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Decisive Tests for Dip Mechanisms

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Some decisive tests for dip mechanisms are proposed: measurements of density-matrix elements of $\pi^+n \to \omega p$ and $\pi^+p \to \omega\Delta^{++}$, and forward behavior of differential cross section of η production. Available data seem to be in disagreement with the simple Dar-Michigan picture, and in favor of the weak-cut model.

INTRODUCTION

Last year, many dip mechanisms[1-3] were proposed in order to explain the apparently erratic behavior of dips at $t \simeq -0.6$ GeV^2 in an impressive list of reactions, which was given by Harari.[1] However, only two of them[1,2] claim to be compatible with all the present experimental data. The first mechanism,[1] which has been proposed by Dar as well as by the Michigan[4] group (SCRAM), is based on a correlation between dips and the helicity structure of the amplitudes. If the dominant amplitude has a total helicity change at the two vertices $|\Delta h| = 1$, a dip must be seen at $t = -0.6$ GeV^2, while no dip is predicted if $|\Delta h| = 0$ or 2.

The second mechanism[2] is based on the following facts:

(a) At present energies, B-meson contributions can be important.

(b) For the reactions listed by Harari,[1] all the dominant Regge-pole exchange amplitudes vanish at $t = 0$; then absorptive cuts, which involve a convolution between Regge-pole exchange amplitudes and elastic amplitudes, are expected to be small. In this case, the cuts are unable to wash out the dip structure of Regge-pole exchange amplitudes, and the model correlates as usual the presence of dip with the nonsense wrong-signature points in the Regge-pole exchange amplitudes.

In this paper, we present some decisive tests of the two mechanisms and point out that some recent experimental data are in contradiction with the Dar-Michigan mechanism and favor the second one.

I. ρ_{00}^s DENSITY-MATRIX ELEMENT IN $\pi^+n \to \omega p$

It is well known that in the t channel the exchange of a vector meson couples only to the ± 1 helicity state of the ω meson at the π-ω vertex. Then, using crossing relations, the s-channel helicity $\lambda_\omega = 0$ amplitudes vanish at the order $1/s$ (for ρ Regge-pole exchange, for example). If the absorptive corrections are diagonal in the helicities – a property which is assumed in all Regge-cut models – then for ρ exchange only,

$$f^{s(\text{Regge+cut})}_{\lambda_\omega=0,\,\lambda_i} = 0.$$

Then the density-matrix element $\rho_{00}^s(t)$ vanishes at the order $1/s^2$.[5]

As the observed value of $\rho_{00}^s(t)$, for example at $t = -0.1$ GeV^2, is at least 30% even at high energy,[6,7] an unnatural-parity contribution must be introduced, either B-meson exchange and its corresponding cuts or double-Regge-exchange cuts. We now invoke some reasons to prefer the first alternative.

(a) It is well known that even in the case where the individual Regge-pole amplitudes show some structure, for example, zero at $t \simeq -0.6$ GeV^2, the double-Regge-exchange cuts which involve a convolution over all t values are in general smooth functions of t. Then one expects a ρ_{00}^s without structure. As the experimental behavior of ρ_{00}^s clearly shows a dip structure at $t \simeq -0.20$ GeV^2, it is unlikely that the effect comes only from double-Regge-exchange cuts.

(b) If the effect comes from B exchange, we see later that only the amplitude which has $|\Delta h|=1$ contributes to ρ_{00}^s. As this amplitude vanishes by angular momentum conservation at $t=0$, $\rho_{00}^s(d\sigma/dt)$, as well as $\rho_{00}^t(d\sigma/dt)$ obtained by using crossing relations, must have a forward dip. On the contrary, in the case of double-Regge-exchange cuts, for example $\rho\otimes\rho$ cuts, one can expect an appreciable contribution to nonflip amplitudes and consequently no forward dip in $\rho_{00}^s(d\sigma/dt)$. The experimental results are not precise, but a forward dip in $\rho_{00}^t(d\sigma/dt)$ is suggested by the data at 5.08 GeV.[7,8] However, more precise data at smaller t are needed.

We now introduce B Regge-pole exchange which contributes to $f^s_{\lambda_{\omega}=0,\lambda_i}$ and examine the consequences on ρ_{00}^s for the $\pi^+n\to\omega p$ reaction in the Dar-Michigan model as well as in a model[2] the author has proposed.

Because of its charge conjugation, the B meson couples only to a non-helicity-flip nucleon-antinucleon vertex in the t channel.. As a consequence, in the s channel, the B meson contributes at high energy only to the nucleon-nucleon helicity-flip amplitude. Then, only one amplitude contributes to ρ_{00}^s and this amplitude $f^s_{0,1/2,\lambda_{\omega}=0,-1/2}$ has a total change of helicities,

$$|\Delta h|=1.$$

The prediction of the Dar-Michigan model is clear: $\rho_{00}^s(d\sigma/dt)$ must have a dip at $t\simeq-0.6$ GeV^2. In the weak-cut model, on the contrary, a dip is expected if $\alpha_B(t)=0$ at this point.

Experimentally, the data are relatively scarce and not sufficiently precise. However, at 5.08 GeV,[7,8] a clear dip is seen in ρ_{00}^s at $t\simeq-0.2$ GeV^2 and no dip structure at $t=-0.6$ GeV^2. These data seem to be in disagreement with the Dar-Michigan picture and suggest a nonsense wrong-signature zero for the B-trajectory contribution at $t\simeq-0.2$ GeV^2.

II. $\lambda_{\omega}=\pm1$ DENSITY-MATRIX ELEMENTS IN $\pi^+n\to\omega p$ AND $\pi^+p\to\omega\Delta^{++}$

We now examine the helicity amplitudes having $\lambda_{\omega}=\pm1$ and consider the combination of density-matrix elements which selects only natural-parity exchanges,[9]

$$\sigma_1^+=\rho_{11}+\rho_{1-1}.$$

The main contribution to σ_1^+ comes from the ρ Regge-pole exchange and its corresponding cut. As ρNN or $\rho N\Delta$ coupling is mainly magnetic, there is a helicity flip at the baryon vertex and the total helicity change is 0 or 2. Then, qualitatively, no dip at $t=-0.6$ GeV^2 must be expected in the Dar-Michigan picture.[10] On the contrary, in the weak-cut model, a dip is naturally expected at $t=-0.6$ GeV^2 as $\alpha_\rho(t)=0$ at this point. The experimental data show a clear dip in σ_1^+ in $\pi^+n\to\omega p$ at 4.19 GeV[11] and 5.08 GeV,[8] as well as in $\pi^+p\to\omega\Delta^{++}$ at 3.7 GeV.[12] The existence of a dip at $t=-0.6$ GeV^2, if confirmed at higher energies, is a typical counterexample of the simple picture given by Dar and SCRAM, and favors the weak-cut model with nonsense wrong-signature points in the Regge-pole amplitudes.[13]

We saw above that experimentally ρ_{00}^s shows a pronounced dip at $t=-0.2$ GeV^2. If we associate this dip with the nonsense wrong-signature point $\alpha_B(t)=0$, then in the weak-cut model, one predicts a dip at the same point for the combination which selects the unnatural-parity exchange,

$$\sigma_1^-=\rho_{11}-\rho_{1-1}.$$

This prediction is qualitatively in agreement with experimental data.[8,11,12] Let us note that in the Dar-Michigan picture, especially for $\pi^+n\to\omega p$, no dip structure is expected for σ_1^-.

III. $\pi^-p\to\eta n$ AND $\eta\Delta$

It is well known that the existence of a clear forward dip in pion-nucleon charge-exchange reactions implies a large helicity amplitude. In this case, the helicity amplitude with $|\Delta h|=1$ dominates and a dip is expected in the Dar-Michigan picture as experimentally observed. On the other hand, some recent experimental data on η production, for $\pi^+p\to\eta\Delta^{++}$ as well as for $\pi^-p\to\eta n$,[14,15] show a forward dip in the differential cross section. If the presence of a forward dip is confirmed by more precise experiments, then it implies a dominant helicity-flip amplitude as in $\pi^-p\to\pi^0n$ and a dip must be expected at $t=-0.6$ GeV^2 in the Dar-Michigan model, contrary to what is observed experimentally, i.e., no dip at $t=-0.6$ GeV^2. On the contrary, in the weak-cut model, the presence of a dip in $\pi^-p\to\pi^0n$ and the absence of a dip in $\pi^-p\to\eta n$ are simply due to the signature of the exchanged trajectories ρ and A_2, respectively. Similar conclusions, i.e., that η production favors the weak-cut model were reached by Bander and Gotsman[16] using density-matrix elements of the Δ in $\pi^+p\to\eta\Delta^{++}$.

We now summarize the different tests. For $\pi^+n\to\omega p$, the Dar-Michigan model predicts a dip at $t=-0.6$ GeV^2 for ρ_{00} and no structure for $\sigma_1^-=\rho_{11}-\rho_{1-1}$, while our model would predict about the same dip structure for ρ_{00} and σ_1^-.

For $\pi^+p\to\omega\Delta^{++}$ or $\pi^+n\to\omega p$, the Dar-Michigan model predicts no dip at $t=-0.6$ GeV^2 for $\sigma_1^+=\rho_{11}+\rho_{1-1}$, in contrast with the weak-cut model prediction of a dip at $t=-0.6$ GeV^2.

For $\pi^- p\to\eta n$ and $\pi^+ p\to\eta\Delta^{++}$, if the forward dip is confirmed, the Dar-Michigan model predicts a dip at $t=-0.6$ GeV^2 as for $\pi^- p\to\pi^0 n$, in contrast with the weak-cut model prediction of no dip.

For these tests, the available data are qualitatively in disagreement with the simple Dar-Michigan picture and favor the weak-cut model, but more precise experimental data are needed to confirm definitely these qualitative conclusions.

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