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Telescope Array; Progress of Surface Array

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The telescope Array (TA) experiment, currently under construction in Utah, USA, is an array of surface detectors with air fluorescence telescopes to study the highest energy cosmic rays of energy beyond 10^{20}eV. The TA surface detector array will consist of 576 plastic scintillation counters, on a square grid with 1.2 km spacing, covering the ground area of 760 km^2. Each surface detector is outfitted with two layers of scintillators of 3m^2 area, readout electronics, and wireless LAN communication system, which are powered by solar system. The test of an Engineering Array with 18 surface detectors is currently operating after being deployed in December 2004. Here we present the design and the progress of the surface detectors of TA, focusing on the status of the Engineering Array.

1. Introduction

The purpose of the TA experiment is to measure the cosmic ray spectrum in the GZK cutoff region decisively and to pin down the nature of cosmic rays exceeding 10^{20} eV. The surface detector consists of an array of 576 plastic scintillators deployed in a grid of 1.2 km spacing covering the ground area of ~760 km^2. For energies greater than 10^{20}eV, more than 90% of the primary energy is transferred to the electronic component (e^+, $e^-$and γ) at the end of the shower development. The plastic scintillator is sensitive to the charged particles in the air shower and the energy measurement is less affected by the difference of the detail of unknown hadronic interactions and the primary composition.. The detector acceptance is approximately 9 times that of AGASA. The detector efficiency is 100% for cosmic rays with energies more than $10^{19.5}$ eV entering the detector with zenith angles less than 45^o.

2. Apparatus of Surface Detector

Each detector consists of plastic scintillators, photomultipliers (PMTs), wave length shifter fibers, electronics system, a communication system, and a solar power system. A simple and robust counter design will make the system easy to deploy and maintain in the desert.

We install wave length shifter fibers of 1 mm diameter in the grooves at 2 cm interval on the surface of the scintillator compouned by C.I. Industry Inc. Scintillation counter consists of two layers of plastic scintillator of 1.2 cm thickness with the area of 3 m^2. Scintillation light is read out by a separate PMT (Electrontubes 9124SA), each connected to the edge of the bundle of fibers on each scintillator layer. A coincidence is taken between 2 layers for obtaining a stable trigger condition against environmental background and PMT noise. Please refer to [1] and [2] for an explanation of the performance of the surface scintillation detector and PMT for the TA experiment.

Signals from PMTs will be continuously digitized with a 12-bit flash ADC with 50 MHz sampling. For a PMT signal exceeding 1/3 of the muon peak, a complete wave form of ~4μs is stored locally in a memory with a time stamp supplied by the Global Positioning System (GPS). We chose Motorola M12+ Timing Oncore Receiver. The rate of local buffering is expected to be less than 1 kHz for the 3 m^2 counter. The relative timing between remotely separated counters should be maintained within 20 ns by the GPS for the good resolution of arrival direction. A list of triggered events containing the pulse height and timing information of the hits is sent to a central DAQ system every second. If a trigger condition of 3 or more muons is adopted, the trigger list would contain ~100 events. An air shower event is identified by the central DAQ software by requiring clustered hits of counters with a good timing of coincidence. The air shower event rate will be significantly less than 1 Hz when we require at least 3 counters are hit at the same time.

The data acquisition system will be composed of a wireless local area network (LAN) using 2.4 GHz spread spectrum technology. Considering a limited reach of the presently available models, two stages of data concentration will be necessary to reach the central DAQ from individual counters. The speed of less than 1 Mbps is, however, sufficient for the expected trigger rate and DAQ throughput even when 2 or more stages of data collection are necessary. Five communication towers would be needed: three for nearby telescope stations and two for the places where communication may be difficult by only three towers. More details on trigger and data acquisition electronics are found in reference [3].

The total electrical power consumed by PMT, ADC, GPS and wireless LAN will be of ~5W. It is locally generated by one solar panel of ~120W and stored in one lead acid battery of 100 Ah for deep cycle applications and supplied through a charge controller.

To check the stability and detection efficiency, we monitor single muon peak and the trigger rate. For the quick check of dynamic range and linearity, we attach two LEDs (NSPB320BS made by NICHIA Corp.) to each layer.

Scintillator platforms are to be constructed of 2 inch square tubular steel legs and frame. Scintillators with fibers and PMTs will be contained in a 2.3m x 1.7 m x 10cm high stainless steel box, which lies on top of the platform and is covered with a thin steel roof in order to avoid sunlight and rain. The solar panel is installed on top of the platform at a 60 degree angle. Behind and below the solar panel will be a metal enclosure containing the storage battery and electronics boards. A lightweight 10 ft. antenna would be attached to each platform. The over-all dimensions of each detector is 7 ft. wid, 12 ft. long, and 6 ft hight (not including the antenna).

Figure 1. A scintillation surface detector deployed in the field for the Engineering Array test.

3. An Engineering Array Test and Prospects

On December in 2004, 18 scintillation surface detectors were placed as an engineering array. The purpose is to test the deployment and technical designs. Figure 2 shows the location of 18 detectors and the single temporary communication tower. The detectors were assembled in Delta City near the site. All the detectors were moved by trucks first to the staging area which is located alongside of an existing road. Each detector was picked up from there by helicopter and taken to the position to be deployed. Data transfer is successful between the detector and the temporary communication tower. The wave form distributions of signals from two PMTs by cosmic rays are successfully recorded through wireless LAN communication system as shown in Figure 3. Based on the engineering array and the basic performance test, we chose Sharp solar panel ND-L3EJE, DYNASTY battery DCS-100L, and decided to produce homemade charge controller for solar system. The electronics are being revised to the final version for mass production. We started mass assembly of scintillators in Japan and mass production of the platforms in Utah. We purchased or started purchasing commercial products such as PMTs, solar panels, batteries, and GPS. The mass deployment of the detectors will begin late in 2005. The surface detectors will be completed and operational by the spring of 2007.

4. Conclusions

On December in 2004, 18 scintillation surface detectors were deployed as an engineering array. Data transfer is successful between the detector and the communication tower, and the wave form distributions of signals by cosmic rays are successfully recorded. We started mass production of the detectors. The mass deployment of the detectors will begin late in 2005 and will be completed by the spring of 2007.

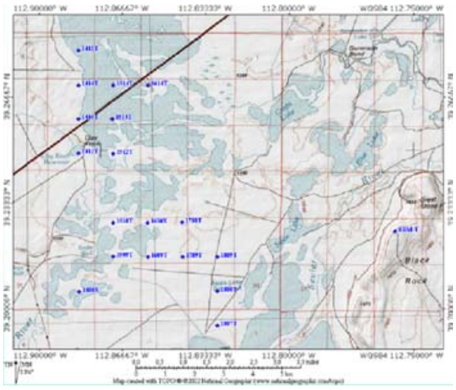

Figure 2. Location of the Engineering Array of surface detectors. 18 detectors and single temporary communication tower are shown as blue dots.

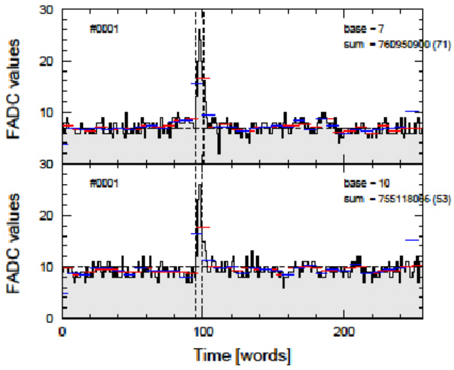

Figure 3. The wave form distributions of signals from two PMTs of the scintillator detector by a cosmic ray.

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