ATL-DAQ-CONF-2007-003
18 January 2007

PERFORMANCES OF THE ATLAS LEVEL-1 MUON TRIGGER PROCESSOR IN THE BARREL

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The ATLAS level-1 muon trigger will select events with high transverse momentum and tag them to the correct machine bunch-crossing number with high efficiency. Three stations of dedicated fast detectors provide a coarse p_T measurement, with tracking capability on bending and non-bending projections. In the Barrel region, hits from doublets of Resistive Plate Chambers are processed by custom ASIC, the Coincidence Matrices, which performs almost all the functionalities required by the trigger algorithm and the readout. In this paper we present the performance of the level-1 trigger system studied on a cosmic test stand at CERN, concerning studies on expected trigger rates and efficiencies.

1. Barrel Level-1 Muon Trigger overview

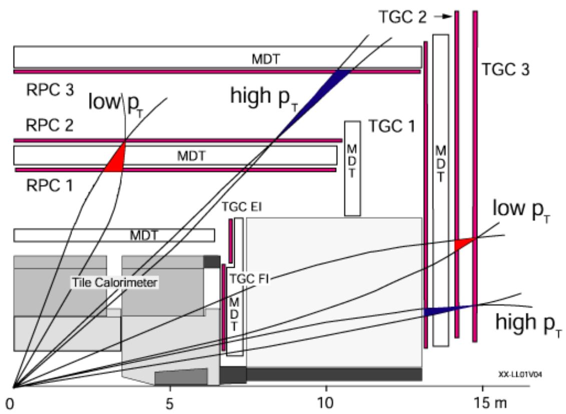

Figure 1. The ATLAS Level-1 Muon Barrel Trigger schema.

The ATLAS muon trigger system [1] provides the correct association of the muon candidates with the corresponding bunch-crossing and classifies tracks based on their transverse momentum. Rejection of cavern background is assured by fine time resolution and required independent coincidence on bending (η) and not bending (ϕ) views in dedicated systems . In the Barrel, three layers of Resistive Plate Chambers (RPC) are used, tightly integrated with the MDT precision chambers in the muon spectrometer. Two of them, located inside the air-core toroids, provide the Low-p_T trigger selection (p_T >6 GeV/c) required by B-physics studies, while an outer station allows to select muons above 20 GeV/c. A detector layer is composed by two RPC gaps, each read out by two layers of orthogonal pick-up strips. A schema of the trigger system is sketched in Fig.1.

The trigger logic identifies candidate muon tracks coming from the interaction vertex within a p_T range. Coincidence of hits is required within geometrical roads, calculated on the basis of the expected curvature of the track, assuring a 90% trigger efficiency at the imposed nominal p_T threshold. The geometrical roads are projected from the central layer, called pivot, on to the coincidence layers, pointing to the interaction vertex. The High-p_T trigger is made more robust by requiring the confirmation of a Low-p_T trigger. The baseline trigger configuration requires a 3/4 majority coincidence for the Low-p_T system and a 1/2 for the High-p_T . Different criteria, allowed by the programmability of all the trigger parameters, can be imposed in order to control the trigger rate under different conditions of luminosity, background and detector performance.

The logic for the Level-1 trigger relies on custom ASICs, called Coincidence Matrix (CMA)[2], which apply time and space coincidences on hits from the pivot and the coincidence layers and provide the trigger result and the readout of the RPC strips with a time resolution of 1/8 of a 25 ns bunch crossing period. The granularity is given by the region of interest (RoI), $\Delta\phi$ x $\Delta\eta = 0.1$x0.1. The trigger and readout information from two ϕ and two η CMA's are combined in a PAD, the on-detector trigger electronics processing unit. The algorithm of a tower is performed by connecting a Low-p_T and a High-p_T PAD. The latest collects all the trigger and readout data and sends them, via a single optical link, to the off-detector electronic system using a time multiplexing approach, which gives highest priority and fixed latency to trigger data. The Receiver and Sector Logic (RX/SL) board [3] combines data from up to eight PAD boards, generating the trigger signal of one of the 64 trigger sectors of ATLAS. When a level-1 accept signal is generated, the readout data are made accessible, through dedicated readout buffers, to the higher level triggers.

Stringent requirements must be fulfilled by the CMA trigger processor ASIC. All the trigger part of the electronics is organized in pipelines, running at the bunch crossing frequency, and the readout buffers contained in the chip allow for a level-1 latency of maximum 2.5 μs. The CMA processor generates the output trigger patterns with a latency of a few bunch crossing periods. After digitization, RPC signals are aligned in time with programmable delay lines and shaped, adding dead-time if necessary, in order to perform the coincidence. The time alignment of signals from different layers and stations within the same bunch crossing window is required, compensating delays due to time of flight of muons, signal propagation along the RPC strips and the cabling. The CMA chip allows a time calibration with 16 channels granularity and the readout windows is optimized to perform bunch crossing identification with high efficiency and preserve the readout information.

2. Studies of performances of a trigger tower

The whole trigger slice has been extensively tested with 25 ns beams to ensure the integrity of readout and trigger chains [4]. The CMA chip underwent a second and final redesign to cope with extended input delay lines of up to about 200 ns [5]. We used some pre-production samples to perform additional tests with real RPC signals at the CERN BB5 site with cosmic

Table 1. Summary of the trigger tower acceptance measurements (Low-p_T , 3/4 majority) with different RPC working conditions. The expected value from the toy MC is 47% at full detector efficiency.

RPC HV (V)	9400	9.500	9600	9700	9600	9600
RPC FE threshold (V)	1.1	1.1	1.1	1.1	0.9	1.0
L1-trigger acceptance ±0.5 (%)	42.7	44.6	45.4	46.0	42.7	44.2

rays[a]. A tower with up to three RPC stations has been equipped with the trigger electronics, in order to set up one trigger tower on each half-chamber side. We used Barrel Medium Small (BMS) chambers, corresponding to the inner chambers of a small sector of ATLAS, and reproduced the complete level-1 trigger slice of ATLAS. A reference trigger signal has been provided by two additional RPC chambers, situated at the top and bottom of the tower. To set up the system, we programmed readout windows with 8 BC's length and used the raw hits time distributions from each RPC layer to extract the calibration constants needed for time alignment. These data were very useful to validate calibration procedures.

For validating the trigger logic and the coincidence procedure, a simple toy Monte Carlo (MC) has been generated reproducing the geometry of the tower and the cosmic rays angular distribution at the ground ($\propto \cos^2\theta$). This model identifies a muon tracks with 100% efficiency, digitizing chamber hits with a cluster size equal to 1. Imposing the Low-p_T 3/4 coincidence in extended full geometrical roads, a 47% expected trigger acceptance is obtained. We measured the same quantity, convoluted with the RPC efficiencies, for detectors at different high voltage values and different front-end thresholds[b]. Results listed in Tab. 1 are coherent with the expected value and show the good robustness of the trigger system.

Using dedicated counters on the trigger processors, we checked the consistency of cosmics trigger rates, when running in self-trigger mode. With the Monte Carlo we calculated a rate of 290 Hz for a single tower, from 2004-PDG estimations of muon fluxes at sea level passing through a horizontal detector (1 hit $\mathrm{cm}^{-2}\mathrm{min}^{-1}$). When the RPC detectors efficiency is introduced, this value is corrected for the expected 3/4 coincidence probability. We gave a raw estimation of the detectors efficiency, measuring the proba-

[a]This location is used for validating RPC-MDT chambers integration before being installed in the ATLAS site.

[b]Front-end logic is inverted, so that the highest low-voltage discriminator threshold is the loosest.

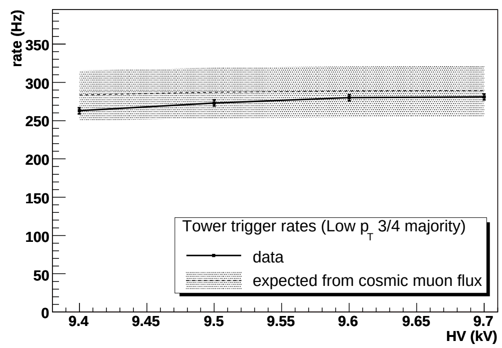

Figure 2. The measured tower trigger rate compared with the values estimated from the Monte Carlo rate, convoluted with detectors efficiency.

bility of a hit on a single layer (on each view) in events where all the other layers have at least one. This is an overestimation of the real efficiency, as it includes the random hits contribution. We introduced a systematic error of 4%, obtained by subsequent measurements with precise MDT tracking for single detector operating point. The comparison between measured and expected values is shown in Fig. 2. Errors on MC estimation take into account the raw parametrization on the muon flux (10%), the MC model (5%) and the estimation of efficiency. Errors on data are given by trigger rate variations during data taking (∼4 Hz), which remained symmetric and stable on both chamber sides.

3. Conclusions

The reported studies allowed the development of tools to control the stability of the Muon Barrel trigger system, monitored with real RPC data. The timing alignment precedures which have been optimized will be the starting point for the commissioning of the system.

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