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The Level-1 Global Trigger for Phase-2: Algorithms, configuration and integration in the CMS offline framework

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The CMS Level-1 Trigger, for its operation during Phase-2 of LHC, will undergo a significant upgrade and redesign. The new trigger system, based on multiple families of custom boards, equipped with Xilinx Ultrascale Plus FPGAs and interconnected with high speed optical links at 25 Gb/s, will exploit more detailed information from the detector subsystems (calorimeter, muon systems, tracker). In contrast to its implementation during Phase-1, information from the CMS tracker is now also available at the Level-1 Trigger and can be used for particle flow algorithms. The final stage of the Level-1 Trigger, called Global Trigger (GT), will receive more than 20 different trigger object collections from upstream systems and will be able to evaluate a menu of more than 1000 cut-based algorithms distributed over 12 boards. These algorithms may not only apply conditions on parameters such as momentum or angle of a particle, but can also do arithmetic calculations, like the invariant mass of a suspected mother particle of interest or the angle between two particles. The Global Trigger is designed as a modular system, with an easily re-configurable algorithm unit, to meet the demand of high flexibility required for shifting trigger strategies during Phase-2 operation of the LHC. The algorithms themselves are kept highly configurable and tools are provided to allow their study from within the CMS offline software framework (CMSSW) without the need for knowledge of the underlying firmware implementation. To allow the reproducible translation of the physicist-designed trigger menu to VHDL for use in the hardware trigger, a tool has been developed that converts the Python-based configuration used by CMSSW to VHDL. In addition to cut-based algorithms, neural net algorithms are being developed and integrated into the Global Trigger framework. To make use of these algorithms in hardware, the HLS4ML framework is used, which transpiles pre-trained neural nets, generated in the most commonly used software frameworks, into firmware code. A prototype firmware for a single Global Trigger board has been developed, which includes the de-multiplexing logic, conversion to an internal common object format and distribution of the data over all Super Logic Regions. In this framework 312 algorithms are implemented at a clock speed of 480MHz. The prototype has been thoroughly tested and verified with the bit-wise compatible C++ emulator. In this contribution we present the Phase-2 Global Trigger with an emphasis on the Global Trigger algorithms, their implementation in hardware, configuration with Python and the novel integration within the CMS offline software framework (CMSSW).

Significance

n this contribution we present the Phase 2 Global Trigger with an emphasis on the Global Trigger algorithms, their implementation in hardware, configuration with Python and the novel integration within the CMS offline software framework (CMSSW).

References

Experiment context, if any

Phase 2 upgrade, Level 1 Trigger, CMS

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