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The present status of the Telescope Array experiment

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The Telescope Array(TA) experiment located at western desert in Utah USA (N39.3,W112.9) is designed for observation of air shower from extreme high energy cosmic rays. The TA detector consists of 2 types of detector to enable a cross check on systematic difference from the two main methods of observation for the energy region. One is a Fluorescence detector (FD) for detecting fluorescence light from air shower and another is surface detector (SD) array for detecting air shower particles at ground level. Each SD consists of 2 layers of plastic scintillator with $3m^2$ of surface and more sensitive to electromagnetic component in air shower. The full operation using 3FD stations and full SD array has started. Here we present the updated status of Telescope Array experiment.

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1. Introduction

Due to the interaction with cosmic microwave background photon, the flux of extremely high energy cosmic ray (EHECRs) are expected to be suppressed at energy of $\sim 10^{19.5}$eV. The effect which was predicted by (Greisen,Zatsepin and Kuzmin) is known as GZK cutoff[1,2].
There are 2 major method of observation for detecting EHECRs. One is the method which were taken at High resolution Fly's Eye (HiRes) experiment that detects air fluorescence light along air shower track using fluorescence detector(FD). Another is that taken at AGASA experiment that detects air shower particles at ground level using surface detectors(SD).
The energy spectrum obtained from AGASA experiment shows that there are 11 events beyond the cutoff[3]. However High resolution Fly's Eye (HiRes) experiment report the existence of the GZK cut-off[5]. The exposure of both experiment were 1.6×10^3 km^2 sr yr for AGASA experiment and for HiRes experiment, it is 2.4×10^3 km^2 sr yr.
Quoted uncertainty of energy determination is 18% for AGASA result[4] and 17% for HiRes result[5] repectively. The spectrum shape are in agree at energy lower than $\sim 10^{20}$eV when energy scale of one experiment are shifted $\sim$20%. So still the claims on existence of GZK cutoff contradicts.

2. Telescope Array Experiment

To solve the discrepancy between results from each type of experiment, the Telescope Array(TA) experiment was designed to have both surface detector array(SD) and fluorescence detectors (FD). Those detectors have been constructed and deployed in desert of western Utah,USA (N39^o,W120^o,1500m asl). At this moment,3 Fluorescence telescopes and 507 surface detectors have been constructed and deployed. Fig1 shows area of deployed surface detectors and position of air fluorescence detectors.

2.1. Surface Detectors(SD)

Each surface detectors are deployed in separate 1.2km.The total surface of coverage is $\sim$700Km^2. Fig 2 shows schematic of inside of surface detector(top view). Each surface detector consists of two layers of plastic scintillators of 3m^2 area with wave length shifter fiber(WLSfiber Y-11 Kuraray make). 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. Local trigger rate to record wave form is around 750Hz at TA site.

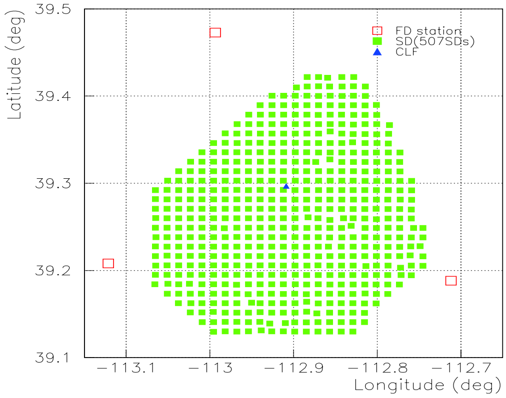

Figure 1. Deployed Telescope Array(TA) detectors (21.Nov.08)

The LED(Nichia: NSPB320BS) also installed for calibration of out put linearity for input light[6]. Installed PMTs are also calibrated for relation of high voltage to gain, and linearity curve.
The important feature of TA surface detector is the fact that those are more sensitive to electromagnetic component in air shower particle rather than muon component. This gives an advantage to be relatively free from the difficulty of the interaction model on montecalro simulation.
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 sampling rate 20ns. Single wave form has a time window of 2.56μsec. These digitized data are stored into buffer. All SD and trigger electronics at communication tower are synchronized by 1PPS crock from GPS satellite. As request comes from control tower,The CPU board

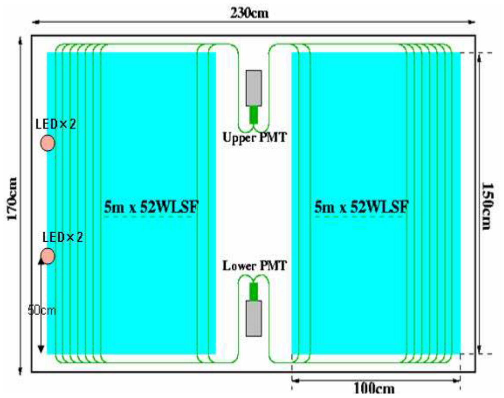

Figure 2. Schematic view of inside of surface Detector

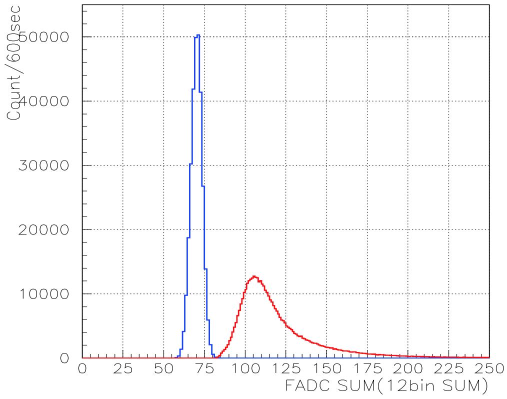

Figure 3. typical charge distribution from single muon and pedestal.

will transmit requested data through Wireless-LAN modem.
The calibration and monitoring data is taken continuously from all SDs at each 10 min without disturbing any air shower trigger schemes. At the monitoring,the most frequent charge out put by single muon injection is used to estimate deposited energy by hitted particles at air shower event. Fig3,shows typical observed charge distribution as a function of summed FADC count. The peak count are known as 2.4MeV of energy deposit from simulated atmospheric muon and GEANT4 simulation. Fig4,shows variation of monitored temperature ,humidity at inside of SD box and the muon peak count.

The SD array are subdivided into 3 sub-array of 110 , 190 and 207 SDs respectively. Each sub-array are controlled from it's communication tower. Each 1 sec the communication tower collect recorded event list from each SD with threshold of more than 3 muon. From the event lists, air shower trigger is generated when adjacent 3 SDs are coincidenced within 8μ sec. From Mar.2008 ,after taking engineering data,full operation of SD array are started. 5 shows trigger efficiency as a function of energy of primary particle. At energy of $10^{18.7}$eV the trigger efficiency of SD array reaches $\sim$ 100% [7]. Typical lateral distribution of shower particle detected SD array are shown as fig6.

2.2. Fluorescence Detector

The Fluorescence Detector were constructed to cover SD array from 3 position. These FD station makes it enable to compare same air shower event between SD observation and FD observation. One of the FD station at north of SD array is transferred station from HiRes experiment. Other 2 FD stations (Black Rock site and Long Ridge site)at west and east side of SD array are newly developed. The new FD stations are consist from 12 telescopes.Each telescope has 6.8m^2 of total area of reflector. The reflector is 18 of hexagonal mirrors. Field of view covers 31° from 3° of elevation and horizontally,108°. Fluorescence light from air shower are collected by these mirrors and detected by mosaic PMT camera on focal plane. Fig7 shows one of FD station(Black Rock Mesa).

Each telescope has a camera consists of hexagonal shaped 16×16 PMTs. Each PMT covers 1° × 1° of field of view. The PMT is equipped with UV filter to avoid night sky background. And the

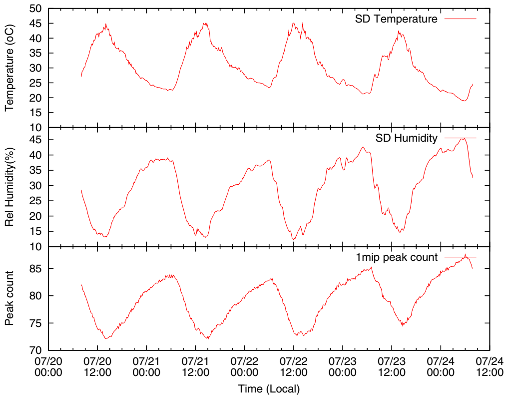

Figure 4. Variation of muon peak and SD environment data

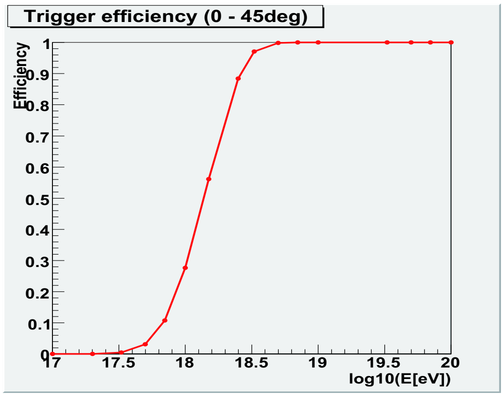

Figure 5. Trigger efficiency as a function of energy of primary particle[7]

signal from PMT are read out vir DC coupled pre-amplifier($\times$ 50).
The signal are digitized by 12-bit 40MHz sample FADC. After evaluating significance of the signal,the information of tubes with signal are sent to trigger decision electronics es.The wave form from FADC are recorded when signals are found at 5 adjacent PMTs[8].

Detailed PMT calibration were done by using light from Rayleigh scattering of the pulsed nitrogen laser. There the Rayleigh scattered photons out of a calibrated N_2 laser (337.1 nm 300μJ) in N_2filled chamber are used as standard light source. More detailed description of the calibration system (called CRAYS system) can be found at[9]. There are three PMTs at each camera those are calibrated by the system. The Xe flasher which is mounted on the center of telescope mirrors are used for relative calibration. The high voltages on each PMTs have been adjusted to obtain equal responce with the absolutely calibrated PMT. The gains of the absolutely calibrated PMTs are monitored by continuously with the YAP pulser which is attached on the surface of UV filter on the surface of PMT cathode. Relative gains of all the PMTs are also monitored using the Xe flasher once in every hour during observations.
By these monitoring and calibration, stability of PMT output responses are confirmed as within 3% of standard deviation. Non uniformities of PMT photo cathodes and gaps between PMTs are also measured with the XY-scanner after installation. The observation using 3 FD stations were started from Nov.2007.

2.3. Atmospheric Monitoring and Calibrations

At the center of 3 FD stations, Central Laser Facility(CLF) are located for relative calibration between 3 FD telescopes and atmospheric monitoring study. The distance from each stations to CLF site are 20.85Km . There,YAG laser($\lambda = 335nm$) will be shooted with output of 5mJ to obtain approximately same number of photon yield with that from air showers with energy of 10^{20}eV. A LIDAR system[10] are also developed at one of FD site(Black Rock Mesa) for atmospheric monitoring. It consists Nd:YAG laser($\lambda = 335nm$) , PMT and telescope to collect back-scattered photons. There, photon's extinction coefficient along the laser path can be obtain. The monitoring are running regularly at each operation. The same system are planned to be installed other stations. IR camera for cloud monitoring to cover FD field

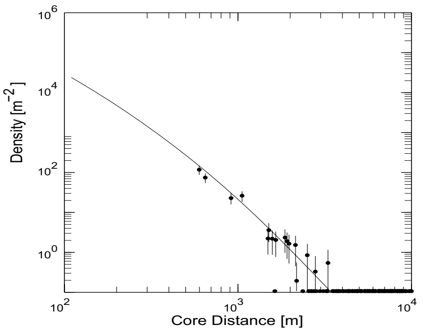

Figure 6. Typical lateral distribution of shower particle

Figure 7. One of FD station (Black Rock Mesa)

of view are also installed at Black Rock Mesa. For confirmation of integrated calibration constant, it is important to have tool for comparison between observed and expected detected signal using known electron beam. A small linear accelerator(LINAC) are developed. Using the LINAC system, at around 100m away from FD station, a beam of 10^9 electrons with energy of 40MeV will be shoot vertically. About details of thisLINAC system please refer[11].

3. Summary and Prospects

The Telescope Array detectors are constructed and started operation. At SD array , total number of detector is increased to 507 SDs. Monitoring of detector response are running together with air shower data taking. Reconstruction of detected air shower are undergoing.
At FD observation, constant observations using 3FD stations are running since Nov.2007.Facilities for atmospheric monitoring are also ready to be operated remotely.
All detectors and facility are constructed and deployed as we planned. Now expected performance with the TA detectors are as shown in table1. The values are estimated at $10^{20}eV$. Acceptance of SD are calculated with zenith angle upto 60∘. Energy resolution is assumed from SD. Energy scale uncertainty is assumed from FD[12].

Table 1
Projecteded performance of TA[12].

Total Acceptance	3220	km^2 sr
SD Acceptance	1600	km^2 sr
FD Acceptance(stereo)	1040	km^2 sr
FD Acceptance(mono)	1830	km^2 sr
Hybrid Acceptance	210	km^2 sr
Energy resolution	25	%
Energy Scale Uncertainty	10	%
SD angular resolution	2.0	degree
FD angular resolution	0.6	degree
Hybrid angular resolution	0.5	degree
FD Xmax resolution	17	g cm^{-2}

Expected performance of TA[12].

4. Acknowledgments

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