PHENOMENOLOGY OF SOFT HADRON INTERACTIONS AND THE
RELEVANT EAS DATA

N.N.Kalmykov, G.B.Khristiansen, M.V.Motova
Institute of Nuclear Physics, Moscow State University,
Moscow II7234, USSR

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 mo-
del of quark-gluon pomeron strings (the QGPS model) satis-
fies this requirement.

2.Model of quark-gluon pomeron strings. The QGPS model com-
bines the supercritical pomeron theory with the modern qu-
ark-gluon pattern of hadron interactions. (The term super-
critical 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 experimen-
tal EAS data /3,4/ and describes also the main data on gam-
ma-families /I0/. The calculations in /3,4,I0/ 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 re-
sults 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 0.12 ± 0.02 /8/. That gives a stronger
violation of scaling than $\Delta=0.07$. Besides, the hadron-nuc-
leus 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 $\Delta=0.I2$
in terms of the Glauber
model. The result is
almost the same as in
work /3/ up to the
energies of $\sim I0^5$ GeV
but the cross-section
increases more rapid-
ly at higher energies

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

than at $\Delta=0.07$. The calculation results agree with the esti-
mates obtained in cosmic ray experiments /II,I2/.

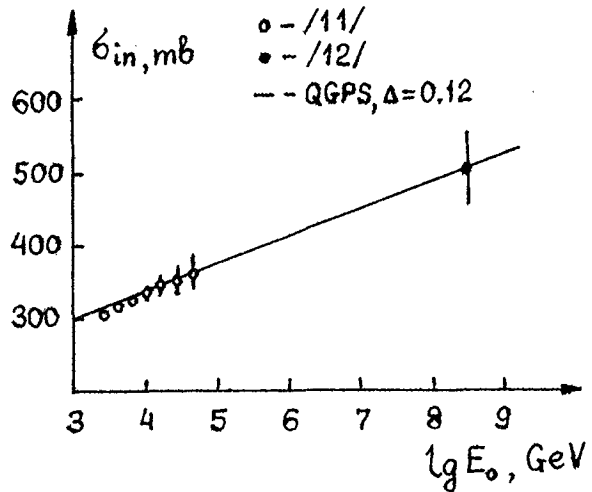Fig.2 shows the dependence of the >I0 GeV muon number
N_μ on the EAS electron size N_e at sea level. The model gi-
ves a good fit to experimental data if allowance is made
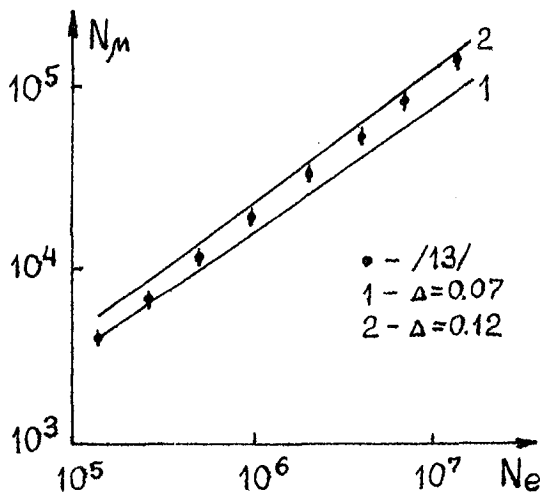for the complex primary composition (40% of protons and I5%
of fractions of nuclei
with A=4,I5,29 and 56).
The fit is better at $\Delta=0.I2$
than at $\Delta=0.07$. The small
difference (~0.05) between
the calculated and experi-
mental values of α in re-
lation

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

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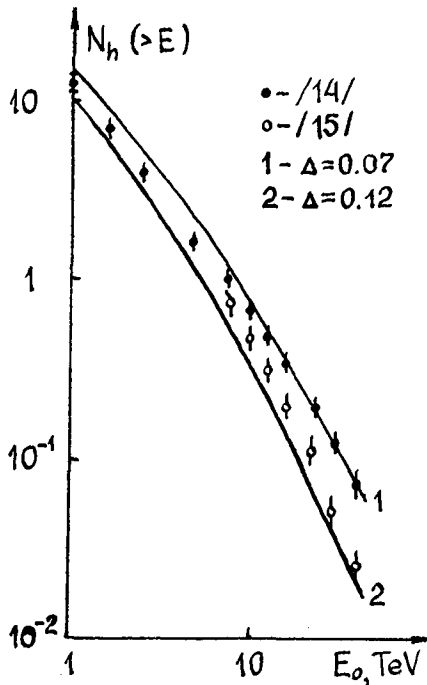increase of the kaon and
barion fractions of secon-

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 /I4/. 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 $E_h \sim$ IO TeV /I5/ one can claim that transition to Δ=O.I2 improves the fit to experimental data.

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

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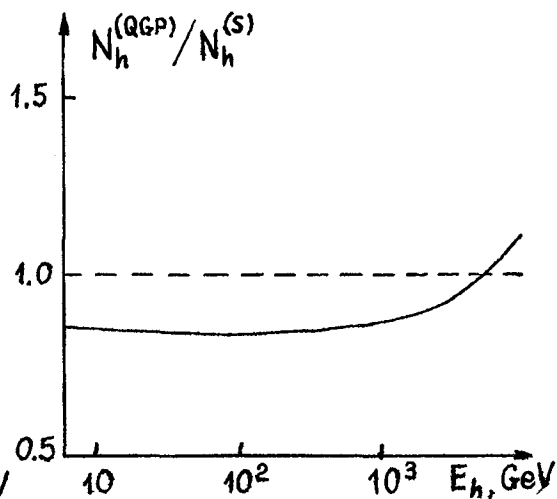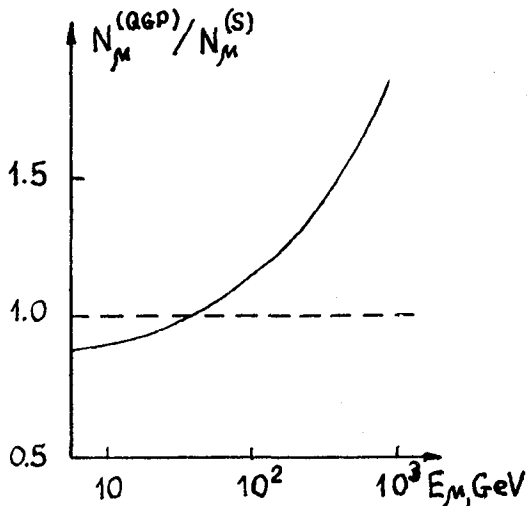

Fig.4. The sea-level energy spectra of muons and the mountain level energy spectra of hadrons in nucleus generated EAS.

4.Quark-gluon plasma. The possible production of quark-glu-
on plasma in nucleus-nucleus collisions has been intensively
discussed since recently /I6,I7/. This model predicts sig-
nificant cumulative effects (production of particles with
energy $>E_o/A$) and a large number of secondary kaons and
barions. Fig.4 shows some characteristics of nucleus gene-
rated EAS (A=56, $E_o=I0^6$ GeV) calculated in terms of quark-
gluon plasma model /I6,I7/ the results being normalised to
the traditional superposition model predictions. The cal-
culations have shown that the shower maximum shifts as
little as by 20 g/cm^2. The significant variations take pla-
ce for hadron spectrum at energy region close to E_o/A and
for muon spectrum at energies above I00 GeV. So to estab-
lish 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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