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The ATLAS Barrel Level-1 Muon Trigger Calibration

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The ATLAS experiment uses a system of three concentric Resistive Plate Chambers detectors layers for the level-1 muon trigger in the air-core barrel toroid region.
The trigger classifies muons within different programmable transverse momentum ranges, and tags the identified tracks with the corresponding bunch crossing number.
The algorithm looks for hit coincidences within different detector layers inside the programmed geometrical road which defines the transverse momentum cut. The on-detector electronics providing the trigger and detector readout functionalities collects input signals coming from the RPC front-end. Because of the different time-of-flights and cables and optical fibers lengths, signals have to be adjusted in time in order to be correctly aligned before being processed. Programmable delay logics are provided in the trigger and readout system to allow for time adjustment, for hit signals as well as for LHC Timing, Trigger and Control signals.
The trigger calibration provides the set of numbers used during electronics initialization for correctly aligning signals inside the trigger and readout system.
The functionality scheme and the algorithm of the calibration are presented.

Summary

The ATLAS barrel level-1 muon trigger system has to identify muon candidates crossing the spectrometer and associate them to a specific bunch crossing, to a detector region of ΔηXΔΦ=0.1X0.1 granularity and classify them by their Pt thresholds.
The ATLAS barrel level-1 muon trigger system has the following main requirements: coarse measurement and discrimination of the muon transverse momentum pT; bunch crossing identification; fast and coarse tracking to identify tracks in the precision chambers that are related to the muon candidate; 2nd-coordinate measurement with a required resolution of 5–10 mm.
The muon trigger system in the barrel is based on full granularity information coming from three station of a dedicated trigger detector, Resistive Plate Chamber, covering a region of $-1<\eta<1$. Two stations are located near the centre of the magnetic field region, inside the air-core toroids, and provide the low-pT trigger (pT > 6 GeV), while the addition of the third station, at the outer radius of the magnet, allows to increase the pT threshold to more than 20 GeV, thus providing the high-pT trigger.
A trigger station is made of two detector layers, each one is composed by two RPC detectors, read out by two orthogonal series of pick-up strips of about 3 cm pitch: the η strips parallel to the MDT wires (z direction) provide the "bending"coordinate of the trigger detector; the φ strips, orthogonal to the wires, provide the second "non-bending"coordinate.
To reduce the rate of accidental triggers, due to low-energy background particles in the ATLAS cavern, the algorithm is performed in both the η and φ projections for both low-pT and high-pT triggers. The first stage of the trigger algorithm is performed separately and independently for the two projections. A valid trigger is generated only if the trigger conditions are satisfied for both projections. The trigger logic requires three out of four layers in the middle stations for the low pT trigger and, in addition, one of the two outer layers for the high-pT trigger. The η and φ trigger information is combined to generate the Regions-of-Interest (RoI), identifying areas in the apparatus in which track candidates are found with a granularity of ˜0.1×0.1 in the η-φ pivot plane.
The signals from the RPC detector are amplified, discriminated and digitally shaped on-detector. In the low-pT trigger, for each of the η and the φ projections, about

200 RPC signals of the two detector doublets, RPC1 and RPC2, are sent to a Coincidence Matrix (CM) board, that contains a CM chip. This chip performs almost all of the functions needed for the trigger algorithm and also for the read-out of the strips. It aligns the timing of the input signals, performs the coincidence and majority operations, and makes the pT cut on three different thresholds. It also contains the level-1 latency pipeline memory and de-randomising buffer. The CM board produces an output pattern containing the low-pT trigger results for each pair of RPC doublets in the η or φ projection. The information of two adjacent CM boards in the η projection, and the corresponding information of the two CM boards in the φ projection, are combined together in the low-pT Pad Logic (Pad) board. The four low-pT CM boards and the corresponding Pad board are mounted on top of the RPC2 detector. The low-pT Pad board generates the low-pT trigger result and the associated RoI information. This information is transferred, synchronously at 40 MHz, to the corresponding high-pT Pad board, that collects the overall result for low-pT and high-pT. In the high-pT trigger, for each of the η and φ projections, the RPC signals from the RPC3 doublet, and the corresponding pattern result of the low-pT trigger, are sent to a CM board, very similar to the one used in the low-pT trigger. This board contains the same coincidence-matrix chip as in the low-pT board, programmed for the high-pT algorithm. The high-pT CM board produces an output pattern containing the high-pT trigger results for a given RPC doublet in the η or φ projection. The information of two adjacent CM boards in the η projection and the corresponding information of the two CM boards in the φ projection are combined in the high-pT Pad Logic board. The four high-pT CM boards and the corresponding Pad board are mounted on top of the RPC3 detector. The high-pT Pad board combines the low-pT and high-pT trigger results. The information is sent, synchronously at 40 MHz, via optical links, to a receiver and Sector Logic (SL) board, located in the USA15 counting room. Each SL board receives inputs from up to height Pad boards, combining and encoding the trigger results of one of the 64 sectors into which the barrel trigger system is subdivided. The trigger data elaborated by the Sector Logic is sent, again synchronously at 40 MHz,, to the Muon Interface to the Central Trigger Processor (MUCTPI), located in the same counting room. Data are read out from high-pT Pad boards only. These data include the RPC strip pattern and some additional information used in the LVL2 trigger. The read-out data for events accepted by the LVL1 trigger are sent asynchronously to Read-Out Drivers (RODs) located in the USA15 underground counting room and from here to the Read-Out Buffers (ROBs). The physical link between on-detector and off-detector electronics is shared between trigger and readout data. In particular the read-out data are sent when trigger results are not available for the detector region of interest.

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