Study of the mechanism for quark-diquark fragmentation in *pp* interactions at 360 GeV/*c*

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(Submitted 16 September 1986)
Pis'ma Zh. Eksp. Teor. Fiz. **44**, No. 9, 411–415 (10 November 1986)

Data on the inclusive production of mesons and baryons in *pp* interactions at 360 GeV/*c* are analyzed. Comparision of the experimental data with the predictions of a simple parton model, in which the nucleon is treated as the bound state of three quarks or of a quark and a diquark, shows that the hypothesis of the existence of diquark structures in nucleons is a necessary condition for a qualitative description of the inclusive production of baryons.

INTRODUCTION

In this letter we analyze the inclusive characteristics of the production of charged hadrons $h^{\pm}$ and also of π^0, K^0, Λ, and $\overline{\Lambda}$ in *pp* interactions at 360 GeV/*c* on the basis of a quark-parton model. The model which we are using here is based on the representation of the structure of the nucleon as a quark-diquark system, which is supported by many experiments on hard scattering processes.[1–8]

1. Experimental procedure and selection of data. We use data from experiment NA23 carried out at CERN with an apparatus consisting of a rapidly circulating bubble chamber and the European hybrid spectrometer. The apparatus and procedure are described in detail; data on the yields of neutral strange particles and π^0 mesons are reported in Refs. 9–11.

The statistical significance of our sample of events is 1.6 events/μb. For a physical analysis we selected only well-reconstructed events for which the relative errors in the momenta of the charged particles, $\Delta p/p$, were less than 20%.

All the charged particles except protons, which were identified on the basis of the ionization density in the bubble chamber, were assigned the masses of $\pi^{\pm}$ mesons. A simulation showed that the residual $\pi/K/p$ uncertainties have essentially no effect on the results reported here.

2. Fragmentation model. In the model which we are using here, one of the "dressed" quarks (or diquarks), *i*, is emitted from nucleon *a* in a soft scattering process (Fig. 1) and is then hadronized, with the result that hadron *c* forms. In the

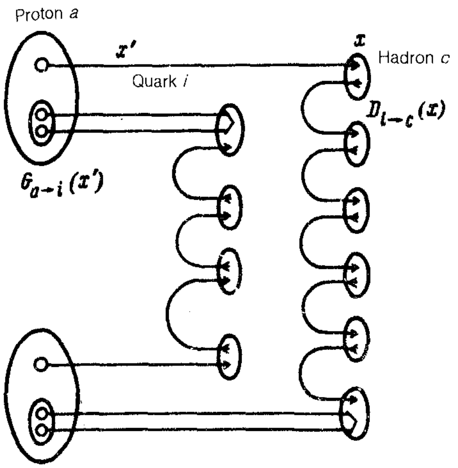

FIG. 1. Parton diagram of the hadronization of a quark and a diquark.

quark-parton approach, this process is described by a convolution of the distribution function $G_{a\to i}(x')$ of the dressed quarks (or diquarks) in nucleon a and the corresponding fragmentation function $D_{i\to c}(x/x')$:

$$\frac{1}{\sigma}\frac{d\sigma}{dx} = \sum_i \int_x^1 dx'/x' G_{a\to i}(x') D_{i\to c}(x/x'), \tag{1}$$

Here x' is the fraction of the longitudinal momentum of hadron a which is carried off by quark i, and x/x' is the fraction of the momentum of quark i which is carried off by hadron c. By "dressed" here we mean valence quarks with their own fields of virtual gluons and sea quarks.

It is assumed that the distributions of quarks and diquarks in the nucleon meet the requirements of the dual Regge theory. A diquark is understood as a cluster which does not decay into its constituent quarks in the course of the hadronization. We introduce two types of distribution functions for nucleon,[12–14] with and without allowance for diquark structures (the QD and IQ versions, respectively):

$$G_{QD}(x') \doteq \frac{1}{B(\alpha_q+1,\alpha_{qq}+1)} x'^{\alpha_q}(1-x')^{\alpha_{qq}}, \tag{2}$$

$$G_{IQ}(x') = \frac{1}{B(\alpha_q+1,2\alpha_q+2)} x'^{\alpha_q}(1-x')^{2\alpha_q+1}, \tag{3}$$

where $B(\alpha,\beta)$ is the beta-function. The dynamic parameters $-\alpha_q$ and $-\alpha_{qq}$ are the intercepts of the meson and baryon Regge trajectories, respectively.[14] For u- and d-quarks we have $\alpha_q = -1/2$ ($\rho-\omega$ trajectory). To determine α_{qq} we need to know the baryon trajectories, but extremely little is known about them. It follows from theoretical considerations[15,16] that we would have $0.5 < \alpha_{qq} < 2.0$.

Figure 2 shows distribution function (2) for the three values $\alpha_{qq} = 0.5$, 1.0, and 2.0 (the solid lines) and distribution function (3) (dashed line). The most important

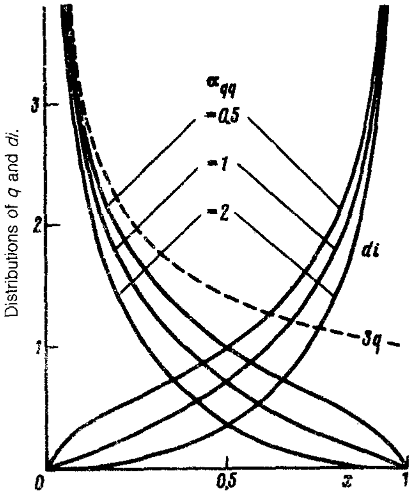

FIG. 2. Quark distribution functions in a nucleon in the configuration of three independent quarks (dashed line) and in a quark-diquark configuration, for three values of the intercept of the Regge trajectory of baryonium, α_{qq}: 0.5, 1.0, and 2.0.

difference between these two configurations is that the average momentum of an individual quark is significantly smaller in the quark-diquark picture than in the picture with three independent quarks. As a result, the hardness of the diquark is greater than that of a simple combination of two independent quarks.

To describe the hardronization mechanism, we use the two most common models: the Field-Feynman model,[17,18] and the Lund string model.[19,20] From the Lund model we take only that part which describes the fundamental mechanism for the production of hadrons through breaks in strings running between quarks.

The parameters fo the FF and Lund models are constructed from experimental data on the hadron yields in e^+e^- annihilation at $\sqrt{S} = 34$ obtained by the TASSO group.[21]

3. Comparison of model-based predictions and experimental data. For comparison with experimental data, we calculated spectra using all possible combinations of the distribution function, (2) or (3), and the hadronization mechanism, FF or Lund. The program implementing the model guaranteed exact conservation of the additive quantum numbers. Since the predictions referring to different hadronization mechanisms differ only slightly, we will restrict the discussion here to the results obtained with the help of the FF fragmentation function.

Figure 3 shows the experimental single-particle distributions in the variable x_F, in comparison with the model-based predictions. The curves in this figure were drawn for the values 1.0 and -0.5, respectively, of the dynamic parameters α_{qq} and α_q. As α_{qq} is varied from 0.5 to 2.0, the single-particle distributions change only slightly (and are not shown in this figure). In the choice of parameters of the model, a global normalization was carried out on the basis of the inclusive cross section for the production of negatively charged hadrons.[10] In the model with a diquark, it is possible to achieve a good agreement with the experimental data in terms of the relative yields of h^+, K_s^0, Λ, and $\bar{\Lambda}$ (Table I). The measured h^+ cross section is slightly larger than that predicted in the region $x_F > 0.65$ (Fig. 3b). This discrepancy is attributed to a contribution of

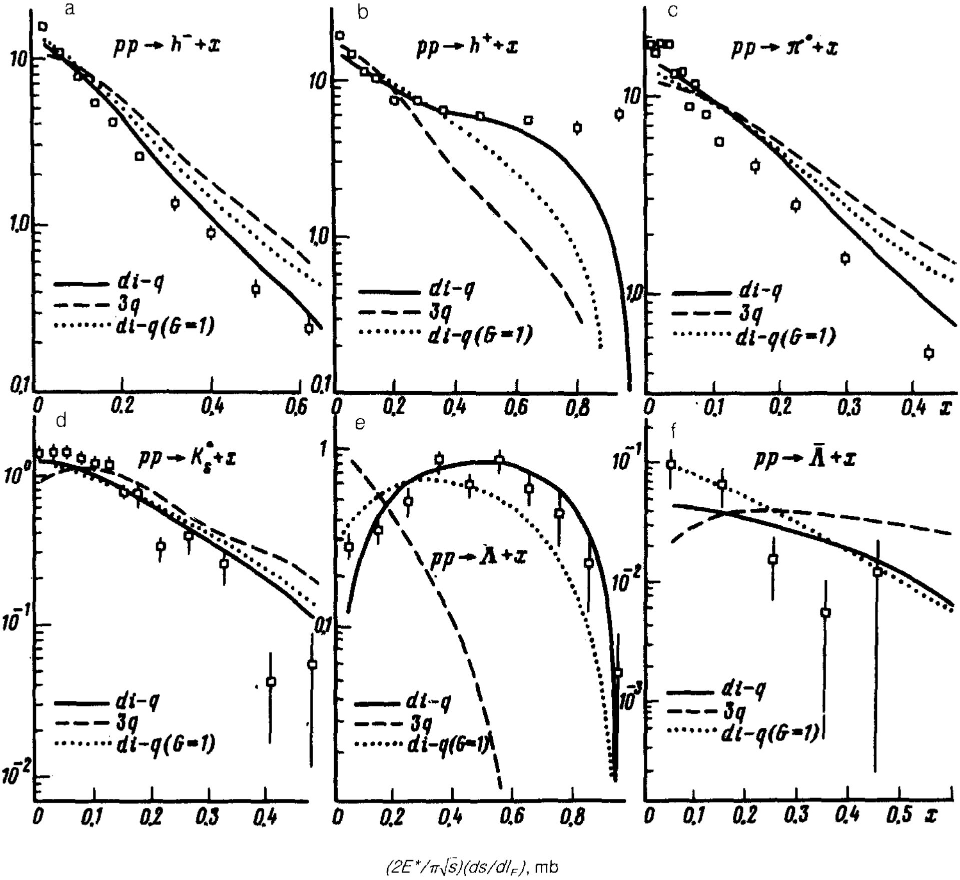

FIG. 3. Comparison of model-based predictions and experimental data on the yields of h^+, h^-, π^0, K_s^0, Λ, and $\overline{\Lambda}$ in pp interactions at 360 GeV/c. The dotted lines are the predictions of the model with the diquark in the case in which the diquark has an isotropic distribution: $G_{QD}(x')=1$.

TABLE I. Total inclusive cross sections: model and experiment.

Particle	Experiment (mb)	Model (mb)
h^-	116 ±5	116
h^+	181 ±2	170
π'^0	132 ±11	141
K^0	8,55 ±0,51	8,28
Λ	4,08 ±0,40	5,00
$\overline{\Lambda}$	0,43 ±0,12	0,31

diffractive dissociation, which is not described by this model. Outside this region of x_F, the predictions of the model with a diquark agree well with the experimental distributions.

At $x_F > 0.3$ the crosss section for the production of Λ-hyperons is entirely saturated by the contribution of (ud)-diquarks with zero spin (Fig. 3e), which constitute the primary component of the wave function of the proton.[13] The model without a diquark describes the spectra of h^-, π^0, and K_s^0 noticeably more poorly and fails completely to describe the Λ spectrum.

To emphasize the effect of the choice of the parametrization of the structure functions of the quark and the diquark on the shape of the secondary-hadrons spectra, we examine the limiting case $G_{QD}(x') = 1$, while leaving the hadronization mechanism unchanged. The results of these calculations are shown by the dashed line in Figs. 3a–3f. As expected, the distribution obtained as a result are, on the whole, softer than the distribution which incorporate diquark structures. Comparison with the experimental data (particularly in the case of the Λ-hyperon) confirms that it is necessary to use nontrivial representations regarding the structure functions of the nucleons.

CONCLUSION

Comparison of the experimental data on the yields of the charged particles ($h^\pm$, π^0, and K_s^0 mesons) and of Λ and $\overline{\Lambda}$-hyperons in pp interactions at 360 GeV/c with the predictions of a simple parton model confirms that diquark structures play an important role, especially in the production of baryons. In the model considered here, the diquark in the proton is an indivisible entity ($\overline{3}$ in terms of color), which undergoes a direct transition into the baryon which is produced in the reaction. Although there are more complicated approaches to the description of the diquark structure in the proton,[22] the simple approximation which we have used here is quite sufficient for describing these single-particle distributions.

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Translated by Dave Parsons