Angular Distribution of EAS at $N > 10^7$ particles

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1. Introduction

The investigation of absorption of hadronic component in EAS cores at energies above 30 TeV has revealed presence of long flying component (LFC) in calorimeter with lead absorber [5]. The presence such component at energies above 50 TeV is revealed also in thick lead X-ray films emulsion chamber of experiment PAMIR [8]. Both results were explained in the assumption of the large role of charmed particles, produced in a lead absorber. The estimations have shown, that charmed particles should be produced with cross-section reaching $\sim 30\%$ of inelastic. In paper [2] it was shown, that at associative production of Λ_c-barion and $\bar{D}$-meson they should carry away an overwhelming share of interacting hadron energy. Because of presence in charmed particles heavy quark they practically keep the pulse down to decay and thus carry the energy deep into absorber. If the role of charmed particles is great, then at high energies they should manifest itself deep in the atmosphere. For the first time Stodolsky and McLerran have paid attention on this [7]. It is obvious, that it is easier to find out such events as excess of EAS detected under large zenith angles. Such excess was really found out by us in work [4], however angular resolution of installation was rather worst.

2. Installation

In the present work we investigated at Tien-Shan angular distribution of showers with the size above 10^7 particles at initial energy more than $\sim 2 \cdot 10^{16}$ eV. In installation 13 detectors controlled the area $4 \cdot 10^4 m^2$ are working. The detector consists of the photo multiplier FEU-49, on which photocathode is placed scintillator by a diameter 15 cm. The factors of amplification of photo multipliers are leveled by adjusting of a voltage at standard light flux. All cables from detectors have equal length. The triggering system selects 6-fold coincedences of signals from the central detector and others 5, located along a circle with radius 70 meters. The system of registration of time consists of the shaper of a mark of time and registrator of a nonius type having the accuracy ± 0.2 ns. The resolution time of detectors (including photo multiplier, shaper of a mark of time, 200 m

pp. 9–12

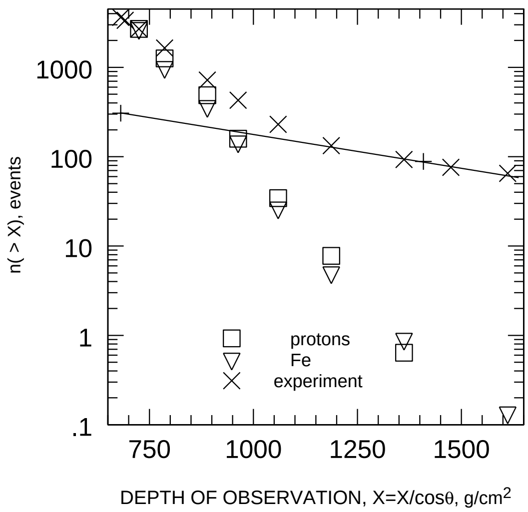


Fig. 1. Angular distribution of EAS at $N > 10^7$ particles at Tien-Shan.

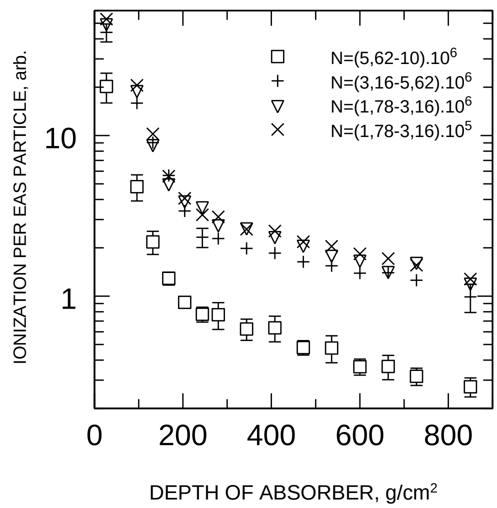


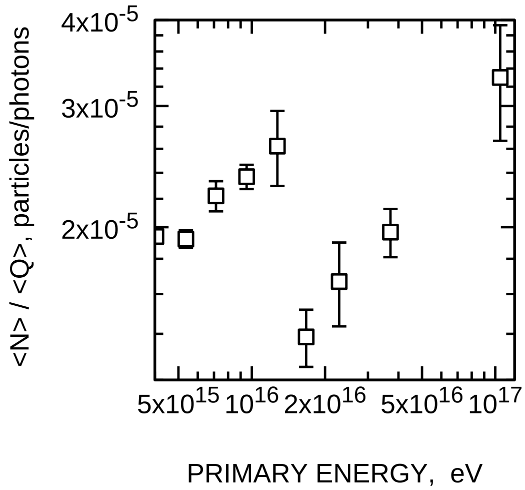
Fig. 2. Cascade curves in the calorimeter at fixed EAS size.

cable and system of registration) is equal 3.5 ns. It was determined by comparison of arrival time of a signal in two detectors placed side by side.

3. Results.

The preliminary experimental angular distribution of showers with $N_e > 10^7$ particles is shown in figure 1.

We have performed also Monte-Carlo calculations of angular distributions of showers with $N > 10^7$ of particles initiated by protons and nuclei of iron. The parameters of calculations were accepted, same, as in paper [6], carried out within the framework of QGS model. It was calculated number of particles in shower $N = N_e + N_\mu + N_{e\mu}$, where N_e number of electrons, produced after of π^0 decay; $N\mu$ - muon number; $N_{e\mu}$ - number of electrons produced by muons. The results of calculations are shown in a fig. 1. As it is visible from figure experimental results specify the component, which penetrates much more deeply, than it follows from calculations. In an interval of depths $(681 \div 960) g/cm^2$ the intensity of showers at size $N > 10^7$ decreases according $exp(-x/\lambda_1)$, where $\lambda_1 = 130 \pm 7 g/cm^2$, and at depth more than $1100 g/cm^2$ the exponent transforms in $exp(-x/\lambda_2)$, where $\lambda_2 = (585 \pm 45) g/cm^2$. If one extrapolate this second exponent in region of vertical zenith angles, i.e. to depth $x = 681 g/cm^2$, the share of such, slow attenuated showers is $(0,0846 \pm 0,0062)$. If to assume, that LFC is born only by protons, and to accept that a share of protons makes 40%, the share of showers containing LFC will make $\sim 21\%$.



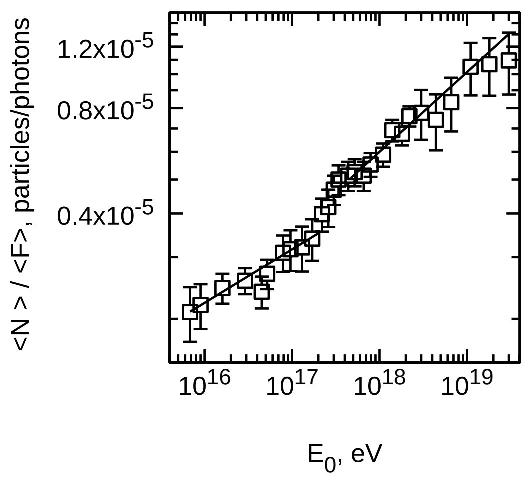


Fig. 3. Ratio $< N > / < Q >$ in dependence on primary energy (Tien-Shan).

Fig. 4. Ratio $< N > / < Q >$ in dependence on primary energy (Yakutsk).

4. Discussion

The results received allow to address to a question on the reason of absence of cutting of the energy spectrum because of GZK-effect. The apparent absence of such cutting has caused a flow of works, which authors offer the various exotic reasons for its explanation.

However on our opinion many experimental data (received at a mountain level), have been collected [3,9-10], which indicate fast approach of a maximum of showers to a level of observation. At energy $\sim (1-3)\cdot 10^{16}$ eV at a level of mountains the maximum of a shower falls through a level of observation and the most energetic component of showers avoids registration. It is accompanied by spasmodic change of a number of EAS parameters [3,9-10]. The examples of such jumps are shown in figures 2 and 3.

In a fig. 2 the set of cascade curves in ionization calorimeter is shown [3]. The cascades were selected in narrow intervals on number of particles in EAS and normalized on number of particles in shower. In a wide interval of primary energy these cascade curves change very insignificant. Only at energy more than $\sim 10^{16}$ eV there is a spasmodic reduction of a flow of energy in the cascade.

In a fig. 3 the attitude of number of particles in EAS, to a flux of Vavilov-Cherenkov radiation $< N > / < Q >$ is given depending on energy. As it is visible from figure at energy $> 1,5.10^{16}$ eV numbers of particles in a shower decrease by jump. If this jump is connected with fall of shower maximum through the observation level, on some more large depths it should reveal itself as relative increase of number of particles in a shower. Indeed, on a sea level at energy more than $2 \cdot 10^{17}$ eV in dependence $< N > / < Q >$ from energy the jump is observed in Yakutsk data [1] in the reverse direction, as it is visible from a fig. 4. The number of particles in shower here increases rather sharply. It confirms the assumption about carrying of energy deep into atmosphere by some leading LFC. The data of installations YAKUTSK, AGASA and HIRES are explained by the authors as essential increase of a share of protons in super high energy area. However only LFC can provide a maximum of shower to shift to a sea level so to explain seeming absense of GZK effect by simple overestimation of shower energy.

5. Conclusion

The results presented strongly indicate on the presence of some leading LFC which manifests itself under the large zenith angles in the atmosphere. This component could be in charge on the seeming absence of GZK effect at energies above $5 \cdot 10^{19}$ eV.

References

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