Optical emission from UHE Cosmic Rays

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Abstract

In addition to production of Cerenkov light, Cosmic Ray electrons in an EAS produce fluorescence light in the atmosphere, which is emitted isotropically and can be viewed at large distance. The fluorescent light and also the scattered Cerenkov light are being detected in coincidence with the mini array experiment of the Gauhati University, usng a fast photomultiplier tube (5" diameter) placed at the centre of the array. Preliminary work on the pulse profile measurement and correlation with the Ultra High Energy (> 10^{17} eV) air shower events recorded by the sophisticated data acquisition system is reported.

1 Introduction :

A rooftop mini array of eight plastic scintillators (50x50x5 cm^3) and fast PMTs covering a carpet area $2m^2$ is operating in the Physics Department , Gauhati University , for detecting giant air showers of primary energy $E_p \geq 10^{17}$ eV, utilising Linsley's effect (Bezboruah , Boruah and Boruah, 1998). The relativistic secondary charged particles (electrons and positrons) of the EAS in the atmosphere produce Cerenkov and scintillation photons. A larger PMT (9792KB) is now being installed at the centre of the array for recording optical pulses in association with the EAS events recorded by the miniarray.

It is wellknown that the slope of the lateral distribution of Cerenkov radiation is linearly related to the depth of shower maximum (Protheroe and Turver, 1979) which is different for different primary mass and energy. Thus, the optical detector operating in coincidence with the miniarray detector will provide extra handle for estimating primary mass composition. EAS events recorded by the present setup are also simulated by assuming pure proton and pure iron primaries and Cerenkov pulse height spectra are compared with experimental data.

2 Method of Simulation :

The miniarray essentially records the particle density and arrival time spread of the EAS particles, from which core distance and shower size are estimated (Bezboruah , Boruah and Boruah,1999). The effective area of acceptance for the miniarray is an annular ring of outer radius determined by the density threshold and inner radius determined by the minimum time spread. Here, shower size (total number of charged particles) N, core distance r and the depth of maximum X_m are simulated as main parameters, while primary energy E_p, Cerenkov lateral distribution parameter δ, fluctuation in X_m are derived as functions of the main parameters.

N is first simulated from the differential shower size spectrum (Hillas, 1975),

$$j(N) = -\gamma D N^{-\gamma-1} \quad \text{.......} \quad (1)$$

where, D= 318 and $\gamma = 1.7$. The core distance 'r' is choosen at random within the acceptance area of the miniarray. Primary energy E_p for each event for an assumed mass composition is derived as a function of N from the transition co-effecient $K=E_p/N$, as given in (Afanasiev 1977).

The X_m distribution is assumed to be Gaussian for $X_m < \langle X_m \rangle$ and exponential beyond $\langle X_m \rangle$ [$\propto \exp(-X_m/\Lambda_t)$]. The index Λ_t is related to $\lambda_{p\text{-air}}$ through the model dependent coefficient 'k' .

$$\Lambda_t = k\,\lambda_{p\text{-air}} \qquad (2)$$

where k=1.2 from the results of Quark Gluon String model (Fomin , 1987). Λ_t is expressed as a function of fluctuation in the depth of maximum (σX_m), using the relation for proton primary (Linsley, 1983),

$$\sigma_1 = 1.4\,\lambda_{p\text{-air}} \qquad (3)$$

After normalization, X_m distribution assumes the form :

$$p(X_m) = \frac{1}{\sigma X_m \sqrt{(2\pi)}} \exp - \frac{(X_m - \langle X_m \rangle)^2}{2\,\sigma X_m^2} \qquad \text{for } X_m \leq \langle X_m \rangle \qquad (4)$$

$$= \frac{1}{\sigma X_m \sqrt{(2\pi)}} \exp - \frac{(X_m - \langle X_m \rangle)}{0.8571\,\sigma X_m} \qquad \text{for } X_m > \langle X_m \rangle \qquad (5)$$

X_m values are simulated using the above distribution , with parameters $\langle X_m \rangle$ and σX_m derived as function of primary energy (Boruah, 1986).

3 Result and discussion :

In fig. 1 (a, b), the simulated pulse height spectra along with calculated χ^2 values have been shown for the two composition models. The results found to agree a proton composition in the ultra high energies.

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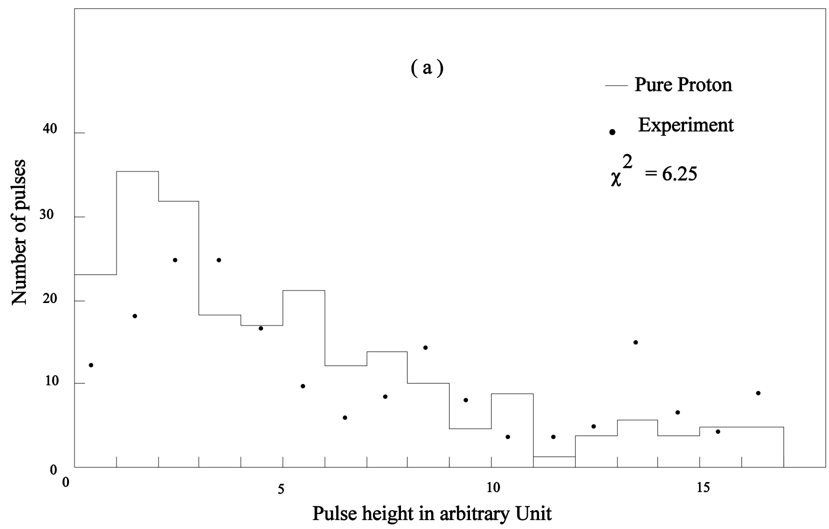

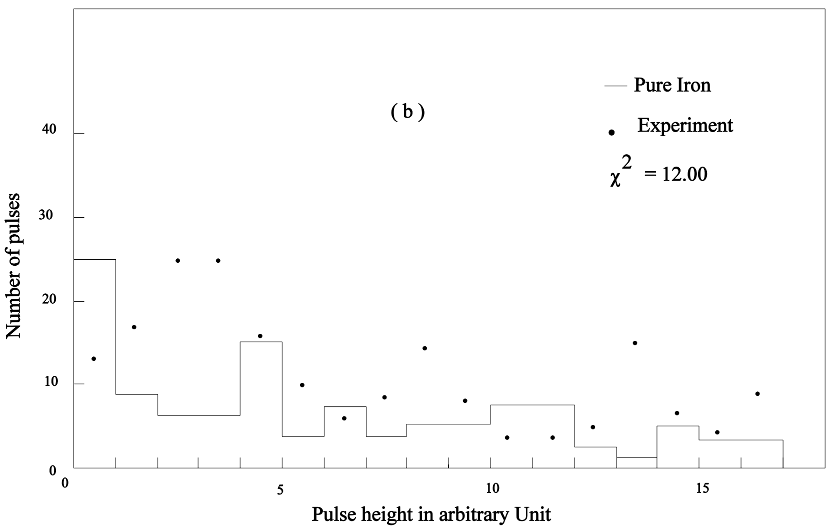

Fig.1. Cerenkov Pulse height spectrum for different mass compositions.