Factorization properties of the two-gluon exchange model

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The cross sections for the zero-angle diffraction of hadrons in $h_1h_2 \to Xh_2$ processes ($h_{1,2} = \pi, K, p$) are calculated in the two-gluon exchange model. The factorization relations of one-pomeron exchange are violated in this model.

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Low[1] and Nussinov[2] have suggested treating the pomeron as the exchange of two gluons. If this idea is correct, then the amplitudes calculated for hadron interactions in the two-gluon exchange approximation should have, in particular, the factorization properties of the amplitudes of one-pomeron exchange.

A careful analysis easily shows that the total cross sections for hadron-hadron interactions calculated in the two-gluon exchange model in Refs. 3 and 4 do not exhibit the one-pomeron-exchange factorization properties. Although the numerical deviations from the factorization relations

$$\frac{\sigma_t^2(h_1h_2)}{\sigma_t(h_1h_1)\sigma_t(h_2h_2)} = 1, \tag{1}$$

derived in the two-gluon exchange model are small,

$$\frac{\sigma_t^2(\pi N)}{\sigma_t(\pi\pi)\sigma_t(NN)} \simeq 0{,}99, \qquad \frac{\sigma_t^2(\pi K)}{\sigma_t(\pi\pi)\sigma_t(KK)} \simeq 0{,}96 \tag{2}$$

and have not been tested experimentally, the very fact that these factorization relations are violated in the two-gluon exchange model is interesting and deserves a more detailed study.

We have accordingly calculated the cross sections for the complete diffraction of one of the hadrons at a zero angle in the reactions $h_1h_2 \to Xh_2$ for $h_{1,2} = \pi, K, p$ in the two-gluon exchange model. We have compared the results with the factorization relations of the Regge-pole model:

$$R_1[h_1(h_2)] = \left.\frac{d\sigma(h_1h_2 \to Xh_2)}{dt} \bigg/ \frac{d\sigma(h_1h_2 \to h_1h_2)}{dt}\right|_{t=0} = \mathrm{const}(h_2), \tag{3}$$

$$R_2[h_1(h_2)] = \left[\frac{d\sigma(h_1h_2 \to Xh_2)}{dt}\right]_{t=0} \bigg/ \sigma_t(h_1h_2) = R_1\,\frac{\sigma_t(h_1h_2)}{16\pi} = \mathrm{const}\,(h_1). \tag{4}$$

Table I lists the calcualted values of $R_1[h_1(h_2)]$. In this approximation, we might note, the relative diffraction cross sections $R_1[h_1(h_2)]$ do not depend on the magnitude of the chromodynamic coupling constant α_s, which is not known accurately at small

TABLE I.

h_1 \ h_2	p	π	K
p	0,288	0.293	0,231
π	0,626	0,634	0.507
K	0.775	0.775	0.634

values of the momentum transfer ($q^2 \sim m_p^2/4$) (Ref. 3) and which is determined exclusively by the relationships between the intrinsic dimensions of the hadrons and the shape of their electromagnetic form factors. The blocks for the emission of two or more gluons by hadrons can be expressed in terms of these form factors in a nonrelativistic quark model. In the calculations, we adopt the meson form factors in the pole form $G_M \sim (1 + 1/6\langle r^2\rangle_M k^2)^{-1}$ and the nucleon form factors in the dipole form $G_N \sim (1 + 1/12\langle r^2\rangle_N k^2)^{-2}$. The details of the calculations will be published separately; here we simply note that on the whole we have followed the approach of Levin and Ryskin[3] in calculating the diffraction cross sections.

Comparison of the results with the experimental values[5,6]

$$R_1[\pi(p)] = 0.6 \pm 0.1 \quad \text{and} \quad R_1[p(p)] = 0.28 \pm 0.06 \tag{5}$$

shows that the predictions of the model agree well with experiment.

Among the significant results of the calculations are the following ratios, which do not satisfy the factorization relations:

$$\frac{R_1[p(p)]}{R_1[p(K)]} \simeq \frac{R_1[p(\pi)]}{R_1[p(K)]} = 1.25, \tag{6}$$

$$\frac{R_2[\pi(p)]}{R_2[p(p)]} = 1.35. \tag{7}$$

The experimental value[5,6] of the latter ratio is 1.35 ± 0.20, which contradicts neither fragmentation relations (4) nor the violation of these relations within the limits predicted by the two-gluon exchange model. The experimental conclusions regarding ratio (6) are even less certain because of large experimental errors.

The results of our study can be summarized as follows.

1) In contradiction of the original idea,[1,2] the approximation of the exchange of two gluons cannot be identified with the exchange of one pomeron, provided that the factorization relations for the Regge amplitudes are rigorous. In this connection, it would clearly be of interest to carry out a more thorough study of the relationship between quantum chromodynamics and the Regge-pole model.

2) It would be very interesting to see some more-accurate experiments on hadron diffraction to test the violations of the factorization relations predicted by the two-gluon exchange model.

The success of the two-gluon exchange model in explaining the relationships between the total cross sections for hadron interactions and the diffraction cross sections raises the hope that further refinement of this model will lay the foundation for a future quantitative theory for *hh* interactions with a small momentum transfer.

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