Contribution ID: **145** Type: **Parallel talk**

Fast Online Trigger using FPGA-based Event Classification for the COMET Phase-I

Friday 12 July 2019 11:45 (15 minutes)

The COMET Phase-I experiment searches for a muon-to-electron conversion at a target sensitivity of 3×10^{-15}, which has never been observed. The event signature is the emission of a mono-energetic electron of 105 MeV from a muonic atom of aluminum. This electron is detected by a Cylindrical Drift Chamber (CDC) and a set of trigger counters (TC) in a 1 T solenoidal magnetic field.

A high intense muon beam is used to achieve our sensitivity goal. It leads to an unacceptable trigger rate of a few MHz. For stable data acquisition, a trigger system which can reduce it down to a few kHz is required. The total system latency of <5 μs is also required due to buffer sizes of readout electronics.

In order to fulfill these requirements, we are developing a fast online trigger system using a machine learning based event classification with Field Programmable Gate Arrays (FPGA). This system finds helical electron tracks from the aluminum target. It differs from finding tracks from a point source, and traditional methods such as Hough transform cannot be processed within the required latency. Therefore, we adopt a Gradient Boosted Decision Tree (GBDT) with using multivariate information from CDC; position, energy deposition, and timing. In this system, the trigger electronics collect the hit information from ˜5000 wires of CDC and make a trigger decision every 100 ns. For the decisions, look-up-tables inside FPGA convert from it to GBDT outputs within a clock cycle.

From a simulation study, it is found that the classification can reject >90% of background events with a 99% of signal acceptance, which corresponds to the trigger rate of a few kHz in conjunction with the information of TC. The prototypes of trigger electronics were developed, and the total latency was measured to be 2.8 μs, which meets the requirement. Furthermore, we successfully took cosmic-ray data by using the trigger system installed in a CDC setup. We present these results and prospects.

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Session Classification: Detector R&D and Data Handling

Track Classification: Detector R&D and Data Handling