DEPENDENCE OF THE AVERAGE SPATIAL AND ENERGY CHARACTERISTICS OF THE HADRON-LEPTON CASCADE ON THE STRONG INTERACTION PARAMETERS AT SUPERHIGH ENERGIES

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ABSTRACT

A method for calculating the average spatial and energy characteristics of hadron-lepton cascades in the atmosphere is described. The results of calculations for various strong interaction models of primary protons and nuclei are presented. The sensitivity of the experimentally observed EAS characteristics to variations of the elementary act parameters is analyzed.

The theoretical analysis of hadron-lepton cascade propagation in the atmosphere is possible at present by two methods: a) Monte-Carlo cascade simulation; b) solving the set of kinetic equations. Despite the advantages, the Monte-Carlo method is at the same time the most cumbersome and demands much computer time. The main drawback of the second method is that shower characteristics for fixed primary energy are obtained, whereas in the experiment the showers with fixed N_e are studied. However the comparison of the results obtained by both methods shows that the dependence of the average shower characteristics on the strong interaction parameters turns out to be qualitatively the same, while the quantitative difference is small. As an example of this, we may point out the conclusion that the average experimental characteristics of EAS can be described using the strong interaction model with increasing cross sections, growing plateau in the pionization region and asymptotic scaling in the fragmentation region; this conclusion, being made from the solution of diffusion equations /1/, was confirmed by the Monte-Carlo simulation results /2/.

In the present paper we describe a method of solving the three-dimensional set of kinetic equations for shower components, based on the calculation of the contributions from the successive generations by Monte-Carlo evaluation of the corresponding multidimensional integrals.

The integral spectrum of the (i + 1)-th pion generation in EAS for depth Z and primary energy E_0 can be presented in the form:

$$\Pi_{i+1}(>E,z)=\int\frac{dz'}{\lambda_\pi}e^{-\frac{z-z'}{\lambda_\pi}}\int_{E_{i+1}\geq E}\frac{d^3p_{i+1}}{E_{i+1}}\quad\frac{d^3p_i}{E_i}\,* \tag{1}$$

$$*\left[N_i(\vec{P}_i,z')f_{\pi N}(\vec{P}_{i+1},\vec{P}_i)+\Pi_i(\vec{P}_i,z')f_{\pi\pi}(\vec{P}_{i+1},\vec{P}_i)\right.$$

where $\Pi(>E,z)$, $\Pi(\vec{p},z)$ and $N(\vec{p},z)$ are the integral and differential momentum spectra of pions and nucleons at depth Z, and $f_{\pi N}(\vec{p},\vec{p}_0)$ and $f_{\pi\pi}(\vec{p},\vec{p}_0)$ are the invariant inclusive spectra of pion production in NA and πA interactions. The expressions for the nucleon and muon spectra can be written in the same manner. For Monte-Carlo computation of integral (1) a set of interaction depths in the atmosphere and particle momenta are randomly simulated. From the known momenta and depths, we calculate the diatance from the shower axis to the particle's arrival point at the observation level. The value of the integrand is calculated for the simulated set. Further on, knowing the energy and the distance of the particle from the axis, we can obtain the integral and differential spectra over E and r. The spatial distribution function (SDF) of electrons is obtained multiplying the γ-production spectrum $\Gamma(E,z,r)$ by the SDF for photon initiated showers in the approximation of ref./3/. The accuracy of the calculation of the integral depends on the variance and the number of simulations of the integrand values. The integral was smoothed to minimize the dispersion. The method will be described in detail in a forthcoming paper.

This work presents the results of calculations for the models of multiple production. The first one is the so-called "standard" model of the scaling type, where the inclusive spectra are taken in the Hillas parametrization /4/, and $\langle P_\perp \rangle = 0.37$ GeV. The second is the model of quark-gluon jets /5/, where the target nuclei effects are taken into account according to ref./6/. In this model, as is well known, there takes place the cross section rise, the plateau grows and the scaling is weakly violated in the fragmentation region. In this model the spectra differ quantitatively from those used earlier, mainly in the fragmentation region. The mean transverse momentum in this model increases logarithmically with energy.

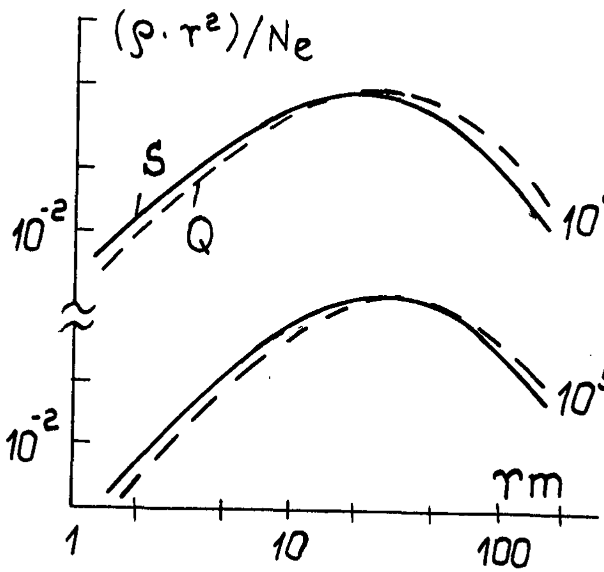

Fig. 1

Figure 1 shows the radial distribution of $\rho_e \cdot r^2/N_e$, where $\rho_e(r)$ is the SDF at 700 g/cm^2. The figures near the curves denote the primary energy in GeV. S labels the "standard" model curve, Q – the models of the quark-gluon jets. The curves differ insignificantly, since the SDF of EAS is mostly due to the electromagnetic interactions. However in the model a more rapid energy dissipation takes place and the SDF is a bit wider.

Figure 2 presents hadron and muon distribution in a circle of radius with E > 5 GeV. The same is shown in

Fig.3 for an energy cut-off 1 TeV. The small energy particles number and the SDF show weak moel dependence. As expected, the high-energy hadrons are concentrated in the narrow region near the shower axis. The same is true for high-energy muons. The SDF of high-energy hadrons is the most model-dependent characteristic. In the Q model the total number of muons with energy > 5 GeV is greater than

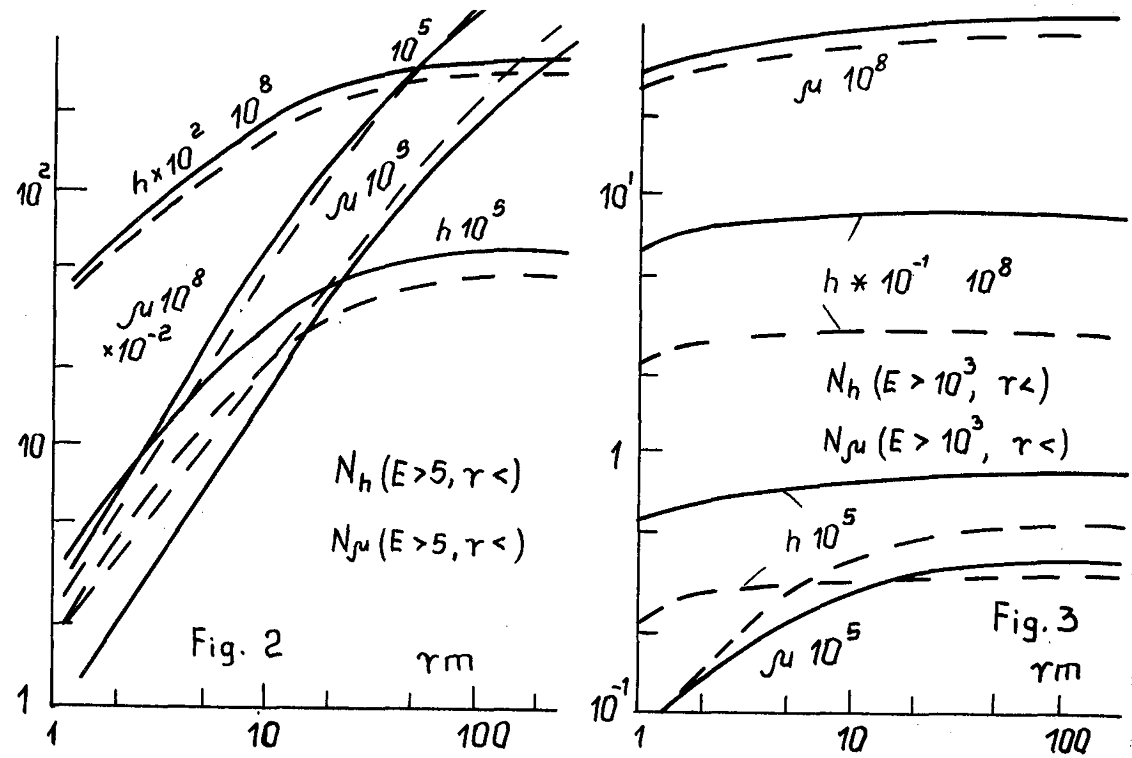

Fig. 2 Fig. 3

in the S model, whereas the number of muons with E > 1 TeV is almost the same but the SDF in the Q model is wider which is due to both rise of the cross section and the average transverse momentum. The total number of hadrons with E > 1 TeV is larger in the S model as compared to that in the Q model by a factor of ~ 2.5 in the range of E_0 and r .

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