Model independent approach to $d + \vec{\gamma} \rightarrow n + p$ for γ beam monitoring

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Introduction

The study of $d + \gamma \rightleftharpoons n + p$ has a long history going back to 1930. Working in the frame work of effective field theory Young Ho et al, [1] state "There still remains a couple of problems which show discrepancy between experiment and theory even in few-nucleon systems at low energies". The experimental and theoretical studies on the spin observables in the $\gamma d \rightarrow \pi p$ reaction has also been emphasized in [2]. Several experiments have been carried out on photodisintegration of deuterons using the 100% linearly polarized photons [3–8] which were motivated by the study of Burles et al. [9].

Neutron angular distribution in (γ, n) reactions with linearly polarized photons [10] were reported recently, in view of their importance of photonuclear reactions [11] for basic science as well as for various applications [12], The linear as well as circular polarized beams are generated by Laser Compton Scattering (LCS) at New SUBARU [13] at the National Institute of Advanced Industrial Science and Technology [14] in Japan. The ELI-NP [15] has a proposal to deliver brilliant γ beams with a high spectral density and a high degree of polarization starting from 2018.

In view of this, we present a complete analysis of $d(\vec{\gamma}, n)p$ for the beam monitoring using the model independent approach developed by us earlier.

In a detailed discussion [16] of the photodisintegration of deuterons with 100% linearly polarized photons, attention was also focussed on the possibility of the three isovector electric dipole amplitudes, $E1_v^j$, being different from each other in the channels with total angular momentum, $j = 0, 1, 2$. Subsequently, it was found that it is indeed so by Blackston et al [17], who reported the first experimental observation of the splitting of the $E1$ p-wave amplitudes at slightly higher energies of 14 and 16 MeV. We may also mention that attention was focussed on photon polarization [18] in $\vec{n} - \vec{p}$ fusion and on analyzing powers [19] in $\vec{d}(\gamma, n)p$ with unpolarized photons. A model independent theoretical analysis of photodisintegration of aligned deuterons at astrophysical energies using linearly polarized photons was presented in [20], where an analysis of the experimental data of Blackston et al [17] was also presented.

Theoretical formalism

We define the state of polarization of the γ beam by

$$\begin{aligned} \hat{\epsilon}(\alpha,\beta) = [&\hat{\epsilon}_{\mathbf{x}} \cos\alpha \cos\beta + \hat{\epsilon}_{\mathbf{y}} \sin\alpha \cos\beta \\ &- i\hat{\epsilon}_{\mathbf{x}} \sin\alpha \sin\beta + \mathbf{i}\hat{\epsilon}_{\mathbf{y}} \cos\alpha \sin\beta]; \\ &0 \le \alpha < \pi; \quad \beta = -\pi/4 < \beta < \pi/4 \end{aligned} \tag{1}$$

where $\hat{\epsilon}_{\mathbf{x}}$ and $\hat{\epsilon}_{\mathbf{y}}$ denote two orthogonal linear states of polarization in a plane perpendicular to the beam characterized by the wave vector $\mathbf{k}$ along the Z-axis. Using natural units and the Coulomb Guage, the vector potential may then be written in the form

$$\mathbf{A(r,t)} = \mathbf{A}\hat{\epsilon}(\alpha,\beta)\mathbf{e}^{-\mathbf{i}(\omega \mathbf{t} - \mathbf{k}\cdot\mathbf{r})} + \mathbf{c.c}, \tag{2}$$

where $\omega = |k|$.

All possible linear states of polarization are represented by setting $\beta = 0$ where as positive and negative values of β represent respectively

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the right elliptic and left elliptic states, with $\beta = \pm\pi/4$ corresponding to right and left circular polarizations states $\mu = \pm 1$ respectively.

Choosing them as basis states, the 2 x 2 density matrix of polarized beam takes the form,

$$\rho^\gamma = \frac{I_0}{2}[1 + \sigma \cdot \mathbf{s}] \tag{3}$$

where $I_o = Tr\rho$ represents the total intensity and s_x, s_y and s_z are the stokes parameters given by

$$I_0\mathbf{s} = Tr(\rho^\gamma \sigma^\gamma) \tag{4}$$

The differential cross section for $d + \vec{\gamma} \rightarrow n + p$ is then given in the c. m frame by

$$\frac{d\sigma}{d\Omega} = \frac{1}{6}\mathbf{M}(\mu)\rho^\gamma_{\mu\mu'}\mathbf{M}(\mu')^\dagger, \tag{5}$$

$$\mathbf{M}(\mu) = \sum_{s=0}^{1}\sum_{\lambda=|s-1|}^{s+1}(S^\lambda(s,1)\cdot\mathcal{F}^\lambda(s,\mu)), \tag{6}$$

using the same notations as in [16]. The result may be written as

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_0}{d\Omega}[1 + \mathbf{s}\cdot\mathbf{a}] \tag{7}$$

where **a** denotes the analyzing powers with polarized photon beam. A detailed analysis of all the features associated with the above result will be presented in the conference.

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