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Test of a demonstrator of an MDT-based first level muon trigger for HL-LHC under realistic operating conditions.

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Selective triggers are essential for the programme of the ATLAS experiment at the HL-LHC. Its first level muon trigger rate is dominated by low momentum muons, selected due to the moderate resolution of the trigger chambers. This limitation can be overcome by including the precision muon drift tube (MDT) chamber data. This requires a fast MDT read-out and fast track reconstruction. A demonstrator of this read-out with an FPGA was successfully tested under realistic conditions at the GIF. The data could be reconstructed with a fast algorithm on an ARM CPU within the first level trigger latency.

Summary

The trigger of the ATLAS experiment at the Large Hadron Collider uses a three-level trigger system. The level-1 (L1) trigger for muons with high transverse momentum p_T is based on chambers with excellent time resolution (better than 20 ns), able to identify muons coming from a particular beam crossing.

The trigger chambers also provide a fast muon p_T measurement, however with limited accuracy due to their moderate spatial resolution along the deflecting direction of the magnetic field. The limited momentum resolution weakens the selectivity of the L1 trigger for high p_T muons above a predefined threshold, like 20 GeV, allowing muons below threshold to cause "fake" triggers, mostly corresponding to event signatures without physics interest.

The higher luminosity foreseen for the phase II of the LHC, the so-called "high-luminosity LHC", puts stringent limits on the L1 trigger rates. A way to control these rates would be to improve the spatial resolution of the triggering system resulting in a drastically sharpened turn-on curve of the L1
trigger with respect to p_T. This is possible without the installation of new trigger chambers with higher spatial resolution by complementing the position measurements of the existing trigger chambers with the much more precise position measurements of the monitored drift-tube (MDT) chambers which are installed in the ATLAS detector to provide an accurate muon momentum measurement.

In this concept, the trigger chambers will be used to define regions of interest (RoI) inside which high p_T muon candidates have been identified. MDT hits in the RoI(s) are passed to the trigger logic, where they are used for an accurate estimate of the track momentum, leading to an efficient suppression of sub-threshold muon triggers.

In order to collect the MDT hit coordinates early enough for use in the L1 trigger logic, the relevant hits are read out through a priority read-out chain,
independent of the standard, asynchronous read-out.

A major difficulty in the ATLAS muon system is the presence of large background of thermal neutrons and γ rays causing occupancies of up to 10\% in the MDT chambers. Simulation studies were used to prove that the proposed MDT L1 trigger scheme can cope with these high background rates.

A demonstatrator of the priority read-out chain using an FGPA for sending and receiving the hit data was successfully tested in CERN's gamma irradiation facility (GIF). No data were lost by the priority read-out chain. The data were then reconstructed on a 200˜MHz ARM Cortex M4F processor with a prototype version of the fast MDT track reconstruction algorithm coded in assembler.The processing time was found to increase a bit with increasing background level, but the track reconstruction could be done within 2200 clock cycles which corresponds to 11~μs. Switching to a 1~GHz Cortex A9 CPU is expected to reduce the processing time to less than 3~μs which is well within the ATLAS trigger latency.

Primary author: BINI, Cesare (Universita e INFN, Roma I (IT))

Presenter: KROHA, Hubert (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D)

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