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Calibration of TA Surface Detectors

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Abstract: The surface detector of Telescope Array(TA) experiment are deployed in desert of western utah,USA. The detector consists of two layers of plastic scintillators of 3m^2 area with wave length shifter fiber(WLSfiber). There are 2 PMTs and each PMT is connected with fibers from corresponding layer. To check PMT linearity, 2 LEDs are equipped for each layer. To estimate no of shower particles with good accuracy,it is needed to know the response for 1 minimum ionization particle and monitoring the environmental effect on it. And PMT linearity are also needed to be monitored and calibrated. Here we report observed variation on detector response and its calibration. And the result of linearity check with LEDs also will be reported.

Introduction

The Telescope Array(TA) experiment is designed for detection of Air shower from extreme high energy cosmic ray particle. In the energy spectrum measured by the AGASA[1] and HiRes[2] experiments,there have been contradiction. And the inconsistence leads the issue of existence of GZK cut off[3]. So especially accuracy in energy estimation around energy of GZK cut off ($\sim 10^{19.5}$eV) is important in the experiment.

To cross check systematic difference between 2 method of observation, the Telescope Array experiment consists from 2 types of detector. One is air fluorescence light detectors and another is surface detectors those detect particles in air shower. At this moment,3 Fluorescence telescopes and 485 surface detectors have been constructed and deployed in desert of western Utah,USA (N39.3^o,W113^o).Fig1 shows area of deployed surface detectors and position of air fluorescence detectors.

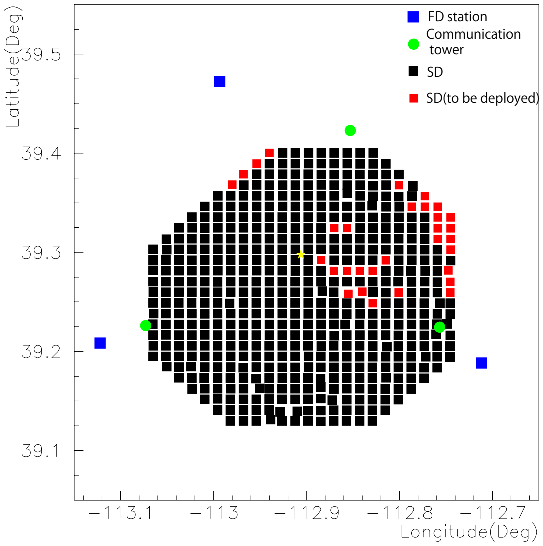

Figure 1: Area of planning 516 detectors. 🟦shows FD station, ■ shows surface detector. ●shows communication tower. Now 485 surface detectors are deployed.

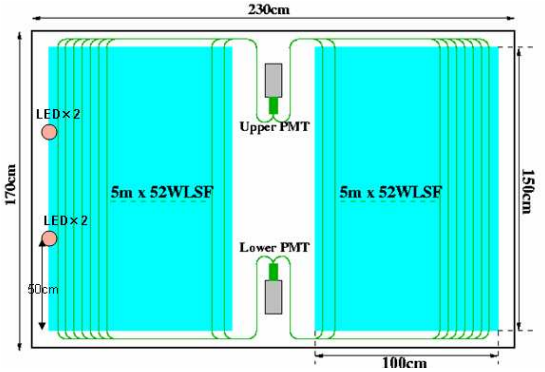

Figure 2: Schematic view of scintillator and PMT of Telescope Array surface detector [4]

Each surface detectors are deployed in separate 1.2Km.The total surface of coverage is $\sim$700Km^2. A schematic of inside of surface detector were shown as Fig 2.Each surface detector consists of two layers of plastic scintillators of 3m^2 area with wave length shifter fiber(Kuraray Y-11). Each layer of scintillators have thick of 1.2cm. There are 2 PMTs (Electron tubes 9124SA) and each PMT is connected with fibers from corresponding layer.

The LED(Nichia NSPB320BS) also installed for calibration of out put linearity for input light[4]. Installed PMTs are also calibrated for relation of high voltage to gain,and linearity curve [5].

At the front end of detector,there is custom made CPU board to record PMT output signal and communicate with control tower. The output signal from PMTs are digitized with 12bit FADC which is running 20nsec of sampling rate. As request comes from control tower,The CPU board will transmit requested data through Wireless-LAN modem.

Detector response for 1MIP

The most frequent charge out put by single muon injection is used to estimate no of detected particle in air shower event. We observe this charge out put and calibrate detector response. Using recorded FADC data,the induced charge out put by atmospheric muon is measured. Fig3,and Fig4 shows typical 1mip pulse recorded by FADC and observed 1mip charge distribution as a function of summed FADC count.

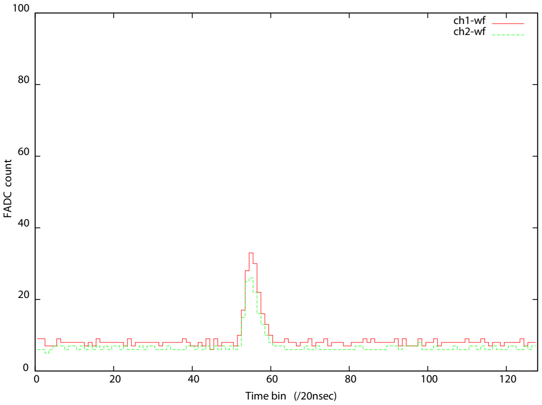

Figure 3: Observed typical 1mip wave form. The FADC sampling rate is each 20nsec. The pulse width due to single muon is around 8bin (160nsec).

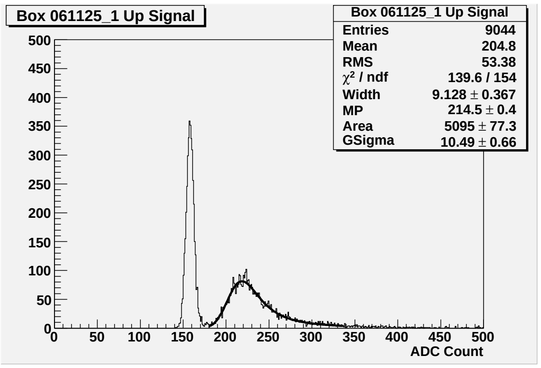

Figure 4: Observed charge output as a function of sum of FADC count. The window for integration was 16bin(320nsec) for triggered pulse.

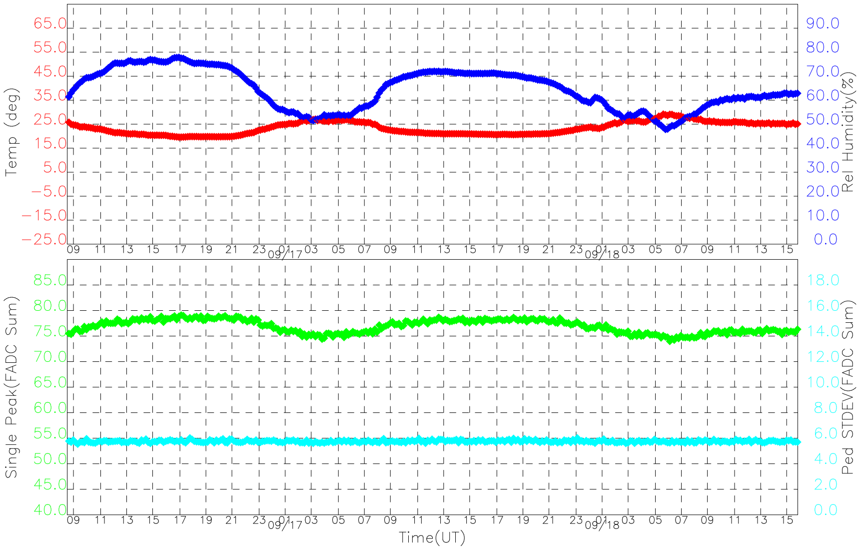

Figure 5: At the top panel, temperature variation of temperature and humidity at inside of the scintillator box are plotted with red and blue marker respectively. At bottom panel,the variation 1mip count and pedestal standard deviation are plotted with green and light blue.

Stability of Detector Response

As a test observation, continuous monitoring for 1MIP charge output was done. Fig6 shows time variation of 1 MIP count and temperature of inside of scintillator box. There clear negative correlation between single peak count and temperature profile are seen. As shown in Fig6 fluctuation of pedestal is not affected by temperature variation. The coefficient A schematic of inside of surface detector is around -0.8$\%/C^{\circ}$. The diurnal range of temperature at inside of scintillator box will be more than 25C°. Thus the 1mip calibration data is needed to retrieve at each few tens of minutes for enough accuracy of 1mip count.

Linearity check with LEDs

To check PMT linearity,2 LEDs are equipped for each layer. At the check of linearity, 2 LED was flashed alternately and simultaneously as changing light amount. If we represent light amount from LED as x and PMT out put pulse's peak current due to the LED light as $F(x)$,the PMT output while driving 2 LEDs simultaneously will be represented as $F(x_1 + x_2)$. The linearity have been checked by comparing $F(x_1+x_2)$ and $F(x_1)+F(x_2)$. As Fig6,a typical example of observed deviation between $F(x_1 + x_2)$ and $F(x_1) + F(x_2)$ are shown as a function of expected signal output. The check were done for all deployed detectors applying high voltage which gives 4×10^6 of gain. Typically the -5% of deviation due to nonlinearity of PMT response were observed at around 30mA of peak current.

Timing calibration

Event time stamp of recorded wave form at local detectors are obtained from 50MHz sub-clock. The sub-clock count are cleared by each 1PPS GPS signal. The offset time for those clear timing also have been measured before install those GPS module. Using 2 detectors which remained to be deployed, the relative accuracy of recorded time stamp also have been checked by sending pulse from single pulse source. In Fig7,an example of distribution of difference of time stamp between 2 detectors were shown. There,time stamp at each detectors were collected using maximum

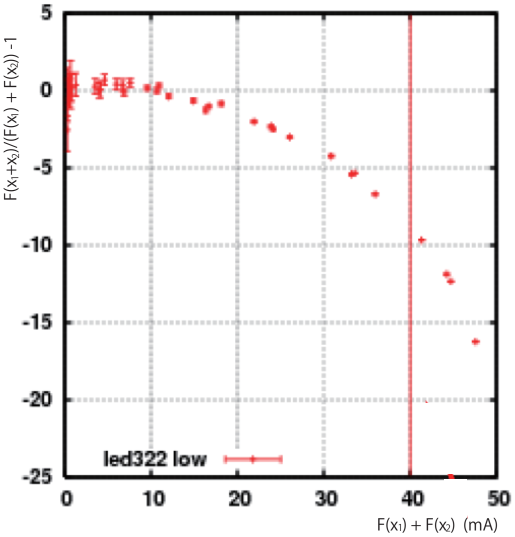

Figure 6: Example of typical deviation curve as a function of expected output pulse hight. Until 30mA the deviation is less tan 5% of observed charge output.[6].

sub-clock count in the each 1PPS pulse. The distribution shows 17nsec of fluctuation in relative time stamp difference.

Summary

Surface detector for Telescope Array was developed and deployed. For all deployed detector , the basic data for calibration of detector response were taken and examined before deployment. The time variation of 1mip response shows negative correlation with atmospheric temperature of coefficient of -0.8%/C°. Using equipped LEDs, we made sure that it perform as a good calibration tool for checking dynamic range of PMTs. The typical current limit for -5% of nonlinearity for PMTs are around 30mA. A timing calibration between 2detectors are also under going. A test with single pulse generator gives a result that relative time stamp between 2 detector have an accuracy of $\sim$20nsec.

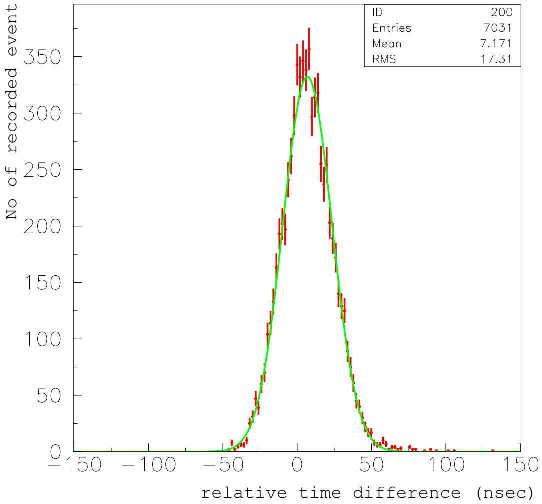

Figure 7: Example of relative time stamp accuracy between 2 electronics

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