29th International Cosmic Ray Conference Pune (2005) **8**, 225–228

Trigger Electronics for The TA Fluorescence Detector

Y. Tameda[a], J. D. Smith[b], M. Tanaka[c], S. Ogio[d], A. Taketa[e], K. Kadota[f], S.B. Thomas[b], M. Fukushima[e], H, Sagawa[e], T. Matsuda[c], S. Udo[e], M. Takeda[e], K. Hiyama[e] and H. Tokuno[e] for the Telescope Array Collaboration

(a) Graduate School of Science and Engineering, Tokyo Institute of Technology, Tokyo 152-8550, Japan
(b) Department of Physics and High Energy Astrophysics Institute, University of Utah, Salt Lake City, Utah, USA
(c) Institute of Particle and Nuclear Studies, KEK, Tsukuba 305-0801, Japan
(d) Graduate School of Science, Osaka City University, Osaka 558-8585, Japan
(e) Institute for Cosmic Ray Research, University of Tokyo, Kashiwa 277-8582, Japan
(f) Faculty of Engineering, Musashi Institute of Technology, Tokyo 158-8557, Japan
Presenter: H. Tokuno (htokuno@icrr.u-tokyo.ac.jp), jap-tokuno-H-abs2-he15-poster

In this presentation, we introduce a triggering system developed for the TA fluorescence detectors. The system consists of two types of VME 9U modules, *i.e.*, a Track Finder (TF) module for each telescope and a Central Trigger Distributor (CTD) module which controls 12 cameras in each station. In a cycle of event recognition, a)SDF (Signal Digitizer and Finder) modules carry out fluorescence signal recognitions for each PMT and the results are transferred to TF. b)The main task of TF is to recognize tracks in a camera image, and it sends the result to CTD. c)The CTD module accumulates the results from all the TF modules in a station, and gives a final decision, which is sent back to all the TF modules to trigger the data acquisition processes. The CTD module generates a master clock to synchronize all the electronics, and has a GPS for recording the absolute event time.

1. Introduction

The Telescope Array fluorescence detectors(FD)[1] measure fluorescence light of N_2 molecules along with air showers. There will be three FD stations and the distance between each station is about 40 km. In each station there are twelve telescopes, each of which has a spherical mirror optics and a PMT camera system. The spherical mirror optics with a diameter of 3.3 m consists of 18 segment mirrors.

A PMT camera system has 256 PMTs, and each PMT is viewing $1° \times 1°$ sky. In total the field of view of one telescope is equivalent to $18° \times 15.6°$. The sensitivity of FD electronics enables for us to detect shower tracks of dozens of km apart.

For recording atmospheric fluorescence signals, we use three different electronics modules which we developed for TA FD detectors. A Signal Digitizer and Finder(SDF) module[2] has 16ch input. One camera has 16 SDF modules. It records PMT output into RAM with digitizing with 12bit 40 MHz FADC. Moreover, it has the 1st level trigger logic, *i.e.*, searches large amplitude signals above a threshold level which is programmable, and discriminates the signal to 0(not hit) or 1(hit). For a whole camera, SDF modules make a 16×16 size map of 0/1 for each 12.8 μs interval, and they transfered this map to the Track Finder(TF) module. The TF module searches air shower fluorescence tracks on the map, and the resultant 2nd level trigger code is sent to Central Trigger Distributor(CTD) module. Finally the CTD module decides to generate the event trigger and distribute the final trigger code for all the TF modules.

In this paper we describe the TA FD trigger electronics, *i.e.*, TF and CTD, in detail.

2. Trigger Electronics

All the electronics for TA FD are VME 9U single width modules. All the trigger logics are built on hardwares, but these logic devices are FPGA and CPLD, so that we achieved a low cost, a short period for developments and re–programmable and easy to maintenance system.

2.1 Track Finder module

One TF is assigned to one telescope. It is mounted on a VME crate, and it is connected to 16 SDF modules through the VME back planes. Also it is connected to CTD via external twisted pair cables. One important role of TF is transferring the system clock which is synthesized by CTD, to SDF for synchronization of all the modules. All the logics for the track finding are written on a FPGA, Xilinx Spartan 2E.

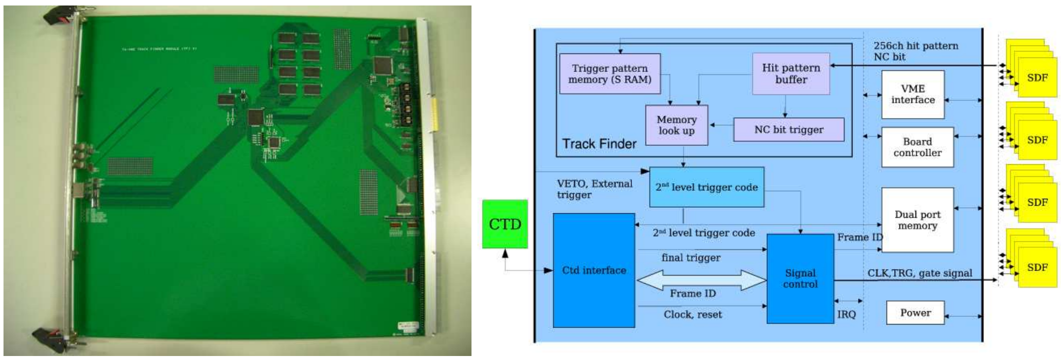

Figure 1. The photograph of the TF module(*left*) and the block diagram of the TF(*right*).

Results of 1st level trigger are transferred as a hit pattern of 256 bits plus and a non conditional(NC) bit. The NC bit is set when a significantly large signal is found on at least one PMT, for example, in the case of measurement of Xe flasher, or of the signal induced by muon hit on a PMT, etc.

When the hit pattern and a NC bit satisfies the triggering conditions, TF generates a 2nd level trigger and sends the 2nd level trigger code to CTD. This trigger code is an integer of 1 to 4.

First, TF send the 2nd level trigger code=1 when it finds a complete track by comparing each 144 sub matrices of 256ch hit pattern with 5x5 trigger pattern matrices (see Figure 2). A complete track is an image of at least 5 adjoining PMTs. The processing time for finding a complete track is 144×25 ns. The trigger pattern is 5 or more PMTs adjoining and all 2^{25} 5×5 sub matrix patterns are memorized in static RAMs(512×8 KB). Second, TF send the 2nd level trigger code=2 when it finds a partial track at the boarder of the camera by comparing 4×4 sub matrix along the edge of camera with trigger patterns (see Figure 3). In this case, the trigger pattern is 3 or more PMTs adjoining at the edge. These patterns are also memorized in one static RAM. Third, TF checks whether the NC bit is 0 or 1. When the NC bit is 1, TF send the 2nd level trigger code=3. Fourth code is the 2nd level trigger code=4, it is the code express an external trigger signal is input to TF. When we need to control triggers with external signals for calibrations, such as shooting LIDAR for atmospheric monitoring, we can send external trigger pulses to TF via the front panel.

Finally, TF transfers the 2nd level trigger code and a frame ID. The frame ID is an identification number labeled to every waveform data of 12.8μs.

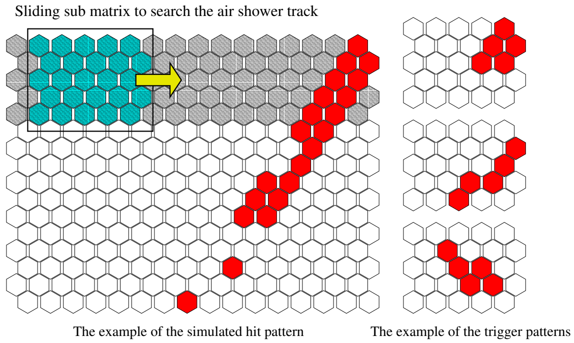

Figure 2. One of the simulated hit patterns and the examples of the trigger pattern.

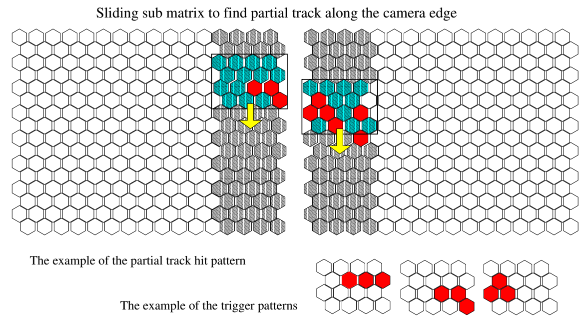

Figure 3. The example of the hit patterns crossing the two camera and the examples of the trigger pattern.

When TF receives a final trigger pulse and a frame ID from CTD, it distributes trigger pulses for all the SDFs mounted on the same crate through a back plane, to prepare a data acquisition process. In parallel, TF stores the triggered frame ID and sends IRQ to the VME control PC.

2.2 Central Trigger Distributor module

One CTD is assigned one station, and it communicated with 12 TF module, *i.e.*, all TF in the station. CTD has two main roles programed in FPGA(Xilinx Spartan 2E).

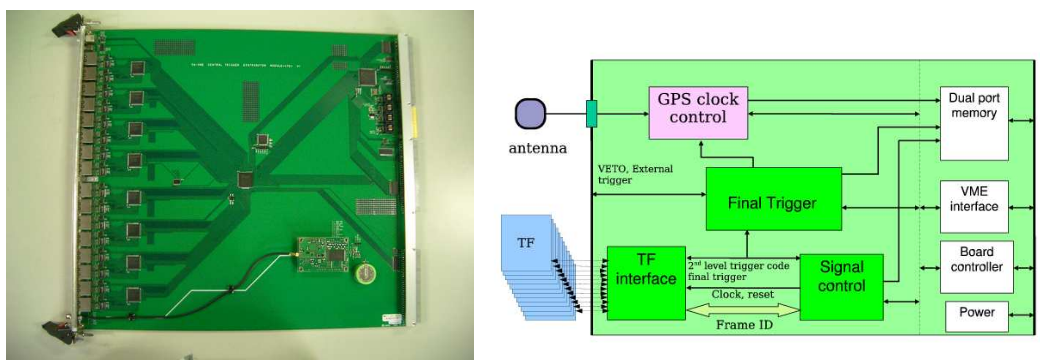

Figure 4. The photograph of the CTD module(*left*) and the block diagram of the CTD(*right*).

One role is to generate and distribute the system clock of all the electronics modules. CTD supplies 40MHz clock and the reset signal distributed to TFs, and through TF, to 16×12 SDFs. Additionally, a GPS receiver module(Motorola M12+) is installed, so that CTD can record an absolute time for each trigger with an accuracy of $\pm$ a few ns. This information is important for coincidences with other stations' triggers and the surface array triggers.

The other main role is the final decision for data acquisitions. CTD accumulates the 2nd level trigger code from TFs every 12.8 μs. If one of the 2nd level trigger codes is equal to an external trigger, a NC trigger or a complete track trigger, CTD generates a final trigger. On the other hand, when CTD receives the 2nd level trigger code of a partial track from two adjacent TFs, a final trigger is also generated. In both cases, CTD sends a trigger pulse to all the TF, and sends IRQ to CTD control PC.

3. Summary

We developed two sets of prototype electronics; 32 SDFs, two TF and one CTD, and we executed a laboratory test with a complete telescope system at Akeno in March, 2005. In this test, we confirmed the performances of programmed trigger logic. Firstly, we obtained data of Xe flasher signals and YAP signals, for checking the adjusting procedure for HV power supplies. Next, we flashed a 64 ch LED matrix light source to make virtual air shower tracks, and confirmed that the trigger logic run correctly.

We have a plan to set up two telescopes in June, 2005 at Black Rock Mesa (Utah) and to observe air shower tracks. We will report the results of the first test observations at this conference.

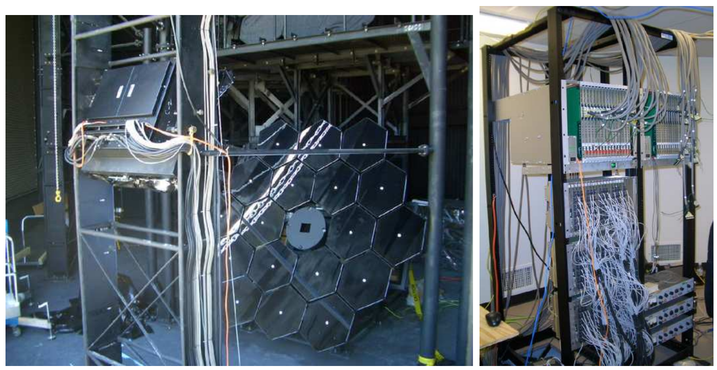

Figure 5. The photographs of one telescope(*left*) and the electronics system(*right*).

4. Acknowledgments

This work is supported in part by Grants-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology in Japan. We would like to thank the Millard County Council and Fillmore BLM.

References

[1] The Telescope Array Project, Design Report(2000).
[2] A. Taketa, et al., 29th ICRC, Pune (2005).