Article ID: 1007－4627(2009)Suppl.－0104－05

π^0 Photoproduction on Deuteron for Photon Energies from 0.6 to 1.15 GeV*

F. Miyahara[1], H. Fukasawa[1], R. Hashimoto[1], T. Ishikawa[1], M. Itoh[2], T. Iwata[3], H. Kanda[4], J. Kasagi[1], H. Kato[3], T. Kinoshita[1], K. Maeda[4], M. Matsuzawa[4], T. Michigami[3], K. Motiduki[1], K. Murakami[3], T. Nakabayashi[1], K. Nawa[1], T. Nomura[3], K. Okamura[1], H. Okamura[5], H. Okuyama[3], Y. Onodera[1], Y. Saito[1], T. Sasaki[3], H. Shimizu[1], T. Shishido[3], S. Suzuki[1], K. Suzuki[1], Y. Tajima[3], S. Takita[3], T. Takahashi[6], H. Ueno[3], S. Yamaguchi[3], H. Yamazaki[1], H. Y. Yoshida[3]

(1 *Laboratory of Nuclear Science*, *Tohoku University Mikamine* 1-2-1, *Taihaku*, *Sendai*, *Miyagi* 982-0826, *Japan*;
2 *Cyclotoron and Radioisotope Center*, *Tohoku University*, *Sendai* 980-8578, *Japan*;
3 *Department of Physics*, *Yamagata University*, *Yamagata* 990-8560, *Japan*;
4 *Department of Physics*, *Tohoku University*, *Sendai* 980-8578, *Japan*;
5 *Research Center for Nuclear Physics*, *Osaka University*, *Ibaraki* 567-0047, *Japan*;
6 *KEK*, *Tsukuba* 305-0801, *Japan*;)

Abstract: Differential and total cross sections of the $\gamma p \to \pi^0 p$ and the $\gamma d \to \pi^0 pn$ reaction were measured for photon energies between 640 and 1 150 MeV. The data have been compared with SAID and MAID model calculations. π^0 photoproduction on the deuteron shows a strong suppression of the 2nd resonance which is clearly seen in the $\gamma p \to \pi^0 p$ reaction.

Key words: pion; photoproduction; resonance

CLC number: O572.33 **Document code**: A

1 Introduction

Photoproduction of neutral mesons is a good tool to understand nucleon resonances. Although the precise measurements of the $\gamma p \to \pi^0 p$ reaction have been performed, experimental data of π^0 photoproduction on the deuteron is very scarce for $E_\gamma > 800$ MeV. The experimental information of the resonances from the γd reaction is highly desired for the following reason.

Kuznetsov et al. recently reported a new narrow structure at around $W=1.67$ GeV in quasifree eta photoproduction on the neutron[1]. The same structure was observed in our preliminary data of the $\gamma d \to \eta pn$ reaction[2].

2 Experiment

The experiments were carried out with a tagged photon system at the Laboratory of Nuclear Science (LNS) at Tohoku University. It provided photons with energies form 0.58 to 0.88 GeV for 0.92 GeV electron beam, and from 0.75 to 1.15 GeV for 1.2 GeV electron beam. Typical tagging rate was about 2×10^7 photons/s.

Neutral pions produced in the solid hydrogen/

* **Received date**: 17 Sep. 2008

Biography: F. Miyahara (1977－), male (Japanese Nationality), Chiba, Japan, Doctoral Student, working on hadron physics; E-mail: miyahara@lns.tohoku.ac.jp

deuterium target were detected with an electro magnetic calorimeter SCISSORS II via their $\gamma\gamma$ decay. The SCISSORS II detector consists of 206 pure CsI crystals with plastic scintillators. The experimental setups were described in detail in Ref. [3].

The π^0 mesons were identified via an invariant mass analysis. In order to select the quasifree single π^0 photoproduction process, a missing mass analysis was performed. The missing mass is defined as

$$M_x = \sqrt{(E_\gamma + M_N - (E_1 + E_2))^2 - (\boldsymbol{k} - (\boldsymbol{k}_1 + \boldsymbol{k}_2))^2} , \quad (1)$$

where $(E_\gamma, \boldsymbol{k})$, $(E_i, \boldsymbol{k}_i)$ are energy-momentum of the incident and detected photon, respectively, and M_N is nucleon mass. The $\gamma\gamma$ events were sorted out into a bin with an angle step $\Delta\cos\theta^* = 0.1$ in the photon - nucleon center of mass system.

Fig. 1 shows the missing mass spectrum of the $\gamma N \rightarrow \pi^0 X$ deduced for $0.2 \leqslant \cos\theta^* < 0.3$ at $E_\gamma \approx$ 860 MeV on the deuteron target. The peak around

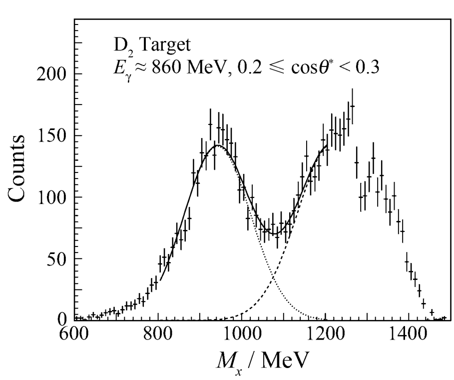

Fig. 1 Missing mass spectrum of the reaction $\gamma N \rightarrow \pi^0 X$.
— the results of fit to the missing mass spectrum. The function of the signal (quasifree peak) and the background are shown as ··· and --- curves, respectively.

940 MeV corresponds to quasifree single π^0 photoproduction. The bump at higher mass is considered to be due to multi pion production process. The tail of the bump causes background events, mainly, for the single π^0 production process, since the coherent π^0 photoproduction is negligible above $E_\gamma \approx 600$ MeV[4]. We have estimated the background by fitting the following function with the data:

$$f(M) = f_{\text{sig}}(M) + f_{\text{back}}(M) , \quad (2)$$

where f_{sig} is a logarithmic Gaussian function[5] and f_{back} is a Gaussian function. The yield of single π^0 photoproduction was deduced by subtracting the estimated background yields.

3 Results

The differential cross sections for the single π^0 photoproduction on the proton for $640 < E_\gamma <$ 1 150 MeV are shown in Fig. 2. The present results are plotted with closed circles and those of Bonn are plotted with squares. Both data sets are in good agreement with each other within errors. In the 2nd resonance region around $E_\gamma = 800$ MeV, angular distributions show a convex function due to $D_{13}(1520)$ resonance.

The total cross section was obtained by summing up the differential cross section. The differential cross section at the most forward and backward points ($\cos\theta^* < -0.9$, $\cos\theta^* > 0.9$), where acceptance of the detection system is almost zero, were estimated by extrapolation of the measured cross section. Fig. 3 shows the total cross section of single π^0 photoproduction on the proton. The present data were shown by closed circles in Fig. 3; those from Mainz[4, 6] are shown by diamonds and those of Bonn[7] are shown by squares. Our data slightly larger than the others. The solid and dashed lines are results of the SAID calculation[8, 9] and the unitary isobar model MAID[10, 11] calculation, respectively. Both calculations fairly reproduce the experimental data. However, the MAID calculation overestimates the experimental data for $E_\gamma < 660$ MeV and around the 2nd resonance peak. Ignoring the small discrepancies above $E_\gamma \approx 1\,020$ MeV, the SAID results better reproduce the experimental data than MAID calculation.

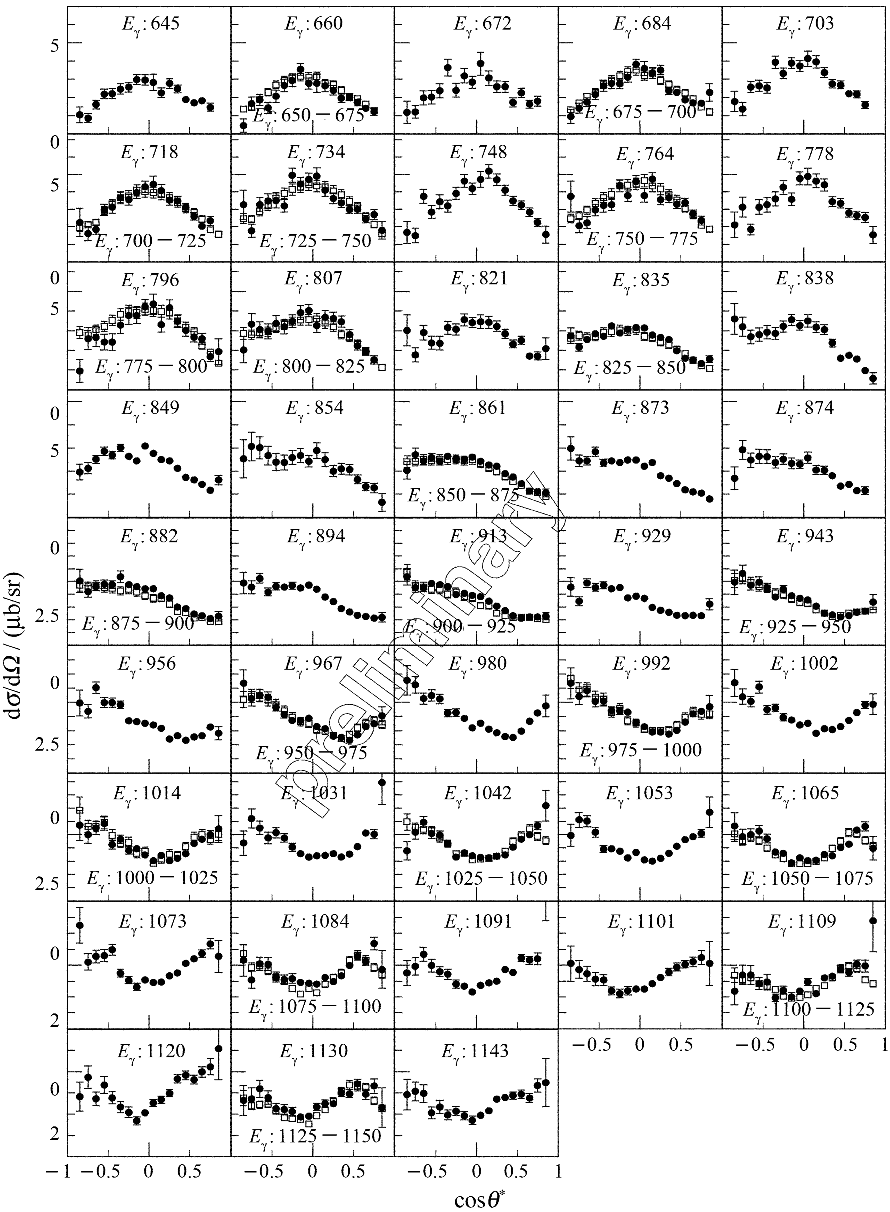

Fig. 2 Differential cross sections for $\gamma p \rightarrow \pi^0 p$ for energies from 0.6 to 1.15 GeV. ● the present result, □ from Bonn. Incident photon energies are in MeV (Bonn values are underneath).

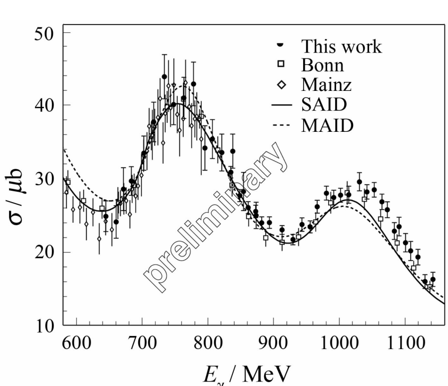

Fig. 3 Total cross section for $\gamma p \rightarrow \pi^0 p$.

Fig. 4 shows the differential cross sections of the d(γ, π^0)np reaction. The present results are shown by closed circles. For comparison, Mainz data for $E_\gamma < 800$ MeV are also shown by diamonds. Below the 2nd resonance peak, our results are in good agreement with the Mainz data.

Fig. 5 shows the total cross section as a function of E_γ. Our data, again, slightly larger than those of Mainz for $E_\gamma < 800$ MeV. Nevertheless, they cover the 2nd and the 3rd resonance region completely. The bumps of the 2nd and the 3rd resonance observed in $\gamma d \rightarrow \pi^0 pn$ reaction are broader than those in the $\gamma p \rightarrow \pi^0 p$ reaction.

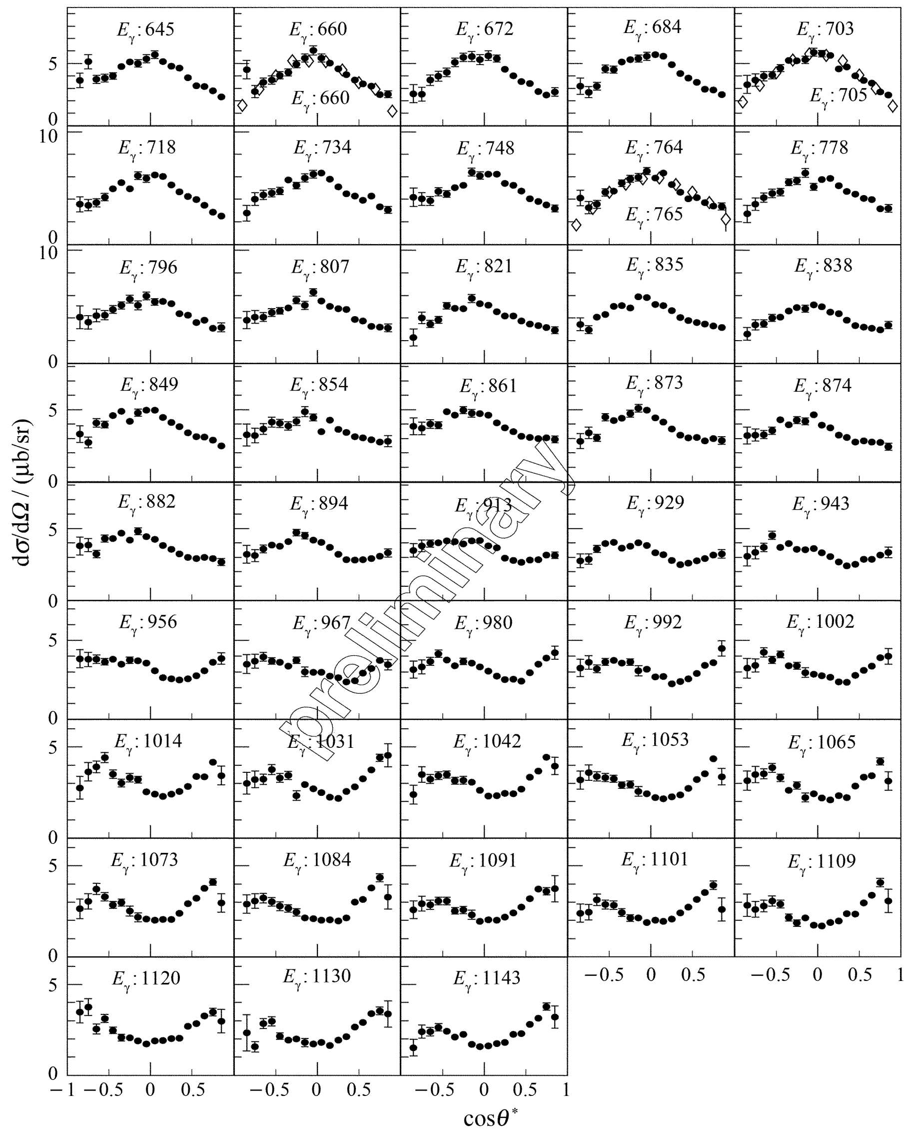

Fig. 4　Differential cross sections for single π^0 photoproduction from the deuteron.

● the present result, ◇ from Mainz.

To understand the shape of the excitation function in Fig. 5, we compared the experimental data with model calculations which take into account the momentum distribution of the bound nucleon. In Fig. 5, the data are compared with MAID model. The dotted line in Fig. 5 represents calculation of the total cross section of γ 'p' $\rightarrow \pi^0$p, where 'p' stands for the proton in the deuteron. The dashed line corresponds to the total cross section of γ 'n' $\rightarrow \pi^0$n reaction. The solid line represents the sum of γ 'p' $\rightarrow \pi^0$p and γ 'n' $\rightarrow \pi^0$n reactions. In the 2nd resonance region, the calculated values are about 1.3 times higher than the measured cross section. Above $E_\gamma \approx 900$ MeV, discrepancy between the calculated values and the data becomes small.

The triangles in Fig. 5 are the yields deduced by subtracting the 'p' yields from those of γd$\rightarrow \pi^0$pn. Thus, in a very naive picture, the triangles correspond to the total cross section of the γ 'n' $\rightarrow \pi^0$n reaction. As seen, the 2nd resonance peak in the neutron almost disappear, while the model calculation still shows a distinct peak structure.

The calculations based on the SAID model are shown in Fig. 6. The solid line corresponds to the $\gamma d \to \pi^0 pn$ reaction, and dotted line and dashed line represent γ 'p' $\to \pi^0$ p reaction and γ 'n' $\to \pi^0$ n reaction, respectively. The calculated values of the $\gamma d \to \pi^0 pn$ are, again, much larger than the experimental data for the 2nd resonance region.

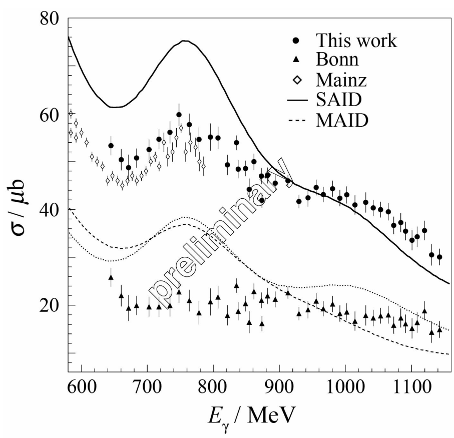

Fig. 5 Total cross section for $\gamma d \to \pi^0 pn$.

⋯ Model calculation for γ 'p' $\to \pi^0$ p, --- Model calculation for γ 'n' $\to \pi^0$ n, — sum of γ 'p' $\to \pi^0$ p and γ 'n' $\to \pi^0$ n. ▲ t the cross section of the γ 'n' $\to \pi^0$ n, which was deduced by subtracting the cross section of the γ 'p' $\to \pi^0$ p from the the measured cross section.

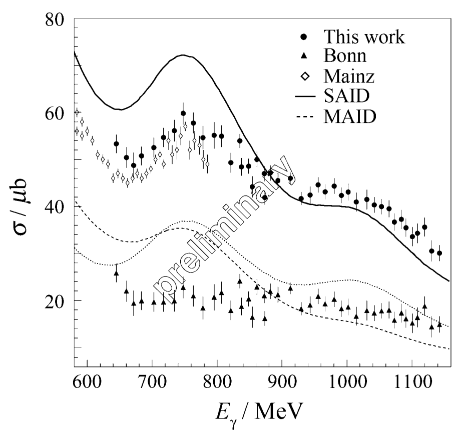

Fig. 6 Total cross section for $\gamma d \to \pi^0 pn$.

⋯ Model calculation for γ 'p' $\to \pi^0$ p, --- Model calculation for γ 'n' $\to \pi^0$ n, — sum of γ 'p' $\to \pi^0$ p and γ 'n' $\to \pi^0$ n. The calculations are based on SAID. The symbols are the same as Fig. 5.

4 Summary

We have measured differential and total cross sections of the $\gamma p \to \pi^0 p$ and the $\gamma d \to \pi^0 pn$ reaction for photon energies between 640 and 1 150 MeV. The cross section of the 2nd resonance region observed in the $\gamma d \to \pi^0 pn$ reaction is much smaller than the simple estimation of using the MAID and SAID models. The deduced total cross section which corresponds to the γ 'n' $\to \pi^0$ p reaction in a naive picture does not show the clear narrow structure observed in the γ 'n' $\to \eta$n reaction. The suppression of the cross section of single π^0 photoproduction in the 2nd resonance peaks are interesting and still open question.

References:

[1] Kuznetsov V, Chrikova S, Gervino G, *et al*. Phys Lett, 2007, B647: 23.

[2] Miyahara F, Kasagi J, Nakabayashi T, *et al*. Prog of Theo Phys, 2007, 168(Supp): 90.

[3] Nakabayashi T, Fukasawa H, Hashimoto R, *et al*. Phys Rev, 2006, C74: 035 202.

[4] Krusche B, Ahrens J, Beck R, *et al*. Euro Phys J, 1999, A6 : 309.

[5] Ikeda H, Satpathy A, Ahn S B, *et al*. Nucl Instr and Meth 2000, A441: 401.

[6] Härter F. Photoproduktion Neutraler Pionen am Proton im ersten und zweiten Resonanzgebiet (Ph. D.). Mainz, Germany: University of Mainz, 1—145. 1996, University of Mainz KPH15/96.

[7] Bartholomy O, Credé, Pee van H, *et al*. Phys Rev Lett, 2005, 94: 012 003.

[8] Arndt A R, Strakovsky I I, Workman L R, *et al*. Int J Mod Phys, 2003, A18: 449.

[9] Center for Nuclear Studies, Website, 2007, http://gwdac.phys.gwu.edu.

[10] Drechsel D, Kamalov Eur S S, Tiator L. Phys J, 2007, A34 : 69.

[11] Institute of Physics, University of Mainz, Website, 2007, http://www.kph.uni-mainz.de/MAID/maid2007.