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LARGE-ANGLE HADRON ELASTIC SCATTERING IN THE QUARK MODEL WITH FACTORIZABILITY ASSUMPTION

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Гипотеза факторизуемости в кварковой модели и упругое рассеяние адронов на большие углы

Модель факторизующихся кварков дополнена динамическим предположением о виде амплитуды рассеяния кварка на самосогласованном потенциале. Получена простая формула для адронных сечений в асимптотической области, содержащая зависимость от числа составляющих кварков. Произведено сравнение с экспериментальными данными по pp - рассеянию.

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Large-Angle Hadron Elastic Scattering in the Quark Model with Factorizability Assumption

The quark model with factorizability is enlarged with the dynamical assumption on the form of the scattering amplitude of a quark on an effective potential. A simple formula with dependence on the number of constituent quarks is found for hadron cross sections in the asymptotic region. The results are compared with the pp - scattering experimental data.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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In the present paper, the cross sections of hadron-hadron elastic scattering in the asymptotic region

$$s, t \to \infty \quad , \quad t/s - \text{fixed} \tag{1}$$

are studied within the framework of the quark model with factorizability assumption [1]. This model assumes the following mechanism for hadron interactions. When hadrons collide, the constitient quarks produce an effective force field $V_{eff.}$. The quarks scatter independently of each other on this field. For independent events, the probability of scattering of the whole set of quarks at angle θ is a product of individual probabilities of scattering of each quark at θ. Accordingly, the amplitude of scattering of two hadrons A and B is taken as follows [1]:

$$M_{AB}(\theta) = \sum \prod_{i=1}^{n} g_i(\theta) \prod_{j=1}^{m} g_j(\theta), \tag{2}$$

where n and m are the numbers of quarks in hadrons A and B, resp., $g_i(\theta)$ is the scattering amplitude of an i-th quark on $V_{eff.}$, and the summation runs over all possible processes with the identical quark exchange [1-3].

We enlarge the quark model with factorizability assumption [1] by the dynamical assumption on the explicit form of $V_{eff.}$ by giving the explicit expression in the relativistic configurational representation (RCR) introduced first in paper [4]. According to [4], the transition from the momentum representation to the RCR is realised through expansions on the Lorentz group, and not through the Fourier-Bessel transform. The role of the plane waves $\exp(i\vec{p}\vec{r})$, in this approach play the functions (5) (in notation of ref.[4] and $\hbar = c = 1$):

$$\xi(\vec{p},\vec{r}) = \left(\frac{p_0 - \vec{p}\cdot\vec{n}}{M}\right)^{-1-irM}, \qquad (3)$$

which realize unitary (infinite-dimensional) irreducible representations of the Lorentz group. Then, the Born amplitude of scattering of a quark on the spherical-symmetric potential $V_{eff}(r)$ is given as follows [4]:

$$g_q(\theta) = 4\pi \int_0^\infty \frac{\sin rM_q y_q}{rM_q y_q} V_{eff}(r) r^2 dr , \qquad (4)$$

where $y_q = Arch(1 - t_q/2M_q^2)$ is the rapidity conjugated to the momentum t_q transferred to one quark $t_q \approx t/n^2$, and M_q is the quark mass.

Taking $V_{eff}(r)$ in the form

$$V_{eff}(r) \sim \frac{1}{4\pi r^2}\,\delta(r) \qquad (5)$$

and inserting (5) into (4) we obtain[5]

$$g_q(\theta) \sim \frac{y_q}{sh\, y_q} = \frac{2M_q^2 \ln\left(1 - \frac{t_q}{2M_q^2} + \frac{1}{2M_q^2}\sqrt{t_q(t_q - 4M_q^2)}\right)}{\sqrt{t_q(t_q - 4M_q^2)}} . \qquad (6)$$

It is obvious that for $t_q \ll 4M_q^2$ $y_q/sh\, y_q \approx 1$ and at large $t_q \gg 4M_q^2$

$$\frac{y_q}{sh\, y_q} \approx 2M_q^2 \, \frac{\ln |t_q|/M_q^2}{|t_q|}. \qquad (7)$$

In the kinematic region (1), where t/s is fixed substituting (6) into (2) results in the following elastic scattering amplitude

$$M_{AB}(\theta) \sim \prod_{i=1}^{n} \frac{y_i}{sh\, y_i} \prod_{j=1}^{m} \frac{y_j}{sh\, y_j} \, . \tag{8}$$

In particular, for pp-scattering in the c.m.s. at $\theta = 90^\circ$, i.e. $t = -s/2$,using (8) one arrives at the cross section

$$\frac{d\sigma}{dt}(pp \to pp) \sim \frac{1}{s^2} \left[\frac{\ln s/18 M_q^2}{s/18 M_q^2} \right]^{12} , \tag{9}$$

which can be represented also in the form of the power law

$$\frac{d\sigma}{dt}(pp \to pp) \sim \left(s/18 M_q^2 \right)^{-n_{eff}(s,\, \theta = 90^\circ)} , \tag{10}$$

where

$$n_{eff.} = 14 - 12 \, \frac{\ln\left(\ln s/18 M_q^2 \right)}{\ln s/18 M_q^2} \tag{11}$$

increases with s what is consistent with the available experimental data on pp-scattering at 90° /7/ (see fig.1). A dependence of the type (10), (11) of n_{eff} on s arises also in theories with asymptotic freedom /8/.

The results of fitting the experimental data on pp elastic scattering at different angles by formula (8) of our dynamical quark model with factorizability assumption (DQMFA) are given in the Table, where for comparison the values of χ^2 per one degree of freedom are presented also which follow from fitting by the quark counting rule formulae $d\sigma/dt(pp \to pp) \sim s^{-10}$. The value of the effective quark mass, obtained by our fitting is $M_q \approx 0.2$ GeV.

θ°	$S(\text{GeV})^2$	$-t(\text{GeV})^2$	$\chi^2/d.f.$	
			DQMFA	$d\sigma/dt \sim s^{-10}$
38°	$36 \div 61$	$3.5 \div 6.1$	2.52	4.49
68	$19 \div 52$	$5 \div 15$	1.90	8.93
75	$19 \div 49$	$6 \div 14$	3.11	9.12
90	$24 \div 43$	$10 \div 20$	1.48	2.61

It should be noted that the DQMFA based on the idea of the effective potential produced by all colliding quarks is a good approximation only when the number of participating quarks is large enough. Nevertheless, if one extends (8) to the process of quark-quark scattering, one obtains

$$\frac{d\sigma}{dt}(qq \to qq) \sim \frac{1}{s^2}\left[\frac{2M_q^2 \ln(|t|/M_q^2)}{|t|}\right]^4 \tag{12}$$

whereas the quark counting rules [9] gives $d\sigma/dt(qq \to qq) \sim s^{-2}$. On the other hand, in [10] it was shown that the experimental data on inclusive processes can be well fitted only by assuming the dependences $d\sigma/dt(qq \to qq) = 2.3 \cdot 10^6/(-st^3)\,\text{GeV}^6$. However, these formulae are obtained in the range $s \sim 10 \div 20$ GeV where the energy per one quark $s_q \sim 1 \div 2$ GeV^2 [11], therefore the logarithmic terms in (12) are essential. Consequently, the cross section (12) reproduces pure phenomonological dependences found in /10/. It is our further aim to allow, like it was done in /11/, for the quark spins in the given DQMFA and to apply our model for meson-baryon elastic scattering and inclusive reactions.

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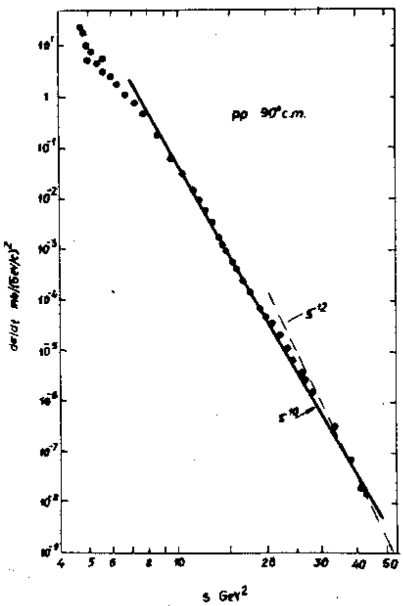

Fig. 1.

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