объединенный
институт
ядерных
исследований
дубна

E2-89-819

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INCLUSIVE CHARACTERISTICS OF π^+p-, K^+p- AND pp-INTERACTIONS AT 250 GeV/c IN THE MODEL OF QUARK-GLUON STRINGS

Submitted to "ЯФ"

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1989

1. INTRODUCTION

The quark-gluon string model[1] which is realized as the COLLI code, reproduces successfully the experimental characteristics of inelastic pp- and $\bar{p}$p-interactions in the energy interval $\sqrt{s}$ from a few GeV to ~1 TeV[2,3].

Agreement with experiment is achieved since the model includes diffractive processes; quite a number of pre-asymptotic interaction mechanisms whose cross sections decrease in a power-law manner as the energy is increasing, and the multi-pomeron branchings, which proved to be essential starting with the momenta as low as 10 GeV/c.

It is of interest to analyze the capabilities of the given model in the description of interactions of high-energy mesons with protons. The experimental investigations of these reactions were carried out at the European hybrid spectrometer (EHS) with the rapid-cycling bubble chamber (RCBC) used as a vertex detector in the meson-enriched beam from the SPS collider[4,5]. The initial momentum was 250 GeV/c. Now this is the maximum attainable energy of meson beams. The experiment at 250 GeV/c contains a wide set of the data for π^+p-, K^+p- and pp-interactions, obtained by the same technique. The data from this experiment were comprehensively analyzed in the existing quark models - Lund model[6], Fritiof model[7] and the dual parton mode (DPM)[8], etc. This makes it possible to compare the present model with the predictions of other models.

A detailed description of the quark string model is given elsewhere[3,4]. The present paper describes the specific features of the simulation of π^+p- and K^+p-interactions and compares the calculated results with experiment for π^+p-, K^+p- and pp-interactions at the momentum of 250 GeV/c.

2. DESCRIPTION OF THE MODEL

Figure 1 shows the diagrams of the processes which contribute to the inelactic interaction cross section of mesons $\sigma_{in}(s)$ and are allowed for in the simulation:

$$\sigma_{in}(s) = \sigma^{P}(s) + \sigma^{uncyl}(s) + \sigma^{pl}(s) + \sigma^{two}(s) + \sigma^{dif}(s) + \sigma^{reg}(s).$$

The terms on the right-hand side are the cross sections for the processes which are described by different diagrams: "the cylindrical diagram" (fig.1a) and the diagram with a more complicated topology representing the multi-pomeron branchings in the elastic scattering amplitude (fig.1b) - $\sigma^{P}(s)$; the "undeveloped cylinder" diagram (fig.1c) - $\sigma^{uncyl}(s)$; the planar diagram (fig.1d) which is nonexistant for K^+p-interactions - $\sigma^{pl}(s)$; the diagram with the quark redistribution (fig.1e) - $\sigma^{two}(s)$; the diagram for diffractive processes with the small (fig.1f,g) and large (figs.1h,i) excited masses - $\sigma^{dif}(s)$; the three reggeon diagram (fig.1) - $\sigma^{reg}(s)$.

The inelastic pp cross section consists of the same processes, except for the planar diagrams. The diagrams for these processes are given in ref.[3]. Included also are the parametrizations used to calculate the cross sections of the above processes. The magnitudes of the cross sections of the above processes for all types of interactions are given in the table.

In the simulation the hadron collisions are considered in their center-of-mass sytem where the initial momentum is equal to P_0.

The structural functions of quarks determine the fraction $x = P_q/P_0$ of the longitudinal momentum of hadron P_0 which is carried away by a quark or a diquark.

The distribution functions of valence quarks (diquarks) $f_{v1}(x_1)$ and $f_{v2}(x_n)$ and sea quarks $f_s(x_i)$ in the hadron are

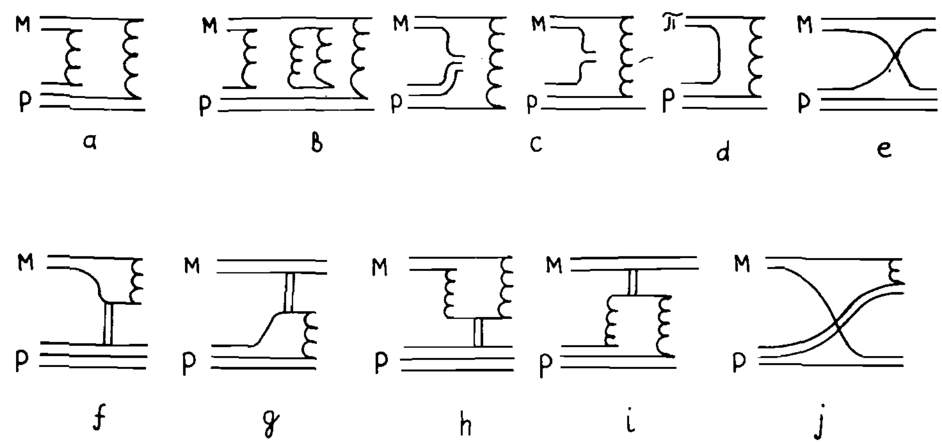

Fig.1. Diagrams of the processes which are allowed for in the quark-gluon string model (QGSM) in the simulation of meson-proton interactions.

Table. The cross sections of the processes taken into account at the π^+p-, K^+p- and pp -interaction simulation at 250 GeV/c

σ^i, mb	π^+p	K^+p	pp
$\sigma^P + \sigma^{uncyl}$*	14.98	13.52	22.24
σ^{pl}	0.316	-	-
σ^{two}	0.0007	0.0007	0.0022
σ^{dif}	4.14	2.35	7.93
σ^{reg}	1.029	0.583	1.969
σ^{in}	20.42	16.45	32.15

*It is more preferable not to separate the "undeveloped cylinder" diagrams while concerning multipomeron branchings.

of the form:

$$f_{v1}(x_1) = 1/\sqrt{x_1}$$

....

$$f_s(x_i) = 1/\sqrt{x_i}, \qquad i = 2, ..., n-1$$

....

$$f_{v2}(x_n) = x_n^{\beta}$$

where β = 1.5 for the uu-diquark } in the
= 2.5 for ud-diquark } proton

β = -0.5 for the u,$\bar{d}$-quark in π^+ and K^+-mesons,

β = 0 for the $\bar{s}$-quark in the $K^{\pm}$ meson.

In the processes with the formation of n-pairs of strings the longitudinal momenta of quarks at the ends of strings P_{q_i} are determined from the probability density ρ that each quark has a fraction of the initial momentum $x_i = P_{q_i}/P_0$:

$$\rho(x_1,\dots,x_i,\dots,x_n) = \rho_0 \cdot \delta(1-\Sigma x_i) \cdot f_{v1}(x_1) \cdot \dots \cdot f_s(x_i) \cdot \dots \cdot f_{v2}(x_n).$$

For the cylindric diagram with the two-string formation (fig.1a) the x_q- distributions of valence quarks are of the

form

$$\rho(x_q) = \rho_0 \cdot \frac{1}{\sqrt{x_q}} \cdot (1-x_q)^{\beta},$$

where β=1.5 for the u-quark in the
=2.5 for the d-quark proton

β=0 for the $\bar{s}$-quark in the K^+-meson

β=-0.5 for the u,$\bar{d}$-quarks in π^+ and the u-quark in the K^+-meson.

In the case of the "cylindrical diagrams" the structure functions of quarks coincide with the ones used in the DPM, except the structure function of d-quark in the proton.

In the simulation of πp- and Kp-interactions all the parameters of the model such as:

1) the degree of suppression of s and c quarks:
2) the probability of producing baryon pairs;
3) the relations of the yields of stable particles and resonances;
4) the mass of the string which decays isotropically;
5) the contributions of multi-pomeron branchings;
6) the transverse momenta of constituents, have the same values as in the simulation of pp-interactions made in /3/.

The string breakage algorithm is analogous to the one described in /3/.

It is taken into consideration that the position of the broad resonance maximum in the M^2-distribution in the diffraction of π- and K-meson and the position of the analogous maximum in the proton diffraction are different.

The difference of the characteristics of π^+p-, K^+p- and pp-interactions is caused, on the whole, by the difference of the structural functions of valence quarks in these hadrons and by the difference of the fragmentation functions of quarks (diquarks) of different flavors.

The $\bar{s}$-quark fragmentation makes the major contribution in the K^+-meson fragmentation region in K^+p-interactions due to the structural functions of u and s quarks in K^+-meson being asymmetrical, as opposed to the symmetric structural function for meson.

The processes which are considered for π^+p-, K^+p- and pp-interactions are the same for all three reactions, except for the contribution of the planar diagrams in π^+p-collisions.

3. COMPARISON OF THE SIMULATED RESULTS WITH EXPERIMENT

Figure 2 presents the experimental multiplicity distributions of charged particles in π^+p-, K^+p- and pp-interactions at 250 GeV/c [4] in comparison with the results of the quark-gluon string model. One can see that the model describes the experimental distributions. It is essential that there exists an agreement with the experimental cross sections in the region of large $n_\pm$. As is shown in [4], the Lund model [6], the FRITIOF model and the DPM [8] predict much smaller cross sections at large $n_\pm$ as compared with experiment. In the quark-gluon string model agreement with experiment is provided by introduction of multi-pomeron branchings (fig.1b) [3].

Figures 3 and 4 present the inclusive distributions $d\sigma/dx$ and $d\sigma/d\eta^*$ from the paper [5] for the reactions

$\pi^+ p \to C^+ + X$,

$\pi^+ p \to C^- + X$,

$K^+ p \to C^+ + X$,

$K^+ p \to C^- + X$,

$pp \to C^+ + X$,

$pp \to C^- + X$,

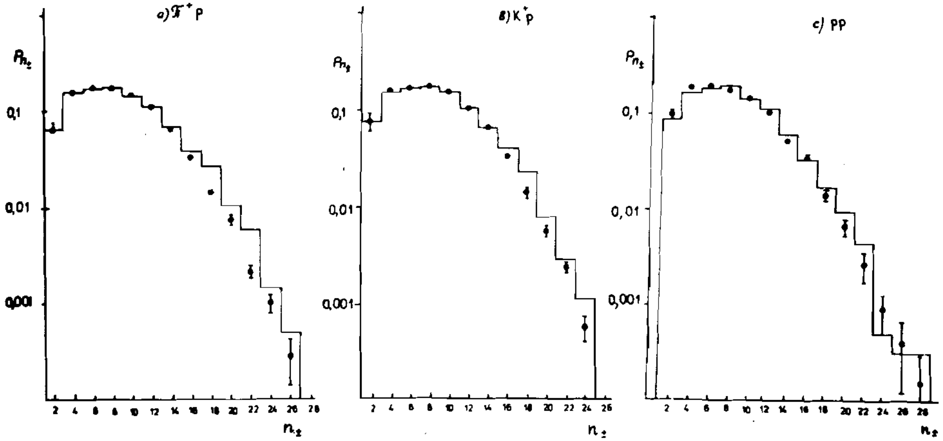

Fig.2. Multiplicity distributions of charged particles $P_{n_\pm} = \sigma_{n_\pm}/\sigma_{in}$ in π^+p-, K^+p-and pp-interactions at 250 GeV/c; the dots represent experiment [4] and the histograms - QGSM.

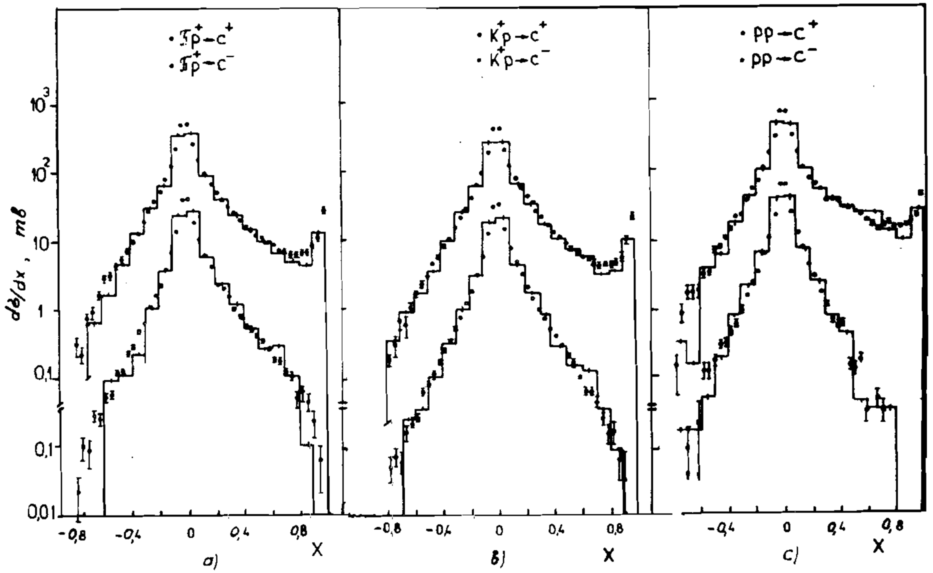

Fig.3. Distributions $d\sigma/dx$ for C^+- and C^--particles in π^+p-, K^+p- and pp-interactions at 250 GeV/c; the dots represent experiment [5] and the histograms - QGSM.

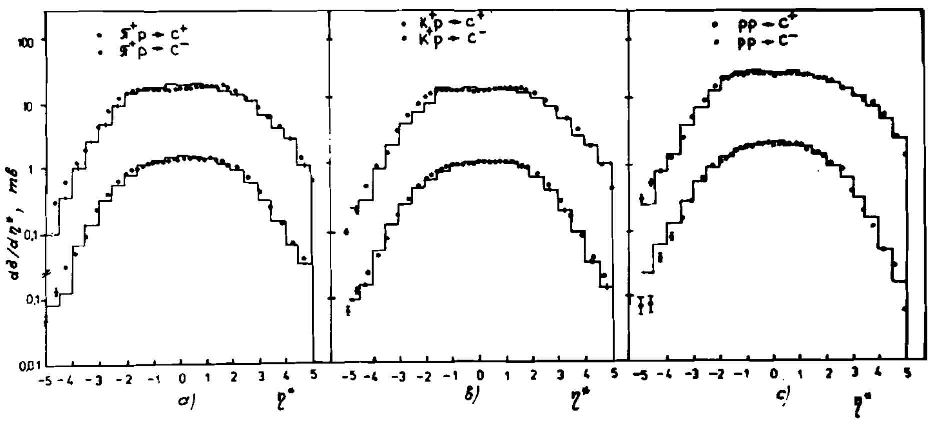

Fig.4. Pseudorapidity distributions for C^+-and C^--particles in π^+p-, K^+p-and pp-interactions at 250 GeV/c; the dots are experiment [5] and the histograms - QGSM.

where C^+ is any hadron with charge +1, except protons with the momentum in the lab.system less than 1.2 GeV/c; C^- is any hadron with charge -1. The parameters of particles C^+ and C^- measured in the lab.system, were converted into the center-of-mass system on the assumption that the mass of these particles is equal to the mass of the π-meson. In the model calculations shown in fig.3 and 4 these peculiarities of the experimental data were taken into account. It is seen that the model reproduces the inclusive distributions of hadrons with charge -1 and +1 as well. In fig.3 and 4 the distributions show that agreement is obtained in the fragmentation regions and in the central region of interaction, respectively. As demonstrated in ref.[5], the Lund model, the FRITIOF model and the DPM adequately describe the distributions over longitudinal variables for the particles with the negative charge but they do not reflect the major features of the spectra of positive particles.

The model and experimental π^0-meson spectra $d\sigma/dx$ for π^+p-, K^+p- and pp-interactions are compared in Fig.5 in the region of $x > 0.025$ where the experimental data are available. The agreement is on the whole satisfactory.

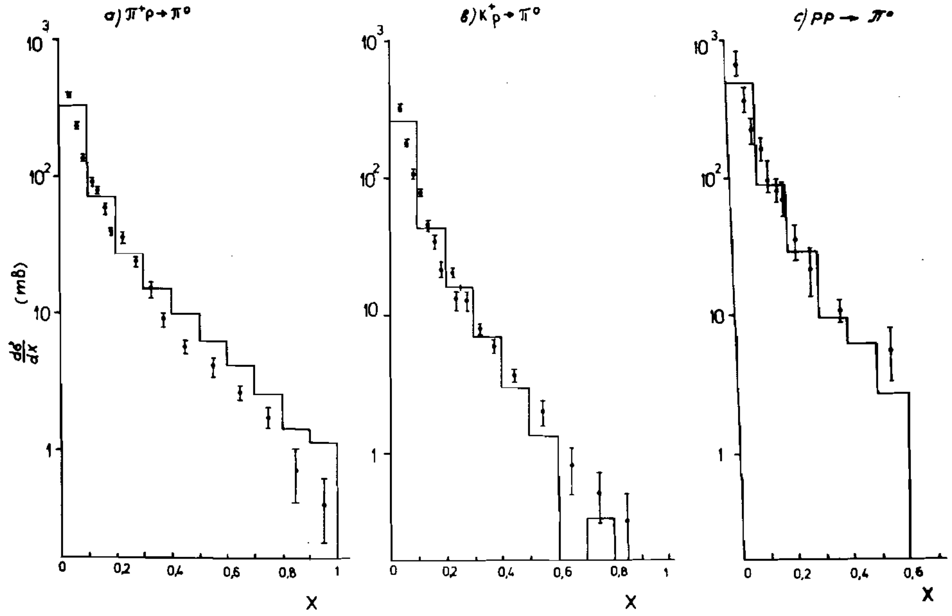

Fig.5. Distributions $d\sigma/dx$ for π^0-mesons in π^+p-, K^+p- and pp-interactions at 250 GeV/c; the dots are experiment[9] and the histograms - QGSM.

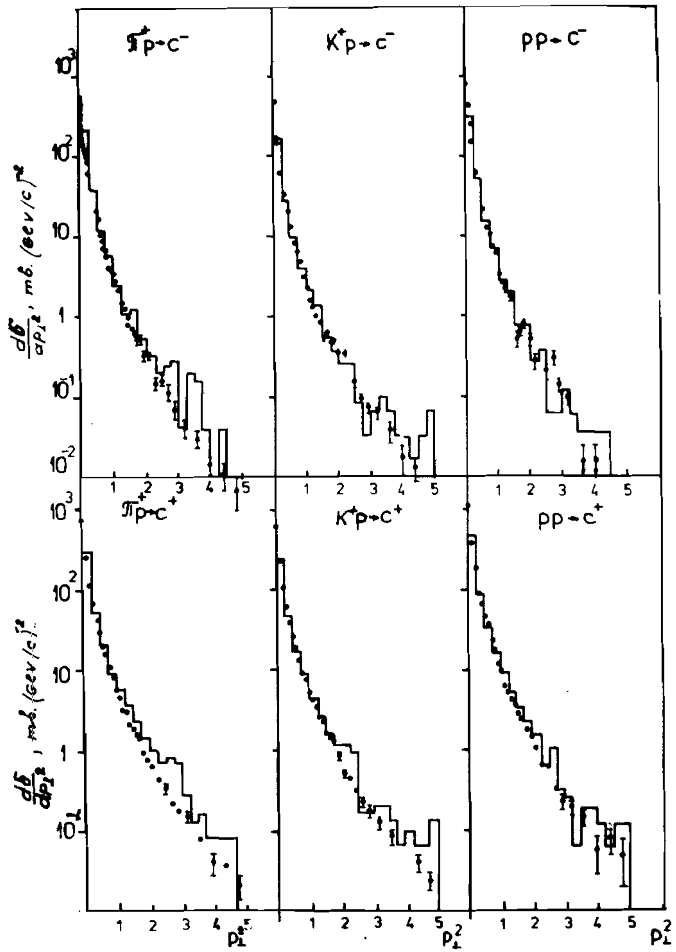

Fig.6. Distributions $d\sigma/dP_T^2$ for C^+-and C^--particles in π^+p-, K^+p- and pp-interactions at 250 GeV/c; the dots are experiment[5] and the histograms - QGSM.

It is of interest to compare between the distributions of secondary particles over transverse momentum. It was shown in ref.[5] that the Lund model, the FRITIOF model and the DPM describe the experimental spectra $d\sigma/dP_\perp^2$ of the reactions under consideration only in the region of $P_\perp < 1$ GeV/c. At large P the calculated curves go below the experimental points. The quark-gluon string model reproduces the experimental distributions at large $P_\perp^2 > 1$ $(GeV/c)^2$, see Fig.6.

4. CONCLUSIONS

It is shown in the present paper that the quark-gluon string model which is realized as the COLLI code [1,2] and describes the experimental characteristics of pp- and pp-interactions at energies $\sqrt{s}$ from a few GeV to ~1 TeV, can be used to simulate the characteristics of meson-proton interactions.

Comparison of the model predictions with experiment was made for π^+p- and K^+p-interactions at 250 GeV/c at the same model parameters as the ones used in the simulation of pp-interactions.

It is shown that the quark-gluon string model reproduces the specific features of the experimental distributions which are not described by the models now in use such as the Lund model/5/, the FRITIOF Model/6/ and the DPM/7/.

The authors wish to express their gratitude to A.B.Kaidalov, L.I.Sarycheva and P.F.Ermolov for their support and interest in the present work.

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Received by Publishing Department
on December 11, 1989.

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Инклюзивные характеристики π^+p-, K^+p- и pp-взаимодействий при 250 ГэВ/с в модели кварк-глюонных струн

Показано, что монте-карловская реализация модели кварк-глюонных струн описывает распределения по множественности частиц и одночастичные инклюзивные спектры для π^+p-, K^+p- и pp-взаимодействий при импульсе 250 ГэВ/с.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1989

Amelin N.S., Bravina L.V., Smirnova L.N. E2-89-819

Inclusive Characteristics of π^+p-, K^+p- and pp-Interactions at 250 GeV/c in the Model of Quark-Gluon Strings

It is shown that the Monte-Carlo realization of the quark-gluon string model describes the multiplicity distributions and the single-particle inclusive spectra for π^+p-, K^+p- and pp-interactions at the momentum of 250 GeV/c.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1989