Potential with a dimensional parameter in the model of rigid collisions

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(Submitted 23 October 1979)
Pis'ma Zh. Eksp. Teor. Fiz. **30**, No. 11, 739–741 (5 December 1979)

Quark scattering by the effective potential containing a dimensional parameter is examined. It is shown that the quark-quark scattering cross section obtained by assuming factorizability of the quark amplitudes describes well the data for the reaction $p\,p \to \pi^\circ X$.

PACS numbers: 12.40.Cc, 13.85.Kf

The cross section of the inclusive reaction $p\,p \to \pi^\circ X$ ($\theta_{\rm com} = 90^\circ$) was recently measured in the region of "very large" π°-meson momenta: $p_\perp \lesssim 15$ GeV/c.[1] It was determined that, unlike in the region $p_\perp \sim 2.4$–6.0 GeV/c, in which the cross section decreased as $p_\perp^{-8}$,[2] in the region $p_\perp \sim 1.0$–15 GeV/c it behaves as $p_\perp^{-6.6}$.[3]

To describe quark scattering in the sub-process of rigid collisions, we propose the potential $V_{\rm eff}(r)$ that can describe the cross section for the reaction $p\,p \to \pi^\circ X$ in a broad range of momenta $p_\perp \sim 2.46$–15 GeV/c.

In the dynamic model of factorable quarks (DMFQ),[4] the potential $V_{\rm eff}(r)$ is expressed as a relativistic configurational representation (RCR). The conversion from the momentum representation to RCR is done by means of the Fourier transform of the functions[5] ($\hbar = c = 1$)

$$\xi(\mathbf{p}, \mathbf{r}) = \left(\frac{p_0 - \mathbf{p}\mathbf{r}}{m}\right)^{-1 - i r m} \tag{1}$$

(m is the quark mass), which produce unitary, infinite-dimensional, irreducible representations of the Lorentz group. In the Born approximation the quark-scattering amplitude is given by the expression[6]:

$$g_i(\theta) = 4\pi \int_0^\infty \frac{\sin rmy_i}{rm \operatorname{sh} y_i} V_{\text{eff}}(r) r^2 dr, \tag{2}$$

where $y_i = \operatorname{Ar\,ch}(1 - t_i/2m^2)$, and t_i is the momentum transfer per quark.

In an earlier work[4] the potential was written in the form $V_{\text{eff}}(r) = \delta(r)/4\pi r^2$, which gave $g_i(\theta) = y_i/\operatorname{sh} y_i$. However, this amplitude can be used to describe the experimental data only in the region $p_\perp = 2.4$–7.0 GeV/c.[7] To allow for the aforementioned substitution $p_\perp^{-8} \to p_\perp^{-6.6}$, we introduce in the potential the dimensional parameter ρ:

$$V_{\text{eff}}(r) = \delta(r + i\rho)/4\pi r^2. \tag{3}$$

Substituting Eq. (3) in Eq. (2), we obtain

$$g_i(\theta) = \frac{\operatorname{sh} \rho m y_i}{\rho m y_i}. \tag{4}$$

In the framework of DMFQ we obtain the following expression for the quark-quark cross section:

$$\frac{d\sigma}{dt} \sim \frac{A}{S^2}\left[\frac{\operatorname{sh}\rho m y_i}{\rho m y_i}\right]^4 \xrightarrow[-t\to\infty]{} \frac{A}{S^2}\left(\frac{|t|}{m^2}\right)^{-N_{\text{eff}}}, \tag{5}$$

where $N_{\text{eff}} = 4(1 - \rho m)$.

For $\rho m y_i \ll 1$, Eq. (4) becomes an amplitude obtained in Ref. 4. If, however, ρ corresponds to the Compton wavelength (CW) of the quark $\rho = m^{-1}$, then $d\sigma/dt \sim S^{-2}$, in agreement with the predictions of the quark count.[8]

We used the expression (5) for the quark-quark scattering cross section to calculate the cross section for the reaction $pp \to \pi^\circ X$, according to the equation for the model of "rigid collisions"[9]:

$$E\frac{d^3\sigma}{dp^3}(AB \to hX) = \int dx_a dx_b \sum_{a,b} G_A^a(x_a) G_B^b(x_b) D_c^h(z_c) \frac{1}{z_c \pi}\frac{d\sigma}{dt}, \tag{6}$$

where $G_A^a(x)$ is the distribution function of quarks in the hadron A and $D_c^h(z)$ is the fragmentation function of the quark c in the hadron h. These functions were selected

TABLE I

$\sqrt{S}$, GeV	$10^3 \times A$, mb·GeV^2	ρ, GeV^{-1}	$\chi^2_{d.f.}$
62.5	4.9 ± 0.7	0.967 ± 0.018	130/44-2
52.7	7.0 ± 0.7	0.818 ± 0.006	67/47-2

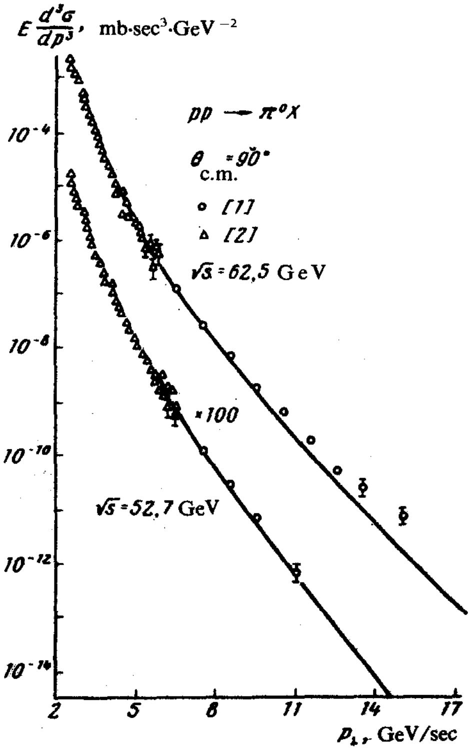

FIG. 1. Comparison with the experimental data of the reaction $pp \to \pi^0 X$, $p_\perp = 2.4$–6.5 GeV[2] and $p_\perp = 6.5$–15 GeV.[1]

in such a way as to be independent of Q^2.[10] We chose typical masses for the quarks u and d $m_u = m_d = 0.33$ GeV, and disregarded, as in Ref. 10, the effects of other quarks.

The results of comparing Eqs. (5) and (6) with the experiment, shown in Table I and in Fig. 1, indicate a good agreement. The obtained value of ρ is one-third of the CW of the quark and is approximately equal to the proton CW, $\rho \approx m_p^{-1}$. The presence of singularities in the $N\bar{N}$ interaction potential at such distances was indicated in Ref. 11.

Thus, the two dimensional parameters m and ρ in the quark-quark scattering potential can be used to describe the data for the reaction $pp \to \pi^0 X$ ($\theta_{\text{c.m.}} = 90°$) in the region of average values of the scaling variable $x = 2p_\perp/\sqrt{s} \leqslant 0.5$.

The authors thank S. P. Kuleshov for his attention to this work.

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