PROCEEDINGS OF SCIENCE

π^0 and η photoproduction on the deuteron at $E_\gamma < 1.2$ GeV

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Baryon spectroscopy is important to understand Quantum Chromo-Dynamics (QCD) at low energies. We investigate exotic hadrons like pentaquark baryons which consist of five quarks at the lowest order of quark configuration. A nucleon resonance $N^*(1670)$ which is observed in η photoproduction on the neutron is a candidate of pentaquark baryons. A series of π^0 and η photoproduction experiments was carried out with an electro-magnetic calorimeter FOREST at Research Center for Electron Photon Science (ELPH), Tohoku University. The incident tagged bremsstrahlung photon energy ranges from 550 to 1150 MeV. The differential and total cross sections were obtained for π^0 and η photoproduction processes on the proton and the deuteron. The analysis of the nucleon and delta resonance contribution in π^0 and η photoproduction on the neutron is underway.

XV International Conference on Hadron Spectroscopy-Hadron 2013
4-8 November 2013
Nara, Japan

PoS(Hadron 2013)095

1. Introduction

Baryon spectroscopy is an important testing ground for understanding the fundamental theory QCD at low energies where the coupling constant becomes very large and perturbative calculations are not applicable. Among the effective theories in this energy scale, the constituent quark model, which describes baryons with three valence quarks, has succeeded, and well reproduces the ground state baryons. Yet, the phenomena that cannot be explained by the model have come out. Some excited baryons are still missing in spite of various experimental efforts [1]. The $\Lambda(1405)S_{01}$ is proposed as a superposition of two states having different properties [2]. A mass-order-reverse problem is claimed between $N(1535)S_{11}$ and $N(1440)P_{11}$, and between $N(1535)$ and $\Lambda(1405)$ [3]. Evidences for Θ^+ pentaquark baryon are reported although its existence is still controversial [4]. These suggest that a new effective degree of freedom emerges such as diquark correlation in a hadron, meson-baryon molecule structure, and so on [5].

Meson photoproduction is utilized for baryon spectroscopy complementary to π-N elastic scattering. It should be noted that the formation of excited baryons highly depend on their production processes. Recently, a narrow resonance has been observed in η photoproduction on neutron. It was observed at Laboratory of Nuclear Science [6], which is the former name of ELPH at Tohoku University, GRAAL [7] and CB-ELSA [8]. The resonance would be attributed to a member of anti-decuplet pentaquark baryons since no signature corresponding to this bump has been observed so far in the proton channel. Fig. 1 shows the baryon octet and anti-decuplet pentaquark baryons. Although the N_5^0 member can be photoproduced from the neutron, photoproduction of the N_5^+ member having a U-spin of 3/2 is forbidden due to the U-spin conservation because the U-spin of the proton is 1/2 and that of the photon is 0. The baryon resonances have been studied by using various meson photoproduction reactions with an electro-magnetic (EM) calorimeter FOREST at ELPH.

2. Electro-magnetic calorimeter FOREST

Meson photoproduction experiments were carried out to investigate baryon resonances at ELPH, Tohoku University. Bremsstrahlung photons were used as a beam, being generated with a carbon fiber inserting into circulating 1200 or 920 MeV electrons in the STretcher Booster (STB) ring. Each photon was tagged by detecting the corresponding post-bremsstrahlung electron inside a bending magnet of the ring. The details of the photon tagging counter STB-Tagger II are described elsewhere [9]. The energies of the tagged photon beam ranged from 740 to 1150 MeV for circulating 1200 MeV electrons and from 580 to 880 MeV for 920 MeV ones.

Two γ rays from $\pi^0 \to \gamma\gamma$ or $\eta \to \gamma\gamma$ were detected with an EM calorimeter complex FOREST. The details of the design are described elsewhere [10]. FOREST consists of different three EM calorimeters: the forward, central, and backward calorimeters consist of 192 pure CsI crystals, 252

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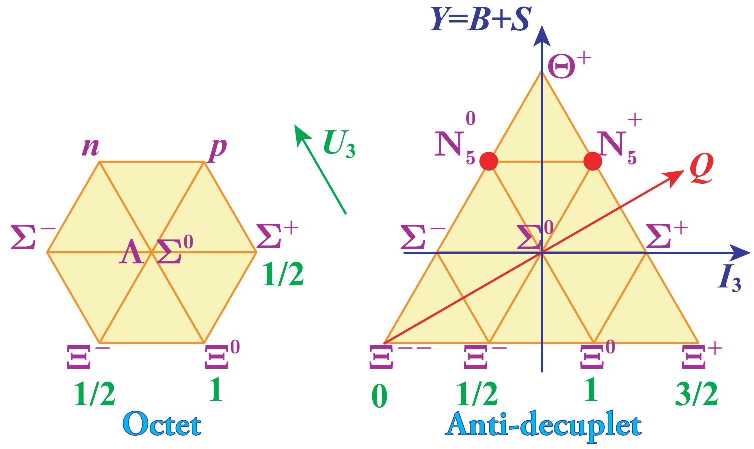

Figure 1: Octet baryons and anti-decuplet pentaquark baryons.

lead scintillating fiber modules, 62 lead glass Čerenkov counters, respectively. Plastic scintillator (PS) hodoscopes are placed in front of each calorimeter. The developed FOREST cryogenic target system [11] enables us to change targets within 6 hours. The high speed data acquisition system (DAQ) FOREST-DAQ dedicated to the FOREST experiments [12] was used. The DAQ efficiency was 76% at the trigger rate of 2 kHz.

3. Preliminary results

Two neutral clusters with the time difference between $[-1,+1)$ ns are selected as two photons from a π^0 and a η decay. A delayed cluster is identified as a nucleon. No other clusters and responses of PS is required in the time range $[-3,+12)$ ns. Since the accidental coincidence events exist between the photon tagging counter STB-Tagger II and FOREST, a sideband background subtraction is made. The five-constraint (5C) kinematical fitting is applied for the event selection where the $\gamma\gamma$ invariant mass constraint and four-momentum conservation are required.

The total cross sections as a function of the incident photon energy are obtained for π^0 and η photoproduction on the proton by using the hydrogen target events. Fig. 2 shows the preliminary results of the total cross section as a function of the incident photon energy. The total cross sections for π^0 and η photoproduction on the proton are consistent with the MAID, SAID, and BoGa calculations.

A similar kinematical fitting is applied for the analyses of the deuterium target where three vector for the momentum of the target nucleon is assumed to be measured as 0 with a resolution of 40 MeV/c. The energy of the target nucleon in the initial state is given by assuming the spectator nucleon should be on mass shell. As for η photoproduction, a similar bump is observed only in the neutron channel to the CB-ELSA one. The $D_{15}(1675)$ bump is observed in the proton channel and a clear bump is not observed in the neutron channel for π^0 photoproduction on the deuteron.

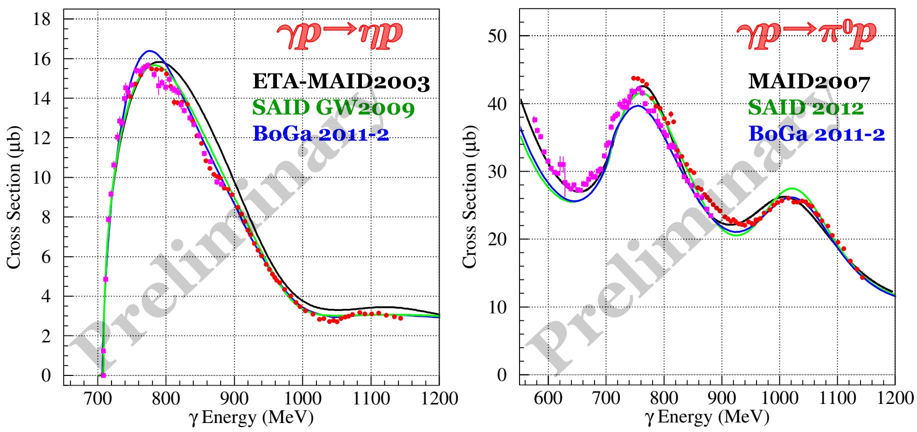

Figure 2: The total cross section as a function of the incident photon energy for π^0 (right) and η (left) photoproduction on the proton. The data obtained for different electron circulating energies 1200 and 920 MeV in the STB ring are described in different gray scales. The data are compared with the MAID [13, 14], SAID [15], BoGa [16] calculations.

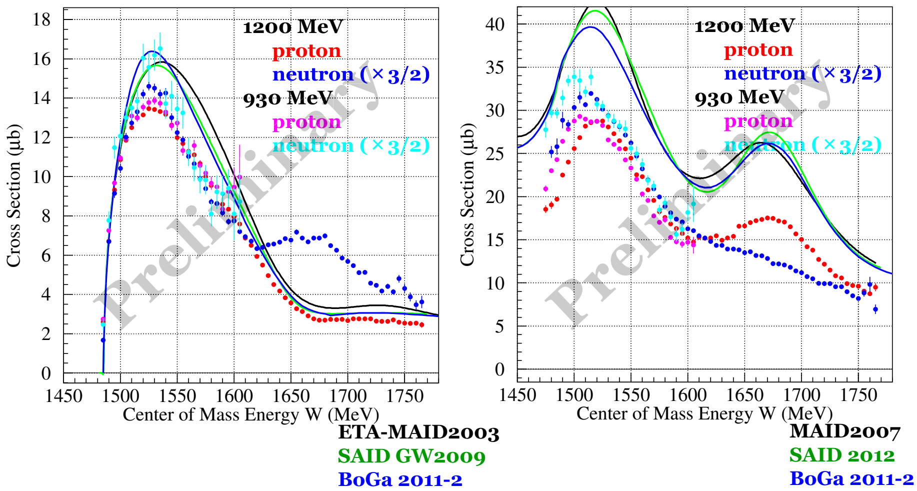

Figure 3: The total cross section as a function of the center of mass energy W for π^0 (right) and η (left) photoproduction on the proton and on the neutron in the deuterium target. The data obtained for different electron circulating energies 1200 and 920 MeV in the STB ring are described in different gray scales. The data are compared with the MAID [13, 14],SAID [15], BoGa [16] calculations.

4. Summary

The main purpose of the FOREST experiments is to study the nucleon resonance $N^*(1670)$, which is a candidate for one of the hidden strangeness members in the antidecuplet pentaquark baryons, via η photoproduction on the neutron. The preliminary results of the total and differential cross sections for the $\gamma p \to \pi^0 p$ and $\gamma p \to \eta p$ reactions are obtained. These are consistent with the SAID and MAID calculations. A bump has been observed around $W = 1670$ MeV in the total cross section for η photoproduction on the neutron, similarly to the CB-ELSA collaboration. The final results will be obtained after the further check of the detector response in the simulation.

Acknowledgment

This work was supported in part by Grant-in-Aid for Scientific Research (B) (17340063) and for Specially promoted Research (19002003).

References

[1] S. Capstick, W. Roberts: Prog. Part. Phys. **45**, S241 (2000);
K. Nakamura *et al*. (Particle Data Group): J. Phys. G **37**, 075021 (2010).

[2] D. Jido, E. Oset, A. Ramos, U.G. Meißner: Nucl. Phys. A **725**, 181 (2003).

[3] B.S. Zou: Nucl. Phys. A **790**, 110c (2007).

[4] T. Nakano *et al.*: Phys. Rev. C **79**, 025210 (2009), and references therein.

[5] M. Kaliner, H.J. Lipkin: Phys. Lett. B **575**, 249 (2003);
R.L. Jaffe, F. Wilczek: Phys. Rev. Lett. **91**, 232003 (2003).

[6] F. Miyahara *et al.*: Prog. Theor. Phys. Suppl. **168**, 90-96 (2007);
H. Shimizu: talk at NSTAR2007.

[7] V. Kuznetsov *et al.*: Phys. Lett. B **647**, 23 (2007).

[8] I. Jaegle *et al.*: Phys. Rev. Lett. **100**, 252002 (2008).

[9] T. Ishikawa *et al.*: Nucl. Instr. and Meth. A **622**, 1 (2010).

[10] T. Ishikawa *et al.*: ELPH Annual Report **1**, Tohoku University, 2012, p. 1 and references therein;
T. Ishikawa: International Journal of Modern Physics E **19** (2010) 2393.

[11] R. Hashimoto *et al.*: Research Report of LNS **41**, Tohoku University, 2009, p. 31.

[12] H. Fujimura *et al.*: Research Report of LNS **41**, Tohoku University, 2009, p. 26.

[13] D. Drechsel, S.S. Kamalov, L. Tiator: Eur. Phys. J. A **34**, 69 (2007);
web site for MAID: ⟨`http://wwwkph.kph.uni-mainz.de/MAID/maid2007/`⟩.

[14] W.-T. Chiang, S.N. Yang, L. Tiator, M. Vanderhaeghen, D. Drechsel: Phys. Rev. C **68**, 045202 (2003);
web site for η-MAID2003: ⟨`http://wwwkph.kph.uni-mainz.de/MAID/eta2003/`⟩.

[15] SAID, CNS Data Analysis Center, web site for SAID ⟨http://gwdac.phys.gwu.edu/⟩.

[16] Bonn-Gatchina Partial Wave Analysis (BoGa), web site for BoGa: ⟨http://pwa.hiskp.uni-bonn.de/⟩.