Analysis of Energy Distributions of Hadrons Registered in the Pamir Experiment

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Abstract

Energy and zenith angles distributions of hadrons registered in the carbon emulsion chambers of the Pamir experiment have been published. Experimental zenith angles distributions are different from the calculated ones.

In this paper we show E_h distributions for hadrons registered in the chosen zenith angle intervals. It is interesting if a stream of high energy hadrons (tens of TeV) changes with the change of zenith angle.

1. Introduction

Basic characteristics for hadrons registered in carbon emulsion chambers of the Pamir experiment at the altitude of 4300 m. a.s.l. (i.e. $600\,g/cm^2$) have been published in former papers [1, 2]. Distributions of energies E_h of registered hadrons have been presented in paper [1]. Received differential distributions were described by the power law function with exponent $\gamma = 3.01 \pm 0.04$ in the interval of energy $(17 \pm 550)\,TeV$.

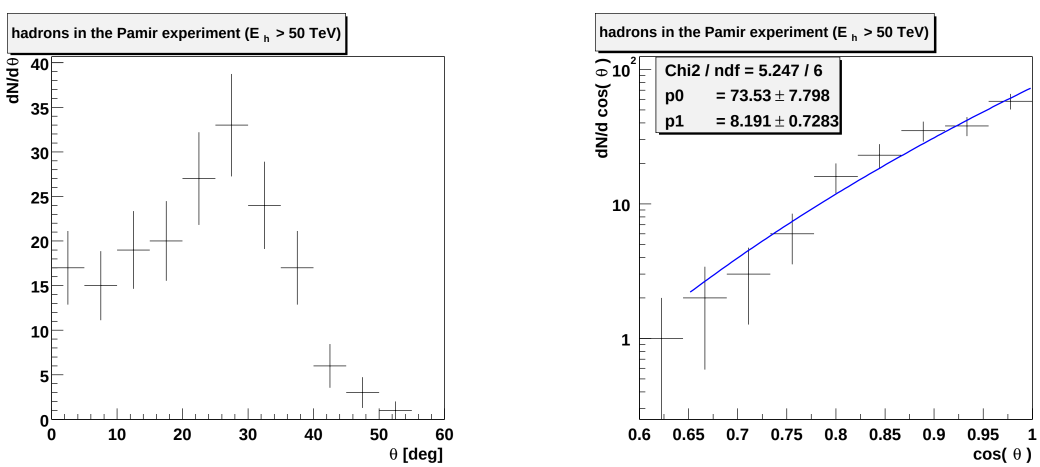

Fig. 1. θ and $cos(\theta)$ distributions of hadrons registered in the Pamir experiment (for $E_h > 50\,TeV$).

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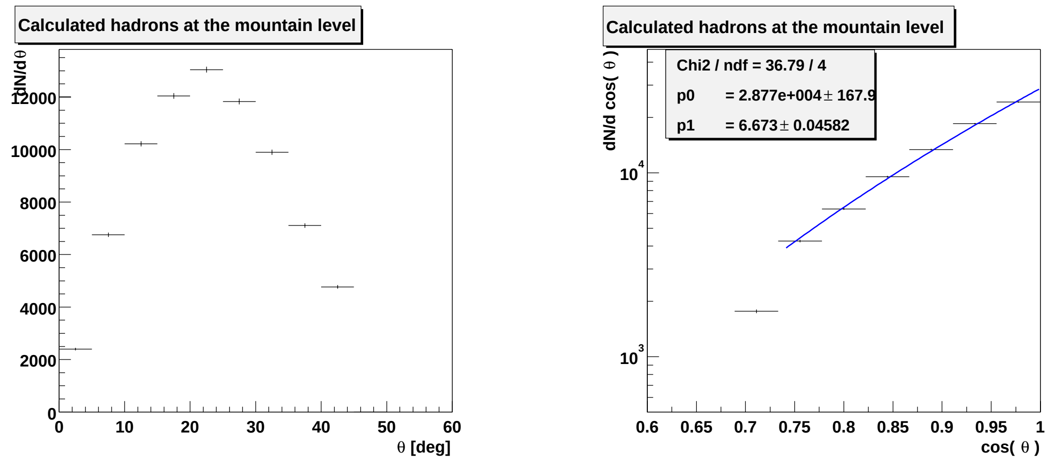

Fig. 2. θ and $cos(\theta)$ distributions of calculated hadrons.

The distributions of zenith angles of hadrons registered in the Pamir experiment and hadrons received in the simulation calculations have been published in papers [2, 3, 4]. Distributions received from calculations (CORSIKA program and QGSJet model) are described well by power function $\sim cos^m\theta$ with exponent $m = 6.67 \pm 0.05$ for all hadrons at registration level. Distributions of hadrons registered in the experiment and calculated have been shown in Figures 1 and 2.

Experimental distributions of zenith angles for the part of data have had an unexpected anomaly. It cannot be explained with methodical errors. Anomalies of zenith angles distributions of hadrons registered in chambers slightly different from the standard ones (15 % of registered hadrons created a peak for $\theta \approx 8^o$) have been analysed in papers [2, 3]. Fitting of experimental data of $cos^m\theta$ with function of the same shape gives values of $m = 8.2 \pm 0.7$ (experimental data from chambers with anomalous θ have been omitted).

That is why we decided to analyse more closely E_h distributions for different zenith angles.

Table 1. Exponent of power law function - fits of energy distributions.

$\Delta\theta$ [in deg.]	$S = 62m^2$ fit in $(17 \pm 500)\,TeV$ intrval	S=120 m^2 fit in $(55 \pm 500)\,TeV$ intrval
$0 \div 15$	3.50 ± 0.13 fitted in $(17 \pm 40)\,TeV$ 2.31 ± 0.21 fitted in $(40 \pm 500)\,TeV$	2.59 ± 0.24
$15 \div 90$	3.16 ± 0.05	3.20 ± 0.17
$0 \div 25$	3.37 ± 0.10 fitted in $(17 \pm 40)\,TeV$ 2.78 ± 0.15 fitted in $(40 \pm 500)\,TeV$	3.00 ± 0.17
$25 \div 90$	3.11 ± 0.07	3.03 ± 0.22

2. Calculations

Distributions of energy of hadrons registered in carbon emulsion chambers for chosen intervals of zenith angles: $(0 \div 15)^o$, $(15 \div 90)^o$, and for $(0 \div 25)^o$ and $(25 \div 90)^o$ have been made. Received differential spectra E_h have been described with power law function.

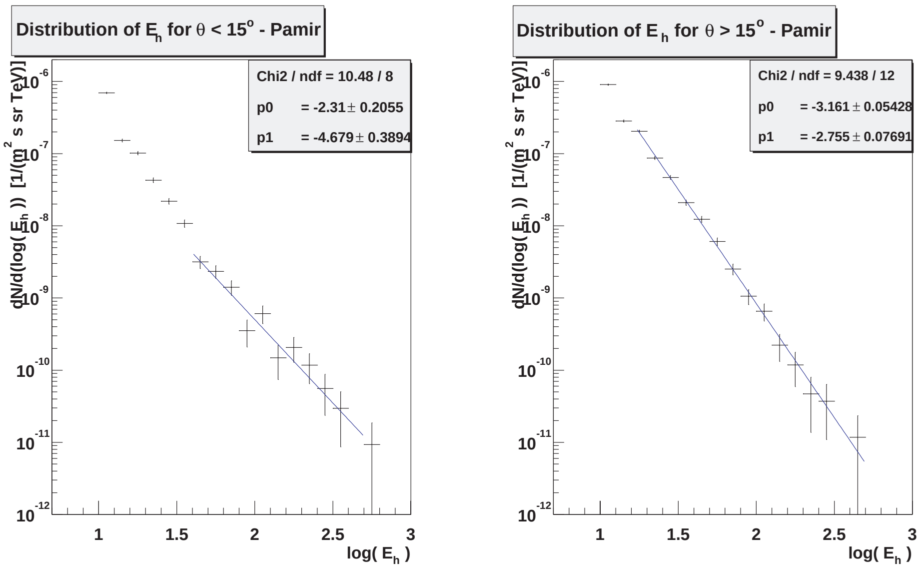

Fig. 3. Experimental spectra of hadrons: for zenith angle $\theta < 15^o$ (left) and $\theta > 15^o$ (right).

Figures 3 and 4 present received experimental E_h distributions at the mountain level for intervals of zenith angles θ given above. Parameters of fitting with power law function have been shown in Table 1. It is visible from Figures 3 and 4 that experimental E_h distribution cannot be described with one power function. Chi-square test of goodness of fit power function with data in the whole energy interval E_h (for hadrons with small zenith angles only) gives χ^2 values over 2 for one freedom degree.

Two functions with energy intervals of $(17 \div 40)\, TeV$ and $(40 \div 500)\, TeV$ give good fitting. Remaining distributions can be described with one power law function. The result of fitting is surprising. Exponent of differential spectrum is very small $(2.3 \div 2.8)$ for small θ and increases up to ~ 3.2 for large θ angles.

3. Conclusions

It has been among others analysed in the paper [5] how the shape of the spectrum registered at the mountain level compared to the primary cosmic ray spectrum changes as a result of strong interaction parameters changing with the energy (cross section, inelasticity coefficient and others). Reasonable approximations of the strong interaction parameters suggest that the spectrum of hadrons

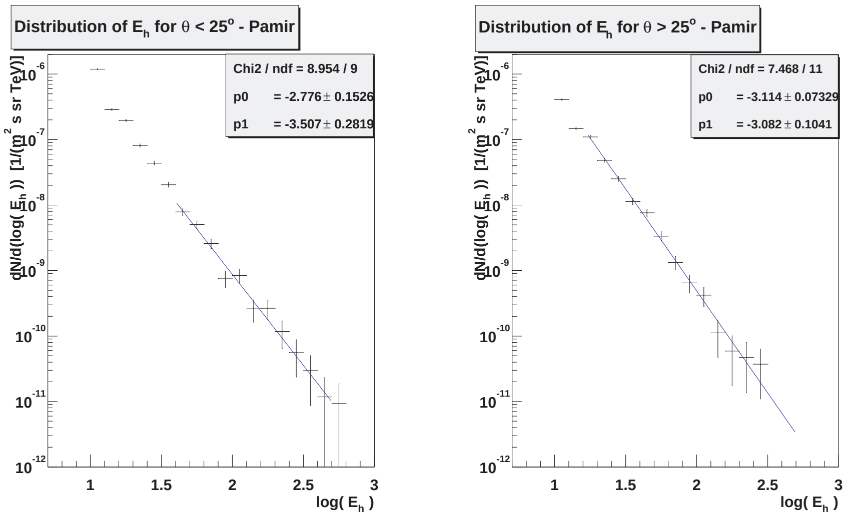

Fig. 4. Experimental spectra of hadrons: for zenith angle $\theta < 25^o$ (left) and $\theta > 25^o$ (right).

observed at the mountain level becomes steeper by 0.30 - 0.35 in comparison to the slope of primary spectrum. It means that if slope of spectrum above the atmosphere ~ 2.7, we should observe then in the Pamir experiment the spectrum with slope $3.00 \div 3.05$

The change of the spectrum slope for small zenith angles is observed by $E_h = 40\,TeV$. It results from the paper [4] that they are hadrons coming from the primary particles with energies of hundreds TeV. It means that primary cosmic ray spectrum by energies of hundreds TeV has an untypical shape or the quick change of mass distribution of the spectrum occurs.

The spectrum for large theta does not have not homogeneous and its slope shows that particles responsible for its occurrence (with energies of PeV) come from the primary spectrum with the slope of about $2.80 \div 2.85$. It can be then concluded that the spectrum primary cosmic ray for E_o in the interval of hundreds TeV $\div$ PeV cannot be described by power low function.

We expect that the exact analysis of the results from the calculations from papers [4, 5] will allow to estimate mass composition of this part of primary spectrum.

4. References

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