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Model Independent Analysis in (γ, n) Reactions Using Deuterium Targets

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Abstract

Photonuclear reactions play an important role in the fields of nuclear physics, astrophysics and in various applications such as non-destructive measurement of nuclear materials (NDT). The study of (γ, n) reactions using deuterium targets *i.e.*, photodisintegration of deuterons in addition to all the other (γ, n) reactions, is of considerable interest to these fields. In this contribution we have studied the photodisintegration of deuterons with unpolarized photons. The angular dependence of the differential cross section is studied by expressing it in terms of Legendre polynomials. The analysis of differential cross-section is presented using the model-independent irreducible tensor formalism.

Keywords: Deuteron, Non destructive testing of nuclear materials, photon, photodisintegration;

1. Introduction:

The importance of precise knowledge on d+γ→n+p was highlighted by Burles et al., [1] and this led to series of experimental measurements [2] on this reaction at the Duke free electron laser laboratory using 100% linearly polarized photons from the high intensity γ-ray source. Neutron angular distribution in (γ, n) reactions [3] was reported recently in view of the importance of photonuclear reactions [4] for science as well as various applications [5]. Uncertainties in the reaction rates contribute substantially to the uncertainties in the determination of relative abundance of heavier elements in the early universe.

Although it was known quite early that the thermal neutron capture by protons is dominated by the isovector magnetic dipole amplitude $M1_v$, Breit and Rustgi [6] were the first to propose a polarized target-beam experiment to look for an isoscalar $M1_s$ amplitude in view of the then existing 10% discrepancy between theory and experiment. The suggestion was more or less ignored in view of the surprising accuracy with which the 10% discrepancy was explained by [7] as due to Meson exchange currents (MEC). However, the measured values for analyzing powers in $p(\vec{n},\gamma)d$ as well as for neutron polarization in photodisintegration of the deuteron were both found to differ [8] from theoretical calculations which included MEC effects. Attention was given to the unambiguous disagreement [9] between experiment and theory on $d(\gamma,n)p$ at photon energy 2.75 MeV and it was concluded that this discrepancy widens when two body effects are taken into account. It may be mentioned that measurements of neutron polarization at energies 7 MeV to 15 MeV [10], abruptly depart from theoretical predictions at around 10 to 12 MeV. Attention was also focussed on the isoscalar M1 and $E2$ amplitudes by several authors [11,12] using different versions of effective field theory. The controversy between these two approaches however could not be settled by a reported polarized beam target measurement of the γ-anisotropy [13].

Over a period of more than six decades, a number of theoretical calculations based on potential models have been reported on $n + p \rightleftarrows d + \gamma$ .Several theoretical groups are working on this reaction using chiral effective field theory and several others using pionless effective field theory [14]. Attention was focussed on the complete set of polarisation obsevables for deuteron photo- and electro-disintegration, spin response of the deuteron and the Gerasimov-Drell-Hearn (GDH) sum rule by [15].

We have developed a model independent theoretical approach to study this reaction [16, 17] where we have focused attention on the existence of three E1 amplitudes and the possibility of all the three amplitudes being unequal. The experimental observations by Blackston et. al [18] have in fact revealed that the three amplitudes are different at 14 and 16 MeV.