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Primary mass composition above 10^{17} eV from optical data

J. P. Phukan[1], P. K. Boruah[2], and K. Boruah[1]

[1]Department of Physics, Gauhati University, Guwahati-781014 ,Assam, India
[2]University Sc. Inst. Centre, Gauhati University, Guwahati-781014, Assam, INDIA

Abstract

Optical pulses are detected in association with UHE Cosmic Ray showers recorded by the G.U miniarray detector ,which is sensitive for primary energy 10^{17} to 10^{18} eV. It is welknown that the characteristics of these associated optical pulses are correlated with the longitudinal shower development and hence the mass composition of the primary particle. Pulse rise time ,height ,FWHM are measured for individual optical pulses using Digital Storage Oscilloscope.The experimental data are simulated using Monte Carlo method for different composition models. The lateral distribution parameter is measured which is correlated with the depth of maximum and hence the mass composition. Priliminary experimental data and comparision with simulation results are presented in this paper.

1. Introduction :

Optical pulses are recorded in association with G.U miniarray ,which records the arrival tme spread (σ in nS) and charged particle density (ρ in particle/ m^2) at the eight (50x50x5 cm^3) plastic scintillation counters covering carpet area $2m^2$ at the roof top (Bezboruah et al., 1998). The measured time spread of the shower particles striking the array gives an estimate of the distance of the shower axis (Linsley's effect) . The measured particle density when fitted to lateral distribution function gives an estimate of shower size N , which in turn measures the primary energy .The Čerenkov counter , a 5" diameter PMT (Type 9792KB) is located at the centre of the miniarray . This miniarray is capable of detecting shower particles generated in the atmosphere by 10^{17} eV to 10^{18} eV primary Cosmic ray particles.

It is welknown that the slope of the Optical Čerenkov pulse lateral distribution is linearly related with the depth of shower maximum, which is different for different primary mass compositions. This parameter is estimated for different shower size bins and results are compared with simulation results assuming different composition models. The details about the method of simulation is presented elsewhere (Boruah et al., 1999).

2. Experimental Setup :

The miniarray detector consists of eight closely packed plastic scintillaton counters each consisting of one fast PMT (EMI 9807 B) , a plastic scintillator block of size

50x50x5 cm^3 having polyvinyltolune base , a pre-amplifier unit and a light tight enclosure.The larger PMT (9792KB) of 5" diameter is located at the center of the array for recording optical pulses in association with EAS events recorded by the miniarray. Fig-1 shows the experimental arrangement of the detector system . Signals from the eight scintilators and the large PMT at the centre are amplified and then carried to the control room via coaxial cables . In the control room , the eight scintillator amplified pulses are discriminated to provide corresponding logic signals which are individually shaped into narrow pulses of 20 nS width to be OR ed together to give a serial pulse train This is branched into one channel of the Digital Storage Oscilloscope (Tektronix ,TDS 520) for display and recording and the trigger circuit for generating the necessary trigger pulse .The triggered pulses from scintillation detectors , associated Čerenkov pulses from optical detector and trigger pulse are recorded by the DSO through the Channel-1, Chanel-2 and AUX-1 respectively. These recorded pules are trasferred to the computer (PC- pentium-III) via GPIB interface. This is done by the DSO in the real time single acquisition mode and waveforms are available in the wave form memory of the DSO.

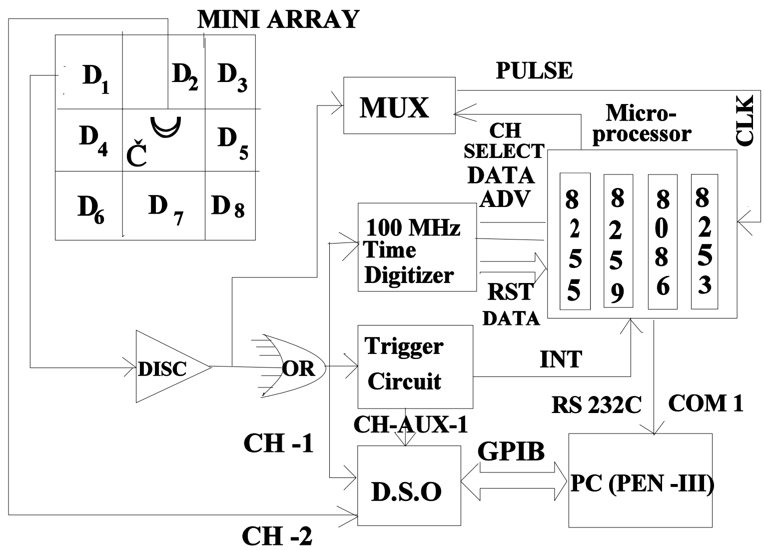

Fig .1. Block Diagram of The Experimental Setup

3. Data Collection :

The sensitive area of the miniarray is an annular ring of inner radius (r_{min} = 340 m) determined by the minimum time spread (100nS) and outer radius determined by the minimum particle density .Core distance and shower size for each event are derived from miniarray data and the associated optical pulse heights recorded by DSO are tested for genuineness by plotting scatter gram and comparing with theoretical prediction.

The collected data are binned according to the measured shower size of each event. In each bin optical pulse heights are normalised with the expected photon density at r_{min}.The slope of the curve between photon density and core distance in a log-log plot gives the exponent of the Lateral Distribution Function .

4. Method Of Analysis :

The thickness of the sower fornt(σ in nS) is related to the core distance (R in m) as derived form experimental data of Volcano Ranch Array (Linsley, 1962)

$$\sigma = BR^{\beta} \quad \text{-------------------------------}(1)$$

Where B = 0.0158 $\beta = 1.5$

Particle density is related to shower size N and core distance ,(Hara,1983)

$$\rho = CN\, R^{-n} \quad \text{-------------------------------}(2)$$

Where C=853 , n=3.8

Čerenkov Lateral Distribution fnction is taken as (Prothroe & Turver, 1979),

$$\Phi\,(R) = C\,(\,R+50\,)^{-\delta} \quad \text{--------------------}(3)$$

Here the stracture functin exponent δ is related to the depth of maximum Xm as (Rao, 1982)

$$\delta = .0014\,X_m + 1.32 \quad \text{---------------------}(4)$$

Using (1) & (3), we get,

$$\text{Log}\Phi = A - \delta\,\log\,(\,R + 50\,) \text{--------------}(5)$$

$$\text{Where } R = (\sigma / B)^{1/n}$$

The recorded pulse height in the optical channel are plotted against corresponding σ and ρ values and are selected on the basis of predicted correlation. Events are grouped into different shower size bins according to measured values of N using (1) and (2).The slope of the lateral distribution of optical pulses in a log-log scale, for different bins gives the experimental values of δ

5. Result :

The slope of the curve for average size 5.59×10^{7} (Ep ~ 2.1×10^{17} eV) is shown in fig.2,where,experimental value of of $\delta = 2.8$. Simulated slope for pure proton composition is estimated as 2.4. A comparision with simulation result gives agreement with pure proton composition of primary cosmic ray.

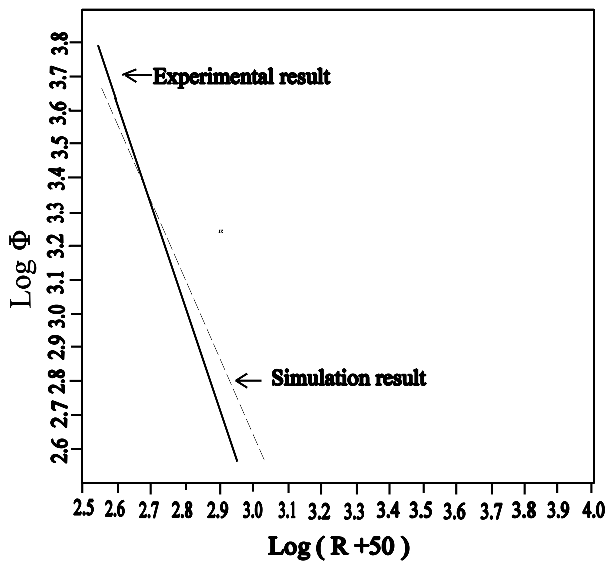

Fig.2. Lateral Distribution of The Optical Pulses.

6. Acknowledgement :

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