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Estimation of the Primary Cosmic Radiation Characteristics

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Abstract: A new method for estimation of the mass composition and the energy of primary cosmic ray radiation based on atmosphreric Cerenkov light flux analysis is proposed. The Cerenkov light flux densities in extemsive air showers (EAS) iniated by primary protons and iron nuclei are calculated with CORSIKA 5.62 code for Chacaltaya observation level. An approximation with nonlinear fit is obatained and the energy dependence of the function parameters is studied. The parameter fit as function of the primary energy is carried out. Two differeent detector displacements are analysed.

1.Introduction

One of the principle problems in the primary cosmic ray study is the precise estimation of energy spectrum and mass composition. One of the possible technics of investigation is based on atmospheric Cerenkov light measurements in EAS.

In general case the lateral distribution function of Cerenkov light in EAS depends of the energy E and the type of the initiating primary particle, the distance R from the shower axis, the observation level the height of first interaction etc…

At Chacaltaya observation level the possibility to detrermine the mass composition of primary cosmic ray radiation using different distributuions of EAS components their fluctuations at different distances is possible (Brankova et al 2001).

2.The Model

A lateral distribution function at Chacaltaya observation level 536 g/cm^2 is obtained with CORSIKA 5.62 code (Heck et al. 1993) using VENUS (Werner 1993) and GHEISHA (Fesefeldt 1985) like hadronic models for primary protons and iron in large energy range 10^4-10^7 GeV. The search of the best fit of this function is based on solution of overdetermined nonlinear problem with REGN code (Alexandrov 1971, Alexandrov et al. 1984) with algorithm simillar to (Drenska et al.1982) according the procedure (Alexandrov et al 98, Alexandrov et al. 99). The simulated data and the fit are presented on fig. 1 for primary protons and fig.2 for primary iron.

The obtained function is

$$Q(R) = \frac{s\, e^{a} e^{-\left[\frac{R}{g} + \frac{R-r_0}{g} + \left(\frac{R}{g}\right)^2 + \left(\frac{R-r_0}{g}\right)^2\right]}}{g\left[\left(\frac{R}{g}\right)^2 + \left(\frac{R-r_0}{g}\right)^2 + \frac{Rs^{2}}{g}\right]}$$

where R is the distance from the shower axis and a, σ, γ and r_0 are function parameters depending of the iniating particle energy. In the model the integral relation

$$E = k\ f(N_q)$$

is used where N_q is the total number of Cerenkov photons in the shower and

$$N_q = 2p \int Q(R)dR$$

The parameter κ in this relation depends of the primary particle energy and type.The dependences of the function parameters on the nenrgy is shown on fig.3 for primary proton and and iron nuclei. One can see their different

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as function of the energy of the initiating primaries. The approximation of parameter dependences on the energy is carried out using a polynom. This permits to distinguish the initiating primaries on the basis of the different χ^2 . For exmple the χ^2 for protons is 10 times larger using the iron fit for the same parameters.

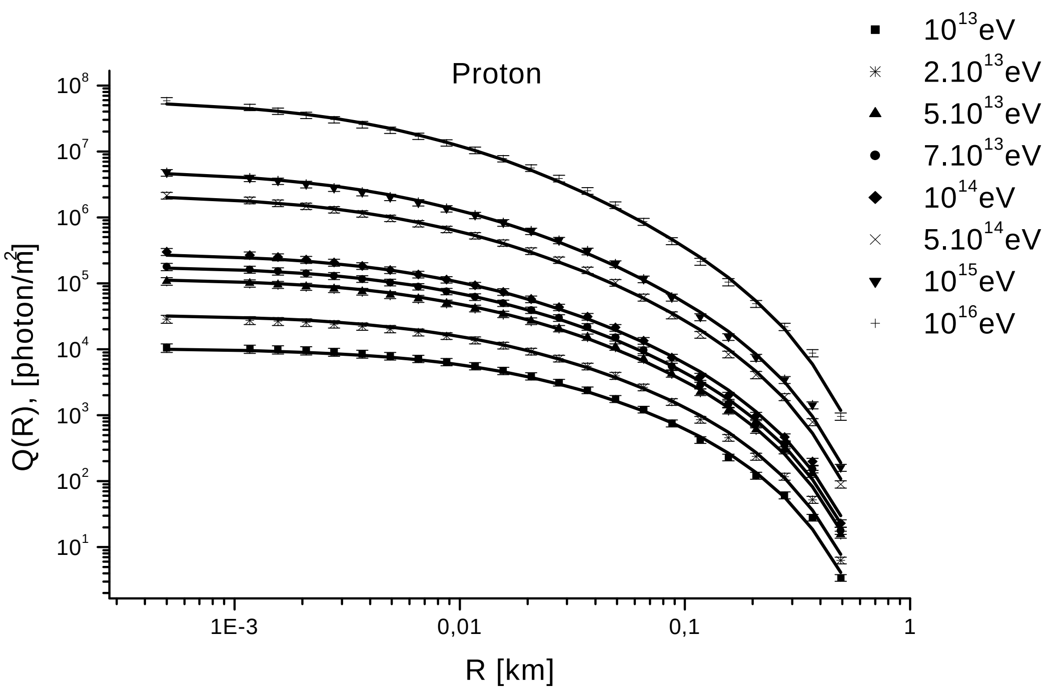

Fig. 1 The lateral distribution function for primary protons

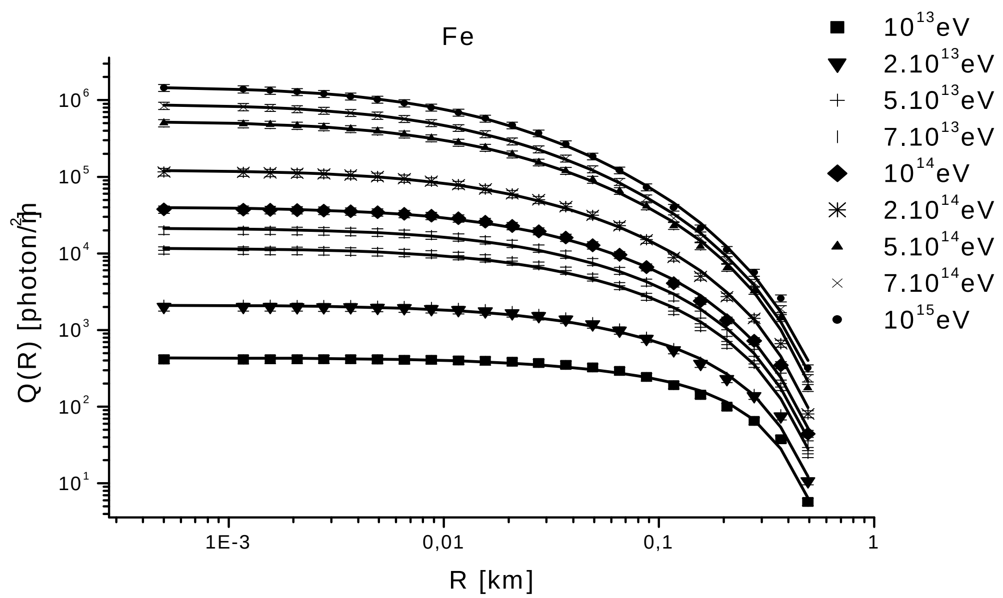

Fig. 2 The lateral distribution function for primary iron.

3.Results

On the basis of the obtained fit the simulation of the response for two different sets of detectors is made in the

very interesting energy range. The first one is according the HECRE proposal (Saavedra and Jones 2000). The second is proposed spiral set of detectors. Taking into account the wellknown relation between R and $x_{0,}$ y_0 which are the coordinates of the shower axis in detector plane, *q ,j* are the zenith and azimuth angles of the shower and x, y and z are the detector coordinates and replacing this in the model and solving the inverse problem one determine the coordinates of the shower axis. Moreover the energy and the type of the initiating primary is also estimated. The accuracies of ethe nergy estimation is less then 10% for the uniform set of detectors independly ot the type of the primary particle. The accuracy of the shower axis determination is 30% in the detector area and groun up to 50% at distances 2r where r is the radius of the detector displacement area. The same result is obtained for a proposed spiral kind of detectors. In this case the number of detectors is less then 30% which permits to reduce the

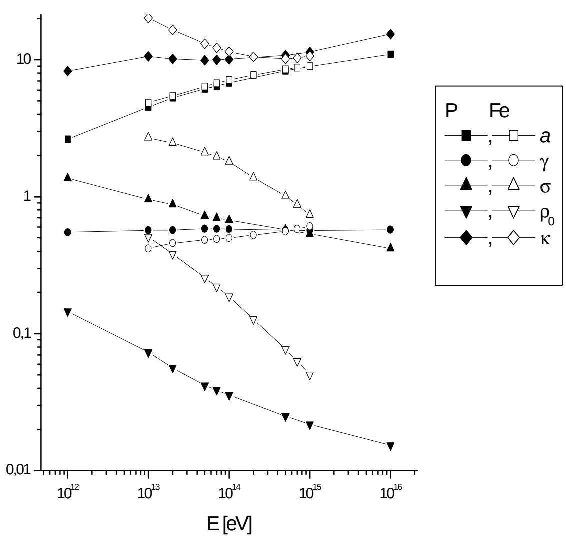

Fig.3 The fit parameters as function of the energy of the initiating primary nuclei

number of detectors which gives information. In both cases about 10% of showers cannot be solved correctly, so the determination of the shower axis and estimatiion of the energy is not precise.

4.Conclusion

A new method for estimation primary cosmic ray characteristics, based on the registration of Cerenkov light flux in EAS at given observation level is proposed and developed. The flux is described with the model functions defined on the basis of analysis of CORSIKA code simulated data. The energy dependencies of the approximation function parameters were studied for Proton, and Iron primaries. It is shown that the detector

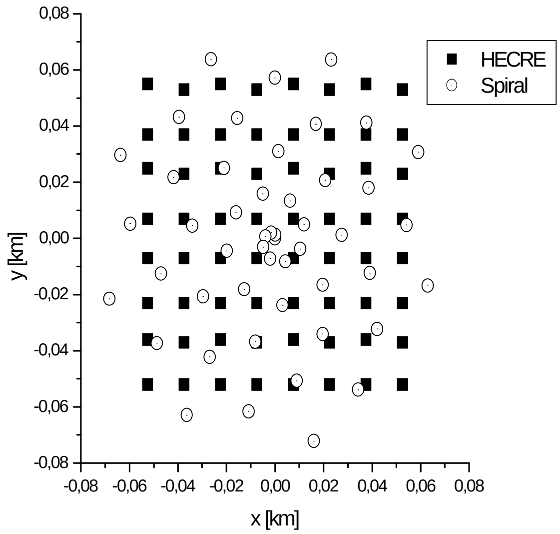

Fig.4 The HECRE detector array and the proposed spiral kind of detectors

displacement according to a new spiral kind permits to estimate with the same precision the shower parameters with much smaller number of detectors in comparison with the usual uniform detector displacement. An analogical method can be applied for other observation levels and detector displacements.

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