Development of an Improved L1 Trigger for the ATLAS Muon Spectrometer at SLHC

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Abstract

When the peak luminosity of 10^{34} $cm^{-2}s^{-1}$ of the LHC will be increased by a factor of 5–7 in about a decade from now ("SLHC"), the selectivity of the ATLAS Level-1 triggering system will have to be improved in order to cope with the maximum allowed trigger rate of about 100 kHz. For the L1 trigger of the ATLAS Muon Spectrometer this calls for an increase of the p_T threshold for single muons. In the present L1 muon trigger system, however, the effective p_T-threshold is not very sharp due to the limited spatial resolution of the trigger chambers, resulting in a large fraction of L1 triggers from muons below threshold. We describe a new, high-speed readout system of the Monitored Drift Tube chambers, which allows to supply the precision coordinates of the candidate muon to the L1 trigger, resulting in an accurate momentum determination, a sharpened p_T threshold and an efficient rejection of unwanted, low-p_T muons.

Keywords: Tracking detectors, Level-1 Trigger, ATLAS, Muon Spectrometer

1. Introduction

The increase of LHC luminosity by nearly an order of magnitude is motivated by the search for new physics processes, which may be found in rare event signatures like high-p_T leptons, large missing E_T and others. The capability to selectively trigger on high-p_T muons (>20 GeV) in the ATLAS Muon Spectrometer (MS) requires an improvement of the spatial resolution of the trigger chambers in order to allow the determination of the sagittae, i.e. the p_T of the candidate muons, with sufficient accuracy. Presently, the large majority of apparent high-p_T L1 triggers is caused by muons below the p_T-threshold. At the SLHC this would lead to unacceptably high trigger rates. In some regions of the detector new trigger chambers with improved performance will be built for the phase-1 upgrade in 2018 (Small Wheel), however, in Barrel and Big Wheel most of the chambers will have to subsist, and only modifications of the readout electronics seem to be a realistic option.

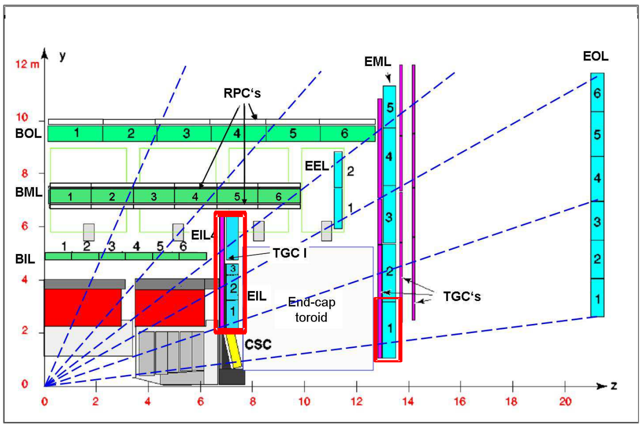

Figure 1: Tower structure of the muon spectrometer showing the matching of trigger and precision chambers. High-p_T tracks are "nearly straight" and mostly travel inside a given tower. Each tower only contributes a small rate of high-p_T L1 triggers (< 100 Hz), resulting in low bandwidth requirements for the readout.

2. Concept for the L1 trigger improvement

The basic idea for improved p_T resolution for the L1 trigger is to combine the good time resolution of the trigger chambers with the excellent position resolution of the close-by Monitored Drift Tube chambers (MDT) [1, 2]. This requires the precision hits of the MDT to be available for the L1 decision shortly after the passage of the particle, respecting the maximum allowed latency. Presently, due to technical limitations in various ATLAS subdetectors, the maximum L1 latency is 2.5 μs. In the phase-2 upgrade, however, the L1 latency will be increased to more than 6.4 μs, allowing sufficient time for the transfer of MDT track coordinates and for their combination with the trigger chamber information.

The implementation of this scheme is facilitated by the fact that high-p_T tracks, due to their small curvature, have a simple projective hit pattern and, if relevant for physics, originate from the primary vertex. The coordinate of a high-p_T muon candidate in the outer trigger chamber thus defines a straight search road for the expected MDT hits, the width of the search road being of about one MDT tube diameter (30 mm). Only MDT hits close to the search road are relevant for the p_T determination and need to be read out for the L1 trigger. The large major-

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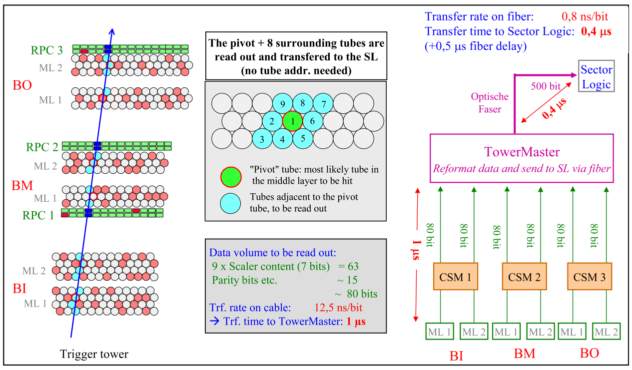

Figure 2: Left: only MDT hits along the search road are read out, reducing the required readout bandwidth. Center: the drift time of a fixed number of tubes around the search road will be read out for the L1 trigger, resulting in a data volume of about 80 bit. Right: the fast readout scheme of the MDT

ity of "background" hits from γ and neutron conversions (see Fig. 2, left) can be ignored for the L1 trigger decision. This limitation of the data volume leads to a dramatic reduction of the required data transfer time and greatly simplifies algorithms for the trigger decision. The straight, high-p_T muon tracks will mostly travel within one trigger tower, and, unlike in the case of low-p_T tracks, the crossing of tower boundaries does not have to be taken into consideration.

3. Technical Realization

The technical realization of this L1 trigger concept requires a communication path between the trigger chamber logic and the MDT readout, separately in each tower. The existing MDT readout [3] has to be complemented by an independent, fast readout path. To assure a strict correspondence between the trigger chamber data and the precision coordinates from the MDT, the readout must be synchronous with the beam crossing clock (BX), i.e. the MDT data must be delivered to the Sector Logic a fixed, predefined time interval after the BX tagged by the L1 trigger.

Figure 3 shows the new readout scheme of the MDT, where hits are recorded twice, once in a TDC for "normal", slow read-out and, independently, in a bank of scalers, one scaler per tube. Scalers are started by a hit in the corresponding tube. All scalers are stopped on reception of a request from the trigger chamber logic of this tower, asking for MDT coordinate information. Scaler which are not stopped during the maximum drift time will be reset automatically, waiting for the next hit. Requests from the trigger chambers will have to arrive a fixed time interval after the passage of the particle, pointing to a definitive beam crossing (BX). This way, the scaler readings correspond to the *absolute* drift time in the MDT tube and, thus, to the *absolute* distance of the track to the wire. The sum of drift times in two tubes, subsequently crossed by a muon, must therefore fall inside predefined limits. This condition provides a valuable quality check on the absence of γ-conversions, which would tend to reduce the drift tube sum, if the conversion was closer to the wire than the track.

The spatial resolution of the track coordinate, as delivered to the L1 trigger, can be relaxed by using e.g. the 40 MHz clock of the readout instead of the 32 times faster clock used inside the TDC, as the inherent spatial resolution of the MDT of $< 100\ \mu m$ is not needed for the L1 trigger. The 40 MHz clock, leading to a spatial a resolution of about 1 mm would be sufficient for the required improvement of the sagitta resolution, which also means that corrections for the non-linearity of the r-t relation, temperature and magnetic field could be neglected, reducing processing time and complexity of the algorithms.

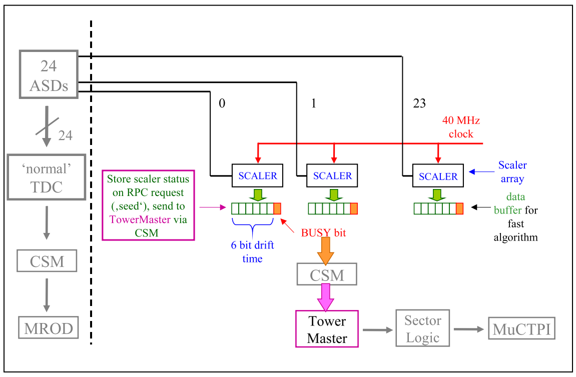

Figure 3: Fast readout of drift times using one scaler per tube.

4. Summary

The upgrade scheme for the Level-1 muon trigger described above allows to sharpen the threshold of the high-p_T trigger by about an order of magnitude, sufficient for the luminosity increase envisioned for the SLHC. This way, most of the existing trigger chambers in barrel and endcap of the MS can stay in place. The readout electronics of trigger chambers as well as MDT will need to be replaced in order to provide an interface for data exchange between the two systems. A number of auxiliary electronics units along the data readout path will have to be developed to contain local intelligence and to allow precise timing to achieve synchronicity between trigger and MDT chambers, as mentioned above. Design, prototyping, production and installation will require a significant effort and a strong contribution from the ATLAS muon spectrometer community.

References

[1] ATLAS Collaboration, *Technical Design Report for the ATLAS Muon Spectrometer*, CERN/LHCC/97-22, May 1997.

[2] The ATLAS collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, JINST **3** S08003 (2008)

[3] Y. Arai et al., *ATLAS Muon Drift Tube Electronics*, JINST **3** P09001 (2008)

[4] J. Dubbert et al., *Upgrade of the ATLAS Muon Trigger for the SLHC*, JINST **5** C12016 (2010)