Tensor Analyzing Powers in $\gamma + d \to d + \pi^0$

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Introduction

Considerable interest has been evinced, in the recent years, on measurements of the tensor analyzing powers associated with coherent pion photo production on the deuteron [1–4]. Several studies are also being carried out on the incoherent pion photo production on deuteron targets [5]. The reaction $\gamma + d \to d + \pi^0$ has been studied by several authors using Impulse Approximation as early as in the 1950's [6]. Employing the well known CGLN amplitudes [7] for photo pion production on nucleons, good agreement was obtained [8] with the then existing experimental data. The differential cross section leading to the different final spin states with $m = 0, \pm 1$ have also been calculated and it was found that the forward cross section for $m = 0$ state predominates. Several model calculations like the MAID [9] and SAID [10] partial wave analysis, effective Lagrangian approach model [11] have also been carried out in the intervening years. Rachek *et. al.,* [4] have measured the tensor analyzing power T_{20} in the reaction $\gamma + d \to d + \pi^0$ at the VEPP−3 storage ring at Budker Institute in the energy range $200 < E_\gamma < 500\,MeV$. They have observed that below $350\,MeV$ there is a good agreement between theory and experiment and noted that 'the quality of agreement between theory and experiment decreases at higher photon energies, hence an improvement in theoretical model seems to be needed'. Recently, theoretical calculations on the tensor target spin asymmetries in coherent π^0-photo production on the deuteron were carried out [12] and when their measurements were compared with the experimental data [1, 13], there was a discrepancy for T_{21} and T_{22} asymmetries.

In view of these experimental and theoretical developments, the purpose of the present contribution is to outline a model independent theoretical approach to $\gamma + d \to d + \pi^0$ using irreducible tensor techniques [14–17]. This approach is valid at both high as well as low energies.

Theory

The reaction matrix for coherent photoproduction is written in the form

$$M(\mu) = \sum_{\lambda=0}^{2} \left(S^\lambda(1,1) \cdot \mathcal{F}^\lambda(\mu) \right) \qquad (1)$$

where S^λ_ν of rank λ are defined following [14] and μ denotes photon polarization following [18]. The notations are the same as in [16]. It is important to note that the reaction can be described by only 6 irreducible tensor amplitudes $\mathcal{F}^\lambda_\nu(\mu)$ with $\lambda = 0, 1, 2$ and $\mu = \pm 1$ at all energies. It is also interesting to note that irreducible tensor amplitudes $\mathcal{F}^\lambda_\nu(\mu)$ can be expressed in terms of partial wave 2^L multipole amplitudes F^{lj}_L as

$$\mathcal{F}^\lambda_\nu(\mu) = 4\pi\sqrt{2\pi} \sum_{L=1}^{\infty} \sum_{l=0}^{\infty} \sum_{j=L-1}^{j=L+1} (-1)^{j+L} (i)^{L-l}\, W(1L1l; j\lambda)\, [j]^2 [L]\, F^{lj}_L\, C(lL\lambda; m_l - \mu\nu)\, Y_{lm_l}(\hat{\mathbf{q}}) \qquad (2)$$

where

$$F^{lj}_L = \frac{1}{2} \left[P_+\, \mathcal{M}^{lj}_L + i\mu\, P_-\, \mathcal{E}^{lj}_L \right] \qquad (3)$$

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and

$$P_{\pm} = \frac{1}{2}[1 \pm (-1)^{L-l}] \tag{4}$$

where $\mathcal{M}_L^{lj}$ and $\mathcal{E}_L^{lj}$ represent the magnetic and electric multipole amplitudes respectively. The unpolarized differential cross section is given by,

$$\frac{d\sigma_0}{d\Omega} = \frac{1}{6}\sum_{\lambda=0}^{2}(-1)^{\lambda}[\lambda]\sum_{\mu}\left(\mathcal{F}^{\lambda}(\mu)\cdot\mathcal{F}^{\dagger\lambda}(\mu)\right) \tag{5}$$

where $\mathcal{F}_{\nu}^{\dagger\lambda}(\mu) = (-1)^{\nu}\mathcal{F}_{-\nu}^{\dagger\lambda}(\mu)^*$.

The tensor polarized target is described following [17] in terms of Fano Statistical Tensors t_q^k. The spin density matrix of the deuteron can then be written as

$$\rho_d = \frac{1}{3}\sum_{k=0,2}\left(S^k(1,1)\cdot t^k\right) \tag{6}$$

Using such initially polarized deuteron the differential cross section is given by

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_0}{d\Omega}\left[1 + (t^2\cdot A^2)\right] \tag{7}$$

where the analyzing powers are given by

$$A_q^2 = \frac{\sqrt{3}}{2}\sum_{\lambda,\lambda',\mu}[\lambda][\lambda']W(121\lambda;1\lambda') \left(\mathcal{F}^{\lambda}(\mu)\otimes\mathcal{F}^{\dagger\lambda}(\mu)\right)_q^2 \tag{8}$$

The model independent approach provides an alternative way to analyze the experimental measurements. A detailed analysis of all the features associated with the above result will be presented in the conference.

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