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Optical fiber center module for the KOTO experiment

M. Bogdan [a,*], C. Lin [b], Y. Luo [a], Y. Tung [a], Y. Wah [a]

[a] The University of Chicago, 5620 S. Ellis Ave., Chicago, IL, 60637, USA

[b] National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei 10617, Taiwan, ROC

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ABSTRACT

We introduce a new Optical Fiber Center Module for the Trigger Upgrade in the KOTO Experiment at J-PARC, Japan. The KOTO DAQ consists of nearly 4000 ADC channels over 18 crates. Running in parallel with the Total Energy based L-1 Trigger, the Cluster Trigger uses cluster bits from all 2716 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 Module. In the first KOTO Cluster Trigger Implementation, a 3-layer Clock Distribution and Trigger Module 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 Clock Distribution and Trigger Modules 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.

Contents

1. Introduction

To deal with the increased data rate brought by the high beam intensity, the KOTO experiment [1] used two levels of trigger. The first level trigger is based on the total energy deposited in the CsI calorimeter. An online veto that requires no activity in the sub-detectors is also applied in this stage, and a Level 1 event is generated.

A new custom-designed Optical Fiber Center (OFC) module is built and used as a new second-level trigger processor for the KOTO DAQ system. By utilizing an algorithm based on topology, the OFC module counts the number of isolated clusters in the CsI calorimeter for each event. This provides information for triggering on the desired decay modes and an enhanced trigger decision can be made based on the physics of interest.

2. Implementation

The simplified block diagram of the new KOTO Trigger System in presented in Fig. 1.

Each crate includes 16 ADC Modules, which require a clock and two trigger pulses: a Level 1 Accept Trigger pulse for each event and a LIVE pulse at the beginning of each data taking interval, called a "spill". In KOTO, a spill is 2 s long and starts every 6 s. The local Clock Distribution and Trigger Module (CDT) receives these signals and distributes them to the ADC Modules. The CDT also gathers the Clustering Bits and the Energy values for the entire crate. The whole system includes 11 crates receiving signals from the CsI Detector and 7 crates connected to the Veto Detector.

There are two OFC Modules installed. One OFC collects the Clustering Bits from the CsI detector, which consists of 2240 small crystals and 476 large crystals arranged in a disc shape. A corresponding map of the entire detector is created inside the OFC module, and cluster numbers are calculated in real time.

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

All information is gathered into one place and the final trigger decision is made.

* Corresponding author.
E-mail address: bogdan@edg.uchicago.edu (M. Bogdan).

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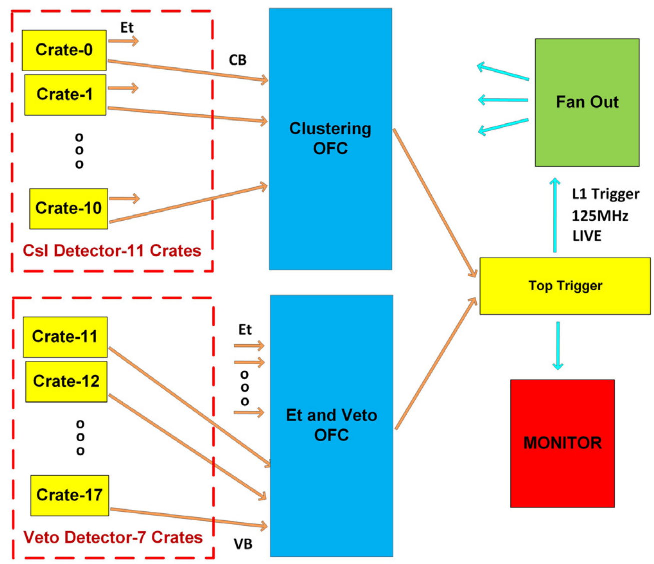

Fig. 1. KOTO Cluster Trigger and Veto Block Diagram. All Cluster Bits (CB) are gathered into one place where the Cluster Map is generated, and Cluster Numbers are calculated. The Veto Bits (VB) are collected in the corresponding ADC crates, and passed along in a similar way for the final L1 Trigger decision.

The picture of the new Optical Fiber Center Module is presented in Fig. 2.

3. Conclusion

Five pieces OFC Module were manufactured and tested at The University of Chicago. They provide the following improvements to the KOTO 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, improve monitoring and debugging of the entire system.

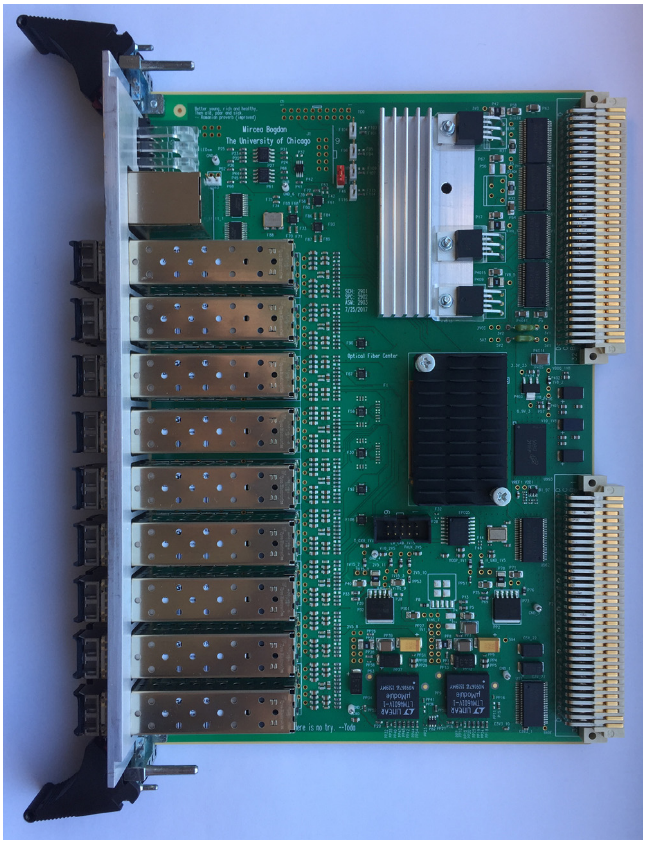

Fig. 2. The Optical Fiber Center Module. This Double Width, 6U VME Module is fitted with 18 SFP Links at max 6.2 Gbps each.

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

Acknowledgment

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