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Zenith angle distributions of hadrons at mountain altitude (600 g/cm^2) in CORSIKA simulations

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Abstract. Zenith angle distributions of hadrons registered in the Pamir experiment have shown unexpected peak for small angles ($\theta \approx 7.5^o$).

Calculations simulating penetration of primary cosmic ray particles through the atmosphere to 600 g/cm^2 level (which corresponds to the Pamir experiment level 4370 m a.s.l.) have been made. Program CORSIKA with QGSJET model has been used.

In this paper distributions of zenith angles θ and of cos(θ) have been shown for various types of hadrons, electrons and gamma quanta at mountain altitude.

θ and $cos(\theta)$ distributions of hadrons registered in the Pamir experiment have been presented and compared with the results of calculations.

1 Introduction

Zenith angle distributions of particles registered in carbon emulsion chambers of the Pamir experiment have been presented in (Kempa, Malinowski et al., 2001) (see Figure 5).

Peak for small θ angles is observed in a part of data from chambers which slightly differ from typical ones.

Calculations simulating primary cosmic ray penetration to observation level (Pamir experiment level) have been made to show what result should be expected. Calculations have been made using CORSIKA program v. 5.62 with QGSJET model (Heck et al., 1998). The primary cosmic ray spectrum according to Nikolski mass composition (Nikolski, 1987) has been used for simulations.

θ and $cos(\theta)$ distributions of particles received from primary protons and Fe nuclei have been analysed. No anomalies or large differences in distributions coming from various primary particles have been observed. That is why only results of calculations for Nikolski spectrum have been presented.

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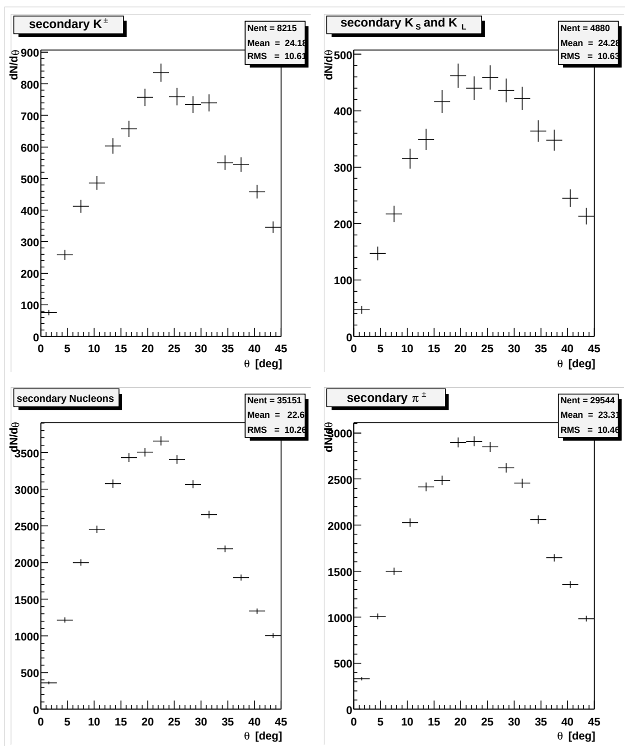

Fig.1. Zenith angle distributions of secondary $K^{\pm}$, K_S and K_L, nucleons and $\pi^{\pm}$.

2 Simulation results

Distributions of θ angles and $cos(\theta)$ for particles coming to registration level have been presented in Figures 1,2,3,4. Distributions of registered hadrons, γ quanta and electrons, nucleons, $\pi^{\pm}$, $K^{\pm}$, K_S and K_L have been shown. $cos(\theta)$ distributions were fitted with following function

$$f\left(cos\theta\right) = Acos^m\theta \quad (1)$$

Exponents of fitted function have been shown in Table 1. Differences of exponent m for different types of observed particles can be caused by different cross sections. Neverthe-

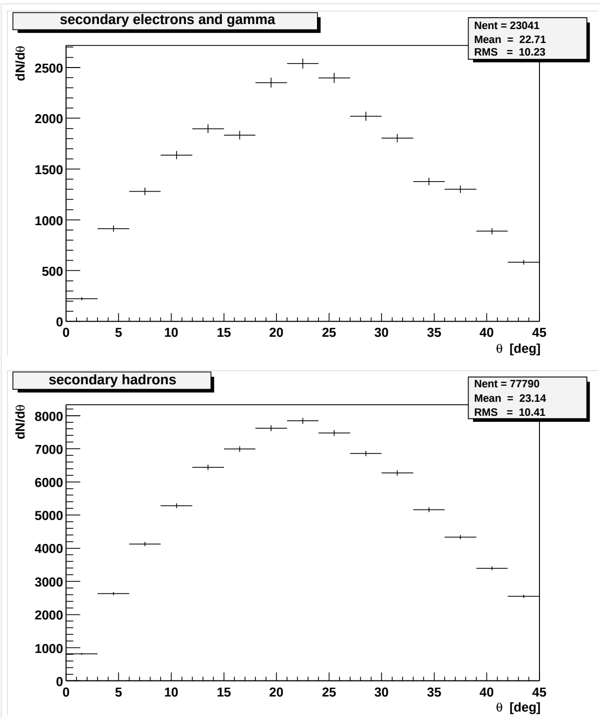

Fig.2. Zenith angle distributions of secondary hadrons and γ and electrons.

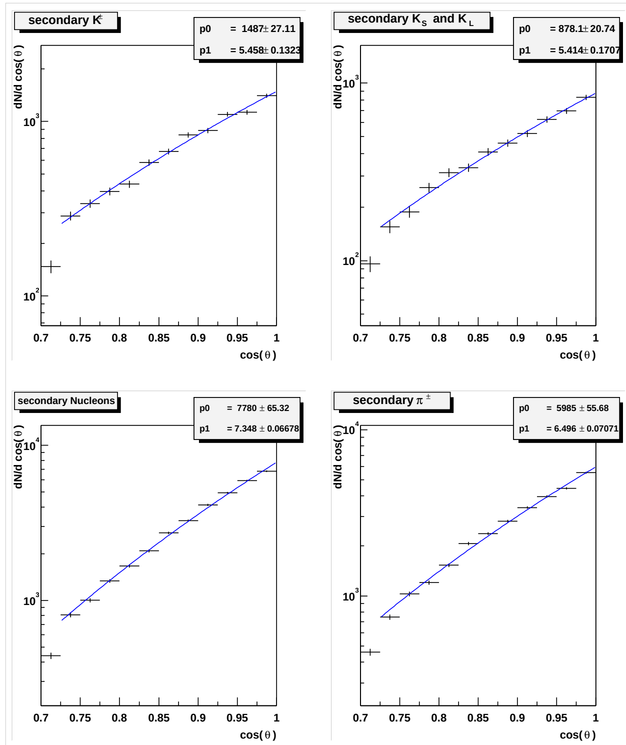

Fig.3. $cos\theta$ distributions of secondary $K^{\pm}$, K_S and K_L, nucleons and $\pi^{\pm}$; distributions were fitted with exponential function; the exponents are presented in Table 1.

less, no anomalies or large differences between particles of various types are observed.

3 Experimental results

θ and $cos(\theta)$ distributions of hadrons registered in carbon emulsion chambers have been shown in Figures 5,6. Figures 5 and 6 contain data from all chambers analysed by the Lodz group (Kempa, Malinowski et al., 2001). Results presented in Figure 6 do not have any data from C200 and C201 chambers, in which anomalies are observed.

I tried to fit exponential function to received $cos(\theta)$ distributions. Fiting with exponential function it possible only for very low confidence level. owever, the fits were made and their exponent m≃8.1 .

4 Conclusions

θ and $cos(\theta)$ distributions received from calculations differ in shape from experimental distributions. Values of exponent m by fiting exponential function to $cos(\theta)$ distribution are different from experimental values.

When comparison for hadrons registered in typical carbon emulsion chambers is made, differences in distributions become smaller.

Simulation of hadrons crossing the chamber have not been made in this paper. This is the next objective. I think that we should not expect large differences in distributions of angles after taking into account response of detector.

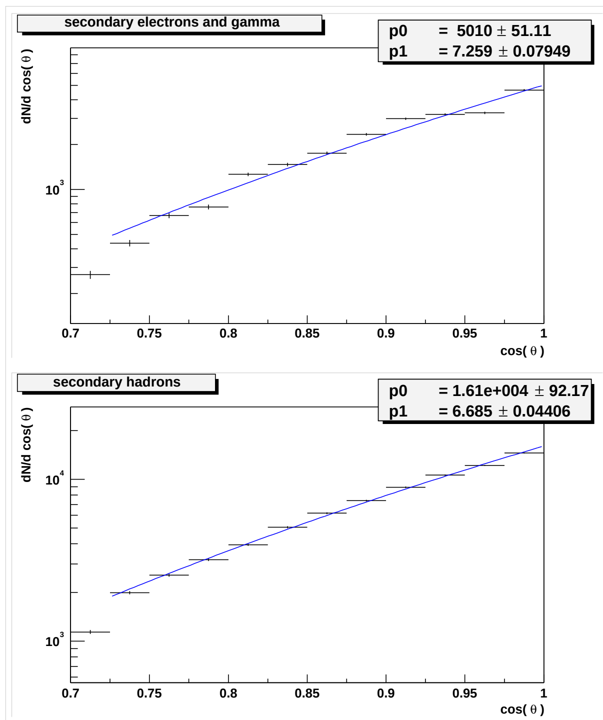

Fig.4. $cos\theta$ distributions of secondary hadrons and γ and electrons distributions were fitted with exponential function; the exponents are presented in Table 1.

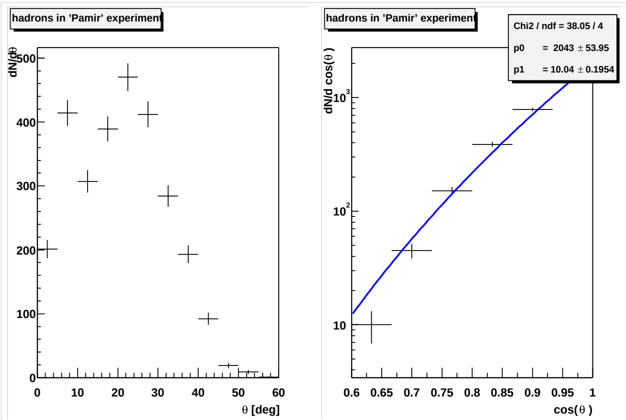

Fig.5. Zenith angle distribution of hadrons from carbon emulsion chambers for $E_h > 15TeV$.

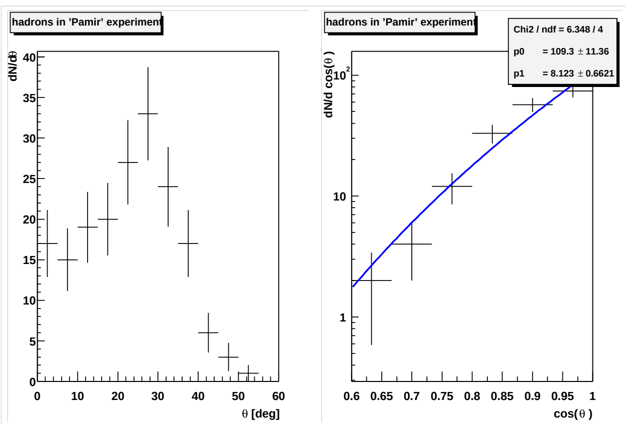

Fig.6. Zenith angle distribution of hadrons from carbon emulsion chambers with omitted C200 and C201 chambers, in which anomalies were observed ($E_h > 50TeV$).

Table 1. Exponents (m) of function fitted to $cos(\theta)$ distribution (from calculations).

all hadr.	Nucl.	$\pi^{\pm}$	$K^{\pm}$	K_S and K_L	γ and $e^{\pm}$
6.69	7.35	6.50	5.46	5.41	7.26

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