Mass composition and energy spectrum studies of primary cosmic rays in energy range 10TeV-10PeV using atmospheric Cerenkov light telescope

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Abstract

The primary cosmic ray flux is investigated using a previously proposed new method for estimation of the mass composition and the energy spectrum of primary cosmic radiation based only on atmospheric Cerenkov light flux analysis. The densities of this flux in extensive air showers initiated by primary proton, helium, carbon, iron nuclei and gamma quanta are simulated with CORSIKA 5.62 code for Chacaltaya observation level in the energy range 10 Tev - 10 PeV. An adequate model for approximation of lateral distribution of Cerenkov light in showers of mentioned above primaries is exploited. The mixed mass composition taken into account the abundances according the latest experimental data is simulated and the influence of energy and shower axis determination accuracies is studied. Two different detector displacements of atmospheric Cerenkov detectors are compared.

1. Introduction

Cosmic rays contain the most energetic particles. One important problem is the precise determination of their mass composition.The precise determination of their spectra in the range above of 10^{14} eV is very important in attempt to obtain information of their origin and acceleration mechanisms. In the range of high and ultra high energies the only possible way of cosmic rays registration is indirect from extensive air showers. The reconstruction of the energy and the mass composition from ground observation alone is very difficult but possible measuring one or few components of an extensive air showers. In this paper taking into account previously proposed method [1] and HECRE [2] experiment proposal the mixed mass composition of primary cosmic ray is studied.

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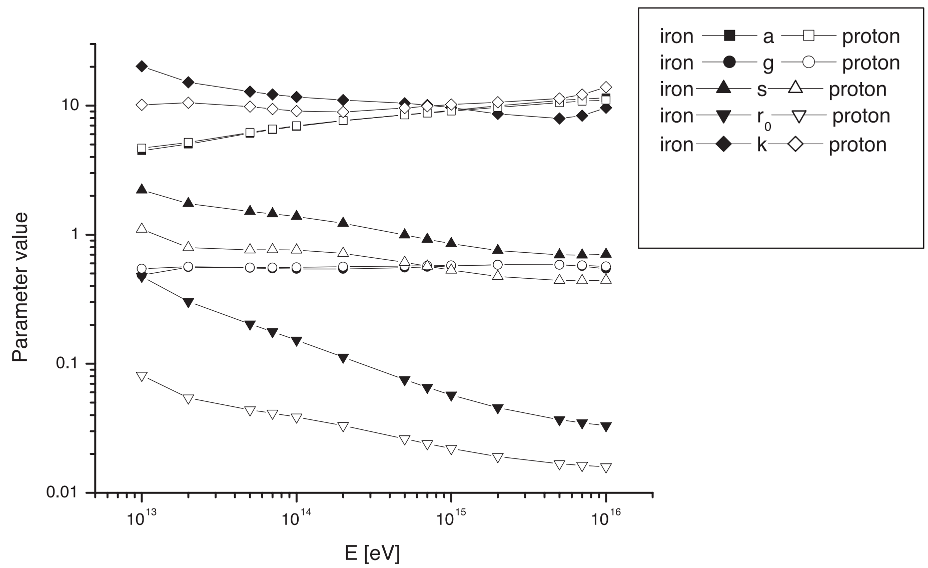

Fig. 1. Difference between iron and proton for the model parameters.

2. The Model and Simulations

Then lateral distributions of Cerenkov light, electrons, muons and hadrons in EAS are obtained with help of CORSIKA [3] code using VENUS [4] and GHEISHA [5] like hadronic models for different primaries proton, helium, carbon, iron nuclei and gamma quanta in the energy range 10TeV-10PeV at Chacaltaya observation level ($536g/cm^2$). An analytical mathematical expression [6] is proposed for all the primaries. The lateral distributions of Cerenkov light for primary protons with the corresponding approximation is presented in fig.1 in [6] as example. Analog calculations are carried out for primary Helium and Carbon and primary gamma quanta. The same approximation is used, but with different function parameters. The differences between the parameters are presented in fig.2 (proton and iron) fig.3 (proton and helium). The model function parameters in dependence of the energy are also approximated.

The strong nonlinearity of the model and this difference permits to distinguish the initiating primaries on the basis of the different χ^2. For example the χ^2 for protons is 10 times larger using the iron fit for the same parameters.

The proposed model gives the possibility to simulate the detector response of atmospheric Cerenkov detectors. The first one is according HECRE proposal [2].The second one is SPIRAL [6].The number of simulated events is 5000 with mixed mass composition (proton, iron, helium and carbon) according the latest experimental data. The simulations are carried out for 30 and 50 percent registration error of the detectors. Using the proposed method and simulated events one more an inverse problem is exploited. The obtained results for energy estimation

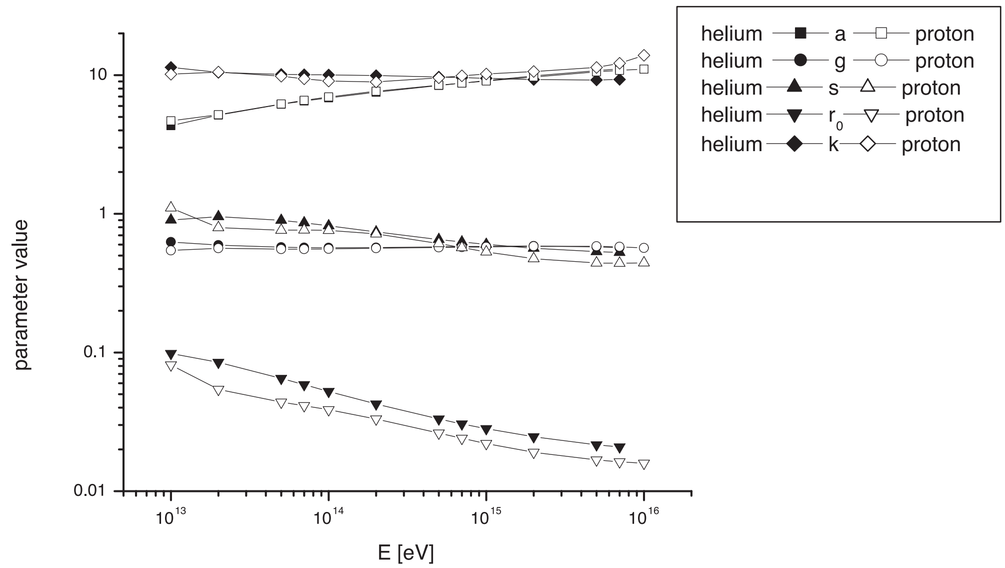

Fig. 2. Difference between helium and proton for the model parameters.

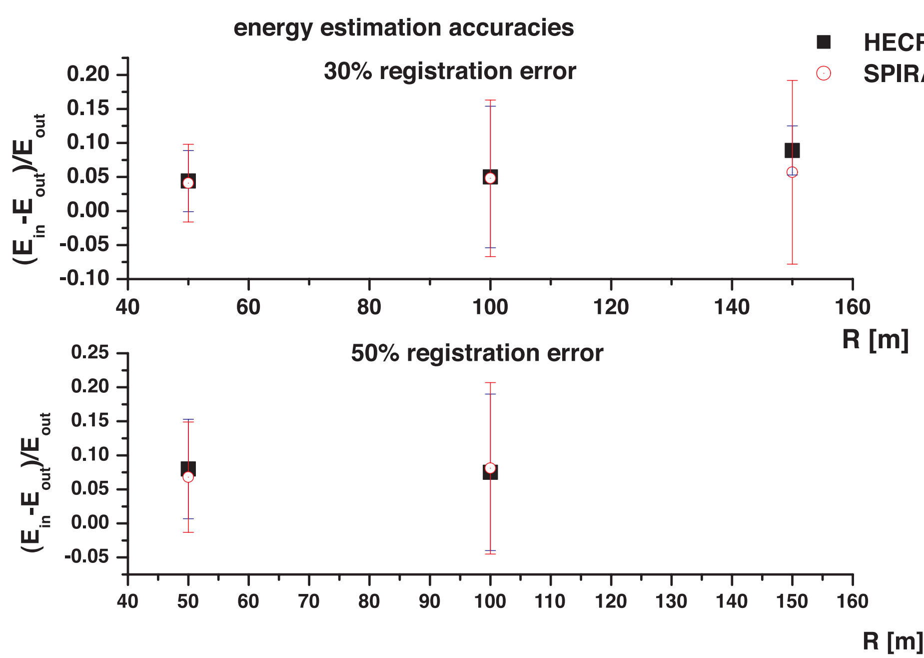

Fig. 3. Energy estimation accuracies for two detector sets and for different distances of the shower from the center of detector.

are presented in fig.4. One can see that the accuracies for energy estimation are less then 15-20 percent. In the case of 50 percent registration error the number of solute events (an adequate solution according χ^2 criteria) diminish with 15 percent and one can't give information about the initiating primary in the case of shower axis more than 100m from the center of detector. The investigation shows that this events don't give any influence into mass composition and energy spectra. So it is possible on the basis of the proposed model and method to estimate the energy of the primary cosmic ray radiation and to determine with big efficiency the mass composition.

3. Conclusions

On the basis of simulated events for primary protons,helium, carbon and iron with Corsika code is obtained the lateral distribution function of atmospheric Cerenkov light in extensive air showers at Chacaltaya observation level in the energy range 10 TeV - 10 PeV. An approximation as nonlinear function is carried out using an overdetermined system solution with REGN code. The model permits to estimate the energy of the primary particle and determine the mass composition. Using the proposed model two different sets of detectors are simulated. This first one is according HECRE proposal, the second one is a new type of spiral like displacement of detectors. The energy determination accuracies are studied for two detector sets. The maximal uncertainty in energy determination is about 15-20 percent. It is clear that this method permits to determine the mass composition in quasi real time using the information of minimum 30 detectors, displaced in distancies from array center up to 150m.

4. References

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