STADY OF THE ENRGY SPECTRA OF THE COSMIC RAY MUONS, γ-QUANTA, AND HADRONS IN THE > 2 TeV RANGE.

T.P.Amineva, M.A.Ivanova, K.V.Mandritskaya, E.A.Osipova, I.V.Rakobolskaya, N.V.Sokolskaya, N.I.Tulinova, A.Y.Varkovitskaya, L. Kuzmichev, V.I.Zatsepin, G.T.Zatsepin.
Institute of Nuclear Physics Moscow State University
Moscow II7234 USSR.

Abstract.

The spectrum of cosmic ray muons at sea level and spectra of γ-quanta and hadrons at the depth 60 g/cm^2 in the stratosphere are measured at the energies (2 - 30) TeV. As compared with our early work (Amineva et al I973, Amineva et al I975) the present results are obtained on the basis of larger statisties.

At present, the total exposition of the chambers for detecting the cosmic ray muons has reached 700 ton.year and the total number of the detected events with energies higher than 2 TeV is 2500. The chamber of 0.5 m^2 area has been exposed at a 60 g/cm^2 in the stratosphere during 360 hours. All the electron-photon cascades (EPC) which originated at the depth of more then four cascade units ($\Delta t \geqslant 4$) were considered as hadron-jets. The total number of such events is 278. 726 events with $\Delta t < 4$ have been detected, 50% of these events being γ - quanta.

As was noted in our previous works (Amineva et al I973, and Amineva at al I975) an increase in the energy spectrum exponent was observed for the events with $\Delta t < 4$ and also muons, and a difference was found between the spectrum exponents for the events with $\Delta t > 4$ and $\Delta t < 4$. These effects are confirmed at present work, with enlarged statistics.

The first problem to be clarify is that the observed effect are not a consequense of technique of X-ray emulsion measuremens.

In our early works the calculations of the EPC development made by Nishimura (I964) were used. The detailed study of the core approximation in the EPC theory was made by Guzhavin et al (I974), who calculated more accurately the lateral distribution of the cascade electrons. In the present work we have used these calculations and have studied a number of experimental methodical effects. First of all, the possibility of underestimating the energies in the high-energy range due to insufficient knowledge of the parameters of the cascade curve $D=f(E,t)$ was stadied. For this purpose the relation between darkness in the cascade maximum measured by circle of small and large radii was analysed. The formula relating the darkness with the electron flux density, $D=D_{\infty}(1-e^{-ns})$ was used, where n is the electron density, S and D_{∞} are the parameters of the film. It was found that D_{∞} =2.5 is in a better agreement with the experimental data, then the value of D_{∞} 9 4.0 adopted earlier. This can be especially clearly seen from the example of EPC generated by a ultra high energy muon (see Fig.I).

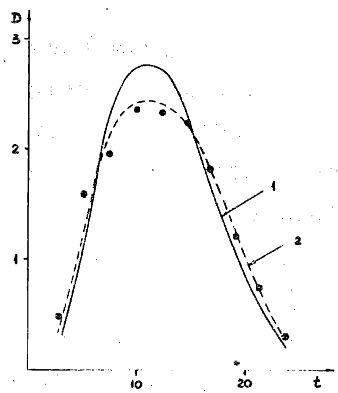
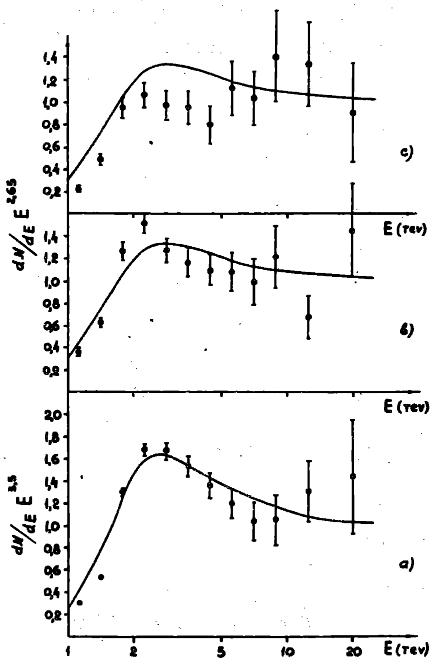


Fig.I shows the cascade curves calculated at D_{∞}=4.0 for E = 45 TeV. (Curve I) and D_{∞} =2.5 for E = 70 TeV (Curve 2). The dots present the experimental values of the darkness, corrected by approximately introduced Landau - Pomeranchuk effect. The experimental values are adequtely described by the curve with D_{∞} = 2.5, the determined energies being the same for the measurements with the circles of different radii.

Reprocessing of the total experimental data on the basis of new cascade curves did not change significantly the derived energy spectra. In particular, in the (2 -30) TeV range the new exponent of the muon energy spectrum has increased by a value 0.05.

Fig.2 presents our experimental data. In Fig.2 a is shown the spectrum of the bremsstrahlung γ -quanta produced by muons (it should be noted that the spectrum exponent of the global γ -quantum flux γ = 3.5, corresponds to the exponent of the vertical muon flux, γ = 3.65). Fig.2b shows the spectrum of the events with $\Delta t < 4$ obtained at a 60 g/cm^2 depth in the stratosphere. Fig.2c presents the spectrum of the events with $\Delta t > 4$ obtained at the same depth.
The greater statistics has allowed to analyze the form of the spectra of the muons and the events with $\Delta t < 4$ (in the larger energy interval) which allowed to discover that the steepest

part of the spectra of the muons and the events with $\Delta t<4$ is in the (2.5 -6.0) TeV range. This energy range is very close to the threshold value where the dispersion of the ènergy determination depends strongly on the energy.



The subsequent points of the spectrum fail to indicate such strong steepening of the spectrum. It is reasonable, therefore, to ask what should be the dispersion of the energy determination for the complete explanation of the observed steep spectrum? To describe the obtained experimental data under an assumption of a power- law primary (nucleon) spectrum with the exponent γ = 2.65 it is necessary to assume that the relative error in the energy determination is $\delta = 0.45 / \sqrt{E}$, where E is in TeV i.e. δ varies from 0.30 at 2 TeV to ~ 0.20 at 5 TeV). Our earlier experimental study (Zatsepin I975) showed that the dispersion changes from 0.I5 to 0.IO with varying energy from 2 TeV to 5 TeV. The value δ =0.30 at E = 2 TeV cannot be, however, safely rejected. The flatter spectrum observed for the events with $\Delta t > 4$ and shown in Fig2c may be due to the difference in the dispersion of the energy measuremets, connected with the different effective geometry of the chamber for the events of the two stadied types. The chamber for the events with $\Delta t > 4$ is of small thickness and, as it follows from the worke of Cheshire et al (I975), the dispersion may weakly increas with the energy, which results in a flatter spectrum.

Thus, the entire set of our experimental data does not contradict, under the accepted assumptions to the concept of the power - law spectrum of the primary nucleons with γ = 2.65 up to the primary energy ~ I00 TeV. and to the consept of the scaling.

REFERENCES

I. T.P.Amineva, I.P.Ivanenko, M.A.Ivanova, K.V.Mandritskay, E.A.Murzina, S.I.Nikolsky, E.A.Osipova, I.V.Rakobolslaya, N.V.Sokolskaya, N.I.Tulinova, A.Ya.Barkovitskaya, E.A.Zamchalova, G.T.Zatsepin. I973. Proc. I3 Int.Cosmic Ray Conf.Denver. v 3,p. I788.

2. T.P.Amineva, I.P.Ivanenko, M.A.Ivanova, K.V.Mandritskaya, E.A.Osipova, I.V.Rakobolskaya, N.V.Sokolskaya, A.Ya.Varkovitskaya, E.A.Zamchalova, G.T.Zatsepin, V.I.Zatsepin. I975. Proc. I4 Int.Cosmic Ray Conference, He- 6 -9. Munchen.

3. J.Nishimura. Suppl.of Progr. Theor. Phys. 32, 72, I964.

4. V.V.Guzhavin, I.P.Ivanenko, T.M.Roganova, G.F.Fedorova. I974. Proc. of Int.Cosmic Ray Simposium on High Energy Phenomena. Tokyo.

5. Zatsepin G.T. Editor. Studies of the high -energy muons. I975. " Nauka ". Moscow.

6. D.L.Cheshire, R.W.Huggett, W.V.Jones, W.K Schmidt. I975. Proc I4 Int Cosmic Ray Conference, Munchen. v 9.p.3233.