Large $p_\perp$ and quark-quark cross section in the dynamic model of factorizing quarks

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It is shown that the data on the inclusive reaction $pp \to \pi^\circ X$ are well described by using the quark-quark scattering cross section that follows from the model with the hypothesis that the quark amplitudes are factorizable.

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The cross sections of the inclusive reactions $A+B \to h+X$ with production of hadrons h with large momentum transfers $p_\perp$ are most successfully described by the formula of the quark–parton "rigid collisions" model[1]

$$E\frac{d^3\sigma}{dp^3}(A+B\to h+X) = \iint dx_a\, dx_b \sum_{a,b} G_{A\to a}(x_a) G_{B\to b}(x_b)\, D_c^h(z_c) \times \frac{1}{z_c}\,\frac{1}{\pi}\,\frac{d\hat{\sigma}}{d\hat{t}}(qq\to qq), \tag{1}$$

where $G_{A\to a}(x)$ is the distribution function of the quarks in the hadron A, while $D_c^h(z)$ is the function of fragmentation of a quark c into a hadron h;

$$\frac{d\hat{\sigma}}{d\hat{t}}(qq\to qq)$$

is the quark-quark scattering cross section.

As shown in Refs. 2 and 3, a good description is obtained if the relation $d\hat{\sigma}/d\hat{t} \sim 1/\hat{s}^2$, which predicts a dimensional quark count[4] for the quark–quark scattering cross section is replaced by the purely phenomenological formula $d\hat{\sigma}/d\hat{t} \sim 1/\hat{s}(-\hat{t})^3$ or $1/\hat{s}^2\hat{t}^2$.[1)]

We shall show in this paper that the data on the reaction $pp \to \pi^0 X$ are well described by using for the quark–quark cross section another relation, which follows from the dynamic model of factorizing quarks (DMFQ).[5] This model, in contrast to the model of additive quarks, describes processes with large momentum transfers (elastic pp scattering, the form factors[2)] of the pion and proton[5] and contains an explicit scale factor–the quark mass M_q.

In the model of the factorizing quarks it is assumed that the amplitude for the scattering of two hadrons is proportional to the product of the amplitudes for the scattering of individual valent quarks by a certain self-consistent potential V_{eff} produced by the quarks in the collisions process:

$$M_{AB\to AB} = \prod_i g_i \prod_j g_j\ . \tag{2}$$

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The quark–quark scattering amplitude was chosen in Ref. 5 in the form ($y = \text{Arcosh}(1 - \hat{t}/(2M_q^2))$):

$$g_q = y/\text{sh}\, y \xrightarrow[-\hat{t}\to\infty]{} \frac{\ln(|\hat{t}|/M_q^2)}{|\hat{t}|/M_q^2}\,. \qquad (3)$$

From (2) and (3) we get for the quark–quark cross section the formula

$$\frac{d\hat{\sigma}}{d\hat{t}}(qq\to qq) \underset{-t\to\infty}{=} \frac{A}{\hat{s}^2}\left[\frac{\ln(|\hat{t}|/M_q^2)}{\hat{t}/M_q^2}\right]^4 \approx \frac{A}{\hat{s}^2(|\hat{t}|/M_q^2)^{N_{\text{eff}}}}\,, \qquad (4)$$

where

$$N_{\text{eff}} = 4 - 4\,\frac{\ln\,\ln(|\hat{t}|/M_q^2)}{\ln(|\hat{t}|/M_q^2)}\,,$$

and the quark mass M_q and the constant A are regarded as free parameters of the model.

To determine from formula (1) the cross section of inclusive production of a π^0 meson at 90° we chose the same functions[3)] $G(x)$ and $D(z)$ as in Ref. 2, which are independent of Q^2. This choice corresponds to possible conservation of scaling in future ep-scattering experiments at large Q^2. The masses of the u and d quarks were

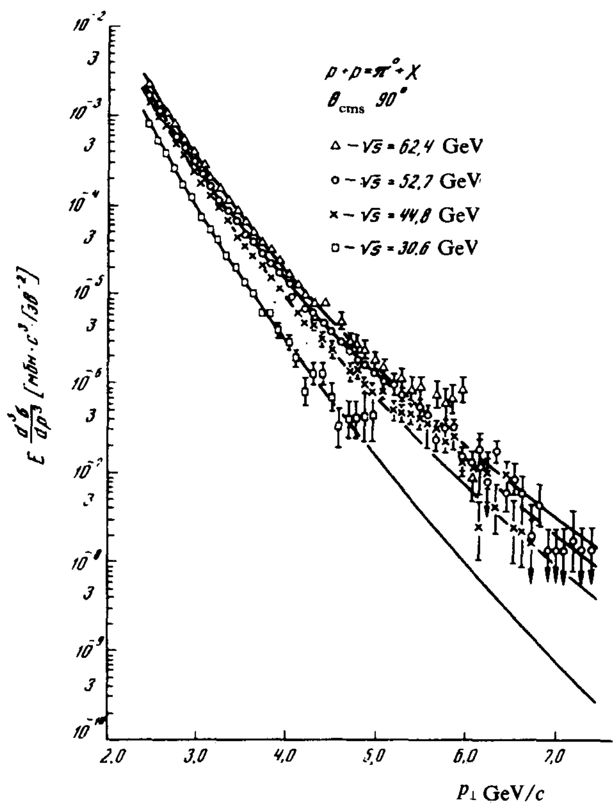

FIG. 1. Comparison of the DMFQ predictions with the experimental data on the reaction $pp\to\pi^0X$ (Ref. 6).

TABLE I.

$\sqrt{s}$ [GeV]	$\chi^2 df = \frac{\chi^2}{N-2}$	M_q [GeV]
62.4	51/40 − 2	0.59
52.7	65/52 − 2	0.69
44.8	100/45 − 2	0.59
33.6	28/27 − 2	0.45
23.5	19/17 − 2	0.44

assumed to be the same, and the contributions of other quarks was disregarded, as in Ref. 2.

The results of the reduction of the reaction[6] $pp \to \pi^0 X$ by formulas (1) and (4) are shown in Table I and in Fig. 1 and attest to good agreement with experiment. If the cross section of reaction (1) is represented in the form

$$E\frac{d^3\sigma}{dp^3}(pp \to \pi^0 X) \sim p_\perp^{-N},$$

then the theoretical curves at constant s (see Fig. 1) indicate that the degree of N increases in accordance with (4) from $N \approx 9$ at $p_\perp = 2.4$ GeV/c to $N \approx 13$ at $p_\perp = 7.5$ GeV/c. This in turn agrees with the fits obtained in Ref. 6 at constant s. We note that the quark mass (see Table 1) is close to the $M_q \approx 0.3$ GeV obtained when the data on elastic pp scattering are described within the framework of the DMFQ,[5] and is of the same order as the $M_q \approx 0.2$ GeV obtained in an analysis of the electromagnetic factors.[5]

[1)]The physical cause of this deviation from the rules of dimensional quark count remained unexplained in Refs. 2 and 3.

[2)]We note that the asymptotic behavior of the form factor, which follows from the DMFQ, satisfies the Drell–Yang–West relation, whereas the predictions of the dimensional quark count for the form factors do not agree with this relation.[5]

[3)]Another possibility was proposed in Ref. 7.

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