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π^+p polarization data and the strongly-correlated-resonances model

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Further tests of the strongly-correlated-resonances model, involving π^+p elastic polarization data, are reported.

In this paper we report results of further testing of the strongly correlated resonances model (SCRM), proposed by one of us (G.T.H.) a while ago,[1] involving π^+p elastic polarization data. This model accounted in a simple-minded fashion for striking regularities observed in fixed-c.m.-angle plots of π^+p elastic differential-cross-section (DCS) data,[1] and has as its fundamental characteristics the following:

(1) the assumption of the existence of a spectrum of baryonic resonances with levels approximately degenerate in mass and width,

(2) resonant partial-wave amplitudes with the same isospin expressed in terms of a single rising phase, and

(3) elasticities which may undergo a sudden change at the energies for which the (common) phase passes through the values $n\pi$ (junction energies), but change at most slowly otherwise (and are therefore set equal to constants).

It gives for the polarization (P) times the differential cross section ($d\sigma/d\Omega$) for processes of the type $P_1+B_1 \rightarrow P_2+B_2$, where P_1 and P_2 stand for pseudoscalar mesons and B_1 and B_2 stand for spin-$\frac{1}{2}$ baryons, the expression[2]

$$P(d\sigma/d\Omega)=2|a_b||b_b|\sin(\alpha-\beta) + |V'|k^{-1}\{\cos[2\delta(s)-\gamma']-\cos\gamma'\}, \qquad (1)$$

where

$$V'=|V'|e^{i\gamma'} = \sum(x_l^J)_{1,2}[-(J+\tfrac{1}{2})P_l(\cos\theta)b_b+(-1)^{J-l+1/2}P_l'(\theta)a_b]$$

and $a_b=|a_b|e^{i\alpha}$ ($b_b=|b_b|e^{i\beta}$) is the spin-nonflip (spin-flip) background amplitude, $\delta(s)$ is the common rising phase, k is the initial c.m. momentum, and $(x_l^J)_{1,2}$ is the square root of the product of the initial and final elasticities. The summation extends over all the possible values of l and J, with elasticities set equal to zero for noncontributing resonant partial waves.

If we introduce, as done before, the clearly oversimplified assumptions about the background amplitudes—(a) $|a_b|$ and $|b_b|$ at each c.m. angle have a k^{-1} dependence with energy, and (b) the phases α and β at each c.m. angle are constants as functions of the energy—the following predictions for the behavior of $k^2P(d\sigma/d\Omega)$ at fixed c.m. angle are obtained:

(i) a full wavelength of a (horizontal) sinusoidal curve (of constant amplitude), displaced vertically in general, between any two consecutive junction energies, and

(ii) sudden changes of the amplitude and phase of the sinusoidal curve at the junction energies.

The first of these predictions is generated by the constancy of the complex function kV' at fixed c.m. angle in the intervals for which $(n-1)\pi\leq\delta(s)\leq n\pi$. The second one is generated by the abrupt change of kV' at the junction energies, the change in $|kV'|$ (γ') giving rise to the change in amplitude (phase) of the sinusoidal curve.[3]

Also, some special predictions, which hold only for special types of background, are of interest.

(iii) In angle regions where the background is small (backward hemisphere) $k^2P(d\sigma/d\Omega)\approx 0$ at the junction energies. Also, $k^2P(d\sigma/d\Omega)=0$ (and therefore $P=0$) in the neighborhood of a junction energy, if this function is monotonically increasing or decreasing in the neighborhood of the junction.

Although the second portion of this prediction does not hold of necessity for all backward angles, the frequent appearance of simple zeros of the polarization (in the plots of P versus the incident laboratory momentum at fixed angle) in the neighborhood of the junction energies is a simple strong test of the SCRM.

(iv) If angle regions exist for which a_b and b_b have the same phase (or one of these amplitudes vanish), there *may* exist special angles for which there are no oscillations (zero amplitude) between two consecutive junction energies. At those special angles, the polarization has a constant value equal to zero [since the background contribution to $k^2P(d\sigma/d\Omega)$ vanishes].

If we make more realistic assumptions regarding the behavior of a_b and b_b demanding only that their phases vary slowly and the products $k|a_b|$ and $k|b_b|$ vary monotonically with energy at each c.m. angle in the region between two consecutive junctions, it is easily seen that there is a breakdown of prediction (i). The sinusoidal curves are neither horizontal nor of constant amplitude. Also, there is no longer an exact full wavelength between two consecutive junctions. A more or less distorted sinusoidal curve of length approximately equal to one full wave is what should be observed instead. Prediction (ii) remains, on the other hand, exactly valid.

In order to carry out exhaustive meaningful tests based on these predictions, it is necessary to use direct measurements of $P(d\sigma/d\Omega)$, as given by Albrow *et al.*[4] Otherwise (multiplying values of P and $d\sigma/d\Omega$ obtained from different experiments), the statistics are in general too poor to arrive at a definite conclusion.[5] Also, measurements of $P(d\sigma/d\Omega)$ over an energy interval slightly larger than the region between consecutive junctions in a single experiment minimizes uncertainties due to differences in normalization errors. The span covered by Albrow *et al.* (from 0.815 to 2.39 GeV/c in steps ranging from 0.03 to 0.12 GeV/c)[6] is thus almost ideal for testing the SCRM, since, according to the π^+p elastic DCS data, the first two junctions in this process occur in the neighborhood of 0.82 and 2.08 GeV/c.

The data of Albrow *et al.* cover completely the angle range $-0.7 \leq \cos\theta \leq 0.8$ with only minor gaps in the central region. It contains also partial measurements for very-near-forward and very-near-backward angles. Although the measurements were not carried at the same angles at the various energies, the typical separation between two consecutive values of $\cos\theta$ (less than 0.1) makes a reliable interpolation possible. We studied the behavior of $k^2P(d\sigma/d\Omega)$ as a function of the incident momentum p at twenty-five different angles in the region $-0.8 \leq \cos\theta \leq 0.9$. Plots for six angles ($\cos\theta = -0.7$, -0.6, -0.5, -0.4, -0.32, and -0.19) in the backward hemisphere are given in Fig. 1. It is seen that prediction (i) is satisfied to a good degree of approximation in the region between the first two junctions (marked by arrows) and that there exists simple zeros in the neighborhood of the second junction in the region $\cos\theta \leq -0.3$ (prediction (iii)). Especially impressive is the behavior for $\cos\theta = -0.32$ in the region between 0.82 and 2.08 GeV/c, where a line of (almost) zero polarization appears to exist (prediction (iv). Although the data above 2.08 GeV/c are too meager to be able to draw curves by hand, it seems that prediction (ii) is fulfilled at the second junction. Also, it appears that a line of (almost) zero polarization exists above 2.08 GeV/c in the neighborhood of $\cos\theta = -0.7$. (It would be of interest to see if this line stops in the neighbor-

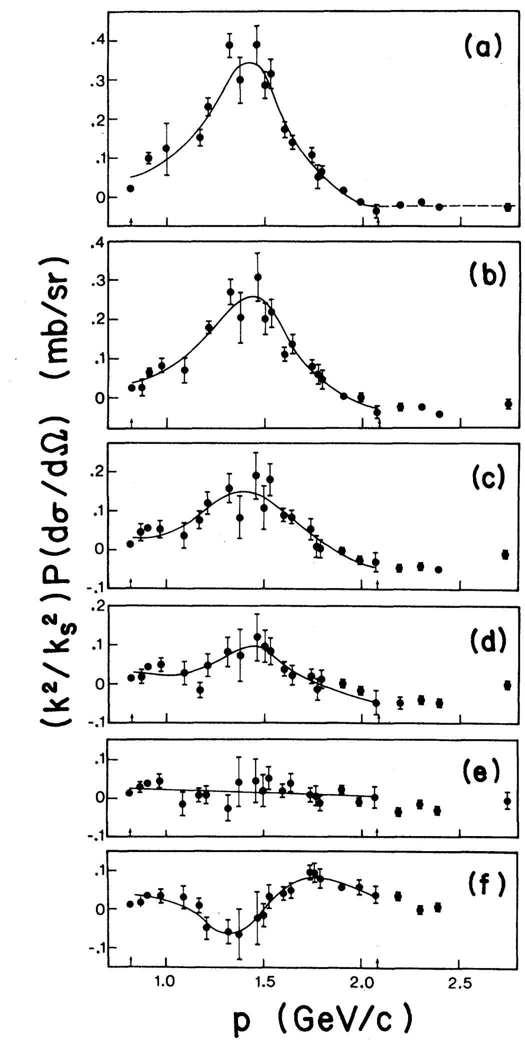

FIG. 1. Plot of $(k^2/k_s^{\,2})P(d\sigma/d\Omega)$ in π^+p elastic scattering versus incident momentum p for (a) $\cos\theta = -0.7$, (b) -0.6, (c) -0.5, (d) -0.4, (e) -0.32, and (f) -0.19 (k is the c.m. momentum and k_s its value for $p = 2.07$ GeV/c). The experimental points were obtained from Ref. 4 by linear interpolation. The continuous and dashed lines have been drawn to guide the eye. The arrows indicate the first two junction energies.

hood of the third junction, located near 3.5 GeV/c.) Plots for forward and central angles ($\cos\theta = 0.8$, 0.7, 0.6, 0.49, 0.2, 0.1, and 0.0) are given in Figs. 2 and 3. Again prediction (i) is satisfied, now to a lesser degree of approximation. Prediction (ii) also appears to be fulfilled. Regarding this last prediction, we would like to call attention to the apparent disconnection between the curves at the right and left of the second junction, with a violent change occurring from $\cos\theta = 0.6$ to $\cos\theta = 0.49$ ($\cos\theta = 0.8$ to $\cos\theta = 0.6$) in the portion at the left (right) and very little change at

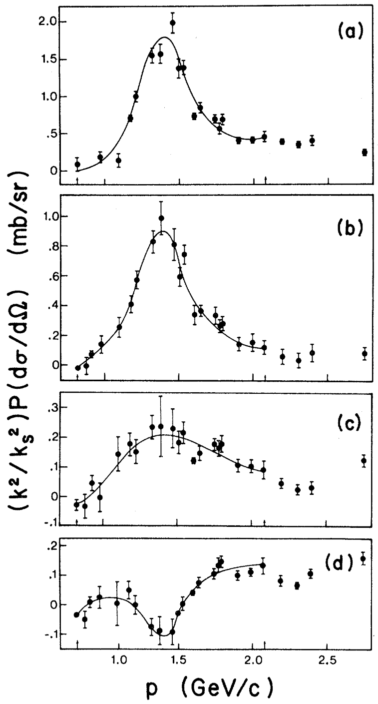

FIG. 2. Plot of $(k^2/k_s{}^2)P(d\sigma/d\Omega)$ in π^+p elastic scattering versus incident momentum for (a) $\cos\theta = 8.0$, (b) 0.7, (c) 0.6, and (d) 0.49. The experimental points were obtained from Ref. 4 by linear interpolation. The continuous lines have been drawn to guide the eye.

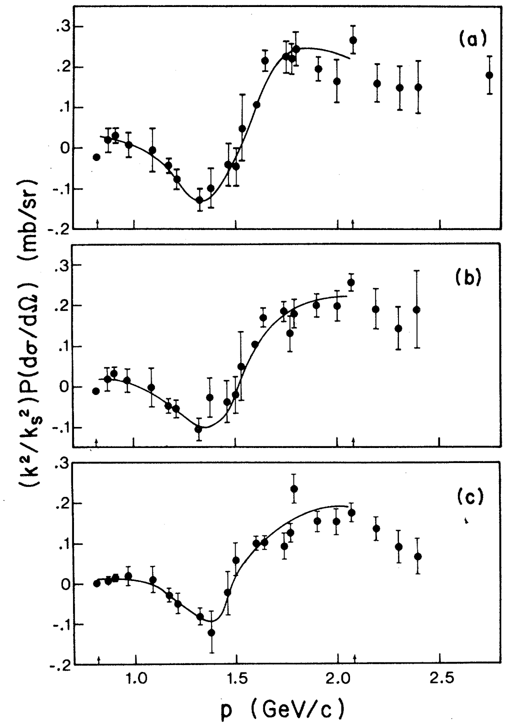

FIG. 3. Plot of $(k^2/k_s{}^2)P(d\sigma/d\Omega)$ in π^+p elastic scattering versus incident momentum for (a) $\cos\theta = 0.2$, (b) 0.1, (c) 0.0. The experimental points were obtained from Ref. 4 by linear interpolation. The continuous lines have been drawn to guide the eye.

the right (left).

We have complemented this study by also plotting the polarization P versus p at fixed c.m. angles using the world compilation[7] (minus Ref. 4 data). We have found general agreement in the location of the simple zeros in the neighborhood of the second junction, and lines of (almost) zero polarization in the neighborhood of $\cos\theta = -0.2$ between the first and second junction and $\cos\theta = -0.8$ between the second and third junctions (i.e., slightly displaced). We have also found the existence of simple zeros in the neighborhood of the first junction in the region $-0.8 \leq \cos\theta \leq -0.2$.

Whether the observed features in the DCS and polarization data are characteristics of π^+p elastic scattering or are also present in the pure-isospin processes $\pi^-p \to \Lambda K^0$, $\pi^+p \to \Sigma^+K^+$, and $K^-p \to \Lambda\pi^0$ is still unknown to us.[8] As soon as enough data become available in these processes and we reach a definite conclusion, our results will be reported.

Before ending we would like to point out that a large part of the resonance features assumed in the SCRM appear in phase-shift solutions.[9] In Argand-plot language, the SCRM with simplified assumptions about the background amplitudes states that the representative points of resonant partial-wave amplitudes describe circles "simultaneously" in the Argand plots. By "simultaneously" we mean in particular that they reach the top and the bottom of the circles at the same energies (resonance energies and junction energies, respectively). In the SCRM the curvature of the circle also changes suddenly at the bottom if there are two consecutive resonances in the same partial wave. This behavior is clearly observed in the neighborhood of the first junction in the Argand plot of the $P_{3/2}$ amplitude obtained by Almehed and Lovelace,[10] while the simultaneity property is observed to hold to a good degree of approximation in the Argand plots of the $F_{5/2}$ and $F_{7/2}$ amplitudes obtained by such authors.

The calculations and plotting for this investigation were done at the Chicago Circle Computing Center. The assistance provided by their staff is acknowledged with pleasure.

[1]G. T. Hoff, Phys. Rev. Lett. 29, 1705 (1972).

[2]This expression becomes identical for elastic scattering ($P_1=P_2$, $B_1=B_2$) to the one given in G. T. Hoff, Phys. Rev. Lett. 18, 816 (1967).

[3]It should be noticed that no change of phase takes place when a_b and b_b have the same phase (or one of these amplitudes is equal to zero) and kV' does not change sign at the junction.

[4]M. G. Albrow *et al.*, Nucl. Phys. B25, 9 (1971).

[5]This is in part due to the fact that a double interpolation (in energy and angle) is often required.

[6]There is also an isolated measurement at 2.74 GeV/c.

[7]G. Giacomelli, P. Pini, and S. Stagni, CERN Report No. CERN-HERA 69-1, 1969 (unpublished); A. Yokosawa, private communication.

[8]Results for K^+p elastic scattering using pre-1973 DCS data have been reported already: G. T. Hoff, UICC report, 1973 (unpublished).

[9]Particle Data Group, Phys. Lett. 50B, 1 (1974).

[10]S. Almehed and C. Lovelace, Nucl. Phys. B40, 157 (1972).