NUCLEON RESONANCES AND MESON PRODUCTION WITH TAPS AT MAMI *

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(Received August 7, 2000)

Results from experiments performed with the electromagnetic calorimeter TAPS in combination with the tagged photon beam facility at the MAMI accelerator in Mainz are presented. In this contribution the photoproduction of pion pairs from the proton is discussed. In addition, preliminary results of the $\pi^0\gamma$ decay of the Δ resonance are reported.

PACS numbers: 13.60.Le, 14.20.Gk, 25.20.Lj

1. Introduction

The aim of the TAPS research program with photon beams is an investigation of the structure of the nucleon by studying the photoexcitation of nucleon resonances and their subsequent meson decay. The nucleon resonances accessible with MAMI beam energies cover the second resonance region. In single-pion production the identification of the individual resonances is hindered by their large widths and strong overlap with each other. However, a separation is possible in double pion and η production processes. The following table lists the resonances along with their characteristic decay modes and total widths.

$P_{11}(1440)$	$N\pi\pi$	(30–40%)	≈350 MeV
$D_{13}(1520)$	$N\pi\pi$	(40–50%)	≈120 MeV
$S_{11}(1535)$	$N\eta$	(30–55%)	≈150 MeV

* Presented at the Meson 2000, Sixth International Workshop on Production, Properties and Interaction of Mesons, Cracow, Poland, May 19–23, 2000.

In photoabsorption experiments on nuclei a strong depletion of the second resonance region is observed and is connected to changes of hadron properties in the nuclear medium. Nucleon resonances mostly experience an appreciable broadening in nuclear matter. The largest effect is observed for the D_{13} resonance and may be attributed to its ρ-meson decay combined with the broading of the ρ spectral function the nuclear in medium [1–3].

A further investigation requires the study of double pion photoproduction as it is the dominant process in this energy region and the dominant decay channel of the ρ-meson. Precise measurements of the total cross section of all isospin channels have been achieved with the DAPHNE- [4, 5] and TAPS-detectors [6, 7] at MAMI. However, the identification of the reaction mechanisms requires more detailed information. Invariant mass distributions of the pion-pion and pion-nucleon pairs have been reported by the DAPHNE group for the $n(\gamma,\pi^0\pi^-)p$ reaction [8]. In this contribution preliminary results for the invariant mass distributions of the $p(\gamma,\pi^0\pi^0)p$ [9] and $p(\gamma,\pi^0\pi^+)p$ [10] reaction channels are discussed. In addition, preliminary results of an investigation of the reaction $\gamma p \to \pi^0\gamma p$ are presented where the photon is emitted from within the Δ resonance [11]. The goal is a first determination of the magnetic moment of the Δ^+ resonance.

2. Experimental setup

The experiments were performed with the TAPS detector in combination with the tagged photon beam facility at the MAMI accelerator in Mainz. Six detector blocks consisting of 64 BaF_2 plastic telescopes, respectively, and a forward wall of 120 telescopes were arranged in one plane around the scattering chamber. The detection system provides time-of-flight, energy, and pulse shape information of the detected particles. In addition, neutral/charged particle identification can be derived from thin plastic scintillators in front of the BaF_2 crystals. A description of the detector and the performance can be found in [12, 13]. In the experimental campaign, data sets using photon beams up to 850 MeV have been acquired where LH_2, LD_2 as well as heavier targets were employed.

3. Double pion photoproduction

The total cross sections for both $\pi^0\pi^0$ and $\pi^0\pi^+$ production from the proton (Fig. 1) stays below 30 nb from threshold up to 370 MeV and rises smoothly to higher energies. The cross section shows a broad peak at the mass pole of the D_{13} resonance (E_γ=740 MeV). The experimental results in comparison to calculations within the model of [14] demonstrate the dominance of this resonance. Appropriately for the neutral channel, this model

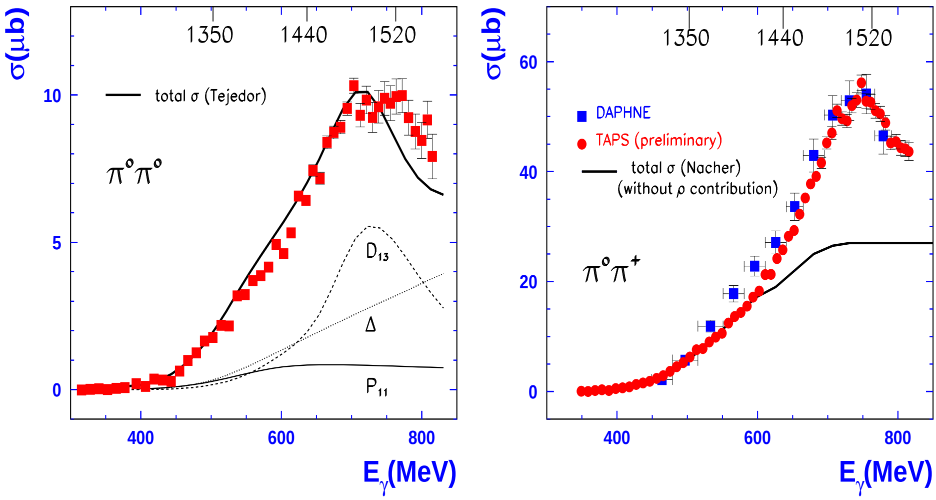

Fig. 1. Total cross section as a function of incident photon energy for $\pi^0\pi^0$ (left) and $\pi^0\pi^+$ production (right) off the proton. The lines correspond to models (see text). On the upper horizontal axis center-of-momentum energies are indicated. The figures are taken from Wolf *et al.* [9] and Langgärtner *et al.* [10].

does not include 2π production from the ρ meson decay. However, the calculation underpredicts the total $\pi^0\pi^+$ cross section by a factor of 2. In Fig. 2, $\pi^0 p$ invariant mass distributions are shown for different beam energies. A strong contribution of a sequential decay with the Δ resonance as intermediate state is observed in agreement with the calculations of [14]. The calculation is in reasonable agreement with the $\pi^0\pi^0$ distributions up to ~750 MeV as can also be seen in the total cross section. The comparison to pure phase space shows that the pions are indeed not strongly correlated. Presumably, the sequential decays originate from the D_{13}- and also the P_{11}-resonance. A comparison with the $\pi^+\pi^0 n$ exit channel is included in Fig. 2. Here, the $\pi^0\pi^+$ mass distributions are shifted towards higher masses. This is considered first evidence for a contribution of an intermediate ρ^+-meson to the 2π decay of the D_{13} resonance. In fact, a recent calculation [15] including this process describes the $\pi^0\pi^+$ mass distribution as well as the total cross section. The ρ-decay of the D_{13} resonance could explain the depletion of the photoabsorption cross section for nuclear matter as observed in the second resonance region because of the strong broadening of the ρ-meson in the nuclear medium and the associated broadening of the baryon resonance [1–3].

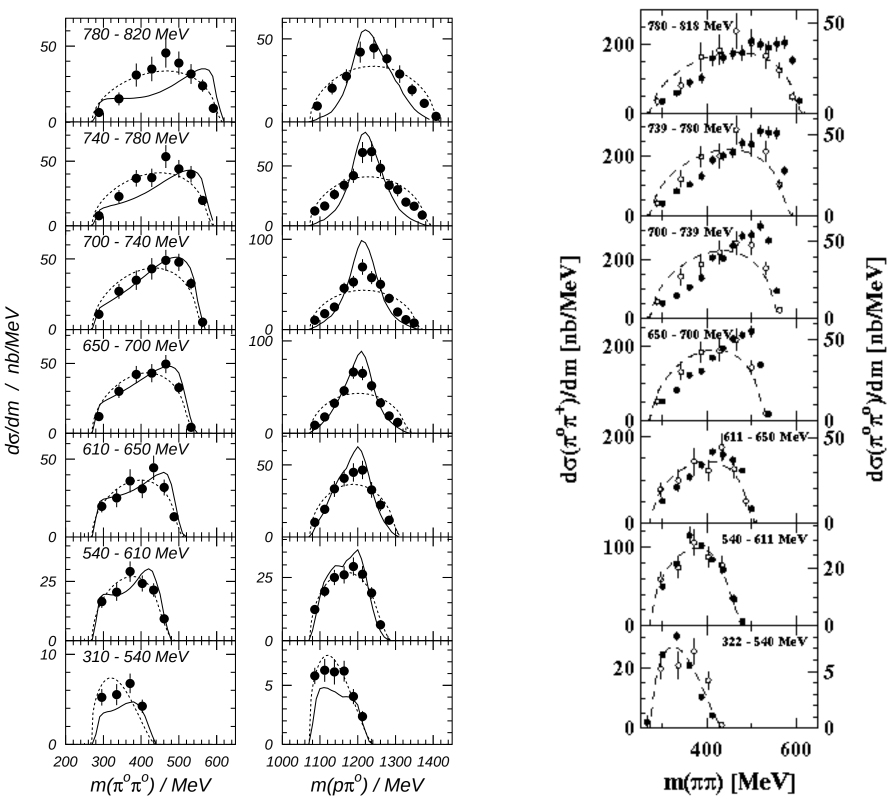

Fig. 2. Left: comparison of $\pi^0\pi^0$ and $p\pi^0$ mass distributions to pure phase space (dashed line) and model calculations [14]; right: comparison of $\pi^0\pi^0$ and $\pi^0\pi^+$ invariant mass distributions (dashed line: phase space).

4. The $\pi^0\gamma$ decay of the Δ resonance

Photons emitted from within the Δ^+ resonance are investigated in the reaction $p(\gamma,\pi^0\gamma)p$ with the aim of studying the electromagnetic properties of the Δ^+ isobar. In particular, the magnetic moment μ_{Δ^+} is at present not known. The total cross section for this process is predicted to be 17 nb from [16] and 5–10 nb from [17]. The contribution from bremsstrahlung alone is estimated to be of the order of 10 nb [18]. The small cross section combined with a noticeable background from $2\pi^0$ production make this experiment a challenge. However, the reaction channel has been identified in a pilot experiment and a very preliminary cross section of several nb has been extracted [11]. The present statistics do not allow a precise determination of the Δ^+ magnetic moment. It is planned to acquire additional statistics in upcoming experiments during the current TAPS campaign at MAMI.

This work was supported by Deutsche Forschungsgemeinschaft (SFB 201). The preliminary experimental results are parts of the theses of M. Kotulla, W. Langgärtner and M. Wolf (U. Giessen).

REFERENCES

[1] U. Mosel, *Prog. Part. Nucl. Phys.* **42**, 163 (1999).
[2] F. Klingl, *et al., Nucl. Phys.* **A624**, 527 (1997).
[3] G. Chanfray, *et al., Phys. Rev. Lett.* **76**, 368 (1996).
[4] A. Braghieri, *et al., Phys. Lett.* **B363**, 46 (1995).
[5] A. Zabrodin, *et al., Phys. Rev.* **C55**, R1617 (1997).
[6] F. Härter, *et al., Phys. Lett.* **B401**, 229 (1997).
[7] B. Krusche, *et al., Eur. Phys. J.* **A6**, 309 (1999).
[8] A. Zabrodin ,*et al., Phys. Rev.* **C60**, 5201 (1999).
[9] M. Wolf, *et al.,* submitted to *Eur. Phys. J.*
[10] W. Langgärtner, *et al.*, in preparation.
[11] M. Kotulla, *et al.*, in preparation.
[12] R. Novotny, *IEEE Trans. Nucl. Sci.* **38**, 379 (1991).
[13] A.R. Gabler, *et al., Nucl. Instrum. Methods* **A346**, 168 (1994).
[14] J.A. Gomez Tejedor, E. Oset, *Nucl. Phys.* **A600**, 413 (1996).
[15] J.C. Nacher, *et al.*, *Acta Phys. Pol.* **B31**, 2413 (2000).
[16] A.I. Machavariani, *et al., Nucl. Instrum. Methods* **A646**, 231 (1999) and private communication.
[17] D. Drechsel, *et al., Phys. Lett.* **B484**, 236 (2000).
[18] R. Timmermans, private communication.