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Lateral distribution of Cherenkov light at high-mountain altitude produced by inclined showers in the energy range 10 TeV – 10 PeV

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The precise determination of the spectrum of primary cosmic rays and their mass composition in the range above of 10^{14} eV is very important towards to obtain some information of their origin and acceleration mechanisms. One of the further experiments now in preparation with several methodological investigations at simulation and reconstruction level is HECRE. This is a complex experiment at Chacaltaya cosmic ray station including detectors for muon registration, electromagnetic component registration and detectors similar to AIROBICC for Cherenkov light registration. In attempt to simulate precisely the detector response and adjust more appropriate trigger condition several characteristics of EAS are simulated using CORSIKA code including vertical and inclined showers up to 30 degrees. One large detector 800x800m is used in attempt to reduce the statistical fluctuations in obtained average values. The obtained lateral distributions are compared with vertical showers, previously obtained approximation and permit to adjust the reconstruction strategy.

1. Introduction

The precise estimation of the primary cosmic rays spectrum and mass composition in the range above of 10^{14} eV and around the "knee" is very important towards to obtain information and build model about their origin and acceleration mechanisms. In the region of high and ultra high energies the only possible way of cosmic rays registration is indirect from extensive air showers produced in atmosphere, precisely by registration of one or more components as example the atmospheric Cherenkov light. Such type of experiment ids the HECRE proposal [1]. It's represent an uniform set of detectors such as AIROBICC [2] The aim of the experiment is the registration and reconstruction of the lateral distribution of the atmospheric Cherenkov light in extensive air shower and afterwards on the basis of several criteria the estimation of the type and the energy of the initial primary. The HECRE experiment is situated at high mountain altitude 536 g/cm^2 at Chacaltaya cosmic ray station and as consequence it is near to the shower maximum. At the same time the registration of inclined showers gives several different possibilities. Comparing vertical and inclined showers it is possible to estimate the relative fluctuations of the number of Cherenkov photons in EAS and at the lateral distribution as well. Moreover the relative fluctuation of the total number of Cherenkov photons in the shower gives additional information about the mass composition. At the same is very important to provide registration of the EAS with quasi-constant efficiency for the different incident particles. In this paper are presented the obtained with CORSIKA 6.003 code [3]. Using the CORSIKA 6.003 code and QGSJET [4] and GHEISHA [5] as hadronic interaction models the lateral distribution of atmospheric Cherenkov light is obtained in large energy range 10^{13}-10^{16} eV for different primaries. In attempt to reduce the statistical fluctuations we use one large detector the aim to collect as much as possible of the Cherenkov photons in the shower. The simulation is carried out at high mountain altitude 536 g/cm^2 at Chacaltaya observation level. In one hand it is possible to compare the obtained distributions with previously obtained vertical showers [6]. On the other hand the obtained result gives the possibility to propose additional criteria for mass composition estimation and finally to adjust the methodology and model parameters for energy estimation and mass composition of primary cosmic ray [7]. In Figure. 1 is presented the obtained lateral distribution of atmospheric Cherenkov light densities for Helium initiated particle for vertical, 15 degrees and 30 degrees inclined showers.

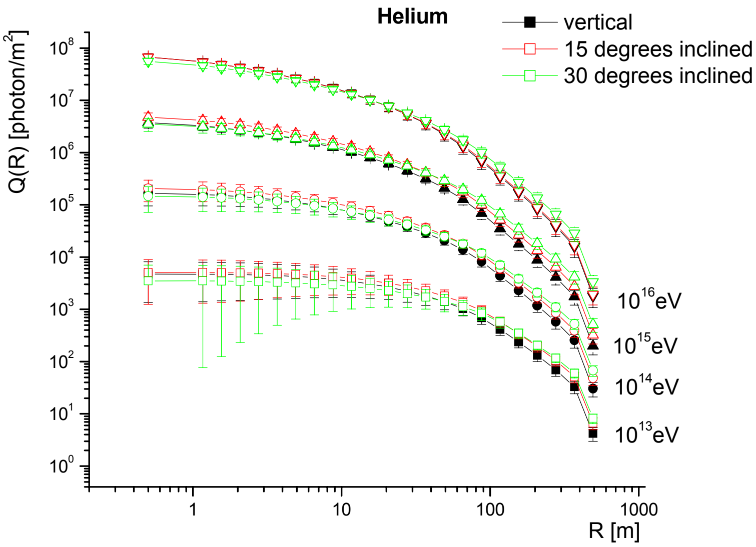

Figure 1. Lateral distribution of atmospheric Cherenkov light flux densities in the energy range 10 Tev – 10 PeV initiated by Helium induced inclined showers at Chacaltaya observation level.

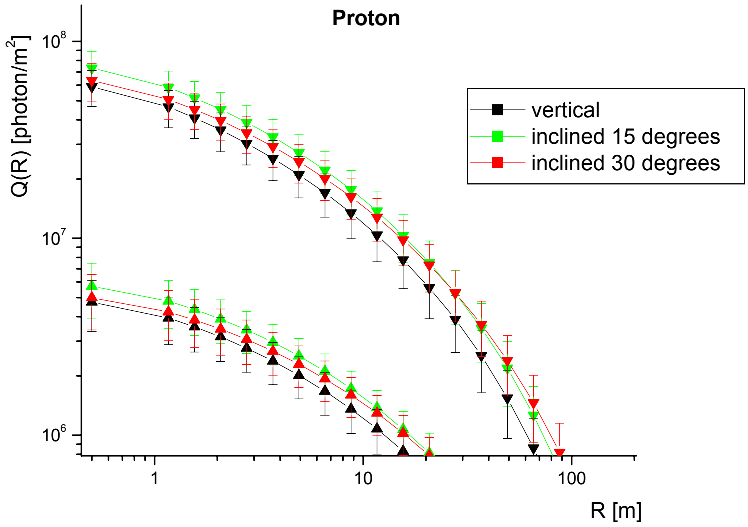

Figure 2. Lateral distribution of atmospheric Cherenkov light flux densities for 10^{15} and 10^{16} eV initiated by Proton induced inclined showers at Chacaltaya observation level.

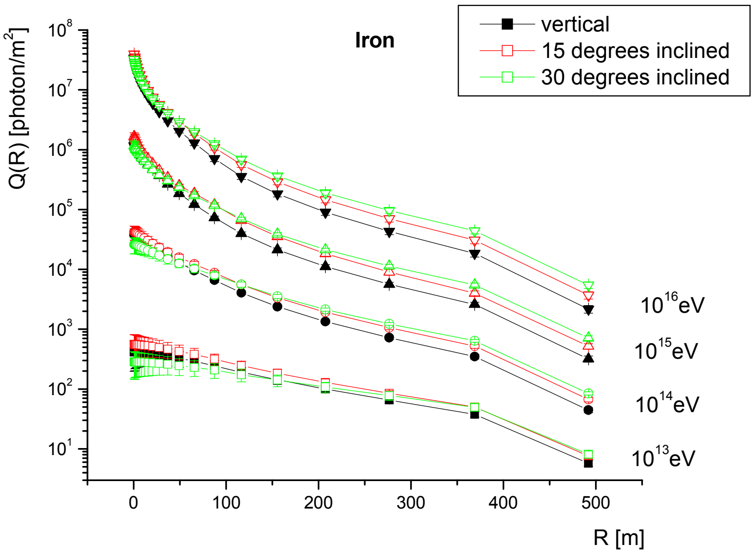

Figure 3. Lateral distribution of atmospheric Cherenkov light flux densities in the energy range 10 Tev – 10 PeV initiated by Iron induced inclined showers at Chacaltaya observation level.

In Figure. 2 is shown the corresponding lateral distribution for primary protons induced showers at energies 10^{15} and 10^{16} eV. And in Figure. 3. the lateral distribution of atmospheric Cherenkov light flux densities in the energy range 10 Tev – 10 PeV initiated by Iron induced showers. In all cases on the plot are presented vertical, 15 degrees and 30 degrees inclined showers.

2. Discussion

Inclined showers up to 30 degrees zenith angle are simulated at 536 g/cm^2 with help of Corsika 6.003 code. The obtained lateral distributions of atmospheric Cherenkov light are compared with similar distributions of vertical showers. The shape of the distributions is quite similar. As was expected as more the shower is inclined as more produces wider distribution (see Figure. 1 and Figure. 2). The observed systematic is the same for all simulated primaries. The obtained characteristics of inclined showers gives the possibility in one hand to build a strategy for mass composition estimation on the basis of registration of inclined with different incoming degrees and the relative fluctuations of the total number of Cherenkov photons in the shower at the given observation level. Moreover the obtained distribution gives the possibility to estimate at the same the local densities of Cherenkov photons at given distance and so with the additional information of the zenith angle to select with constant efficiency the different primaries using the previously proposed selection parameter [8]. On the other hand the obtained lateral distribution is approximated with the proposed model function [7] for HECRE experiment with similar results as expected. This permits to adjust the model parameters, which is connected for uncertainties estimation. This is very important to reduce the limits of the model parameters for the different primaries and as ea result to estimate the mass composition of the primary cosmic ray with higher precision and efficiency. And finally the obtained distributions are excellent check for the previously obtained methodology [7]. The good agreement between the model parameters as their behavior as a function of the energy pf the initial particle show that the model and the proposed methodology are adequate and are usable for HECRE proposal.

At the same it is possible to use other characteristics as muon and soft component in attempt to make a multi component analysis. Further such type of analysis of vertical and inclined showers permit in one hand to adjust the obtained parameters of reconstructed events and on the other hand to provide the registration of the different primaries with constant efficiency, which is very important of the experimental point of view. In the future an additional simulation for other primaries as Helium, Carbon and Oxygen are necessary to obtain more precise parameterization and to summarize the observed systematic. The final aim is to build a data bank of simulated data for the different primaries at this observation level, including inclined showers, which permits to propose a good reconstruction strategy.

3. Conclusions

The lateral distribution of atmospheric Cherenkov light flux densities at Chacaltaya observation level are obtained with Corsika 6.003 code in the very interesting energy range around the “knee” for proton and iron primary particle and for inclined showers up to 30 degrees zenith angle. The obtained results are compared with previously obtained similar characteristic of vertical showers. They confirm the proposed model and methodology for event reconstruction at high mountain altitude based on atmospheric Cherenkov technique and permits to adjust several parameters and estimate the method constraints.

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