Development of the Fast Online Trigger System using FPGA-based Classification for COMET Phase-I

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The COMET Phase-I experiment searches for a muon-to-electron conversion at a target sensitivity of 3×10^{-15}. While it is forbidden in the Standard Model, many new physics models predict this process at a rate which is detectable in COMET Phase-I. Thus, a discovery of this conversion would be clear evidence of new physics. The converted electrons, which have mono-energy of 105 MeV, are detected by a Cylindrical Drift Chamber (CDC) and a set of trigger counters (TC) in a 1 T solenoidal magnetic field. The world's highest intensity muon beam is used to achieve our sensitivity goal, and it leads to an unacceptable trigger rate of a few MHz. A trigger rate needs to be reduced to a few kHz for stable data acquisition. This requirement can be satisfied by using an event classification in the detector system, which retains 99% of signal events. The processing time is limited to 5 μs by buffer sizes of CDC readout electronics.

In order to satisfy these requirements, we are developing a fast online trigger system using Field Programmable Gate Arrays (FPGAs). A machine learning based event classification is adopted to find the signal-like trajectories. For the classification, the trigger electronics collect the hit information from 5000 wires of CDC and make a trigger decision. Look-up-tables (LUTs) inside FPGA has good compatibility to simple classifiers of machine learning since they convert the hit information to the outputs of the classifiers within a clock cycle. This trigger system also works for other types of events such as cosmic-ray events by changes of the LUTs. The prototypes of trigger electronics were developed last summer, and the communication systems for the related electronics were also constructed. Then, the total latency was measured to be 2.8 μs, which satisfies the requirement. We develop CDC online self-trigger for cosmic-rays and confirm the feasibility of this hardware logic. The trigger electronics were already installed in a CDC setup for cosmic-ray measurement, and the data acquisition was successfully done by using the CDC self-trigger. I present these results and prospects.