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Data Acquisition System of Surface Detector Array of the Telescope Array experiment

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Abstract: The Telescope Array(TA) experiment will investigate the origin of the extremely high energy cosmic rays (EHECRs). This experiment is a hybrid observation of an air shower array and fluorescence telescopes installed in Utah, USA. We finised deploying 485 Surface Detectors(SDs) for AS array to our site in winter of 2006-2007, and start operation from April 2007. Effective area of this array is 760km^2, each detector set up at intervals of 1.2km and has 2 layers of 3m^2, 1.2cm thick scintilator. Its energy threshold for air shower event is 10^{19}eV or more. The detector has the power supply to operate electronics and them for the data collection respectively. The data from detectors are transmited to a trigger center by wireless LAN modem. We develop a data acquisition system for SDs on this wireless communication. In this presentation, we will report about the data acquisition system of SD array.

Introduction

The Telescope Array (TA) experiment search for the highest energy cosmic rays above 10^{20} eV. These super GZK events and the event clusters observed by AGASA at first.

The TA experiment has two kind of observational equipments such as Surface Detector (SD) array and three Fluorescence Detectors(FD). SD array is composed 512 scintillation counters which measure the distribution of charged particles at the ground. FD stations observe fluorescence light from air shower at the night sky above the SD array. These correspond to AGASA and HiRes respectively, we designed these detectors to be able to verify about the differences of observations.

The TA observatory is located in Millard County, Utah, USA(39.3°N, 112.9°W) and this site is about 1400 m above sea level. Since the land of site is a vast and a protection object of natural environment, we have reduce the influence on nature as our operation. Therefore, each SD has an independent power supply respectively, and all communications are done by the wireless LAN. To decide air shower trigger or not, the brief data output from SDs are collected once, and the data of the wave form of PMT and timing of the selected event is collected from SDs.

Surface detector

Each SD consists of plastic scintillators, photomultipliers (PMTs), wave length shifter (WLS) fibers, readout electronics, wireless LAN communication system, and a solar power system. The WLS fibers 1mm in diameter (Kuraray Co.) are installed in the grooves at 2cm interval on the surface of the plastic scintillator (C.I. Industry Inc.). The scintillation counter consists of two layers of plastic scintillator 1.2cm thick with the area of 3m^2. The scintillation counter is contained in a 2.3m×1.7m×10cm stainless steel box. The configuration of scintillator box is shown in Figure1.

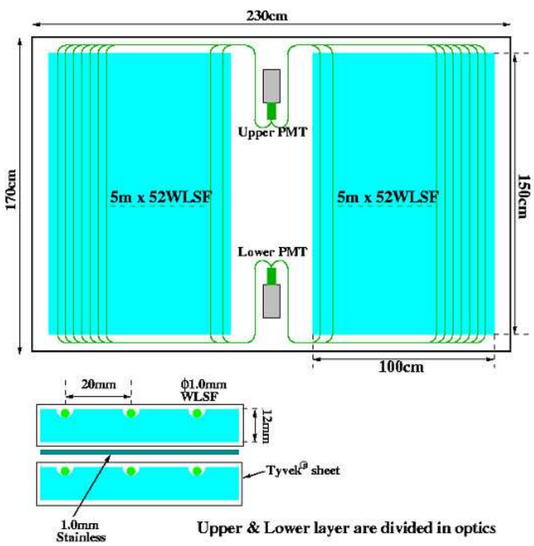

Figure 1: The figure of scintillation counter. Optical fibers are 5m length and read out from both terminal of fiber bundle. Fiber bundle termination is bellow. This terminator is joined to surface of PMT with optical grease.

Figure 2: A photograph of a SD deployed in the field. SDs are carried from the accumulation place in several places to each coordinates position by the helicopter.

The total electrical power consumed by all the electronics is less than 6W. It is locally generated by a solar panel of about 120W/125W (Kyocera, KC120J or KC125TJ) and stored in a battery (C&D Technologies, DCS-100L) of 100 Ah for deep cycle application and supplied through a custom-made charge controller. A solar panel is installed on the platform at 60° angle. Behind and below the solar panel is a metal enclosure containing a 12V battery and all the electronics except for the PMTs and the power bases. A deployed SD is shown in Figure2.

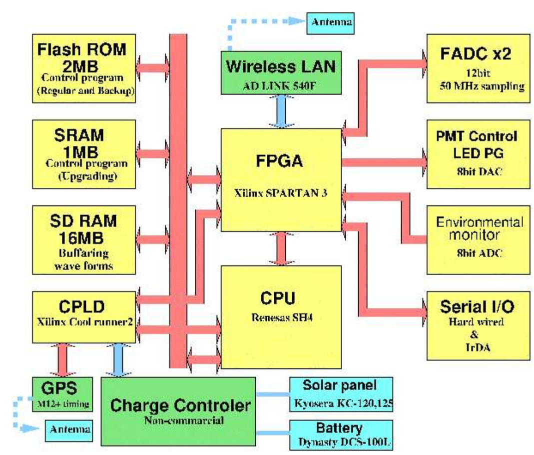

Figure 3: The block diagram of SD electronics. The control program can be updated by the wireless including even the firmware of FADC.

The data recording on each SDs

The signal from PMTs is received by Flash ADC, and recorded in the memory installed in the electronics(Block diagram is shown Figure3). The trigger rate is assumed ∼1kHz if the threshold is set to 0.3MIP, and can keep the data between 30s or more. The sampling rate of FADC is set to about 50MHz. A wave form which sampled by SD electronics is shown in Figure4. This electronics in-

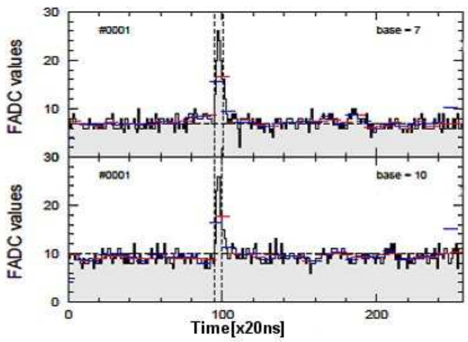

Figure 4: The example of wave form from PMT sampled by FADC.

cludes a GPS module(Motorola M12+ oncore timing), and FADC sample a wave form synchronizing with this module. All GPS module are calibrated by using GPS simulator(GSS7700) and we confirmed the individuality of the 1PPS signal what is generated by GPS is 20ns or less(See Figure5).

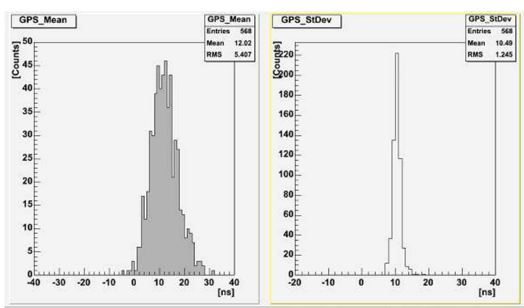

Figure 5: Measurement result of 1PPS offset of GPS by the simulator. Left is a mean value of the gap at standard time of the simulator. Right is standard deviation of mean value. As for staggering of 1PPS timing, it installs in about 10ns, and it is understood that accuracy is good.

Additionally, the electronics include environmental monitor (sensors for thermometer and humidity) and power management module and these are controlled or measured with CPU. The regulating system is composed real time operating, excellent in conformity.

Trigger decision and data acquisition

The trigger system of SD array is used wireless LAN for communication from the trigger center to each SDs. The trigger center is same as electronins of SDs. At first, SDs transmit brief table of trigger information what include 3MIP or more to the center. A list of triggered events with higher trigger threshold containing the pulse height and timing information for the hits is transmitted from SD to the corresponding trigger center at regular intervals such as 1Hz. The trigger center decides the final coincidence trigger based on the trigger table to take wave forms from the surface detectors for a shower event. Figure6 is a exsample of coincidence event at the north area of SD array.

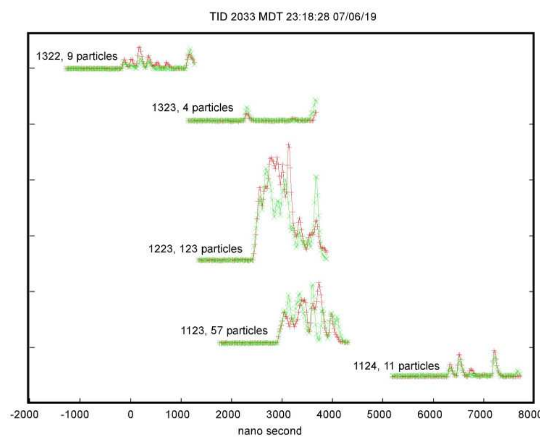

Figure 6: The example of selected time gate data. This event coincidence 5 SDs during about 7μs.

The trigger efficiency is expected to be about 100% for cosmic rays with energies more than 10^{19}eV entering the scintillation counter with zenith angles less than 45°. The data are transmitted to a central data acquisition system via tower-to-tower wireless LAN communication system which is commercially available.

Summary

The construction and the installation work of SD array are almost finished, and we are tuning and testing now. Figure7 shows detector arrangement

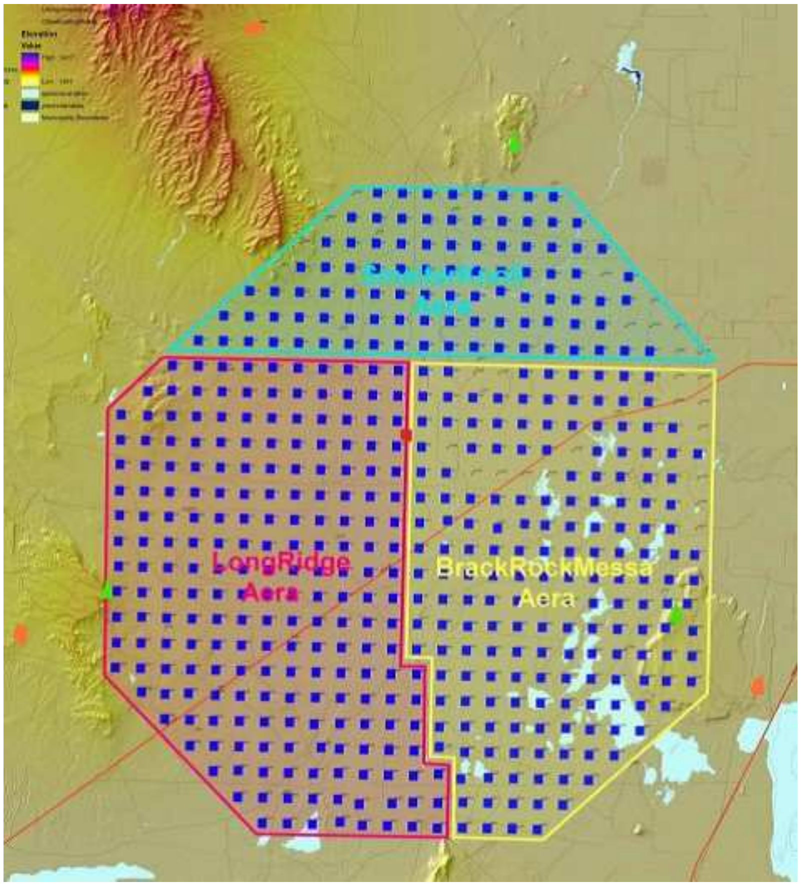

Figure 7: The map of area of TA observation site. SD is marked by small square. each DAQ center takes charge for communication.

of TA observation site. We installed three communication tower for setting trigger center. The trigger center is set up three places presently, and is collecting information from SDs in the each divided area,now Though this trigger judgment logic is executed by CPU now, and we will examine to execute it on FPGA to judge more efficiently. In the near future, we would develop and install the program to treat air shower events around the boundary of any areas. And we would develop hybrid observation system of SD and FD.

Some SDs are scheduled to be deployed to the points which is not turned blue in above map this autumn. We will start full operation by SD array as soon as possible.

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