Model Independent Approach to Coherent Photo Pion Production on Deuterons

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Introduction

Deuteron being the simplest nuclei with one proton, neutron and electron, can be used to study reactions involving proton, neutron and electrons. The processes that can be studied using deuteron are photodisintegration, photoproduction and electro-production. Photoproduction can take place through coherent and incoherent processes. Considerable interest has been evinced, in the recent years, on coherent pion photo production [1, 2] and on the incoherent pion photo production on deuteron targets [3, 4]. These reactions have been studied by several authors [5, 6] using Impulse Approximation from the 1950′s. Employing the well known CGLN amplitudes [7] for photo pion production on nucleons, good agreement was obtained [6] 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 have also been carried in the intervening years, employing Partial Wave Analyses like the Maniz Unitary Isobar Model (MAID)[8] and Scattering Analysis Interactive Dial-in (SAID)[9]. The Effective Lagrangian Approach was employed[10] and a statistical modeling [11] was used [2] to analyze some of the recent experiments. The reaction amplitude was calculated using the model described in [12].

It is now, possible to produce photon beams of the order of GeV energy due to several advances in the accelerator technology, which initially focused attention on photonuclear reactions. The usage of photon beams for hadron physics became a reality as the threshold for pion photoproduction was reached. A review on the measurement of production of mesons using photon beams is presented[13], where he provides a brief description of various experimental facilities like Jefferson lab, CLAS, ESRF, MAMI and many other. One such facility, VEPP−3 storage ring in Budker Institute, Novosibirsk measures the tensor analyzing power T_{20}, T_{21} and T_{22} of the reaction $\gamma + d \to d + \pi^0$ [2, 14]. Unpolarised cross section, total cross section and vector and tensor spin asymmetry have been calculated [15] and there still is discrepancy between theory and experiment. In a more recent analysis [16] the role of D-wave component on spin asymmetries have been identified.

In view of these experimental and theoretical developments, we present here a model independent theoretical approach to study the unpolarized differential cross section in $d + \gamma \longrightarrow d + \pi^0$ at the near threshold energies.

Theoretical formalism

Let $\mathbf{k} = k\hat{\mathbf{k}}$ denotes the photon momentum which is chosen along the $z-$axis. Let $\hat{\mathbf{q}}$ denote the the $c.m.$ momentum of π^0. We may conveniently choose a right-handed Cartesian coordinate system with $\mathbf{q}$ coming out with an angle θ in the $zx-$plane. The reaction matrix for coherent pion photoproduction can be 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 [17]. The polarization of photon is denoted by $\mu =$

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± 1 following Rose [18]. The notations are the same as in [19]. The irreducible tensor amplitudes $\mathcal{F}_\nu^\lambda(\mu)$ can be expressed in terms of partial wave 2^L multipole amplitudes F_L^{lj}.

The differential cross section with unpolarized photons and unpolarized deuterons is given by,

$$\frac{d\sigma_0}{d\Omega} = \frac{1}{2} Tr \left[M(\mu) M^\dagger(\mu) \right] \tag{2}$$

using Racah algebra and multipole analysis, the above expression can be simplified in terms of multipole amplitudes as

$$\frac{d\sigma_0}{d\Omega} = \frac{1}{6} \sum_{\lambda=0}^{2} (-1)^\lambda [\lambda] \sum_\mu \left(\mathcal{F}^\lambda(\mu) \cdot \mathcal{F}^{\dagger\lambda}(\mu) \right) \tag{3}$$

where $\mathcal{F}_\nu^{\dagger\lambda}(\mu) = (-1)^\nu \mathcal{F}_\nu^{*\lambda}(\mu)$ and $\mathcal{F}_\nu^{*\lambda}(\mu)$ represents the complex conjugate of $\mathcal{F}_\nu^\lambda(\mu)$.

We are using model independent irreducible tensor approach to analyze the experimental data. It is important to study the spin structure of multipole amplitudes in reaction $\gamma + d \rightarrow d + \pi^0$. In view of the observations made about the irreducible tensor amplitudes and the unpolarized differential cross section, analysis of the result at the near threshold energies will be presented.

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