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To cite this article: Z Z Vilakazi and the Alice Collaboration 2006 J. Phys.: Conf. Ser. 50 381

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The dimuon High Level Trigger

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Abstract. The CERN-ALICE experiment will produce global data sizes in excess of 75 Mbytes/event, which at event rates of 200-1000 Hz will yield global data streams of 15 Gbyte/s. Online processing – in the form of pattern recognition – is necessary to filter interesting (sub-) events and/or compress data correctly by modelling techniques. A layer of trigger – selecting topologically distinct physics signals ($J/\psi$ and $\gamma$) – is currently being developed and benchmarked under stringent conditions. An emphasis is placed on the implementation of this high level trigger (HLT) for muon reconstruction efficiency studies. Investigations thus have alluded to the HLT being able to reduce background by a factor of 4 for low transverse momentum muons and a factor of 100 for high $P_t$ single muons. Furthermore the invocation of the HLT will help refine the resolution of the $P_t$ cut efficiency.

1. Introduction

The CERN-ALICE experiment [1] will study physics associated with heavy-ion collision processes at centre-of-mass energies of about 5.5 TeV per nucleon pair and 14 TeV for a pp collision process. The ALICE detector will yield global event sizes (for Pb-Pb central events) typically in the range of 75 Mbytes/event [2]. The maximum allowed DAQ bandwidth to permanent storage is set at 1.2 GB/s, thus meaning that the ALICE central detectors can only run at 20 Hz.

Of particular importance is the implication this has on the dimuon spectrometer [3] – a sub-detector located at the backward part of the ALICE detector and covers an angular region of $171^\circ < \theta < 178^\circ$, corresponding to the (pseudo) rapidity range $-2.5 \geq \eta \geq -4.0$. The dimuon spectrometer is tasked with the responsibility of measuring the colour screening effects using heavy-quark resonances $J/\psi$ and $\Upsilon$. These resonances will be studied through their decay, as a function of their centrality, into dimuons. However, the task of identifying muon candidates is made difficult by the effect of large particle multiplicities and pile-up in the spectrometer, thus requiring the use of an online event filter – the high-level trigger – whose basic functionalities are implemented in a form resembling that of a massive parallel computing system. The dimuon High level trigger (dHLT) – will, upon its realisation – have to perform fast, online pattern recognition in real time [4] and will thus, in the process help in the selection of topologically distinct signals corresponding to good physics events. As a result, the dHLT will help reduce data produced by the detectors without any loss of good physics events. This, it is envisaged will result also in a great reduction in taping costs.

2. Architecture and data flow

Studies of the HLT architecture and data flow processes for the global ALICE event readout are outlined in detail by the HLT-TPC group [5], where it is shown how data get transferred via optical fibres, into the ReadOut Receiver card (RORC) of the DAQ system (D-RORC). These data streams
are also replicated into the HLT-RORC. The HLT-RORC has an embedded FPGA co-processor which does all data intensive tasks for local pattern recognition. Also embedded in the architecture of the HLT-RORC is an external memory to be used as a storage of look-up tables and these can be used to perform a variety of applications.

Likewise, the data flow inside the HLT and its boundaries is driven by the physics requirements and operating scenarios. Of importance are the following considerations to be taken into account when implementing/optimising the high level trigger: (i) Fast data rates coming from the front end electronics, and (ii) data rates that DAQ can handle. In particular, we are interested in maximal rates from the spectrometer which must be handled. These numbers therefore affect the following design choices for the dHLT:

- Algorithm design: Fast and effective algorithms must be implemented to cope with high data rates and remove a high percentage of backgrounds.
- The number of processors (CPUs) is required to scale with required data rates and algorithm speed.
- Required buffer sizes and network capacity will have to scale proportionally with incoming data rates.

The raw data from the dimuon cathode readout is then sent out into the HLT computing cluster. These events are first validated by the fast (1.2 µs) level 0 (L0) trigger [6], whose main function is to perform – as described in detail below – a “loose” cut in transverse momentum. The next level of triggering in the data-flow chain involves the pattern recognition algorithms performed either on the FPGA or on PC’s. In accordance with the dHLT design [7], data from Resistive Plate Chambers (RPC) [3] come in the form of a selection of trigger events from a transverse momentum Pt-cut on a single muon. However, the limited segmentation of the RPC and the muon filter [8] do not allow for a sharp Pt cut. Thus for this purpose, the correlation of information/hits from the RPC and the tracking information will be used in order to validate the HLT trigger decision. To this end, the main dHLT algorithm consists of three successive steps; namely, clusterisation or fast hit reconstruction on the tracking planes, application of the fast online track reconstruction algorithm and improved transverse computation subsequent to the validation and/or rejection of a muon event.

Figure 1: Layout of the dimuon HLT architecture

![Figure 1: Layout of the dimuon HLT architecture](image-url)
Data from the detectors is shipped out via the source interface unit (SIU) across an optical fibre network into the HLT processing farm as shown in Figure 1. The first stage of HLT processing – cluster finding – is performed directly on the front end processors (FEP) which are connected to terminators (DIU) of the optical detector data link (DDL) transmitting data at 100 MB/s. After the execution of the two-dimensional cluster finder, the FEPs will ship data – in the form of reconstructed space points – one level down the logical trigger hierarchy, where online HLT track reconstruction takes place. Trigger information will be made available by means of data shipped by the trigger stations. Thus the online tracker will rely on the information given by the combination of available trigger and clustered space points. The most important feature of the online tracker is the refinement of the algorithm, which is naturally evolving over time and will be adjusted accordingly. Furthermore, the number of compute nodes at the tracking stages depends on the tracking performance and/or the type of algorithm used and can thus also be adjusted dynamically. The application of the dHLT has to be carried out under (semi-) real time conditions and thus it is essential that information about processing time (latency) both for the cluster finder and the tracker be ascertained. Using a 2 GHz processor, total dHLT latency (both for the cluster finder and the tracker) of 20 ms was obtained. Of course, when cognizance of Moore’s law is taken, then this CPU latency will drop – at least by a factor of three when data taking commences at the start of the LHC physics run.

3. HLT Physics performance

![Graph of efficiency distribution function of single muons as a function of transverse momentum.](image)

The results of the HLT transverse momentum cut efficiency are shown in Figure 2. What is clearly elucidated in the figure is how efficient the HLT (right panel) is in obtaining a sharper and a more refined Pt cut than the hardware L0 trigger (left panel). These results show that the use of the HLT greatly improves the momentum cut resolution of the spectrometer, meaning therefore that the dHLT will, indeed, introduce a higher and more accurately selectivity on incoming raw data streams. Furthermore, the High Level Trigger tracking abilities can also be used for online reconstruction of the invariant mass spectrum of the heavy quarkonia resonances. Earlier investigations into the feasibility of the HLT [6] have alluded to the fact that the HLT will also decrease the data acquisition rate by a factor of four and 100 for Pt-cuts of 1 GeV and 2 GeV, respectively. These results, representing an extreme case of a central Pb-Pb collision, are shown in Table 1.
Table 1. Acquisition rates for the both the L0 trigger and the HLT for the low and high Pt single muon cuts.

|                | L0      | Dimuon HLT |
|----------------|---------|------------|
| Low pt cut     | 2000 Hz | 500 Hz     |
| High pt cut    | 550 Hz  | Few Hz     |

4. Conclusions
The dimuon HLT is an online buffering filter with a primary task of rejecting background coming mainly from low Pt contamination. To this end, first studies of the HLT have shown that background rejection of a factor of 4 and 100 can be achieved when HLT Pt-cuts of 1 GeV and 2 GeV, respectively, are invoked. Further, the HLT can also improve the resolution of the Pt cut efficiency and thus making it easier for online mass reconstruction of the \( J/\psi \) and \( \Upsilon \) resonances – currently being planned for investigation at the dimuon spectrometer of the ALICE detector. The HLT is currently undergoing stringent benchmark tests in preparation for implementation at the LHC.

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