PRODUCTION OF VECTOR MESONS AND THE MODEL OF FACTORIZING QUARKS

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Abstract

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A. P. KOBUSHKIN

PRODUCTION OF VECTOR MESONS AND THE MODEL OF FACTORIZING QUARKS

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One of the simplest examples of the application of the quark model to the problem of high-energy hadron scattering is the additivity hypothesis ([1,2]), which states that the amplitude of high-energy hadron–hadron scattering is the sum of all possible quark–quark amplitudes. Such an approach makes it possible to describe very well total cross sections and forward differential cross sections; however, it is not applicable to scattering at large angles. In order to describe high-energy scattering at large angles, the hypothesis of factorization of quark amplitudes was proposed ([3,4]). However, in the proposed form the factorization hypothesis has the following shortcomings. First, in the case of forward scattering the factorization hypothesis does not give additivity. Second, the relation for total cross sections is not consistent with experiment. Third, some relations between differential cross sections at large angles are in disagreement with experiment. In order to eliminate these shortcomings, an attempt was made to take into account, in the factorization hypothesis, the spins of the quarks composing the scattering hadrons ([5,6]).

It was shown that in the case of meson–baryon scattering, under certain approximations that are valid in the case of small scattering angles, the results of factorization go over into the results of additivity. The total cross sections, even if no additional approximations are made, are in good agreement with the experimental data. The relations for scattering at large angles are also substantially improved.*

In the present work we use the technique developed in ([5,6]) for processes of the type $0^- + P \to 1 + \frac{1}{2}^+$ at high energies. An important point in finding the amplitudes of processes of the type $0^- + P \to 0^- + \frac{1}{2}^+$ was that the effect of quark spin flip was neglected everywhere ([6]). Using the assumptions of ([6]), we obtain the following amplitudes for production of $K^*(890)$-mesons:

$$T(K^+P \to K^{*+}P) = G^4(\theta)K(\theta)r^2(\theta),$$

$$T(K^- P \to K^{*-} P) = T(K^- P \to K^{*0} N) = 0, \tag{1}$$

where $G(\theta)$ is the scattering amplitude of p- and n-quarks (antiquarks) in the effective potential created by a system of repelling hadrons, $K(\theta)$ is a λ-quark or antiquark, $r(\theta) = G(\pi - \theta)/G(\theta)$; θ is the scattering angle in the center-of-mass system of the colliding hadrons. However, it follows from experiment that the forward differential cross sections for the processes $K^+ P \to K^{*+} P$ and $K^- P \to K^{*-} P$ are of the same order in the region of laboratory momentum from 4 to 10 GeV/c ([8]). Consequently, one can draw the following conclusion: the amplitu-

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* In work ([7]) the spins of quarks were also taken into account in the model of factorizing quarks, but in a somewhat different way than in ([5]). Therefore the predictions of works ([5,7]) differ substantially from one another.

quark spin-flip amplitudes, although small in comparison with the amplitudes $G(\theta)$, $K(\theta)$, $P_1(\theta)$, $P_2(\theta)$, are nevertheless comparable with $r(0)$. They are essential in processes of vector-meson production. $P_1(\theta)$ and $P_2(\theta)$ are defined as follows: $P_1^2(\theta)$ is the amplitude of the processes: $\mathrm{p}\uparrow \bar{\mathrm{p}}\uparrow \to \lambda \uparrow \bar{\lambda}\uparrow$, $\mathrm{p}\uparrow \bar{\mathrm{p}}\downarrow \to \lambda\uparrow \bar{\lambda}\downarrow$, $\mathrm{n}\uparrow \bar{\mathrm{n}}\uparrow \to \lambda'\uparrow \bar{\lambda}\uparrow$, $\mathrm{n}\uparrow \bar{\mathrm{n}}\downarrow \to \lambda\uparrow \bar{\lambda}\downarrow$; $P_2^2(\theta)$ is the amplitude of the processes: $\mathrm{p}\uparrow \bar{\mathrm{p}}\uparrow \to \mathrm{n}\uparrow \bar{\mathrm{n}}\uparrow$; $\mathrm{p}\uparrow \bar{\mathrm{p}}\downarrow \to \mathrm{n}\uparrow \bar{\mathrm{n}}\downarrow$.

Let us introduce the following amplitudes: $G^2(\theta)\omega^2(\theta)$ is the amplitude of the processes $\mathrm{p}\uparrow \bar{\mathrm{p}}\downarrow \to \mathrm{p}\downarrow \bar{\mathrm{p}}\uparrow$; $\mathrm{p}\uparrow \bar{\mathrm{n}}\downarrow \to \mathrm{p}\downarrow \bar{\mathrm{n}}\uparrow$, etc.; $G(\theta)K(\theta)\omega(\theta)\nu(\theta)$ is the amplitude of the processes: $\mathrm{p}\uparrow \bar{\lambda}\downarrow \to \mathrm{p}\downarrow \bar{\lambda}\uparrow$, $\mathrm{n}\uparrow \bar{\lambda}\downarrow \to \mathrm{n}\downarrow \bar{\lambda}\uparrow$, etc.

Neglecting in the amplitudes terms of second order of smallness $r^2(\theta)\omega^2(\theta)$, $r^2(\theta)\omega(\theta)\nu(\theta)$, etc., one can obtain the following amplitudes of processes of the type $0^- + P \to 1^- + \frac{1}{2}^+$:

$$T(\pi^- \mathrm{P} \to \rho^- \mathrm{P}) = \frac{1}{3\sqrt{2}} G^5(\theta)[1 + a(\theta)]^2 [1 + 2a(\theta)]\{\omega^2(\theta) - r^2(\theta)\};$$

$$T(\pi^+ \mathrm{P} \to \rho^+ \mathrm{P}) = \frac{1}{3\sqrt{2}} G^5(\theta)[1 + a(\theta)]^2 \{r^2(\theta) - 2(1 - \sqrt{2})\omega^2(\theta)\};$$

$$T(K^+ \mathrm{P} \to K^{*+} \mathrm{P}) = \frac{1}{3\sqrt{2}} G^4(\theta)K(\theta)\{(1 - 3\sqrt{2})\omega(\theta)[\nu(\theta) - \omega(\theta)] + $$

$$+ 3\sqrt{2}\, r^2(\theta)\};$$

$$T(K^- \mathrm{P} \to K^{*-} \mathrm{P}) = \frac{1 - 3\sqrt{2}}{3\sqrt{2}} G^4(\theta)K(\theta)\omega(\theta)[\nu(\theta) - \omega(\theta)]; \tag{2}$$

$$T(K^-\mathrm{P}\to\bar{K}^{*0}N)=\frac{3\sqrt{2}-7}{3\sqrt{2}}\,G^3(\theta)P_1^2(\theta)\omega(\theta)[\nu(\theta)-\omega(\theta)];$$

$$T(K^-\mathrm{P}\to K^{*+}\Xi^-)={}^2/_3G^3(\theta)P_2^2(\theta)r^2(\theta);$$

$$T(K^-\mathrm{P}\to\rho^-\Sigma^+)=-\frac{1}{3\sqrt{2}}\,G^3(\theta)G(\pi-\theta)K(\pi-\theta)[1+a(\theta)]^2[1+2a(\theta)].$$

Here $a(\theta)$ takes into account the possible annihilation channel in the processes $\mathrm{pp}\to\mathrm{pp}$, $\mathrm{nn}\to\mathrm{nn}$.

Assuming $\omega(\theta)$ and $\nu(\theta)$ to be of order $r(0)$, and choosing the parameters $|r(0)|$, $|K(\pi)/K(0)|$, $\left|P_{1,2}(\pi)/P_{1,2}(0)\right|$, $\left|\frac{[1+2a(\pi)][1+a(\pi)]^2}{[1+2a(0)][1+a(0)]^2}\right|$ the same as in work [(6)], one can qualitatively describe the magnitude of the ratio of backward-to-forward peaks of the differential cross sections for the processes (2).

From (2) and from the formulas for the processes $K^\pm\mathrm{P}\to K^\pm\mathrm{P}$, $\pi^-\mathrm{P}\to\pi^-\mathrm{P}$ [(5)], $K^-\mathrm{P}\to\bar{K}^0N$ [(6)], there follows a relation connecting the differential cross sections at small angles:

$$\frac{d\sigma}{dt}(K^-\mathrm{P}\to K^{*-}\mathrm{P})\frac{d\sigma}{dt}(K^-\mathrm{P}\to\bar{K}^{*0}N)=$$

$$=\frac{(3\sqrt{2}-1)^4}{9(3\sqrt{2}-7)^2}\,\frac{d\sigma}{dt}(K^+\mathrm{P}\to K^+\mathrm{P})\frac{d\bar{\sigma}}{dt}(K^-\mathrm{P}\to K^-\mathrm{P})\times$$

$$\times 1\Big/\frac{d\bar{\sigma}}{dt}(\pi^-\mathrm{P}\to\pi^-\mathrm{P})\frac{d\sigma}{dt}(K^-\mathrm{P}\to\bar{K}^0N). \tag{3}$$

$d\bar{\sigma}/dt$ denotes the differential cross section divided by a kinematic factor, which we choose in the form:

$$sp_{\mathrm{in}}^2/p_{\mathrm{out}}^2. \tag{4}$$

Comparison of relation (3) with experiment is carried out at equal values of the kinetic energy Q of the produced hadrons [(9)] and θ. The comparison is made in Table 1.

Table 1

Comparison with experiment [(8, 10–14)] of relation (3)

Q, GeV	$\cos\theta$	Right-hand side	Left-hand side	Q, GeV	$\cos\theta$	Right-hand side	Left-hand side
1,66	0,92	$6,2^{+3,8}_{-3,6}$	$1,1^{+0,5}_{-0,4}$	2,72	0,97	$19,0^{+8}_{-6}$	$32,0^{+68}_{-17}$
1,66	0,89	$3,9^{+3,3}_{-2,0}$	$1,8^{+3,4}_{-0,8}$	2,72	0,96	$16,5^{+9,5}_{-9,0}$	$14,0^{+48}_{-10}$
1,66	0,86	$1,3^{+0,9}_{-0,3}$	$1,0^{+0,7}_{-0,4}$	2,72	0,95	$13,0^{+7,5}_{-7}$	~ 20
1,66	0,84	$1,0^{+1,6}_{-0,6}$	$0,2^{+0,3}_{-0,13}$	2,72	0,94	$22,0^{+9}_{-7}$	< 67
1,66	0,81	$2,6^{+4,6}_{-1,3}$	$< 0,27$	2,72	0,92	$12,5^{+14,5}_{-8,5}$	~ 60
1,66	0,78	$3,6^{+5,1}_{-2,7}$	$0,5^{+0,8}_{-0,3}$	2,72	0,90	$12,5^{+13,0}_{-5,5}$	~ 60

In addition, one can write down certain relations for the differential cross sections of these backward processes, which, however, because of the lack of experimental data cannot yet be checked.

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Institute of Theoretical Physics
Academy of Sciences of the Ukrainian SSR
Kiev

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Note: Figure translations are in progress. See original paper for figures.