Contribution ID: **128** Type: **Plenary**

Upgrades to the CMS Level-1 calorimeter trigger

Friday 2 October 2015 11:25 (25 minutes)

The CMS Level-1 calorimeter trigger is being upgraded in two stages to maintain performance as the LHC increases beam energy and instantaneous luminosity. In the first stage, improved algorithms including event by event pileup corrections are used. In the second stage, higher granularity inputs and a time-multiplexed approach allow for improved position and energy resolution. Data processing in both stages of the upgrade is performed with new, Xilinx Virtex-7 based AMC cards.

Summary

Starting in 2015, instantaneous luminosity at the LHC will exceed design performance. To maintain acceptance for proton and heavy ion collision events of interest without exceeding the 100 kHz limit, the CMS Level-1 (L1) trigger is being upgraded. As a part of this, the L1 calorimeter trigger, which finds jet, tau, and electron/photon candidates and computes energy sums, is being upgraded in two stages. Both stages of the upgrade make use of new, Xilinx Virtex-7 based AMC cards.

In the first stage of the upgrade, the Global Calorimeter Trigger is replaced with a single Master Processor, Virtex-7 (MP7) card. The card features a high performance Xilinx Virtex-7 FPGA and total input and output optical bandwidths of up to 740 Gbps. Calorimeter detector data communication is handled with optical links operating at up to 10 Gbps per channel. A MicroTCA crate designed for high power applications and the option of power module redundancy is used. Communication for system control and local data acquisition is via Ethernet with additional backplane links used for global data acquisition and fast feedback. The system is enhanced with the development of a crate JTAG switch module that allows remote debugging.

The Xilinx Virtex-7 FPGA is used to execute improved trigger algorithms. For proton collision running, the main improvement is event by event estimation and removal of the effects of pileup. In addition, tau candidates are formed from smaller detector areas, isolated tau candidates are found for the first time, and new algorithms for supersymmetry searches are included. A dedicated suite of algorithms for heavy ion collision running has also been developed.

In the second stage of the upgrade, higher granularity inputs, algorithms operating on a wider field of view, and a time-multiplexed approach allow for improved position and energy resolution of regional and global quantities. Calorimeter trigger primitive data is transmitted on 1,152 links running at either 4.8 Gbps or 6.4 Gbps. This is pre-processed at Layer-1 before being time multiplexed to Layer-2 where each node, in the current design a single card, processes data from the entire calorimeter. Data is then de-multiplexed before sequential transmission to the Global Trigger.

Calorimeter Trigger Processor, Virtex-7 (CTP7) AMC cards serve as the Layer-1 pre-processors, and MP7s serve as the Layer-2 nodes. This approach is designed to allow for a high processing clock speed of 240 MHz and thus efficient use of logic resources. The system is designed to operate in a manner similar to the High Level Trigger, in which a large switch concentrates all data from a single event onto a single computing node.

Optical interconnects are via 10 Gbps optical links, which allow easy reconfiguration or expansion as required. This has been made substantially easier with the early adoption of Molex Flexplane technology, which has allowed a rack of 864 individual fiber interconnects to be shrunk into three pizza sized boxes. This novel technology may be useful in future LHC electronics systems because it can massively simplify and shrink fiber installations at no extra cost.

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Session Classification: Plenary