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Influence of intermediate ηNN interaction on spin asymmetries for $\gamma d \to \pi^0 d$ reaction near the η-threshold within a three-body approach

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ABSTRACT

The influence of intermediate ηNN interaction on spin asymmetries for coherent π^0-photoproduction on the deuteron in the energy region around the η-threshold is studied using a three-body model with separable two-body interactions. We calculate all possible spin asymmetries with polarized photons and/or oriented deuterons and compare our results with available data. The calculations are based on a theoretical approach which includes the amplitudes of the impulse approximation, two-body process with πN- and ηN-rescattering, and the higher order terms in the multiple scattering series for the intermediate ηNN interaction. We found that the results for spin asymmetries of the differential cross section differ significantly from those calculated by a simple model in which only the impulse approximation and first-order rescattering contributions are considered. The effect of intermediate ηNN interaction is significant in certain spin asymmetries, specially at extreme backward pion angles. It turns out that the inclusion of a full ηNN three-body contribution is quite essential. The spin asymmetries of the total cross section are much less affected by rescattering contributions. Compared to the experimental data from

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YerPhi Collaboration for the linear photon asymmetry, sizeable discrepancies are found.

1. Introduction

During the last two decades, pseudoscalar meson production in electromagnetic reactions on nuclei has become a very active field of research in medium energy nuclear physics. A particularly interesting role plays the deuteron, since it is the simplest nucleus on whose structure we have abundant information and a reliable theoretical understanding. Moreover, it constitutes the simplest and cleanest neutron target, and thus allows one to obtain information about the unknown reaction on the neutron, considering the deuteron as an approximate neutron target in view of its weak binding. In order to extract this information, the incoherent process appears to be very suited, since in this case the reaction is dominated by the quasifree contribution. For this contribution, interference effects between the elementary amplitudes of proton and neutron are very small. Thus, the contributions from proton and neutron add incoherently to a very good approximation. On the other hand, the coherent process offers a special bonus, because the deuteron constitutes an electromagnetic isospin filter. This means that in the coherent reaction one selects the isospin $t = 0$ channels, in other words, only the isoscalar excitation strength determines the reaction. Thus, the coherent process will provide information on this small quantity independently from the incoherent reaction, which clearly is dominated by the isovector amplitude. Moreover, whereas one obtains from the incoherent reaction the moduli of the amplitudes only, i.e., their relative phases remain unknown, the coherent reaction allows to extract new information on these relative phases of the elementary amplitudes.

Coherent π^0-photoproduction on the deuteron in the energy range from π-threshold to the $\Delta(1232)$-resonance region has been studied as a source of information on the elementary π^0-photoproduction off the neutron (see Refs. [1–8] where also references to earlier research can be found). This reaction is quite well understood at energies between π-threshold and the $\Delta(1232)$-resonance region. But, in the second resonance region, this reaction is not well understood, because the resonances and mechanism of multiple scattering play an important role for description of the process. Therefore, the study of coherent π^0-photoproduction on the deuteron in the energy region near the η-production threshold is of interest both for development of theory and future experimental investigations (for an experimental overview see Ref. [9]). This work is motivated by the measurements of the CLAS Collaboration at Jefferson Laboratory [10,11], where a cusp structure in the energy dependence of the differential cross section in the energy region of 600–800 MeV has been observed. We would like to mention that the quasifree photoproduction of η-mesons off the deuteron, $\gamma d \to \eta np$, plays also an important role in the claim of the observation of a narrow resonance structure in the quasifree cross section of the $\gamma n \to \eta n$ reaction [12] which is not seen in the cross section on the proton. This has been previously found in the pion production [13]. With a slightly different mass it was also observed in the kaon photoproduction process $\gamma p \to K^+\Lambda$ [14].

The $\gamma d \to \pi^0 d$ reaction near the η-production threshold at backward center-of-mass (c.m.) pion angles was studied by Kudryavtsev et al. [15]. Their model is based on the impulse approximation (IA) and two-step process with intermediate production of both π- and η-mesons [called also first-order rescattering] (henceforth denoted by FOR). Their treatment shown that the observed cusp structure can be explained by the contribution of two-step process diagram. Later on, this effect was analyzed in Ref. [16] on the basis of a theoretical model which includes in addition to the IA and FOR the full dynamics in the intermediate ηNN three-body system only in the s-wave state ${}^1S_0$ [$J^\pi,\ T = 0^-,\ 1$] (in what follows denoted by TBM). It was concluded that a three-body treatment of the intermediate ηNN interaction is of special importance. The results of the two models in Refs. [15,16] shown that the differential cross section cannot describe the *preliminary* experimental data from [10]. The differential cross section was found to be revealed remarkable differences even if the rescattering effects are included.