PHENOMENOLOGY OF SOFT HADRON INTERACTIONS AND THE RELEVANT EAS DATA

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I.Introduction.

The interpretation of the experimental data in superhigh energy cosmic rays requires the calculations using various models of elementary hadron interaction. One should prefer the models justified by accelerator data and giving definite predictions for superhigh energies. The model of quark-gluon pomeron strings (the QGPS model) satisfies this requirement.

2.Model of quark-gluon pomeron strings.

The QGPS model combines the supercritical pomeron theory with the modern quark-gluon pattern of hadron interactions. (The term supercritical pomeron theory was used in the works /3,4/ where EAS calculations were first made in terms of the QGPS model) The QGPS model, called also the dual parton model /5,6/, allows at present to calculate all necessary characteristics of hadron-nucleon and hadron-nucleus interactions /7-9/.

The QGPS model gives a good agreement with experimental EAS data /3,4/ and describes also the main data on gamma-families /IO/. The calculations in /3,4,IO/ were made at $\Delta=\alpha_p(0)-I=0.07$ (see /I,2/), where $\alpha_p(0)$ is the intercept of Regge pomeron trajectory. In this work we present the results of the EAS calculations in terms of the QGPS model with the parameters specified using the ISR and SPS data. The value of Δ is now $0.I2\pm0.02$ /8/. That gives a stronger violation of scaling than $\Delta=0.07$. Besides, the hadron-nucleus interactions are also treated in the QGPS model, so we don't need the additive quark model (AQM) that was used in /3,4/. It should be noted that values of function

$$R(x)=\left(\frac{1}{\sigma_{in}^{hA}}\times\frac{d\sigma^{hA}}{dx}\right)\Bigg/\left(\frac{1}{\sigma_{in}^{hN}}\times\frac{d\sigma^{hN}}{dx}\right)$$

for AQM and QGPS models are the same with a good accuracy

(~I0%).

3.Comparison with EAS data. Fig. I shows the inelastic nucleon cross-section in air calculated at Δ=0.I2 in terms of the Glauber model. The result is almost the same as in work /3/ up to the energies of ~I0^5 GeV but the cross-section increases more rapidly at higher energies than at Δ=0.07. The calculation results agree with the estimates obtained in cosmic ray experiments /II,I2/.

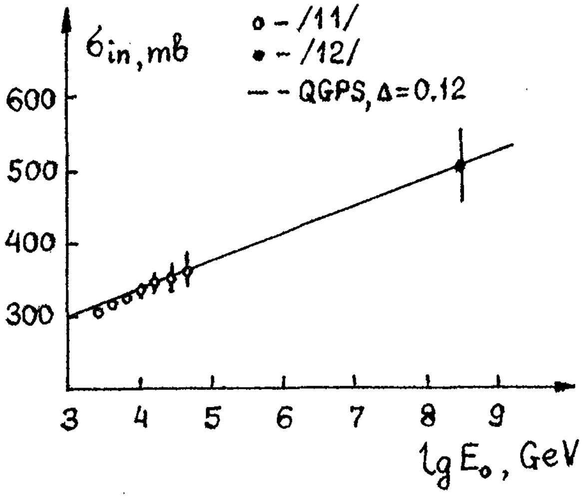

Fig.I. The inelastic nucleon cross-section in air.

Fig.2 shows the dependence of the >I0 GeV muon number N_μ on the EAS electron size N_e at sea level. The model gives a good fit to experimental data if allowance is made for the complex primary composition (40% of protons and I5% of fractions of nuclei with A=4,I5,29 and 56). The fit is better at Δ=0.I2 than at Δ=0.07. The small difference (~0.05) between the calculated and experimental values of α in relation

$$N_\mu \sim N_e^{\alpha}$$

may be easily compensated considering the possible changes of the composition with energy in terms of the diffusion model /I3/ or the increase of the kaon and barion fractions of secon-

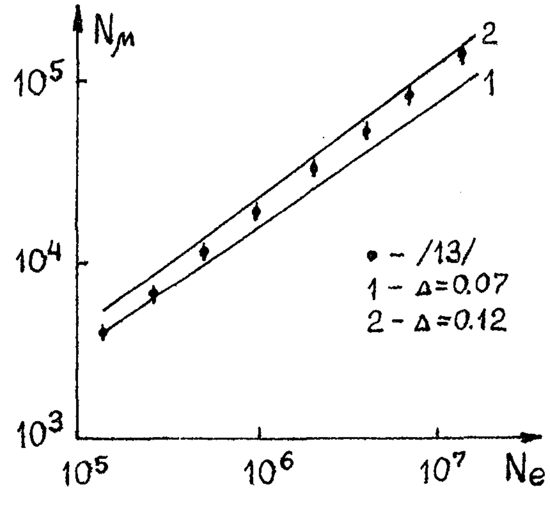

Fig.2. The number of >I0 GeV muons as function of the EAS electron number at sea level.

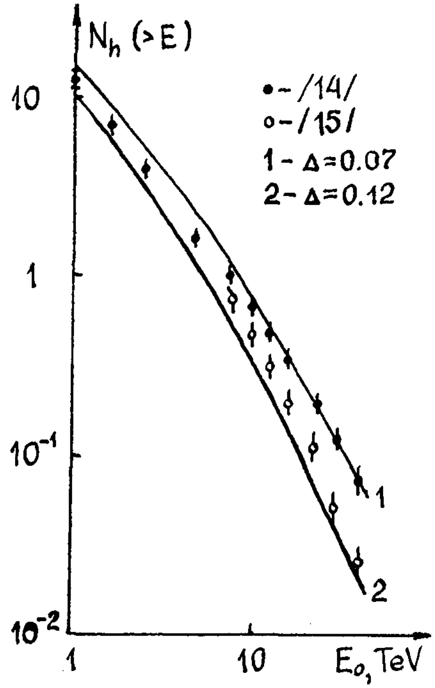

Fig.3. The energy spectrum of hadrons in EAS with $N_e \approx 9\cdot 10^5$ at mountain level.

daries as the energy increases /8/. A better agreement in the absolute values may be attained by slightly varying the primary cosmic ray composition.

Fig.3 shows the energy spectrum of EAS hadrons at mountain level and experimental data /14/. Considering that incidence of hadron groups onto EAS array causes difference between the hadron spectrum and measured spectrum of energies released in the ionization calorimeter at $E_h \sim 10$ TeV /15/ one can claim that transition to Δ=0.12 improves the fit to experimental data.

The EAS maximum depth varies little as a function of primary energy (by 10-20 g/cm^2) at different E_0, so the earlier conclusions concerning the agreement of the QGPS model predictions with experimental data /3,4,10/ remain valid.

Thus a certain variation of the QGPS model parameters improves the description of EAS experimental data as a whole.

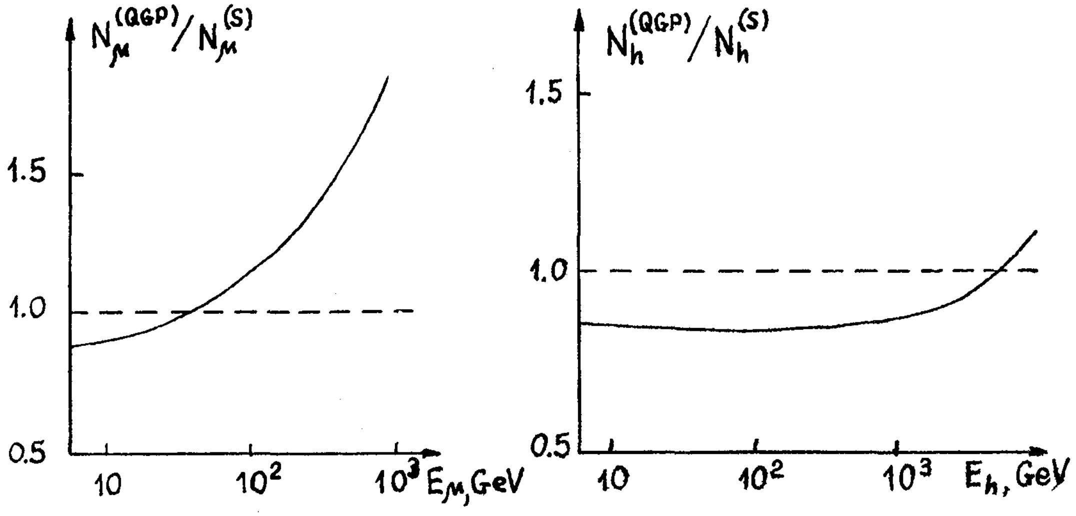

Fig.4. The sea-level energy spectra of muons and the mountain level energy spectra of hadrons in nucleus generated EAS.

4.Quark-gluon plasma. The possible production of quark-gluon plasma in nucleus-nucleus collisions has been intensively discussed since recently /I6,I7/. This model predicts significant cumulative effects (production of particles with energy >E_0/A) and a large number of secondary kaons and barions. Fig.4 shows some characteristics of nucleus generated EAS (A=56, E_0=IO^6 GeV) calculated in terms of quark-gluon plasma model /I6,I7/ the results being normalised to the traditional superposition model predictions. The calculations have shown that the shower maximum shifts as little as by 20 g/cm^2. The significant variations take place for hadron spectrum at energy region close to E_0/A and for muon spectrum at energies above IOO GeV. So to establish the existence of the quark-gluon plasma one should study hadron and muon spectra in nuclei generated showers at sufficiently high energies.

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6.References.

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