Single and Double Pion Photoproduction off the Deuteron

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There is evidence that the photoproduction of single and double pions off bound nucleons inside a nucleus are not only affected by Fermi motion but also by other nuclear effects, such as final state interactions or meson rescattering. We will present preliminary results of a high statistics measurement of single and double pion photoproduction of quasi-free protons and neutrons off the deuteron carried out at the Mainzer Microtron.

1 Introduction

The following paragraphs present preliminary results about single and double π^0 photoproduction off the deuteron that both originate from the same experiment accomplished in December 2007 at the Mainzer Microtron (MAMI) in Mainz, Germany. The MAMI electron beam facility produces a continuous photon beam with energies up to 1.5 GeV. The photon beam was circularly polarized and the main detectors used in this experiments providing nearly full angular coverage are the *Crystal Ball* calorimeter (CB) surrounding the target and the TAPS-detector which is placed as a forward wall. The separation of neutral and charged particles is done with plastic scintillators, either as bars arranged in a cylindrical setup surrounding the target (CB) or as hexagonally shaped vetos (TAPS). Furthermore a χ^2-test is used to identify the photons stemming from the meson decay and to isolate the recoil neutron.
The single and double π^0 cross sections were measured throughout the second and third resonance region in coincidence with recoil protons (quasi-free exclusive reaction on the proton), in coincidence with recoil neutrons (quasi-free exclusive reaction on the neutron) and without a condition for the detection of recoil nucleons (quasi-free inclusive reaction). Both quasi-free exclusive reactions sum up to the quasi-free inclusive channel, since the contribution of the coherent process is negligible in the energy region of interest.

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2 Results

The left-hand side of figure 1 shows the preliminary single π^0 total cross section of the quasi-free exclusive reaction on the proton $\gamma + d \rightarrow \pi^0 + p(n)$ (filled blue circles) together with the quasi-free exclusive reaction on the neutron $\gamma + d \rightarrow \pi^0 + n(p)$ (filled red circles). The right-hand side of figure 1 shows the preliminary single π^0 total cross section of the quasi-free inclusive reaction $\gamma + d \rightarrow \pi^0 + (N)$ (filled black circles) together with the sum of the two quasi-free exclusive reactions (open magenta circles). As well shown are previous results [1] for the inclusive reaction (open green circles) and the predicted cross sections from the theoretical models MAID [2] (dashed lines) and SAID [3] (full lines) folded with Fermi motion.

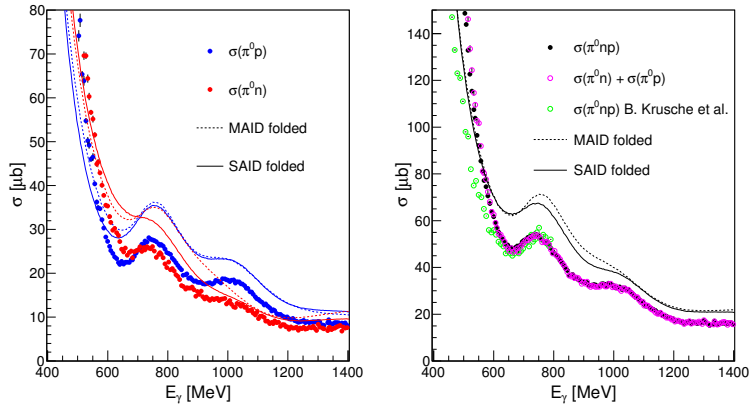

Figure 1: Preliminary single π^0 total cross sections of the quasi-free exclusive (left-hand side) and quasi-free inclusive (right-hand side) reaction. The labelling is explained in the text.

It can be seen in figure 1 that the shapes of the measured cross sections (full red, blue and black circles) are in nice agreement with the theoretical MAID [2] and SAID [3] models but there is a disagreement in magnitude. Furthermore, the sum of the quasi-free exclusive cross sections (open magenta circles) add up perfectly to the measured quasi-free inclusive cross section (full black circles). This indicates a very clean identification of the reaction channels. In addition, the measured quasi-free inclusive cross section (full black circles) is in good agreement with earlier results from MAMI B [1].

The left-hand side of figure 2 shows preliminary results for the $2\pi^0$ total cross sections of the quasi-free exclusive reaction on the proton $\gamma + d \rightarrow \pi^0\pi^0 + p(n)$ (filled blue triangles) together with the quasi-free exclusive reaction on the neutron $\gamma + d \rightarrow \pi^0\pi^0 + n(p)$ (filled red triangles) and the quasi-free inclusive reaction $\gamma + d \rightarrow \pi^0\pi^0 + (N)$ (filled black triangles).

The right-hand side of figure 2 illustrates the measured beam helicity asymmetries $I^{\odot}(\Phi) = 1/P_{\gamma}(d\sigma^+ - d\sigma^-)/(d\sigma^+ + d\sigma^-) = 1/P_{\gamma}(N^+ - N^-)/(N^+ + N^-)$ [4] of the quasi-free exclusive

reaction on the proton (full blue triangles) and on the neutron (full red triangles) for different regions of beam energy. The dashed lines correspond to a fit to the data.

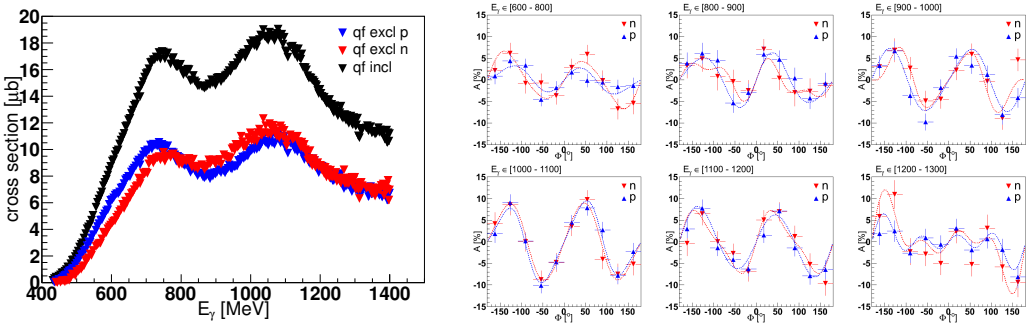

Figure 2: Very preliminary double π^0 total cross sections (left-hand side) and beam helicity asymmetries (right-hand side). The labelling is explained in the text.

3 Interpretation

The identical shape of the measured single π^0 total cross sections and the theoretical MAID [2] and SAID [3] models (see figure 1) demonstrates a correct understanding of the resonance contributions to the different reactions, i.e. mainly $D_{13}(1520)$, $F_{15}(1680)$ to single π^0 photoproduction on the proton and $D_{13}(1520)$, $D_{15}(1675)$ on the neutron. The discrepancy in absolute height between the measured single π^0 total cross sections and the theoretical models (see figure 1) can not be explained by nuclear Fermi motion. The fact that folding the theoretical models with Fermi motion does not overcome this problem reveals the importance of other nuclear effects, such as final state interactions, meson rescattering or others. This discrepancy was already earlier observed by B. Krusche *et al.* [1] and H. Shimizu [5]. H. Shimizu reported an overestimation of the data by models of $\sim 125\%$, as shown at the left-hand side of figure 3. The same level of overestimation was observed in this work, as depicted on the right-hand side in figure 3, where the models are scaled down by a factor of 0.8.

Double π^0 photoproduction is mainly used to study the properties of sequential decays since this is the dominated decay mechanism. Even though the MAID model [2] predicts a nearly identical total cross section for the production on the proton and on the neutron, the resoncance contribution to the two reactions is rather different. For example, the electromagnetic excitation of the $F_{15}(1680)$ ($D_{15}(1675)$) is predicted to be much stronger on the proton (neutron) than on the neutron (proton). For this reason one would suggest that sensitive quantities such as the beam helicity asymmetry would depend on such a coupling and hence will not be the same on the proton and on the neutron.
The measured $2\pi^0$ total cross sections on the proton and neutron (left-hand side of figure 2) show no big difference and hence confirm the predictions. However, it is rather astonishing

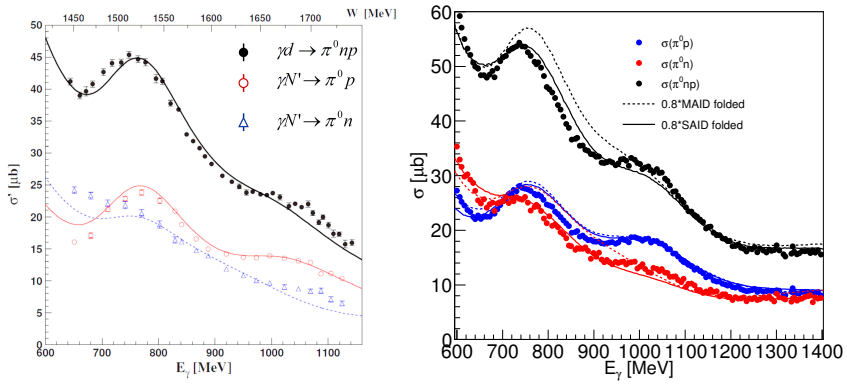

Figure 3: Quasi-free exclusive total cross sections compared to the MAID [2] and SAID [3] models scaled down by a factor 0.8. Left-hand side: H. Shimizu [5], right-hand side: This work. Note the reverted color coding on the left figure between red and blue.

that the measured beam helicity asymmetries for the proton and neutron are as well identical within the error bars. Additionally, the results on the quasi-free proton were defolded from Fermi motion and compared to published data on the free proton and are in good agreement with each other (not shown here) which indicates a correct reconstruction of the reaction. Yet, earlier works [4] also contradicted many model predictions concerning the asymmetries, therefore further input is needed in order to understand this behavior.

Acknowledgments

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