Optical Fiber Center Module for the KOTO Experiment

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We introduce a new Optical Fiber Center (OFC) Module for the Trigger Upgrade in the KOTO Experiment at J-PARC, Japan. The KOTO DAQ consists of nearly 4,000 ADC channels over 18 crates. Running in parallel with the Total Energy (Et) based L-1 Trigger, the Cluster Trigger uses cluster bits from all 2,716 channels in the CsI detector. For each ADC channel, a number of successive samples are analyzed upon a L-1 Trigger, and a bit is set High when the peak sample is above a defined threshold. These values are calculated inside the 176 CsI-ADC modules, and collected for each crate into a Clock Distribution and Trigger (CDT) module. In the first KOTO Cluster Trigger Implementation, a 3-layer CDT pyramid scheme was employed to bring all cluster bits in one place. This new Optical Fiber Center is a 6UVME module with 18 SFP transceivers and one Intel Arria 5 FPGA. It can communicate directly with all 18 CDTs and generate a cluster map for the entire detector with minimal dead time and latency. Cluster numbers are then calculated and sent to the Trigger Master. They are used in combination with Et, for an enhanced L-1 Trigger decision.

KOTO Cluster Trigger and Veto – Architecture

The Block Diagram of a KOTO crate, is presented in Figure 1. Each crate includes 16 ADC Modules, which require a clock and two trigger pulses: Level 1 Accept Trigger (L1A) and LIVE. The Crate Distribution and Triger Module (CDT) receives these signals and distributes them to the ADC Modules. The whole system includes 11 crates receiving signals from the CsI Detector and 7 crates connected to the Veto Detector.

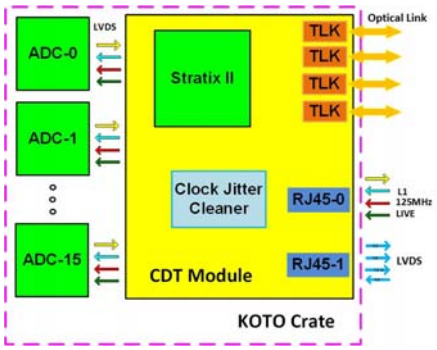

Figure1. Block Diagram - KOTO Crate

The simplified block diagram of the new KOTO Trigger System in presented in Figure 2. There are two Optical Fiber Center (OFC) Modules installed.

One OFC collects the Clustering Bits from the CsI detector.

The 2nd OFC Module connects to all KOTO crates, CsI and Veto, and collects both the Veto Bits and the Energy Values.

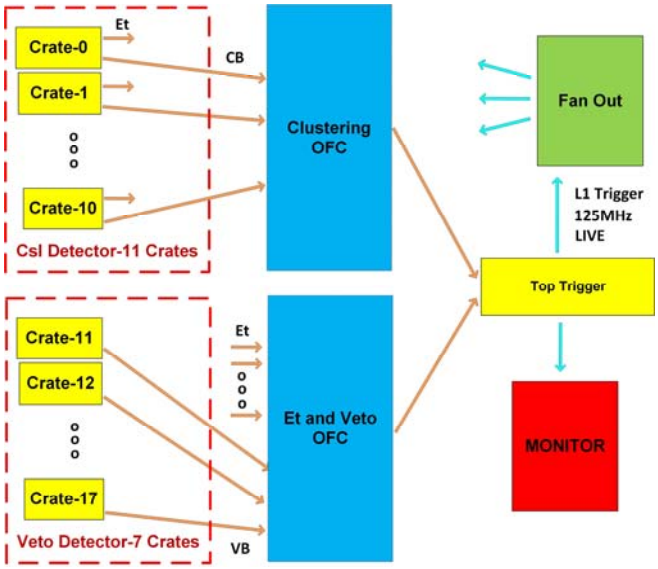

Figure 2. KOTO Cluster Trigger and Veto Block Diagram. All Cluster Bits (CB) are gathered into one place where the Cluster Map is generated, and Cluster Numbers are calculated. The Veto Bits (VB) are collected in the corresponding ADC crates, and passed along in a similar way for the final trigger decision.

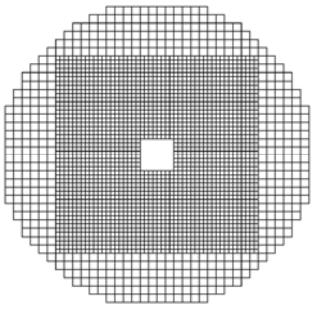

Figure 3. Layout of the original CsI grid and the bit-map for counter counting.

In the KOTO experiment, the CsI Caloirmeter consists of 2240 small crystals and 476 large crystals arranged in a disc shape, as shown in Figure 3. A corresponding Map of the entire CsI Detector is created for each energy based event inside the OFC Module. By utilizing an algorithm based on topology, the numbers of isolated clusters in the CsI calorimeter are calculated in real time. This Cluster Map provides information for triggering on the desired decay modes. The trigger decision can be made based on the physics of interest.

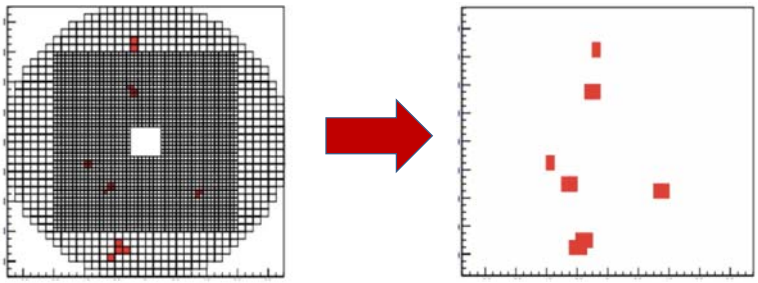

Figure 4. Cluster Bits and the corresponding Cluster Map for one Event.

Conclusions

Five pieces OFC Module were manufactured and tested at The University of Chicago. They provide the following improvements to the DAQ:

- Reduce trigger dead-time from 100 to 18 clocks, and trigger latency from 250 to 100 clocks;
- Lower CsI Total Energy threshold, therefore increase physics sensitivity;
- Eliminate the largest systematic error (5.5%) from L1 Veto, by using OFC veto as first level veto, and allow for Veto decisions on every clock;
- Expand the capability of doing complex trigger logic and improve monitoring and debugging of the trigger system.

Provided with a powerful Intel Arria V FPGA, this module can be a useful tool for many other HEP applications.

Figure 4. The Optical Fiber Center Module. This Double Width, 6U VME Module is fitted with 18 SFP Links running at max 6.2Gbps each.

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