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Study of coherent π^0–photoproduction on the deuteron

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Abstract. We consider the coherent π^0–photoproduction reaction on the deuteron, $\gamma d \to \pi^0 d$, in the energy region from π-threshold up to 1 GeV using an enhanced elementary pion photoproduction amplitude on the free nucleon and a realistic high-precision NN potential model for the deuteron wave function. Numerical results for total and differential cross sections are presented for which the sensitivity to various models for the elementary pion photoproduction operator is investigated. Considerable dependence of the results on the elementary amplitude is found at photon lab-energies close to π-threshold and above 600 MeV. In addition, the results for differential and total cross sections are compared with the available experimental data and a satisfactory agreement was found.

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Key words: Meson production, photoproduction reactions, Baryon resonances

1 Introduction

The study of pion production processes on the deuteron are of fundamental interest in nuclear physics. The photoproduction of mesons is an excellent tool for the study of nucleon resonances [1] and in consequence of the structure of the nucleon. In this context, meson production on the deuteron is of specific importance due to the lack of free neutron targets. With respect to pion production, both possible reactions, the coherent and the incoherent one, are worth to be studied. Coherent pion photoproduction on the deuteron may be used as an isospin filter and is especially sensitive to the coherent sum of the $\gamma p \to \pi^0 p$ and $\gamma n \to \pi^0 n$ amplitude. On the other hand, incoherent pion photoproduction on the deuteron may be used

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to obtain information about neutron cross section in quasi-free kinematics. Due to its relative simplicity, the deuteron is the ideal target for such studies.

Most recently, an improved calculation of the incoherent pion photoproduction on the deuteron has been performed in Ref. [2] in which final-state interactions (FSI) are included completely in the NN- and πN-subsystems and an enhanced elementary pion photoproduction operator taken from Ref. [3] has been used. The influence of the elementary operator on cross sections and spin observables for both the neutral and the charged pion production channels has been investigated and was found to be very important. In many cases the deviation among results obtained using different operators is very large.

For a long time, coherent π^0-photoproduction on the deuteron has been studied as a source of information on the elementary π^0-photoproduction off the neutron. This reaction has been first studied by Koch and Woloshyn [4] by including the contribution from pion rescattering with charge exchange contributions. This effect was then verified by Bosted and Laget [5] in studies of coherent π^0-photoproduction from the deuteron in the threshold region. In Ref. [6] an approach of $NN-N\Delta$ coupled channels for describing coherent π^0-photoproduction from the deuteron in the $\Delta(1232)$-resonance region was used. In another approach, developed in Ref. [7], relativistic Feynman diagrams have been evaluated. Blaazer *et al.* [8] studied rescattering corrections to all orders by solving Faddeev equations of the πNN-system. They have concluded that the contributions of the neutron and the proton cannot be separated because of the charge-exchange rescattering of the pion. Using a microscopic approach based on the Kerman-McManus-Thaler (KMT) multiple scattering theory [9] in momentum space, Kamalov *et al.* [10] have studied coherent π^0-photoproduction from the deuteron in the $\Delta(1232)$-resonance region in a coupled channel approach.

The coherent π^0-photoproduction from the deuteron was studied by Kudryavtsev *et al.* [11]. In particular, it was demonstrated that at large c.m. angles and photon lab-energies between 600 and 800 MeV, the two-step process with the excitation of an intermediate η-meson dominates over single-step process photoproduction and pion rescattering. The main conclusion of Ref. [11] were reproduced in another paper [12], where it was shown that in addition to this two-step process, the full dynamics in the intermediate $NN\eta$ system could be important as well. Unfortunately, none of these theoretical studies considers the energy region above the $\Delta(1232)$-resonance region and/or investigates the sensitivity to the elementary pion photoproduction operator on the free nucleon. Therefore, the coherent π^0-photoproduction reaction on the deuteron has been investigated in the $\Delta(1232)$-resonance region Ref. [13] with special emphasize on the doubly polarized cross sections. The sensitivity of the results to the elementary pion photoproduction amplitude was investigated, and considerable dependence has been found.

Our purpose in the present paper is, therefore, to extend the model, recently presented in [13], to make theoretical predictions for unpolarized total and differential cross sections of the process $\gamma d \to \pi^0 d$ in the energy range from π-threshold up to 1 GeV. For the elementary $\gamma N \to \pi N$ amplitude, an enhanced elementary pion photoproduction operator taken from Ref. [3] is used. This model displays chiral symmetry, gauge invariance, and crossing symmetry, as well as a consistent treatment of the interaction with spin-3/2 particles. It also provides a reliable