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B. Saghai
Atomic Energy and Alternative Energies Commission

Frank Tabakin
University of Pittsburgh

Jassem Ajaka
Lebanese University Council

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η-Meson Photoproduction Dynamics and Missing Resonances

B. Saghai[1], F. Tabakin[2], J. Ajaka[3], and P. Hoffmann-Rothe[3]

[1]*Service de Physique Nucléaire, DAPNIA, CEA-Saclay, 91191 Gif-sur-Yvette, France*
[2]*Department of Physics & Astronomy, University of Pittsburgh, Pittsburgh, PA 15260*
[3]*Institut de Physique Nucléaire, 91406 Orsay, France*

Abstract. The general nodal structure approach is applied to the recent $\gamma\vec{p} \rightarrow \eta p$ T-asymmetry data from ELSA. The reaction mechanism is found to require, in addition to the dominant S_{11} and D_{13} resonances, contributions from P_{13} and D_{15} resonances. This finding is confirmed within a simple dynamical approach. An indication on the presence of a predicted P_{13} nucleonic resonance is observed.

INTRODUCTION

Using a density matrix approach [1] in a multipole truncated framework, we have examined the energy dependent evolution of the nodes that can occur in meson photoproduction spin observables [1–3] and have obtained general *model independent constraints* on the cross section and on all of the other 15 spin observables asymmetries for pseudoscalar meson photoproduction processes: $\gamma p \rightarrow \pi^+ n$, $K^+\Lambda$ and ηp.

The angular structure of selected spin observables were then proven [2,3] to provide powerful means for deepening understanding of the underlying reaction mechanisms, and especially [3] for studying a possible role played by the Roper resonance and for revealing some of the low-mass missing nucleonic resonances. A rather large number of missing baryonic resonances have been predicted by quark-based studies [4] of the baryon spectrum. These undiscovered resonances are typically weakly coupled to the πN channel, but should appear in other meson-nucleon systems, such as ηN. These well identified observables can be measured at CEBAF, ELSA, ESRF, and MAMI.

RESULTS AND DISCUSSION

In previous publications, we had anticipated the interest in the target asymmetry T, and produced predictions [3]. It was shown that the pro-

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file function $T(\theta)$ is of Legendre class $\mathcal{L}_{1b}$ and hence has the general form: $T(\theta) = \sin\theta \sum_{L=0}^{n} a_L \cos^L \theta$. The polynomial coefficients can be expressed as functions of imaginary parts of bilinear products of the electric, $E_\ell^\pm$, and magnetic, $M_\ell^\pm$, multipole amplitudes. The conventions and expressions in Ref. [3], involve a simple notation in which $S \equiv E_0^+$, while P denotes the $P-$wave $J = 1/2$ (E_1^-, M_1^-) multipoles. Similarly, $P' \equiv [P-\text{wave } J = 3/2\ (E_1^+, M_1^+)]$, $D \equiv [D-\text{wave } J = 3/2\ (E_2^-, M_2^-)]$, $D' \equiv [\ D-\text{wave } J = 5/2\ (E_2^+, M_2^+)]$. Using that abbreviated notation, the structures of a_0 to a_3 are described by:

$$a_0 \to \boxed{\text{S}}P' \oplus P\boxed{\text{D}} \oplus PD' \oplus P'\boxed{\text{D}} \oplus P'D',$$

$$a_1 \to P' \oplus \boxed{\text{D}} \oplus D' \oplus \boxed{\text{S}}\boxed{\text{D}} \oplus \boxed{\text{S}}D' \oplus PP' \oplus \boxed{\text{D}}D',$$

$$a_2 \to PD' \oplus P'\boxed{\text{D}} \oplus P'D', \quad a_3 \to D' \oplus \boxed{\text{D}}D'.$$

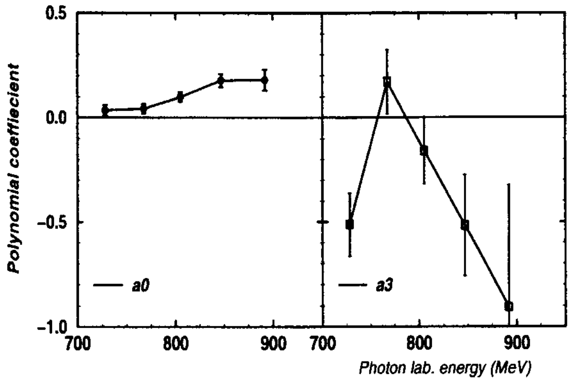

FIGURE 1. Polynomial coefficients a_0 and a_3 for $T(\theta) = \sin\theta \sum_{L=0}^{3} a_L \cos^L \theta$ as functions of energy as obtained by fitting the data from Ref. [5]. The curves are eye guides.

Here we apply [6] our method to the recent $\gamma\vec{p} \to \eta p$ data from Bonn [5], which provides angular distributions of the polarized target asymmetry T. Notice that if the intervening resonances were limited to S_{11} and D_{13} , only a_1 would be nonzero. As shown in Fig. 1, a_0 and a_3 assume finite values at all five measured energies. From the above expressions for a_0 to a_3 coefficients, our analysis (Fig. 1) shows clearly that, in addition to the dominant $S_{11}(1535)$ and $D_{13}(1520)$ resonances [7], these data require contributions from P_{13} and D_{15} resonances. Moreover, contributions from P_{11} resonances can not be excluded by the present data base.

Finally, in Fig. 2, we show the results of a simple dynamical approach [6], where electric and magnetic multipole amplitudes are expressed in terms of various nucleonic resonances (described by "relativized" energy-dependent Breit-Wigner forms), plus a smooth background including S- and P- waves.

This analysis, fitting the Bonn T-asymmetry data [6], confirms the presence of the P_{13} and D_{15} resonances in the dynamics of the η photoproduction. Here, the best agreement with the data is obtained by introducing a P_{13} missing resonance with M=1880 MeV (and Γ=150 MeV). Investigations using more realistic dynamical models [7,8] are anticipated.

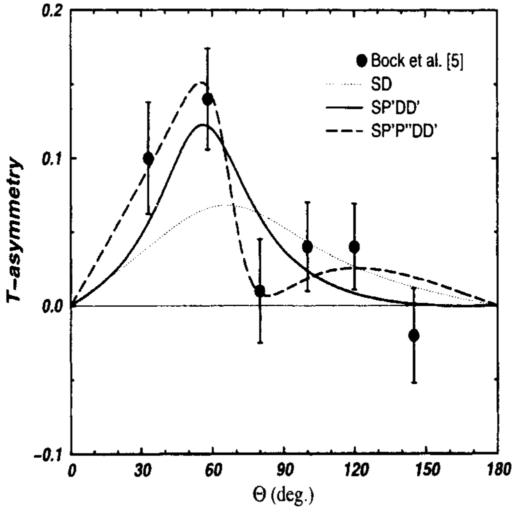

FIGURE 2. T-asymmetry angular distribution for the reaction $\gamma\vec{p} \to \eta p$ at E_γ^{lab} =767 MeV. Curves result from a simple dynamical model including the dominant $S_{11}(1535)$ and $D_{13}(1520)$ resonances (SD), an additional P_{13} and D_{15} resonances ($SP'DD'$). The effect of a predicted P_{13} resonance is also shown ($SP'P''DD'$). Data are from Ref. [5]

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