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A small prototype 'Linsley-effect' detector

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A small-scale detector utilizing the finite thickness of air-shower has been developed and operated on the roof of the physics building at the University of Gauhati. The objective of the work was to investigate the extensive work of Linsley and others with such detectors. The experiment was initiated with eight plastic scintillation detectors operating in coincidence to look at showers from 10^{17} to 10^{19}eV and to develop techniques for using such type of compact arrays. Some of the results and design will be discussed.

1. Introduction

Studies of EAS, produced by interactions of the Ultra High Energy (UHE) cosmic ray particles in the earth's atmosphere is one of the important branches of Cosmic Ray investigations. Since its first detection, the different components of EAS have been extensively studied in the primary energy range, $E_p \approx 10^{14} - 10^{17}$ eV. Presently more efforts are being given on detection of giant ($E_p \sim 10^{20}$eV) and super giant air showers $\geq 10^{20}$eV, as the investigations of EAS in these energy ranges would give necessary information on characteristics of the high energy interactions and the problem of proton spectrum cutoff by relic background radiation. However the intensity of UHE cosmic rays being extremely low, conventionally require a large area ground based particle detector array for their detection. Prof. J. Linsley [1] suggested a low cost method to detect UHE cosmic rays requiring a few closely packed detectors called a mini array. This type of detector array can measure arrival time spread of secondary shower particles at large core distances.

With the motivation of utilizing the capabilities of small scale, compact detector for investigation of cosmic ray air showers whose core fell outside of the detector array, a roof top detector was installed in the Physics Building at Gauhati University. The plan was to rely upon fast timing to measure the extended thickness of the shower front from high energy air showers. The present setup can provide the measurement of the local particle density and their arrival time spread up to 2.5 microseconds with a resolution of 10nS.

2. The Hardware

The prototype detector consists of Bicron BC-416 scintillator arranged in tiles, each read out by a fast Thorn EMI photomultiplier tube. Data read out is through Microprocessor based, with indigenous discriminator and low-level coincidences requiring three out of the eight of the tiles to have minimal signals. The signals from the eight detectors are amplified by fast timing amplifier [2] and then carried to the control room via coaxial cables. All the signals are comparated to provide corresponding logic signals. The comparated output is then regenerated into narrow pulses of 20nS width and OR'ed together to give a serial pulse train. The serial pulse train is then branched into the time digitizer [3], the oscilloscope and the trigger unit. The trigger circuit senses the incoming pulse train and generates the necessary trigger pulse. Once triggered, the number of detector pulses and their relative time positions are stored in the time digitizer and the scope. The time digitizer data is transferred to the microprocessor and then to the PC via serial port for permanent storage. The pulse waveform is recorded by the scope and transferred to the PC via GPIB interface.

3. Data Selection

Numerical calculation [4] shows that for a given threshold density, the minimum detectable shower size increases and the shower rate decrease with increasing time spread. A mini array should be able to pick out the very few large air shower events from a swarm of irrelevant events including the counter noise, the background soft radiations and small air shower. In order to eliminate the large number of small air shower, a minimum time spread has to be assigned. For a detector array of $2m^2$ area, a minimum acceptable shower size of 7.5×10^6 requires a minimum time spread σ1=100nS. In view of the small particle density encountered, each scintillator is not expected to receive more than one particle at a time from a shower.

4. Data Analysis

Analysis of the data was based on empirical formulation for the shower event time envelope (thickness) and on Monte Carlo simulations of extensive air showers. Figure 1 shows the empirical template for timing t with distance for a moderate N_e. The points on the plot are taken from Monte Carlo simulations. Vertical errors arise from timing errors in measurement and horizontal errors from the distribution of possible solutions. This distribution is due to the unresolved angular dependencies of the air shower and the intrinsic shower-to-shower fluctuations.

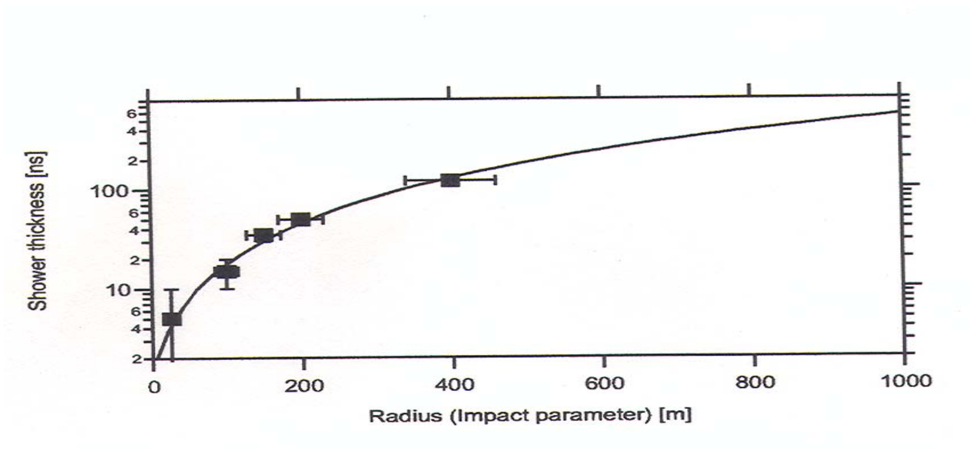

Figure 1. The shower thickness to radius for showers near 10^{19}eV. The curve is the empirical formulation of Linsley (1986) and the square marks are the results of Monte Carlo simulation.

The all particle spectrum is shown in Figure 2. There is no geometrical factor calculated for these data. Only the raw number of events versus reconstructed energy is plotted.

Considering all the densities and shower front thicknesses above the threshold, the energy spectrum is obtained with an overall spectral slope of -2.95. This value is lower than that calculated by other large groups [5]. The overestimation in the higher energy side is due to inclusion of some delayed particles, which are not part of the true shower front and thereby falsely increasing the thickness of the shower front. We consider the overall spectrum for the array up to 10^{18}eV with a slope of -2.98 ± 0.10, which is in reasonable agreement with that calculated by the other group.

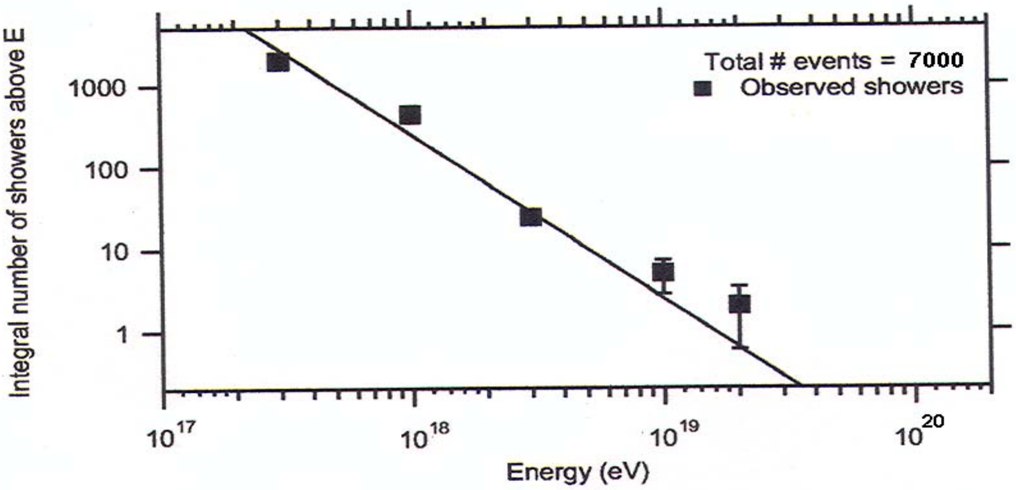

Figure 2. Integral number of events as a function of energy, which is not inconsistent with a power-law spectrum.

4. Conclusions

The investigations on the over all performance of the present detector array is encouraging. As a result the technique of such type of small detector arrays may be best utilized by small research group as a better tool for study of air showers in the UHE region.

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