PHYSICAL REVIEW D VOLUME 9, NUMBER 3 1 FEBRUARY 1974

Impact picture and diffractive dissociation

Hung Cheng*
Department of Mathematics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

James K. Walker†
Physics Department, National Accelerator Laboratory, Batavia, Illinois 60510

Tai Tsun Wu‡
Gordon McKay Laboratory, Harvard University, Cambridge, Massachusetts 02138

(Received 1 August 1973)

Based on the impact picture, we give quantitative predictions on the following three reactions: (a) $p+p\to p+N^*(1470)$, (ii) $\pi+p\to\pi+N^*(1470)$, and (iii) $K+p\to K+N^*(1470)$. Factorization is predicted to be approximately valid except near the dip in reaction (i).

Last year, within the framework of the impact picture[1-3] we predicted[4] a rise of several millibarns in the proton-proton total cross section in the energy range covered by the Intersecting Storage Rings (ISR) at CERN. Subsequent to that time, a rise of about 4 mb has been observed in two independent experiments.[5] Using the observed rise in the proton-proton total cross section, we have presented elsewhere[6,7] predictions on total cross sections, elastic scattering differential cross sections, and phases of the forward amplitudes for other channels. These predictions will soon be tested at the National Accelerator Laboratory.

There will shortly be measurements[8] on diffraction dissociation at the ISR for the channel $p+p\to p+N^*(1470)$. In this paper, we explore the process of diffraction dissociation and make quantitative predictions on the differential cross sections of the following three reactions: (i) $p+p\to p+N^*(1470)$, (ii) $\pi+p\to\pi+N^*(1470)$, and (iii) $K+p\to K+N^*(1470)$.

The amplitude for two-body diffractive dissociation processes at high energy is given by[3]

$$M(s,\vec{\Delta})=\frac{is}{2\pi}\int d\vec{x}_\perp e^{-i\vec{\Delta}\cdot\vec{x}_\perp}D(S,\vec{x}), \tag{1}$$

where S is defined below and $\vec{\Delta}$ is the momentum transfer. As was discussed in Ref. 3, D vanishes in the black core and is appreciable only in the gray fringe. As the simplest model for a phenomenological fit, we choose

$$D(S,\vec{x})=C\,SF(x_\perp{}^2)\exp[-SF(x_\perp{}^2)], \tag{2}$$

with

$$F(\vec{x}_\perp{}^2)=f\exp[-\lambda(x_\perp{}^2+x_0{}^2)^{1/2}] \tag{3}$$

and

$$S=(Ee^{-i\pi/2})^c. \tag{4}$$

In the above, the numbers c and λ are channel-independent and have been determined by our earlier fits of elastic scattering to be

$$c=0.08, \tag{5}$$

$$\lambda=0.60. \tag{6}$$

The numbers x_0 and f are channel-dependent. We shall make the *assumption* that x_0 and f are the same as those in elastic scattering. Thus there is only one number, C, to be determined. Since C appears as a multiplicative constant, the shapes of the differential cross sections for reactions (i)-(iii) are entirely determined by our earlier fits of elastic scattering. We also call attention to the fact that c as given by (5) is an effective value, as logarithmic factors of s have been ignored to retain simplicity. From a purely theoretical basis, (4) should be replaced by[1]

$$S=\frac{(se^{-i\pi})^c}{[\ln(se^{-i\pi})]^{c'}}+\frac{s^c}{(\ln s)^{c'}}. \tag{7}$$

If we choose $c'=1$, as supported by some field-theoretic models, then c is about 0.2. However, the fits obtained in these two choices have only slight differences. Thus we shall, for simplicity, adopt $c'=0$ here. A more complete fit will be reported elsewhere.

Figures 1(a), 1(b), and 1(c) show the predicted cross sections $d\sigma/dt$ for the reactions (i), (ii), and (iii). Figure 1(a) shows the experimental data[9] for the reaction

$$p+p\to p+N^*(1400).$$

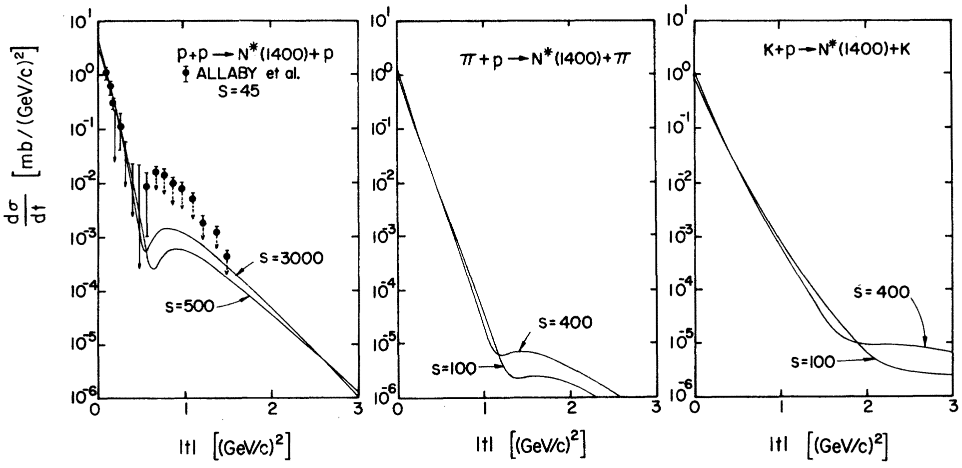

FIG. 1. (a), (b), (c) Diffractive inelastic scattering for the three reactions $p+p \to p+N^*(1400)$, $\pi+p \to \pi+N^*(1400)$, and $K+p \to K+N^*(1400)$, respectively. The curves are predictions of the impact picture with parametrization given in the text. The two energies in (a) cover the range accessible at the ISR. The two energies in (b) and (c) cover the range available at the National Accelerator Laboratory.

The calculated curve is for the reaction

$$p+p \to p+N^*(1470),$$

and we have normalized the cross section by choosing C^2 equal to 0.1. The $N^*(1400)$ is shifted in mass relative to the $N^*(1470)$ which is well established in pion-nucleon phase-shift analysis. The explanation for this mass shift is not clear. However, if our identification of these two resonances as the same particle is correct, then the steep slope $[b \sim 15\ (\text{GeV}/c)^{-2}]$ observed for this reaction is accounted for in the present model. We predict a dip in the cross section at $|t| = 0.5\ (\text{GeV}/c)^2$ and furthermore a slow movement of the dip position as the energy is increased. Comparison of Figs. 1(b) and 1(c) shows that we expect the slope of $d\sigma/dt$ for reactions (ii) and (iii) to be less than for reaction (i). In addition we predict the existence of structures in reactions (ii) and (iii).

We turn our attention now to a discussion of factorization in these reactions. In the impact picture the Pomeron singularity in the complex angular momentum plane does not lead to exact factorization. On the other hand, there is experimental evidence[10] that indicates that, for total cross sections, factorization works to about 20% in several reactions. Therefore, it is a quantitative question to ask whether the present model is consistent with this small departure from factorizability. In addition we inquire if there are any regions of the kinematic variables where factorization is predicted to be badly violated.

We have calculated the ratios of the following reactions:

$$R(pp) = \frac{p+p \to p+p}{p+p \to p+N^*(1400)}$$

and similarly for the πp and Kp channels to obtain $R(\pi p)$ and $R(Kp)$. If factorization is valid then

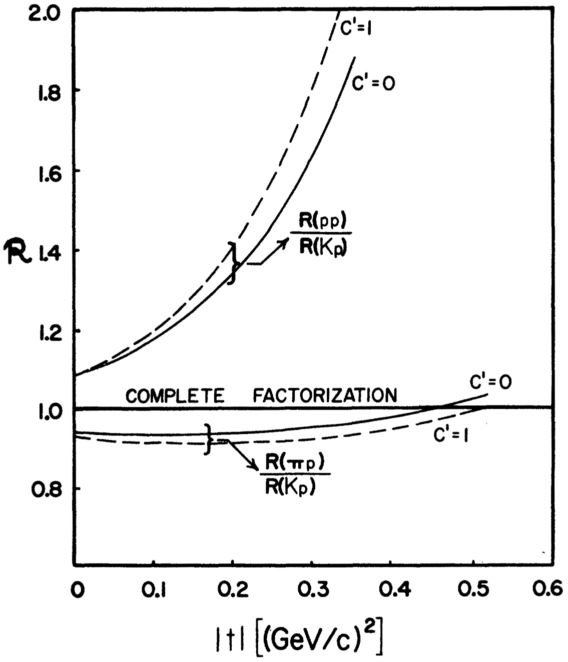

FIG. 2. The impact-picture prediction for $\mathcal{R} = R(hp)/R(Kp)$ plotted versus momentum transfer $|t|$ for $s = 100$ GeV^2. $R(hp)$ is defined as the ratio of the elastic to diffractive inelastic channel for an incident hadron, h, where h can be a proton or a pion.

$$\mathcal{R}=\frac{R(pp)}{R(Kp)}=\frac{R(\pi p)}{R(Kp)}=1\,.$$

Figure 2 shows the predictions of the model as a function of momentum transfer $|t|$. It can be seen that at small $|t|$ the model predicts that to within about 5–10% factorization should hold. At larger $|t|$ factorization continues to be good for the comparison of πp and Kp. However, in the comparison of pp and Kp there is an increasing degree of violation of factorization. Because the differential cross sections are heavily weighted to small $|t|$, the integrated cross sections are predicted to satisfy factorization to about 10%. Thus, the model predictions are in good accord with experimental checks of factorization for integrated cross sections. However, it is predicted that in the region of the dip in pp diffraction scattering, which should develop around $|t|\simeq 0.5$ (GeV/c)^2, *factorization fails drastically*.

All of these three reactions can be studied using the high-resolution strong-focusing spectrometer presently being constructed in the Meson Laboratory of the National Accelerator Laboratory, and it appears that an encounter of our results with experiments may be realized in the not-too-distant future.

We wish to acknowledge stimulating discussions with Professor Francis Low and Professor Maurice Jacob.

---

[*] Work supported in part by the National Science Foundation under Grant No. GP-29463.

[†] Work supported by the U. S. Atomic Energy Commission under Contract No. AT(49-8)-3000.

[‡] Work supported in part by the U. S. Atomic Energy Commission under Contract No. AT(11-1)-3227. Part of the work was carried out at the National Accelerator Laboratory during the summer of 1972.

[1] H. Cheng and T. T. Wu, Phys. Rev. Lett. 24, 1456 (1970).

[2] H. Cheng and T. T. Wu, Phys. Lett. 34B, 647 (1971).

[3] H. Cheng and T. T. Wu, Phys. Lett. 36B, 357 (1971).

[4] H. Cheng, J. K. Walker, and T. T. Wu, paper No. 524 submitted to the XVI International Conference on High Energy Physics, Chicago-Batavia, Ill., 1972 (unpublished).

[5] U. Amaldi, R. Biancastelli, C. Bosio, G. Matthiae, J. V. Allaby, W. Bartel, G. Cocconi, A. N. Diddens, R. W. Dobinson, and A. M. Wetherell, Phys. Lett. 44B, 112 (1973); S. R. Amendolia, G. Bellettini, P. L. Braccini, C. Bradaschia, R. Castaldi, V. Cavasinni, C. Cerri, T. Del Prete, L. Foà, P. Giromini, P. Laurelli, A. Menzione, L. Ristori, G. Sanguinetti, M. Valdata, G. Finocchiaro, P. Grannis, D. Green, R. Mustard, and R. Thun, *ibid.* 44B, 119 (1973).

[6] H. Cheng, J. K. Walker, and T. T. Wu, Phys. Lett. 44B, 97 (1973).

[7] H. Cheng, J. K. Walker, and T. T. Wu, Phys. Lett. 44B, 283 (1973).

[8] These measurements will be performed with the split-field magnetic spectrometer which has recently been installed at the ISR.

[9] J. V. Allaby *et al.*, Nucl. Phys. B52, 316 (1973).

[10] D. W. G. S. Leith, in *Proceedings of XVI International Conference on High Energy Physics, Chicago-Batavia, Ill., 1972,* edited by J. D. Jackson and A. Roberts (NAL, Batavia, Ill., 1973), Vol. 3, p. 321.