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NEW RESULTS FROM MESON PHOTOPRODUCTION EXPERIMENTS WITH TAPS AT MAMI*

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Some recent experimental results for the photoproduction of neutral mesons from the deuteron and the measurement of inclusive-, coherent-, and double-π^0-photoproduction from heavy nuclei are disscussed. The results were obtained in a series of experiments carried out with the TAPS-detector at the Mainz MAMI accelerator in 1992. Some first preliminary results from a second experimental campaign with TAPS at MAMI in 1996 are presented.

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1. Introduction

So far two series of experiments focussed on meson photoproduction from the pion threshold up to the second resonance region were carried out with the TAPS-detector [1, 2] at the Mainz MAMI accelerator. A summary of the investigated reactions is given in Table I. From the first campaign the results for η-photoproduction from the proton, the deuteron, and from heavy nuclei, for π^0-photoproduction at threshold, and for double π^0-photoproduction from the proton are published elsewhere [3–11]. The data for double π^0-photoproduction from the deuteron, inclusive-, coherent-, and double π^0-photoproduction from heavy nuclei have now been analysed and first results are discussed in this contribution.

In the first generation experiments only the neutral mesons were observed via their 2γ-decays, the photons being detected in TAPS. The TAPS-detector was supplemented with a forward wall detector consisting of BaF_2-plastic phoswich modules [12] for the second generation experiments. This

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TABLE I

Summary of the experimental program carried out with the TAPS-detector at the Mainz microtron MAMI. The main difference between the first and second generation experiments is that the latter allowed the identification of recoil nucleons and nuclei by a forward detector in addition to the detection of the neutral mesons via their 2γ-decays.

period	**targets**	**E_γ [MeV]**	**reactions**
1992	^{1}**H**	680 - 792	$p(\gamma,\eta)p$
		200 - 792	$p(\gamma,\pi^0)p$, $p(\gamma,\pi^0\pi^0)p$
	^{2}**H**	520 - 792	$d(\gamma,\eta)np$, $d(\gamma,\eta)d$
		200 - 792	$d(\gamma,\pi^0)np$, $d(\gamma,\pi^0)X$
			$d(\gamma,\pi^0\pi^0)np$
	^{12}**C,** ^{40}**Ca,** ^{93}**Nb,** $^{\rm nat}$**Pb**	200 - 792	$A(\gamma,\eta)np$, $A(\gamma,\pi^0)X$
			$A(\gamma,\pi^0)A$
1995/96	^{1}**H**	200 - 830	$p(\gamma,\eta)p$, $p(\gamma,\pi^0)p$
			$p(\gamma,\pi^0\pi^0)p$, $p(\gamma,\pi^0\pi^+)n$
	^{2}**H**	200 -830	$d(\gamma,\eta)np$, $d(\gamma,\eta)d$
			$d(\gamma,\pi^0)np$, $d(\gamma,\pi^0)d$
			$d(\gamma,\pi^0\pi^0)np$
	^{4}**He**	200 -830	^{4}He$(\gamma,\eta)np$, ^{4}He$(\gamma,\eta)^4$He
			^{4}He$(\gamma,\pi^0)np$, ^{4}He$(\gamma,\pi^0)^4$He

setup allowed to register recoil nucleons and deuterons in coincidence with the meson decay photons. The additional information from the recoil particles is essential for the study of coherent η-photoproduction from the deuteron or for the clean extraction of photoproduction cross sections from the neutron using a deuterium target.

2. Photoproduction of neutral mesons from the deuteron

On the deuteron all meson photoproduction reactions with neutral pions in the final state have now been studied up to 800 MeV incident photon energy. The results for the total cross sections are summarized in figure 1.

The reaction $\gamma d \to pp\pi^-\pi^0$ was investigated with the DAPHNE-detector [13]. The experiment also showed, that the cross sections for $\gamma p \to p\pi^+\pi^-$ measured on the free proton and measured on the bound proton from deuterium in quasifree kinematics are almost equal, so that the quasifree measurements from the deuteron can be used to extract the free neutron cross section. Since furthermore the result for $\gamma d \to pp\pi^-\pi^0$ is not significantly different from $\gamma p \to n\pi^+\pi^0$ [13] we have taken twice the cross section of

$\gamma d \to pp\pi^-\pi^0$ as an estimate of the sum for the cross sections for the final states $pp\pi^-\pi^0$ and $nn\pi^+\pi^0$.

The reactions $\gamma d \to np\pi^0$ and $\gamma d \to np\pi^0\pi^0$ have been measured in quasifree kinematics with the TAPS-detector [14] as well as the earlier reported $\gamma d \to np\eta$ [5]. Finally the inclusive π^0-photoproduction cross section $\gamma d \to \pi^0 X$ was deduced from the TAPS experiment accepting all events with at least one neutral pion [14].

It is demonstrated in figure 1, that the sum of all partial quasifree cross sections individually weighted with their π^0-multiplicities, agrees excellently with the measured inclusive cross section. This demonstrates not only the consistency of the data taken with two very different detector setups, but also shows, that at least in the neutral channels no significant non-quasifree contributions are present. Such contributions were *e.g.* claimed for the reaction $\gamma d \to np\pi^+\pi^-$ [15] arising from $\Delta^{++}\Delta^-$-production.

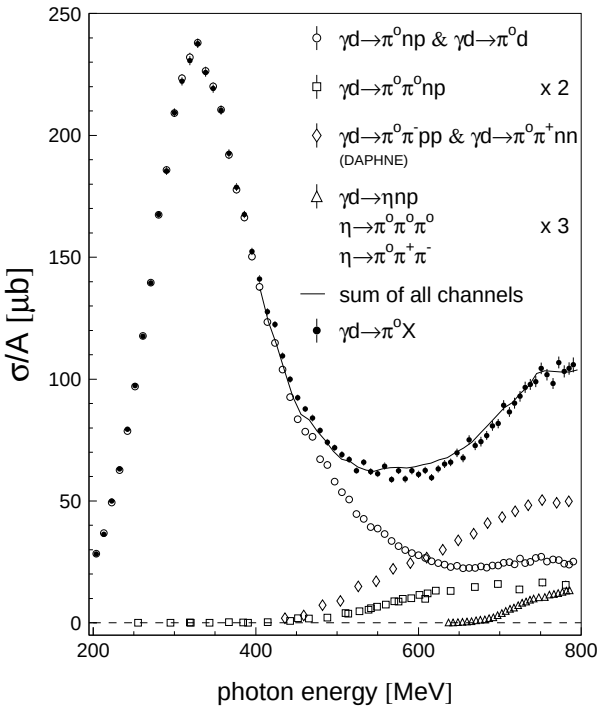

Fig. 1. Neutral meson photoproduction from the deuteron. The cross section for the final states $\pi^0\pi^- pp$ and $\pi^0\pi^+ nn$ was deduced from the DAPHNE data [13]. Quasifree cross sections for the other final states and for inclusive π^0-photoproduction were obtained with the TAPS-detector [5, 14]. The solid line shows the sum of all individually measured partial cross sections.

3. Inclusive and double π^0-photoproduction from heavy nuclei

In a previous experiment [7] we had investigated quasifree η-photoproduction from nuclei and found a strong final state interaction (FSI) of the η-meson in nuclear matter, leading to a scaling of the cross sections with $A^{2/3}$. Taking into account FSI-effects and medium effects in resonance excitation and decays like Fermi smearing and Pauli-blocking of final states, the cross sections were reproduced by several models [16–19]. No unexplained depletion of the in-medium strengths was observed, which is somewhat surprising in view of the results from total photoabsorption experiments [20].

Since η-photoproduction is completely dominated by the excitation of the $S_{11}(1535)$ resonance we have now extended this work to inclusive and double π^0-photoproduction [14] which is expected to be more sensitive to the excitation of the $D_{13}(1520)$ resonance. Total cross sections for inclusive π^0-photoproduction scaled to the nuclear mass numbers are shown in figure 2. The mass number dependence of the cross sections again indicates the expected strong FSI-effects. This is demonstrated in figure 3 where the cross sections scaled to $A^{2/3}$ and normalized to carbon are shown as function of the pion lab momenta. The cross sections scale almost perfectly like $A^{2/3}$ for momenta larger than 200 MeV, indicating, that only pions from the nuclear surface regions are observed. The excitation probability of the $\Delta(1232)$ resonance via pion absorption decreases at smaller pion momenta where the nuclei become more transparent for pions.

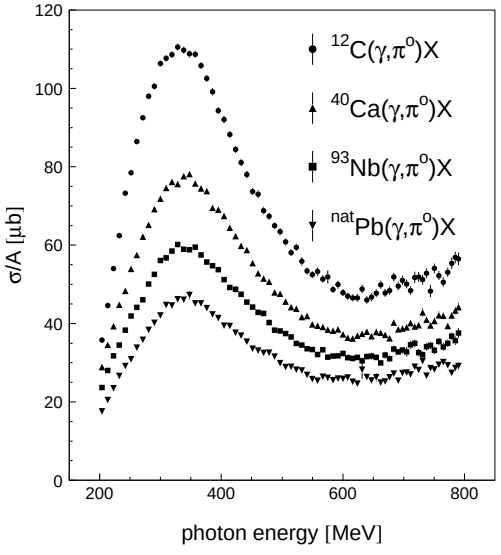

Fig. 2. Preliminary total cross sections for the reactions $\gamma A \rightarrow \pi^0 X$, A=^{12}C,^{40}Ca,^{93}Nb,$^{\rm nat}$Pb scaled to the nucleon numbers [14].

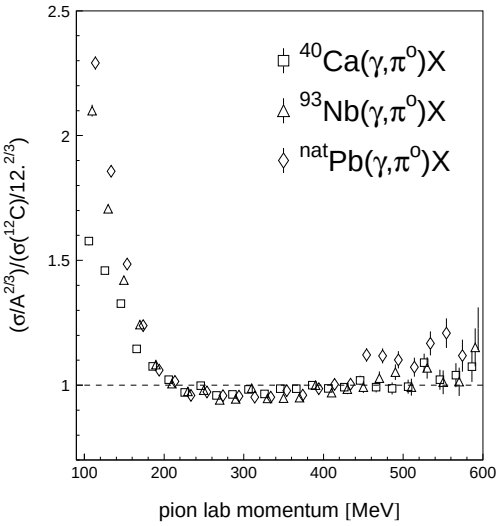

Fig. 3. Preliminary total cross sections for the reactions $\gamma A \rightarrow \pi^0 X$ for ^{40}Ca,^{93}Nb,$^{\rm nat}$Pb scaled by $A^{2/3}$ and normalized to carbon [14].

A detailed comparisons of total cross sections, angular and energy distributions to predictions in the framework of the BUU-model [21] is underway. Preliminary results seem to indicate, that in contrast to η-photoproduction the measured cross sections are overestimated by the model in the second resonance region, although the shapes of the differential cross sections are quite well reproduced.

From the subset of the data with more than two photons detected total cross sections for $2\pi^0$-photoproduction from nuclei were derived. So far only results below the η-photoproduction threshold were obtained because the statistical quality of the data is not good enough to separate the background produced by from $\eta \rightarrow 3\pi^0$-decays. A comparison of the preliminary results [14] to model predictions seems to indicate an even stronger overestimation of the data than in the case of inclusive π^0-production. Data with far better statistical quality will be measured in a dedicated TAPS experiment in 1999.

4. Coherent π^0-Photoproduction in the Δ-resonance region

Coherent π^0photoproduction in the Δ-resonance region is of particular interest as a tool for the study of possible in-medium modifications of the $\Delta(1232)$. Events from the coherent reaction were selected by a missing energy analysis, exploiting the kinematical overdetermination of this two-body reaction. Events from breakup reactions are completly removed by this cut. The energy resolution obtained so far is not good enough to suppress effectively incoherent events from the excitation of low lying nuclear states,

which however play only a minor role for the heavier nuclei due to the A^2-scaling of the coherent part.

The preliminary result [14] for the differential cross section on lead is shown in figure 4. The diffraction structure due to the nuclear mass formfactor is nicely visible. Detailed comparisons to models [22] in order to extract a medium induced mass shift and/or a broadening of the Δ-resonance are under way.

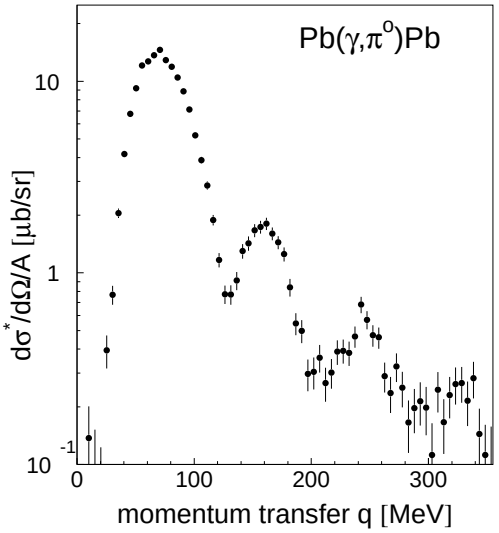

Fig. 4. Preliminary differential cross section for the reaction $\gamma\mathrm{Pb} \to \mathrm{Pb}\pi^0$ as function of momentum transfer averaged over incident photon energies from 200–250 MeV [14]

5. Second generation TAPS experiments at MAMI

The TAPS setup used for the experiments in 1995/96 is shown in figure 5. The structure at forward angles consists of BaF_2-plastic phoswich modules shown in figure 6. These detectors allow the separation of photons, protons, neutrons and deuterons based on pulseshape analysis [12]. An additional separation of photons, protons and deuterons by time-of-flight versus energy is possible. The setup therefore allows a clean identification of recoil nucleons and nuclei in coincidence with the meson decay photons, which is essential for the extraction of exclusive cross sections.

As an example a preliminary result for the identification of the reaction $\gamma d \to d\eta$ is shown in figure 7. The deuterons are clearly separated in the pulseshape plot at the left hand side. From the photons pairs measured in coincidence η-mesons are identified by the usual invariant mass analysis.

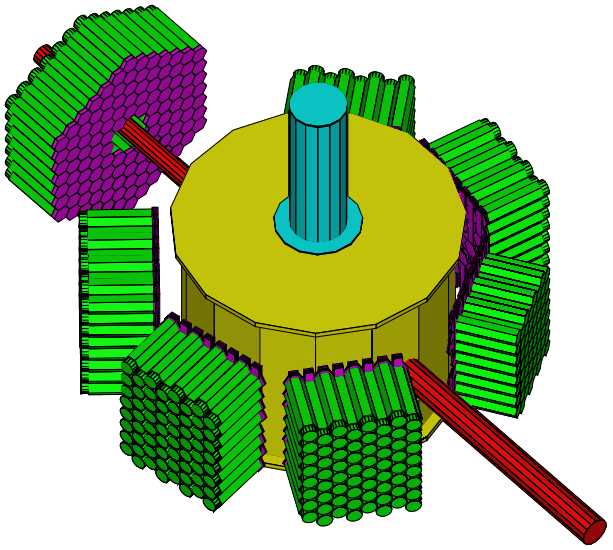

Fig. 5. TAPS setup used in Mainz in 1995/96. The photon beam comes from the lower right hand side.

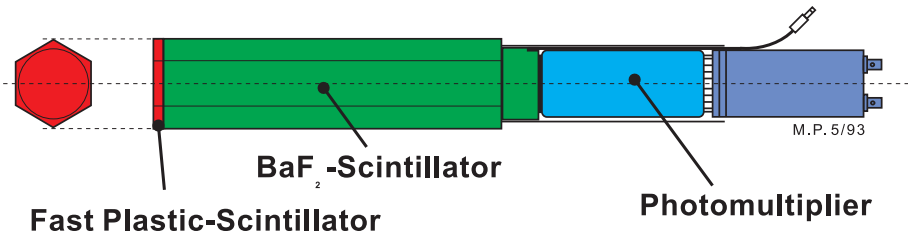

Fig. 6. Schematic view of a forward wall phoswich module

Only a small fraction of the data is shown. Time-of-flight versus energy separation of deuterons and protons and missing energy analyses for both, deuterons and η-mesons will be additionally applied so that the $\gamma d \to d\eta$ reaction can be measured practically free of background.

The experiments carried out with this setup are all still under analysis. Final results for coherent η-photoproduction from the deuteron and upper limits for this reaction from ^{4}He, exclusive quasifree η-photoproduction from the deuteron and ^{4}He with coincident registration of the recoil nucleons, as well as total cross sections and Dalitz-plots for the reactions $\gamma p \to p\pi^0\pi^0$ and $p \to n\pi^0\pi^+$ will be available within the next 12 months [23].

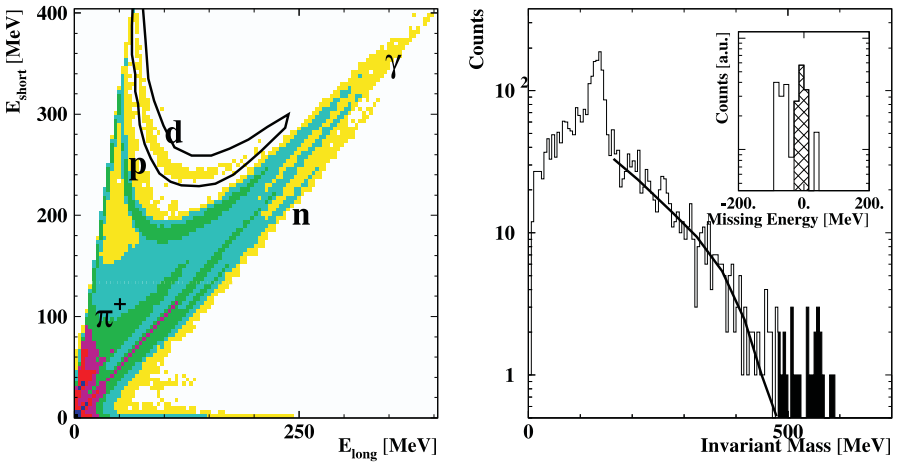

Fig. 7. Identification of coherent η-photoproduction from the deuteron. Preliminary results obtained from a small fraction of the data sample. The phoswich pulse shape spectrum is shown on the left hand side. The right hand side shows the invariant mass spectrum obtained in coincidence with deuterons. The insert shows a missing energy spectrum for events with an entry in the η-invariant mass range [23]

6. Third generation TAPS experiments at MAMI

The TAPS-detector will be brought back to MAMI in fall 1998. During 1999 a diverse program of new experiments will be carried out in Mainz, among others a high statistics measurement of double π^0-photoproduction close to threshold as test of chiral pertubation theory, a investigation of η-photoproduction from ^{3}He which is the best candidate for coherent η-photoproduction, a detailed study of quasifree double π^0-photoproduction from nuclei, and a measurement of coherent π^0-photoproduction from nuclei from threshold throughout the Δ-resonance with improved energy resolution. Furthermore TAPS will be combined with other subdetector systems like neutron time-of-flight walls and wire chambers in an attempt to measure the polarizability of the π^+-meson [24].

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