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Polarization Observables in Pion Photoproduction: A Coupled Channels Model Predictions

Yiharn Tzeng and Shin Nan Yang†

Institute of Physics, Academia Sinica, Taipei, China
†Department of Physics, National Taiwan University
Taipei, China

Δ-isobar plays a significant role in medium energy π-nucleus reactions. Coupled channels model[1] (CCM), which enlarges the Hilbert space in conventional nuclear many-body theory to include explicitly the Δ degrees of freedom, has been constructed to deal with this fact. Such a model has now been applied to NN and πd scattering, pion absorptions by deuteron,pion production in NN collision with considerable success. We have recently extended[2] the CCM to photopion processes in the hope that it may serve as a unified theoretical framework for π-nucleus and photopion production reactions.

For the simpler cases of πN scattering and $\gamma N \rightarrow \pi N$, the Hamiltonian of such an unified model can be written as

$$H = H_0 + H_{\pi N\Delta} + H_{\gamma N\Delta} + \bar{V}_{\pi N} + V^{(B)}_{\gamma\pi}, \tag{1}$$

where H_0 is the sum of relativistic free-energy operators for N, Δ, π and γ. $\bar{V}_{\pi N}$ is the πN interaction except in P_{33} channel. $V^{(B)}_{\gamma\pi}$ is the transition potential operator whose matrix elements will give rise to a transition amplitude for $\gamma N \rightarrow \pi N$ as given by standard effective Lagrangian approach[3] which includes the Born terms in pseudovector coupling and contributions form t-channel (ω,ρ) vector-meson exchanges. $H_{\pi N\Delta}$ and $H_{\gamma N\Delta}$ are the $\pi N \leftrightarrow \Delta$ and $\gamma N \leftrightarrow \Delta$ vertex interactions, respectively, in P_{33} channel. The transition matrix for $\gamma N \rightarrow \pi N$, to first order in e, is then given by

$$t_{\gamma\pi} = t_{\pi N} G_0 V_{\gamma\pi} + V_{\gamma\pi}, \tag{2}$$

with

$$t_{\pi N} = t_{\pi N} G_0 V_{\pi N} + V_{\pi N} \tag{3}$$

$$V_{\pi N} = \bar{V}_{\pi N} + H_{\pi N\Delta}(E-E_\Delta)^{-1} H_{\pi N\Delta} \tag{4}$$

$$V_{\gamma\pi} = V^{(B)}_{\gamma\pi} + H_{\pi N\Delta}(E-E_\Delta)^{-1} H_{\gamma N\Delta}. \tag{5}$$

$G_0 = (E-H_0)^{-1}$ is the propagator and E_Δ denotes the free energy of Δ. We emphasize

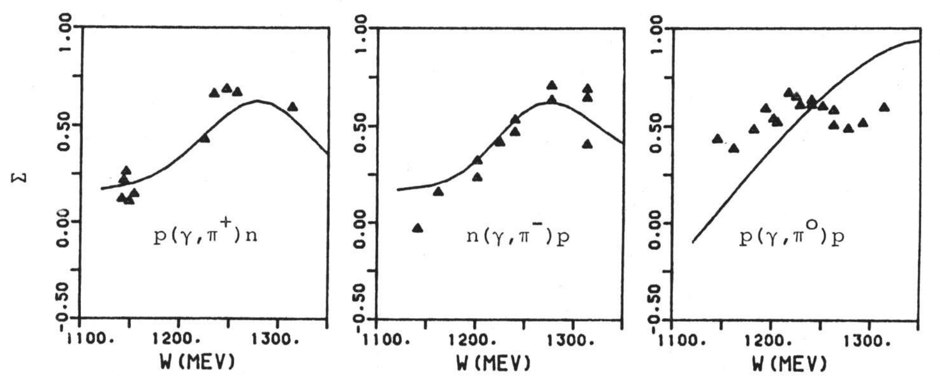

Fig. 1. Our model predictions for polarized photon asymmetry Σ at $\theta=90^\circ$.

that the $\gamma\pi$ amplitude thus obtained above satisfies the Watson's theorem becasue the unitarity has been built into the model by treating microscopically the pion multiple scatterings. This is a feature which distinguished our model from others constructed before[4].

With proper choices of $\overline{V}_{\pi N}$ and coupling constants in $H_{\pi N\Delta}$ and $H_{\gamma N\Delta}$, good fits to πN phase shifts and $\gamma\pi$ multipole amplitudes in all channels have been obtained[2]. It is known that the polarization data provide a severe testing ground for the complicated spin and isospin structure of the photopion production amplitudes, and we present here the predictions of our model for these quantities. Fig.1 gives the results for polarized photon asymmetry Σ at $\theta=90^{\circ}$ for reactions $p(\gamma,\pi^{+})n$, $n(\gamma,\pi^{-})p$ and $p(\gamma,\pi^{0})p$, respectively. The results for recoil nuclei polarization P and polarized target asymmetry T, both at $\theta=90^{\circ}$, are shown in Fig.2 for $p(\gamma,\pi^{+})n$. The results shown here are obtained without the (ω,ρ) contributions in $V_{\gamma\pi}^{(B)}$, Nevertheless, the agreement with experiments are impressive except in the case of Σ for $p(\gamma,\pi^{0})p$. It is expected that the agreement will further be improved after we finish the full calculation with the inclusion of (ω,ρ) contributions.

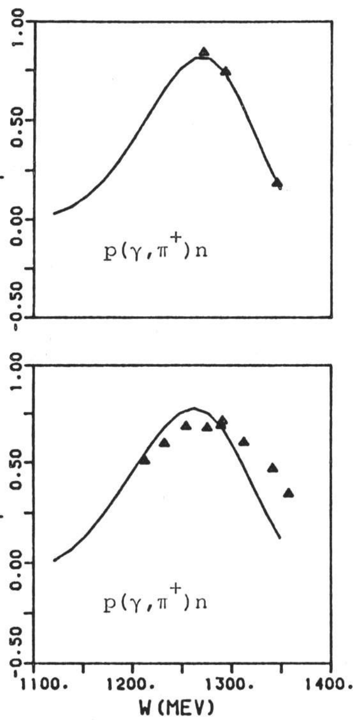

Fig. 2. Our model predictions for polarized target asymmetry T and recoil nuclei polarization P at $\theta=90^{\circ}$.

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