higher than the design value. The experience gained from the p+p collisions in combination with the hardware upgrade of the HLT computing farm led to a fruitful Pb+Pb run, yielding high and stable quality data.

For the coming year the HLT is focusing on providing online selection of events with interesting physics content, in order to reduce the amount of data sent to permanent storage. Detailed trigger studies are on the way and the first trigger algorithms are anticipated to run online after the restart of LHC in 2011.

References
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