PROCEEDINGS OF SCIENCE

Study of the angular spectra of HADRONS in X-RAY emulsion chamber

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ANNOTATION

The zenith angular spectra of the hadron families detected in X-ray emulsion chamber of experiment HADRON (Tien-Shan) are analyzed. The deviations from the exponential absorption in the atmosphere are observed for the special choices of family energy intervals $\sum E_h^{\gamma}$ and multiplicity n_h. The main difference relates with the existence of the flat spectrum parts in the area of the small angles $\theta < 35^0$

36th International Cosmic Ray Conference -ICRC2019-
July 24th - August 1st, 2019
Madison, WI, U.S.A.

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1. Introduction

The article presents the angular distributions of hadrons according to carbon x-ray emulsion chambers (XREC) exhibited in the HADRON experiment [1]. The design of XREC and the scheme of registration of secondary particles of atmospheric shower is shown in figure 1.

In the trunks of shawls there are high-energy hadrons, mainly $\pi^0, \pi^{\pm}$ mesons and nucleons, as well as gamma quanta and electrons (hereinafter simply gamma quanies) formed in the decays of . High-energy gamma rays generate electromagnetic cascades in the lead G-block, which create visible darkening spots on the x-ray film.

To register charged hadrons, a carbon Converter (60 cm of rubber) is used, converting their energy into an electromagnetic component, which is similarly registered in the H-block. In contrast to gamma t-quanta, in the case of charged hadrons only part of the energy transferred to $\pi^0 - E_h^{\gamma}$ registered.

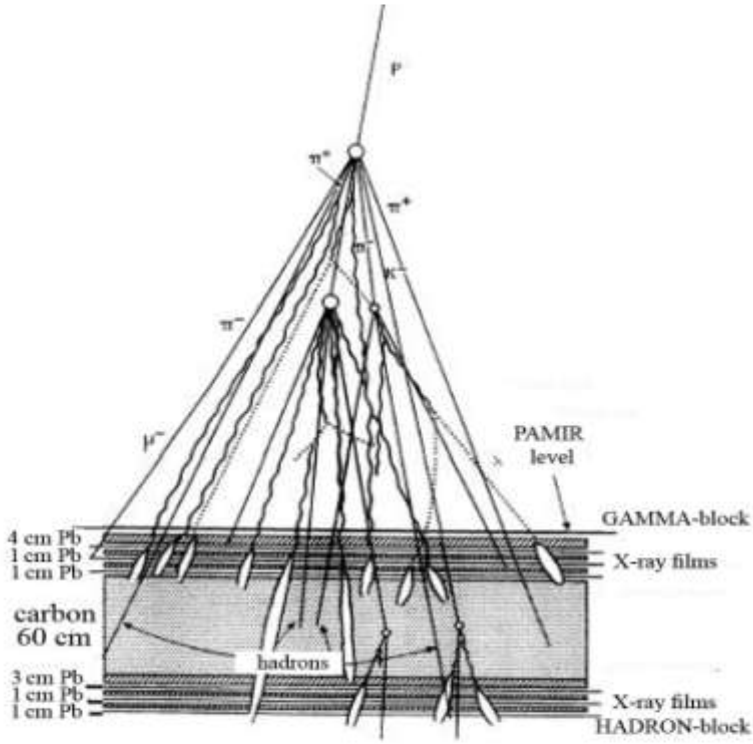

Figure 1. The scheme of carbon XREC in the HADRON experiment.

2 Method of measuring Zenith angles θ [2]

The RT-6M X-ray films used in the XREC has two emulsion layers applied on both sides to a substrate with a thickness of 200 mkm. The zenith angle ϑ of the cascade passage through the film is measured by the relative shift of the darkening spots in the upper and lower layers. The scheme for measuring the angles is shown in the figure 2.

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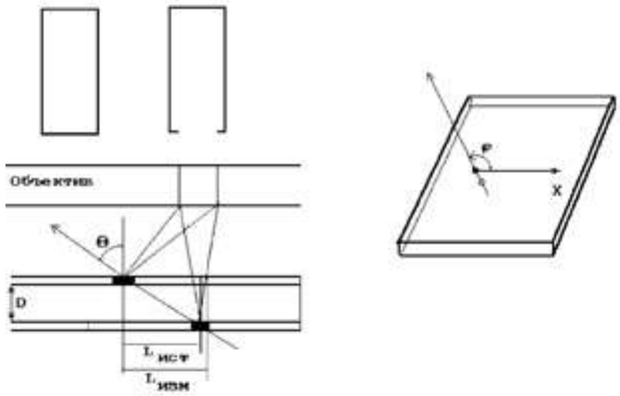

Fig. 2: Scheme measurement of angles ϑ, φ on the x-ray films.

The measurement is carried out using the BSM-2 microscope, which has a linear scale for determining the distance l between the spots of darkening. The zenith angle ϑ was determined from the ratio $tg\vartheta = l/d$, where d is the thickness of the substrate. In addition, the microscope has an angular scale along which the azimuth angle of the cascade φ was determined. The azimuth angle is formed by the coordinate axis x and the straight line in the plane of the film passing through both darkening spots in the direction "towards the source". The angle φ is measured from the x-axis in a counter-clockwise direction.

The measurement errors for ϑ and φ are obtained from the geometric relationships in the following form [3]:

$$\delta\vartheta = K\cos^2\vartheta; \quad \delta\upsilon = Kctg\vartheta, \tag{1}$$

where K=0.058.

In the region of small angles ϑ the azimuth angle is not determined due to the overlap of the spots. The magnitude of this region depends on the diameter of the spots D, i.e. from the energy of the cascades. The spot diameter is related to the energy by the empirical relationship $D = 35\sqrt{E_\gamma}$ mkm, where E_γ in TeV. The accuracy of determining the center of the spot $\delta l \cong 0.2D$. Then, assuming that the overlap area of the spots is $\delta l \cong 0.5D$, we obtain the estimate of the overlap angle $\vartheta_{olp} \approx 10^0$ for $E_\gamma = 4$ TeV. In cases where the angle θ cannot be determined, it is assumed that $\theta = 0^0$, and φ is undefined.

3 The experimental results

Full event statistics registered in hadron block of REK is 7802 family. Figure 3 shows the angle spectra θ for $\sum E_h^\gamma > 20TeV$ and $n_h \geq 1,\ 2, 3\, and\, 5$.

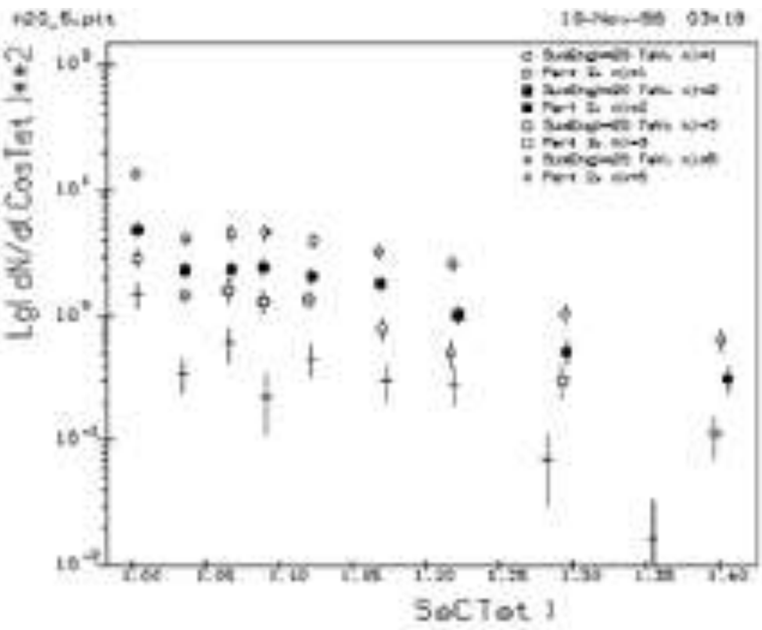

Fig 3. Spectrum of Zenith angles θ for hadrons and their families with $\sum E_h^\gamma \geq 20\ TeV,\ E_h^\gamma \geq 4 TeV,\ n_h \geq 1, 2, 3$ and 5

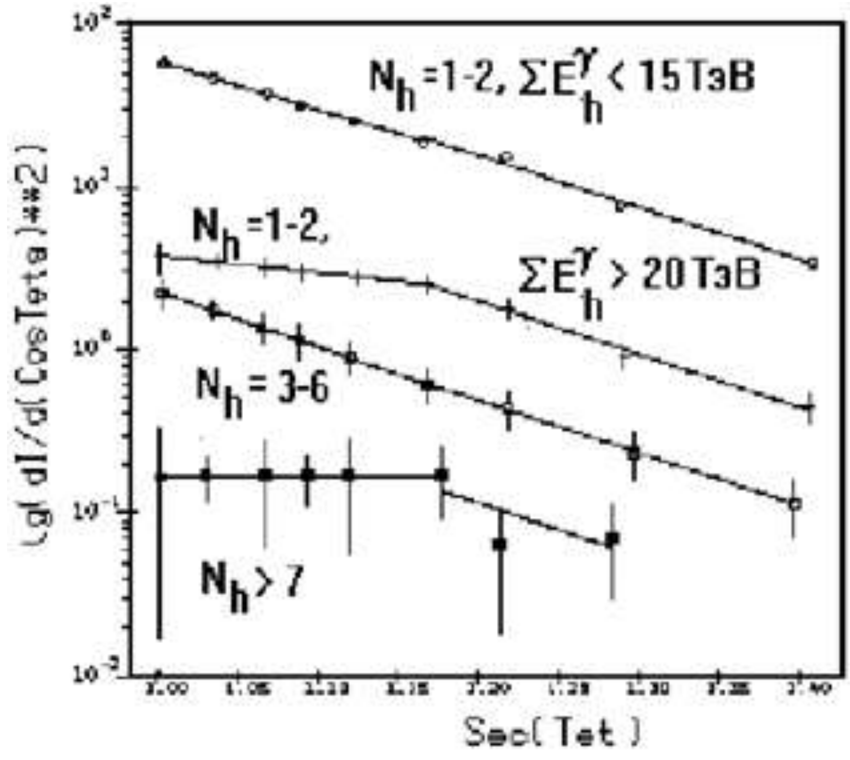

Fig 4. The corrected spectra for Zenith angles θ for hadrons and their families with $\sum E_h^\gamma \geq 20 TeV, E_h^\gamma \geq 4 TeV, n_h = 1-2, 3-6, 7-20$ and with $\sum E_h^\gamma = 4-15 TeV, n_h = 1-2$.

In the area of small angles there is a methodical emission associated with the overlap of darkening spots. Spectrum distortion is eliminated by the spread of attracted events at the nearest points [3].

Figure 4 shows the corrected spectra for $\sum E_h^{\gamma} > 20TeV$. In addition, here is the spectrum for $\sum E_h^{\gamma} = 4-15TeV$ and $n_h = 1-2$.

In the region of large angles $\sec\theta \geq 1.17$, all spectra have approximately the same slope $b \sim 7$, which corresponds to the absorption of hadrons from $\lambda_{abs} \sim 100 g/cm^2$. In the region of small angles, with a sufficiently large total energy of hadrons, for events with a small plurality of $n_h = 1-2$ and the maximum available and the $n_h \geq 7$ EXPERIMENT, an abnormally weak absorption of families is observed.

Tables 1 and 3 show the slope and the corresponding absorption lengths for different parts of the angular spectra.

Table 1. The value of the slope of the spectra $\ln(dI/d\cos^2\theta)$ for different intervals $\sec\theta$, $\sum E_h^{\gamma}$ and n_h

Event selection		Points 1-9	Points 2-9	$\sec\theta \geq 1.17$		$\sec\theta \geq 1.17$
$\sum E_h^{\gamma}$ *TeV*	n_h	Exp.	Exp.	Exp.	corrected	Exp.
4-15	1 - 2	-6.5 ± 0.1	-6.5 ± 0.1	-5.2 ± 0.3	-6.8 ± 0.2	-7.3 ± 0.3
≥ 20	1 - 2	-6.5 ± 0.4	-4.2 ± 0.5	-0.1 ± 1.1	-2.4 ± 0.5	-7.6 ± 0.9
	3 - 6	-7.2 ± 0.7	-6.9 ± 0.8	-5.4 ± 1.9	-7.9 ± 0.8	-7.4 ± 1.8
	7 - 20	-4.7 ± 2.1	-2.8 ± 2.7	-0.1 ± 2.4	-4.7 ± 4.6	-8.1 ± 6.9

Table 2. The values of the absorption lengths $\lambda_{abs}\ g/cm^2$ corresponding to the slopes of the spectra given in table 1.

Event selection		Points 1-9	Points 2-9	$\sec\theta \geq 1.17$		$\sec\theta \geq 1.17$
$\sum E_h^{\gamma}$ *TeV*	n_h	Exp.	Exp.	Exp.	corrected	Exp.
4-15	1 - 2	106 ± 2	106 ± 2	173 ± 10	101 ± 3	95 ± 4
≥ 20	1 - 2	106 ± 8	164 ± 20	>1000	287 ± 60	91 ± 11
	3 - 6	96 ± 9	100 ± 11	128 ± 45	87 ± 9	93 ± 23
	7 - 20	147 ± 66	246 ± 238	>1000	144 ± 144	85 ± 72

4 Conclusion

The nature of the distortion of the angular spectra is not clear, so the formally obtained values of λ_{abs} for different parts of the spectrum may not correspond to the absorption of the real hadron components of the NEC. In standard models of hadron cascade development in the atmosphere there is no reason for exponential absorption of families.

5 Acknowledgments

This work was supported by the IRN program #BR05236494” Fundamental and applied studies in related fields of physics of terrestrial, near-earth and atmospheric processes and their practical application”.

References

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