The First Observation with the Fluorescence Detectors of the Telescope Array Experiment

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Abstract: The fluorescence measurement is the key in observations of ultra high energy cosmic rays and in determinations of their primary energies in the TA experiment. All the fluorescence detectors of TA will be in operation from June 2007. In this talk, we will present the characteristics of the telescopes and the status of the associated systems including for the atmospheric monitoring and the PMT calibrations. We will also present preliminary results from the first observation run with the full telescope configurations.

Introduction

The Telescope Array (TA) Project[2] is designed to study cosmic rays with energies above 10^{19} eV. The TA observatory will measure the energy spectrum, arrival direction distribution (anisotropy) and composition of Ultra-High Energy Cosmic Rays (UHECRs). It will look for the super–GZK events[5] and the event clusters[6] observed by AGASA (the Akeno Giant Air Shower Array) and will resolve the discrepancy between the AGASA results and those of HiRes (the High Resolution Fly's Eye)[1].

The TA observatory is a hybrid detector system consisting of both a Surface Detector (SD) array (ala AGASA) as well as a set of Fluorescence Detectors (FD) (ala HiRes). It consists of 576 scintillation SDs which measure the distribution of charged particles at the ground and three FD stations which observe the night sky above the SD array[3]. The SD array covers an area nine times greater than the AGASA detection area. We can observe both the longitudinal development and the lateral distribution of air showers simultaneously with the hybrid system. Thus, we will use the measured parameters for complementary calibrations and can improve the energy and the angular resolutions of each component of the hybrid system.

The TA observatory is located in Millard County, Utah, USA(39.1°N, 112.9°W). The site is about 1400 m above sea level. As with the AGASA and HiRes experiments the TA observatory is located in the northern hemisphere, and then this allows the TA to directly compare with AGASA and HiRes measurement and to compare with southern experiments to search for a potential north–south asymmetry in energy spectra or source distribution.

Fluorescence Detector

The Telescope Array consists of three FD stations. The stations are located on a triangle with about 35 km separation and consists of 12-14 telescopes. Each station is centered on the central laser facility in the middle of the array and views 3°-33° in elevation and $\sim$108° in azimuth, and thus each one views nearly the entire array at high energies.

We have completed installation of telescopes at the first and second FD stations in the south–east and south–west corners of the array. The third station near the north–west corner is currently under construction. The site construction was complete and we are installing some of the HiRes–I telescopes to this station right now.

The telescopes (Figure 1) at the first two sites have a combined spherical mirror with a diameter of 3.3 m, a focal length of 3.0 m and a spot size of 30 mm on the focal plane. The pointing accuracy of the telescopes is $0.07°$.

Each telescope has a fluorescence light camera which consists of 256 PMTs (HAMAMATSU R9508). The sensitive area of the camera is 1 m $\times$ 1 m, which corresponds to the field of view of $15°$ in elevation times $18°$ in azimuth. Thus the pixel size of the camera is nearly equal to $1°$.

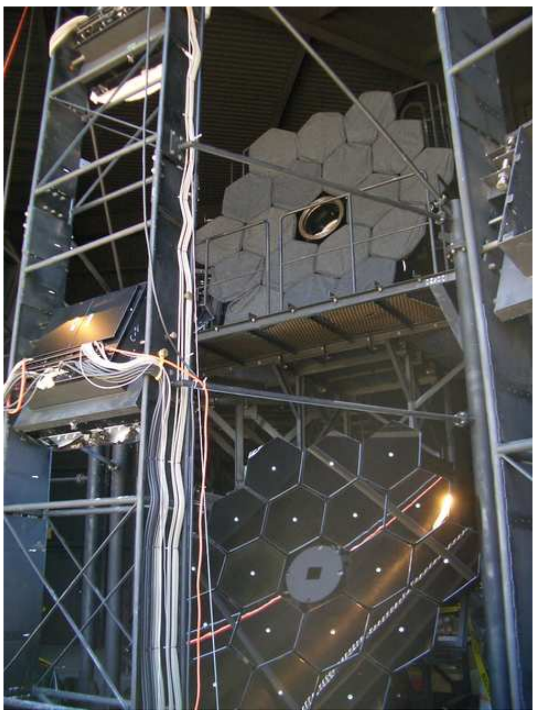

Figure 1: Telescopes and cameras in the first TA FD station. Every segment mirror of the upper mirror has a cover to avoid dust.

In each camera three PMTs among the 256 are absolutely calibrated with a standard light source. Moreover, the gain of each calibrated PMT is monitored through the constant measurements using a YAP light pulsar attached on the photo cathode. The YAP pulsar[4] consists of $^{241}\mathrm{Am}$ and a $\mathrm{YAlO_3}$:Ce scintillator, and its dimension are 4 mm in diameter and 2 mm in thickness. The gains of other PMTs are calibrated relative to the absolutely calibrated PMTs by comparing output signals of PMTs when they are exposed to a Xe flasher installed at the center of a mirror. The accuracy of absolute and relative gain determinations is 7% and 2.5%, respectively. Finally, the PMT–gain is set at 8×10^4 and the gain of the pre–amplifiers at the PMTs is 50.

The FD electronics[7] consists of the following three main components: the Signal Digitizer/Finder (SDF), the Track Finder (TF), and the Central Trigger Distributer (CTD). Each component fits on a single width VME–9U module. The effective dynamic range and the sampling frequency of SDF is equivalent to 16 bits at 10MHz. The signal finder logic measures the significance of the excess photons above night sky background in every 12.8 μs window, which we call "frames".

Each TF processes the hit patterns of one camera in every frame. The TF recognizes 5–fold hit pixel patterns as a track and 4–fold hit on the edge of the camera as a partial track, and sends the track recognition result to the CTD. The processing time for single track finding routine is 5.4 μs.

One CTD processes the track recognition results of whole the camera in a FD station. When one or more TFs find tracks, CTD distributes trigger signals to start data recording procedures for all the SDFs and the TFs. Moreover, when each of two neighboring TFs finds a partial track, the CTD also triggers the DAQ system. The total triggering time including SDF and TF processing is 9.8 μs.

Observation

The first and second of three Fluorescence Detector stations are operational in May 2007. The shower image shown in Figure 2 was obtained by the first FD station in May 2007. We confirmed the electronics and DAQ system have the quality and performance being up to our expectations.

The third site is under construction and should be operational in 6/2007. We will soon be collecting hybrid data at the Telescope Array.

In the conference, we will report the results of observations for background photons, noises, triggering rates and so on. Moreover, we will report the results of the planned first observation in June 2007 with stereo FD system of our experiment.

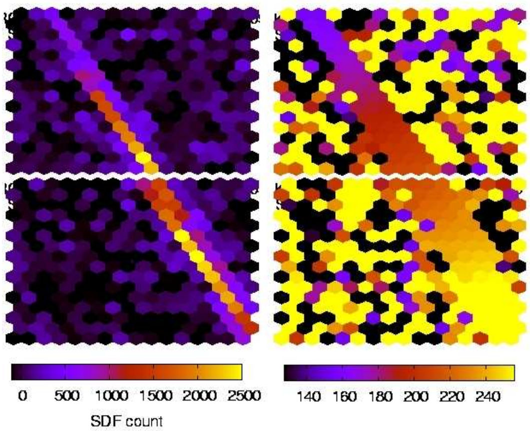

Figure 2: An example of multi mirror shower image detected with TA–FD station. The left panel shows the relative light intensities recorded by the FD cameras. The right panel is a map of the relative arrival time on each PMT determined from each signal recorded by SDFs.

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