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Telescope Array; Progress of Fluorescence Detector

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We start the construction of the fluorescence detector in 2004. At the present time, the construction of the shed of the south-east station is finished, and 12 telescope mounts were placed in the shed. Moreover, the power generators for the station and one LIDAR system 100m apart from the station are installed. At the same time, we advance development of the PMT cameras and the electronics. In 2005, we completed the constructions of a prototype telescope. This telescope has all the elements for detections of fluorescence light. We measured light pulses from artificial light sources, for development of the electronics, the data acquisition system and the calibration system. We will start test observations with two mirror–detector system at the first fluorescence detector station in July 2005.

1. Introduction

We steadily implement the construction of detectors for the Telescope Array(TA) experiment which measure ultra high energy cosmic rays at Utah with strong cooperative activities of Japanese and US researchers. These will become a hybrid detection system which consists of a huge air shower array and an atmospheric fluorescence detector array. In this report, we will offer a broad introduction of fluorescence detectors of TA, and we will show the results of test observations and the construction schedule.

2. Telescopes, LIDAR and Laser Facility

The site of the TA experiment is located at Milard county in the state of Utah, and the altitude is about 1500 m. The deployment of TA detectors is shown in Figure 1. The TA fluorescence detector array consists of three telescope stations, and each station contains 12 telescopes. The stations are placed on edges of the surface detector array, and the distance between stations is about 40 km. Every station is observing atmosphere above the array, and the stereoscopic coverage is 97 % of the array area.

Every telescope has a mirror with a diameter of 3.3 m and with a focal length of 2.96 m which is composed of 18 hexagonal shape segment mirrors. The FWHM of an image on the focal plane for a point-like light source is less than 30 mm, which is less than half pixel size of the imaging camera.

The imaging camera has a size of 1 m × 1 m, and has a close–packed structure of 256 hexagonal PMTs. The size of the photo cathode is nearly equivalent to 1°. Thus one camera has a field of view(FOV) of $18^\circ \times 16^\circ$. The viewing fields of adjacent telescopes overlap for about 0.5°. Thus for a whole station the elevation angles of the FOV is $3^\circ - 34^\circ$, and the azimuthal viewing angle is about 108°.

Every PMT has a UV transparent filter, BG3 by Schott, attached on the PMT head, and the front panel of a camera is a UV transparent acrylic plate, Paraglass 00 by Kuraray.

A LIDAR system for TA, which measures atmospheric transparency, mainly consists of of a 355 nm 5 mJ laser,

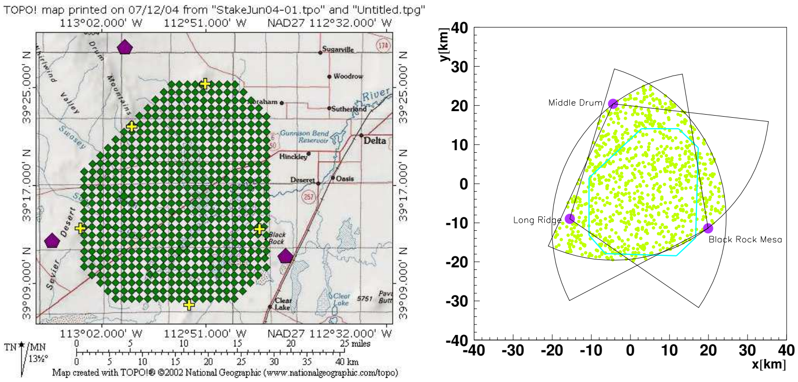

Figure 1. The left panel is a detector layout drawing for the TA experiment. The green rhombuses indicate the positions of surface detectors, and the violet pentagon-shaped markers indicated the locations of the fluorescence stations. The yellow cross markers are planned positions of radio repeater stations. In the right panel, the arcs shows the viewing areas by the stations projected on the ground, where the radius of the arcs is 40 km. The area filled with green markers is the stereoscopic coverage area with the stations.

Figure 2. The left panel is an external view of the fluorescence detector station. In this picture the shutter is open, and then a telescope mount held segment mirrors is seen. The right panel is a close–up view of a telescope mount. The lower part of it held segment mirrors and a imaging camera. The picture was taken at a workshop of a production company in Japan.

a 12” light corrector with a 3/4” PMT, a CCD camera for monitoring clouds and data recording electronics. Every station has the LIDAR system, which installed 100m apart from the telescope building.

In addition to the LIDAR systems, we will install 16 mJ Nd:YAG laser as a standard candle, which is called “Central Laser Facility(CLF)”. The CLF located in equal distances from every stations.

3. Electronics and DAQ

The block diagram of electronics and DAQ system for a fluorescence station is shown in Figure 3.

The signal induced by photons entering a PMT is amplified by the pre–amplifier attached on the PMT, and fed into a Signal Digitizer/Finder(SDF) module. The gain of the PMTs is adjusted to 8×10^4 and that of the pre–amplifiers is 40. In the SDF the signal travels through shaper–amplifiers, and then is digitized by 12 bits FADC with the sampling frequency of 40 MHz. Finally, the successive digital values are summed in fours and

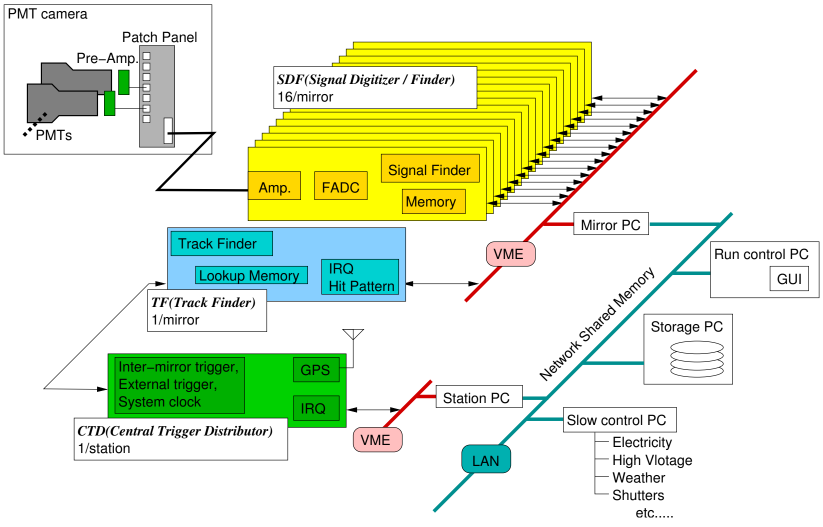

Figure 3.

recorded in a memory. As a consequence, the sampling frequency and the resolution for recorded waveforms corresponds to 10 MHz and 14 bits, respectively.

In the electronics described above, we adjust applied high voltages(HV) for every PMT to the condition in which one ADC count is equivalent to 0.2 photo electrons. High voltages are controlled for each PMT as individual over the range of -200 V to -1200 V. In our HV system, the maximum current is 0.35 mA per channel and the ripple is less than 50 mVp-p.

The measured linearity of the whole electronics is better than ± 1 % over a dynamic range of 0 to 660 p.e./10 ns. Moreover, the measured noise level is less than 1 mV, which is equivalent to 0.4 p.e..

We have implemented the following 3 steps of the triggering processes.

1. SDFs has a hit recognition process for each pixel, which is called 1st level trigger.
2. On a Track Finder(TF) module the 2nd level trigger logic searches tracks in a camera image, which are compared by pattern recognition algorithm.
3. A Central Trigger Distributor(CTD) module accumulates 2nd level trigger information from all the TF modules in a station, and determines to generate a final trigger. The final trigger information is distributed to all the TF modules to initiate readouts of buffered data. Moreover, the final trigger logic on CTD also recognizes inter–camera tracks and external triggers.

Triggering processes are executed for every sequence of pixel data equivalent to 12.8 μs, and this width is shorter than the total processing time for each trigger decision. Farther information for the electronic modules will be presented in other reports at this conference[1][2] [3][4].

When the DAQ system is triggered, Mirror PCs and the Station PC accumulate data from SDFs, a TF and a CTD through VME bus and upload data to a file server(Storage PC) through the local area network. On this server online analysis processes are running during observation times. The Slow Control PC communicates many types of hardwares, such as two power generators, the high voltage controllers for every telescopes, a weather station, the Xenon flashers for every cameras, the shutter controllers for the building, etc. Every computer has own resident process to control operations on each PC, and the resident process on the Run Control PC has ultimated control over all the processes on every computers. We make interactions between computers with UNIX/Linux socket programing and use the NSM(Network Shared Memory) package[6] for communications between remote processes, which have been developed for the Belle collaboration[5].

4. Laboratory Tests in Akeno

We have already finished constructions of the first station building, which is located on Black Rock Mesa(BRM), in 2004, and we have installed the telescope mounts and the LIDAR system in early 2005. Moreover, segment mirrors has been installed for two telescopes in the station, which optics are adjusted.

Moreover, we produced two sets of photon detectors including the PMT cameras and the electronics (except high voltage controllers), and we executed laboratory tests for these detectors, which are mounted on a proto–type telescope at Akeno observatory during February to May 2005. In these tests we did not observe atmosphere, and measured photons from the calibrated artificial light sources, such as a Xenon light flasher and a LED array. Then, we verified that the PMTs and the electronics meet specifications and measured noise levels in the electronics. Moreover, we checked cabling, hardware logic programs and performances of DAQ and high voltage control processes.

5. Conclusions

After the laboratory tests, we sent these sets of the detectors to Utah. The cameras and the electronics will be installed on telescopes in the BRM station in June, and we will test all the mirror–detector system and will observe side–scattered photons emitted by the LIDAR system and fluorescence light induced by air showers. At this Conference, we will present the results of these test observations.

In parallel with the test observations, we continue productions of mirrors, PMTs and electronics, and constructions of other stations. The installations of all the station will be completed by the spring of 2007.

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