Comments and Addenda

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Comment on the photoproduction of the $\rho'(1500)$ *

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The absence of a decay mode for the photoproduced $\rho'(1500)$ into two pseudoscalar mesons suggests a kinematic interpretation for the enhancement observed in the reaction $\gamma p \to \rho'(1500)p \to 2\pi^+2\pi^- p$ at 9.3 GeV/c. A naive Reggeized-Deck calculation satisfactorily describes the observed mass spectra.

The recent observation of an enhancement in the four-pion mass spectrum,[1] coupled with the fact that the helicity properties of the produced system were similar to those observed in ρ-meson photoproduction,[2] has led the LBL-SLAC collaboration to propose a resonant interpretation for the four-pion peak at ~1500 MeV observed in the reaction[3]

$$\gamma p \to 2\pi^+ 2\pi^- p. \qquad (1)$$

A complete study of the data at 9.3 GeV/c, using a polarized photon beam, has suggested that the quantum numbers of the four-pion system are most consistent with the presence of a $J^P, I^G = 1^-, 1^+$ state which decays mainly into $\rho^0\pi^+\pi^-$. This state has been identified with the ρ' vector meson, for which there appears to be some evidence from work based on e^+e^- colliding-beams studies.[4]

In this note we wish to examine an alternative interpretation for the $\rho'(1500)$ found in reaction (1). We are basically motivated by two considerations: (i) the absence of the decay mode of the $\rho'(1500)$ into two pseudoscalar mesons, and (ii) the relatively clear analogy between reaction (1) and the previously examined diffractive production of low-mass states in pp, πp, and Kp incident channels, yielding the well-known $N^*(1400)$, A_1, and Q objects.[5]

The model we propose for a kinematic[6] interpretation of the ρ' as observed in reaction (1) is shown in Fig 1. The simplest matrix element which contains the kinematic essence of the triple Regge-pole exchange diagram in Fig. 1 is

$$|M|^2 \simeq \frac{t_1 S_{\pi_1\rho}{}^{2\alpha_\pi(t_1)} S_{\pi_2\rho}{}^{2\alpha_\pi(t_2)} S_{\pi_2 p}{}^2 e^{6t}}{[\alpha_\pi(t_1)]^2[\alpha_\pi(t_2)]^2}. \qquad (2)$$

The first t_1 factor is due to the transversality of the photon.[7] For the π-meson trajectory $\alpha_\pi(t_i)$ we use the standard form $\alpha_\pi(t_i) = t_i - \mu_\pi{}^2$. The exponential slope of 6 is appropriate for the elastic πp scattering at the Pomeranchuck (P) vertex. For the ρ-meson mass shape we use a simple Breit-Wigner form with a cutoff at ±300 MeV from a central value of 760 MeV (four full widths). The matrix element given in expression (2) was integrated using a Monte Carlo program over phase space for a photon momentum of 9.3 GeV/c. Figure 2 displays three experimental spectra from reaction (1). (The cuts given for the data were also imposed in the theoretical calculation.) We see that the model, normalized to the data, gives an adequate description of the results. The position and width of the peak in the four-pion mass, in particular, is quite consistent with the parameters obtained using a resonant interpretation.[1] Predictions of the calculation appear to be also in general agreement with the other mass projections in reaction (1) (not shown).

One important aspect of the properties observed for the $\rho'(1500)$, which led the LBL-SLAC collaboration to conclude that the object was resonant, was the fact that the $\rho'(1500)$ appeared to be produced in a state of polarization with its helicity as the axis of quantization. That is, just as in the case of ρ photoproduction, the $\rho'(1500)$ appears

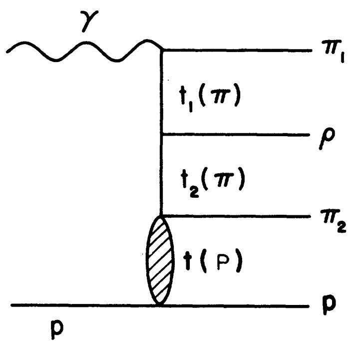

FIG. 1. Model for the ρ' effect in reaction (1).

largely to conserve the helicity of the incident photon. Because our calculation ignores the effects of spin, we cannot make any firm remarks pertaining to this interesting result. However, we believe that there may be enough freedom in the model (particularly if other diagrams[8] with the same kinematic properties as Fig. 1 are introduced) to account even for this subtle spin-alignment effect.[9]

We conclude that a kinematic interpretation for a large fraction of the observed $\rho'(1500)$ enhancement in reaction (1) cannot be excluded at this time. Our model for the $\rho'(1500)$, which we feel is the analog in γp collisions of the A_1, Q, and $N^*(1400)$, is also appealing in that it explains the absence of a two pseudoscalar decay mode of the supposed vector meson. It is, of course, possible

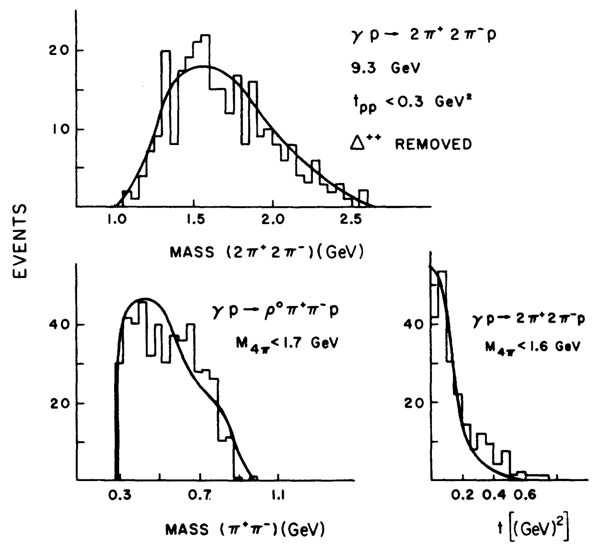

FIG. 2. Comparison of t and mass spectra for data from reaction (1), with the predictions of our model.

that in addition to the large kinematic peak near 1500 MeV there is also a new vector meson ρ'; however, its production cross section would be substantially below the quoted ~1.6 μb value.

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[1]H. H. Bingham *et al.*, Phys. Lett. 41B, 635 (1972), and M. Davier *et al.*, Nucl. Phys. B58, 31 (1973).

[2]J. Ballam *et al.*, Phys. Rev. D 5, 545 (1972).

[3]A more extensive discussion of these data is given in G. Smadja *et al.*; *Experimental Meson Spectroscopy—1972,* proceedings of the Third International Conference, Philadelphia, 1972, edited by Kwan-Wu Lai and Arthur H. Rosenfeld (A.I.P., New York, 1972).

[4]See G. Barbarino *et al.*, Nuovo Cimento Lett. 3, 689 (1972), and F. Ceradini *et al.*, Phys. Lett. 43B, 341 (1973), and references given therein. Also see the calculation of S. Rudaz, Nuovo Cimento Lett. 6, 292 (1973), for an interesting interpretation of these results in terms of a continuum of vector mesons.

[5]See, for example, D. Cohen *et al.*, Phys. Rev. Lett. 28, 1601 (1972), and references given therein to these types of calculations. Also see P. H. Frampton and N. A. Tornquist, Nuovo Cimento Lett. 4, 233 (1972).

[6]We stress the work *kinematic* because duality arguments are inappropriate here (see references given in Ref. 5).

[7]We thank E. L. Berger for pointing out to us that $|M|^2$ must be linear in t_1. This simple spin factor has very little effect on the mass spectra [see, for comparison, T. Ferbel and P. Slattery, University of Rochester Report No. UR428 (unpublished)]; it provides, however, better agreement between the model and the data in the angular distributions.

[8]A strong contribution could be expected from A_2 exchange at the first vertex (t_1). The properties of this diagram are not dissimilar from the one shown in Fig. 1. An interesting effect of an A_2 exchange contribution is to shift the predicted four-pion mass spectrum to even smaller values (~1350 MeV).

[9]We wish to point out that the angular distributions of π_1 and π_2 along the ρ' direction (calculated in the ρ' rest frame) are somewhat more peaked in the model than in the data (private communication from George Yost), thus apparently favoring the resonance hypothesis. However, it is known that angular spectra in Deck calculations involving the A_1 and Q tend to be extremely sensitive to the details of the model and to the cuts imposed on the kinematic variables; see, for example, H. Yuta, University of Rochester Report No. UR-875-271, 1969 (unpublished).