Coherent Pion Photoproduction on Deuterium

Y. Ilieva*, for the CLAS Collaboration

*The George Washington University/Jefferson Lab, 12000 Jefferson Avenue, Newport News, VA 23606, USA

Differential cross sections of the $\gamma d \rightarrow d\pi^0$ reaction were measured at photon beam energies between 0.5 and 2.0 GeV over a wide angular range in the CM system. The experiment was performed in Hall B at Jefferson Lab using the CLAS detector. The excitation function, especially at backward CM scattering angles, has been studied with regard to effects due to intermediate on-shell $\eta$ and $\omega$ rescattering. At CM scattering angles greater than 123° our data clearly show an enhancement around 0.7 GeV, which could be attributed to an intermediate on-shell $\eta$-state.

1. INTRODUCTION

In a previous measurement [1] of the reaction $\gamma d \rightarrow d\pi^0$, covering several backward-pion CM scattering angles and photon energies between 0.5 and 1.0 GeV, a structure has been observed in the excitation function at $\theta_{cm}=130^\circ$ between 0.7 and 0.8 GeV which could not be explained in terms of non-exotic mechanisms [2]. However, an approach including an intermediate on-shell $\eta$-meson rescattering (which has been successful in describing a similar feature of the $\pi d$ elastic backward excitation function [3]) might be able to account for such an enhancement around the $\eta$-photoproduction threshold. An intermediate on-shell $\omega$ formation should appear in the $\gamma d \rightarrow d\pi^0$ excitation function close to the $\omega$-photoproduction threshold [4]. Thus, if the finding in [1] is confirmed, a detailed study of this process extended to higher beam energies and broader angular range may prove to be a valuable tool for studying $\eta N$ and $\omega N$ interactions, which is the goal of our efforts.

2. EXPERIMENT

The experiment was performed in Hall B at Jefferson Lab using the CLAS detection system [5]. Electrons from the CEBAF accelerator hit a thin gold radiator and produced a bremsstrahlung beam that was then incident on a 10-cm thick liquid-deuterium target. The energies of the incoming photons were measured directly with the Hall-B Photon Tagger [6], whereas the reaction products were detected using CLAS. The intensity of
the photon beam was $\sim 10^7$ tagged photons/s and the generated luminosity was around $4 \times 10^{30}$ s$^{-1}$cm$^{-2}$. Data were obtained for electron energies of 2.5 and 3.1 GeV, which corresponds to photon energy ranges of 0.5-2.4 and 0.8-2.9 GeV. The number of collected $d\pi^0$ events was $\sim 1.8 \times 10^5$ and $\sim 2.8 \times 10^4$ for the two electron beam energies, respectively.

Since CLAS is very well suited for detecting charged particles and has limited acceptance for neutrals, our analysis is based on detecting the deuteron and applying the missing-mass technique to identify the reaction. The data were divided into 50-MeV-wide photon-energy bins and 0.1- or 0.2- (depending on the statistics) wide $\cos\theta$ bins. For each energy and angular bin, background subtraction was done by fitting the background in the deuteron missing-mass-squared distribution and subtracting it from the total yield. In order to determine the detector acceptance, $10^6$ phase-space-distributed $d\pi^0$ events were generated and processed through the GEANT-based simulation code GSIM \cite{7} and the same analysis chain as the data. The acceptance varies between 40% and 70%, depending on the beam energy and CM scattering angle. Roughly estimated, the acceptance systematic uncertainty is at the level of 10%. Preliminary cross sections were extracted by normalizing the yields to the photon flux and the number of target nuclei, and applying an acceptance correction.

3. RESULTS

After analyzing the 2.5-GeV data set, we were able to extract preliminary differential cross sections up to a photon energy of 1.2 GeV for backward-pion CM scattering angles and up to 2.0 GeV for forward angles. The most backward-pion CM scattering angle accessible in our data is 148$^\circ$ and is defined by the forward hole in CLAS. The most forward accessible CM angle varies between 32$^\circ$ and 76$^\circ$, depending on the beam energy, and is limited by the detector energy acceptance for deuterons.

Our preliminary results for several pion CM scattering angles, compared with previous measurements, are presented in Fig. 1. The uncertainties shown are statistical (3-12%) and systematic due to background subtraction (up to 3%) added in quadrature. Fairly good agreement with the previous data is observed. All excitation functions corresponding to $\theta_{\pi} > 123^\circ$ show a structure around the $\eta$-photoproduction threshold, which becomes more prominent as the CM angle increases. This confirms the finding reported in \cite{1}. However, the shape of the structure we see is somewhat different compared with the results of the previous measurement: at $\theta_{\pi} = 130^\circ$ our data show an enhancement around 0.7 GeV, whereas the data from \cite{1} show a broad plateau between 0.7 and 0.8 GeV. In order to understand this difference we are currently in the process of a detailed analysis of the systematics of our experiment. Due to statistics limitations, we might not be able to study the effect of an intermediate on-shell $\omega$-state.

4. SUMMARY

The reaction $\gamma d \rightarrow d\pi^0$ was measured at photon beam energies above 0.5 GeV. This is the first detailed measurement of that process spanning wide ranges in energy and angle. At photon energies and CM angles where there are existing data, our preliminary cross sections are in good agreement with the previous measurements \cite{1,8}. We confirm the existence of a structure in the excitation function at $\theta_{\pi} = 130^\circ$ close to the $\eta$-photoproduction
Figure 1. Preliminary differential cross sections for the reaction $\gamma d \rightarrow d\pi^0$ obtained with the CLAS detector (solid symbols). Previous data [1,8] are also shown (open symbols). The $\eta$- and $\omega$-photoproduction thresholds are indicated by arrows.

threshold. Moreover, our data extend to larger CM angles where the structure is clearly more prominent. An approach including intermediate on-shell $\eta$-meson formation [3] will be used to describe the data in order to study the properties of the $\eta N$ interaction.

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