Abstract

High Luminosity LHC (HL-LHC) is an upgrade of LHC that aims to achieve higher luminosity, enabling experiments to reach better physics sensitivity. Operation of HL-LHC is scheduled to start in 2027 with an instantaneous luminosity of $7.5 \times 10^{34}$ cm$^{-2}$s$^{-1}$. To cope with the high luminosity at HL-LHC, the trigger and readout system of the ATLAS detector will be replaced. The design for the level-0 endcap muon trigger of the ATLAS experiment at HL-LHC and the status of the development are presented.

Introduction

- **Main detector of endcap muon trigger**
  - Thin Gap Chamber on Big Wheel (TGC BW)
    - Multi wire-proportional chamber
    - Two-dimensional position measurement using signals from wires and strips orthogonal to wires
    - Consisting of three stations, M1 (wire: 3 layers, strip: 2 layers), M2 (2 layers) and M3 (2 layers)
- **Inner detectors**
  - TGC in Endcap inner station (TGC EI)
  - Resistive Plate Chambers (RPC BIS78)
  - Tile hadronic calorimeter (TileCal)
  - New Small Wheel (NSW) : Tracking in 1.3 < |η| < 2.4 by small-strip TGC and Micromegas
- **Original algorithm of level-1 endcap muon trigger in Run 1-3**
  - Muon track candidates identification by simple coincidence logic in on-detector boards on TGC BW
  - Transverse momentum ($p_T$) evaluation by look-up tables in off-detector trigger logic boards
  - Signals from inner detectors used to take coincidence with TGC BW to suppress backgrounds such as low-$p_T$ "fake" muons from out of interaction point
- **New algorithm for level-0 endcap muon trigger for HL-LHC**
  - All hit information from TGC BW transferred to off-detector boards to reconstruct track segments
  - Complex coincidence logic of combination of TGC BW track segment with signals from inner detectors → Improved $p_T$ resolution
  - Monitored Drift Tube (MDT) is used to improve $p_T$ resolution succeeding the decision by TGC and inner detectors
  - Trigger logic of TGC BW and inner detectors implemented in an FPGA on Sector Logic boards (SL)

TGC track segment reconstruction

- **"Pattern Matching"**
  1. Compare TGC hits with pre-defined hit lists for high $p_T$ muons
  2. Each pre-defined hit pattern returns position and angle information
- **Requirement for hits**
  - Run 2 : At least two (one) hits in inner three (two) layers and at least three hits in outer four layers for wires (strips)
  - HL-LHC : A looser coincidence with at least five (four) hits in seven (six) layers for wires (strips) to improve efficiency
  - Angular resolution of reconstructed track segment evaluated to be 4 mrad (Total) by a software-based simulation [2]
- $p_T$ pre-determined by angle of reconstructed track segment

Improvement of trigger performance

- **Performance of level-0 endcap muon trigger (not including more precise $p_T$ measurement in MDT) evaluated by software-based simulation**
  - **Efficiency [3]**
  - **Trigger rate [5]**
  - Higher than 90% in plateau region thanks to looser coincidence than that in Run 2
  - Better rejection for low $p_T$ muons thanks to the good angular resolution

Development of trigger firmware

- **Virtex UltraScale+ FPGA by Xilinx on SL board for implementation of trigger algorithm [2]**
  - Trigger firmware
    - Wire/Strip segment reconstruction
    - Wire/Strip coincidence
    - Inner coincidence
    - Track selector
  - Each part of trigger firmware being developed in parallel.
- **TGC wire segment reconstruction for a specific region (2.13 < |η| < 2.16) implemented on FPGA on an evaluation kit VCU118 and good angular resolution obtained [3]**
  - Development for whole trigger chain in limited region and expansion to full region ongoing
  - Slice test of trigger firmware planned in summer