Backward-angle photoproduction of ω and η' mesons from protons at E_γ = 1.5 - 3.0 GeV

A linearly polarized photon beam with an energy of a few GeV can be produced by backward-Compton scattering (BCS) from head-on collisions between laser photons and 8-GeV electrons in the storage ring. Photon beam in the energy range from 1.5 to 3.0 GeV have been utilized for nuclear physics experiments at beamline **BL33LEP**. LEPS experiment has been performed to study nuclear science using 355-nm and deep-UV 257-nm lasers to produce Compton-scattered photons in the range of 1.5 to 2.4 GeV and 1.5 to 3.0 GeV, respectively.

Although many nucleon resonances have been identified using pion beam experiments, many resonances predicted by the constituent quark model remain to be discovered. This dilemma is known as the "Missing resonance problem". Some of these missing resonances may not be observed in pion beam experiment due to weak coupling with the pion. Therefore, measurements of meson production with a photon beam provide a complemental tool to study nucleon resonances. Recently, differential cross section and polarization variable of η, η' and ω mesons have been measured in experiments with large acceptance spectrometers such as CB-ELSA, GRAAL and CLAS. Partial wave analysis (PWA) of their results indicates a significant contribution from nucleon resonances in the differential cross section of meson photoproduction at large scattering angle ($\Theta_{CM} \sim \pi/2$) at $\sqrt{s} \sim 2$ GeV, although the list of resonances depends on models.

At backward angles in the center of mass system, the contribution from the baryon exchange (u-channel) should become significant. In general, the differential cross section from the baryon exchange is much smaller than that from the meson exchange, which has a significant contribution at forward angles. On the other hand, the angular distribution of mesons from nucleon resonances could have a rapid change at forward and backward angles when the nucleon resonances have high angular momenta. The contribution of nucleon resonances with high angular momenta tends to be stronger at forward and backward angles than at intermediate angles. Therefore, the differential cross section at backward angles is sensitive to nucleon resonances with high angular momenta and becomes a good tool to identify and search these resonances.

A new measurement was carried out at BL33LEP with a time projection chamber (TPC) to detect the decay products. We used a liquid hydrogen target. Production of ω and η' mesons was clearly identified by detecting protons at the LEPS forward spectrometer and pions at the TPC. In addition, the incident photon energy, E_γ, was extended to 3.0 GeV by using a new deep-UV laser.

The photoproduction of the ω and η' mesons were measured via the following decay modes:

$$\gamma\, p \to p\, \omega \to p\, \pi^+ \pi^- \pi^0$$
$$\gamma\, p \to p\, \eta' \to p\, \pi^+ \pi^- \eta$$

Protons were measured by the LEPS forward spectrometer. Charged pions were detected in the TPC. π^0 or η mesons were identified by the missing mass information to select the above reactions. The events generated in the target were selected by the determined position of the reaction point. The acceptance was evaluated using a Monte-Carlo simulation. The yields of detected ω and η' mesons were corrected by the number of photon, the number of target protons, and the efficiency to determine the differential cross sections.

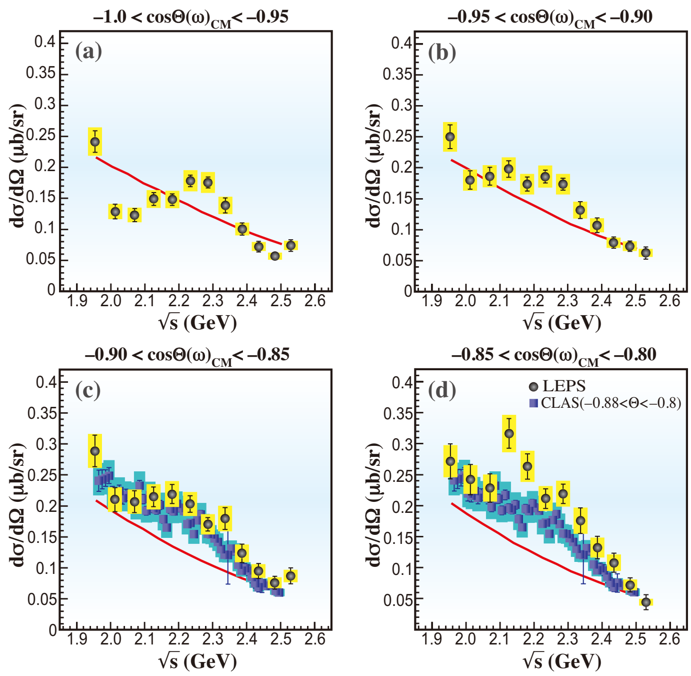

Fig. 1. Differential cross sections for ω photoproduction as a function of $\sqrt{s}$. Black circles are the present results [1]. Shaded bars represent the systematic uncertainty. Blue squares are the CLAS results [2]. Smooth lines represent the theoretical calculation [3].

Figure 1 shows the differential cross sections for ω production as a function of $\sqrt{s}$ [1-3]. Each panel shows the results in the ω scattering angle regions. In $-0.9<\cos\Theta_{CM}<-0.8$, the results of CLAS are consistent with the present results. The previous results of LEPS are also consistent with the present results. The differential cross section decreases as $\sqrt{s}$ increases above $\sqrt{s}$ ~2.3 GeV in all the scattering angle bins. The smooth lines in Fig. 1 represent the theoretical calculations, which do not include the contribution of nucleon resonances. The LEPS results show that the present $\sqrt{s}$ dependence of the differential cross section differs from the theoretical calculation implying that the present $\sqrt{s}$ dependence is difficult to explain by only the baryon exchange process, and that there is a significant contribution from nucleon resonances in this energy range.

A possible candidate with high angular momentum is $G_{17}(2190)$. The coupling of the $G_{17}(2190)$ to pω decay is supported by the analysis of the CLAS results [2]. The difference between the present data and the theoretical curve can be interpreted as an influence of $G_{17}(2190)$.

Figure 2 shows the differential cross sections for η' production as a function of $\sqrt{s}$ [1,4,5]. Each panel shows the results at the η' scattering angle regions. The results of CB-ELSA in $-1.0 < \cos\Theta_{CM} < -0.8$ are also shown in Fig. 2. The bump structure at $\sqrt{s}$ ~2.35 GeV appears clearer in the most backward scattering angle bins, $-1.0<\cos\Theta_{CM}<-0.90$. Theoretical calculation is also shown in Fig. 2. In the calculation, various parameters such as the resonance mass and width in this calculation are tuned to reproduce the various experimental results [4]. The dotted lines in Fig. 2 show the baryon exchange contribution in the theoretical calculation [4]. It should be mentioned that the theoretical baryon exchange contribution at $\sqrt{s}$ > 2.35 GeV is just an extrapolation. The dominant contribution at backward angles is from nucleon resonances at $\sqrt{s}$ < 2.10 GeV and the $\sqrt{s}$ ~ 2.35 GeV region according to the comparison between the LEPS results and the theoretical baryon exchange contribution. Since the rapid change at only the backward angle may indicate a resonance with a high angular momentum, PWA, including the present results that show the bump structure, will be important information to be clear for the involving nuclear resonance.

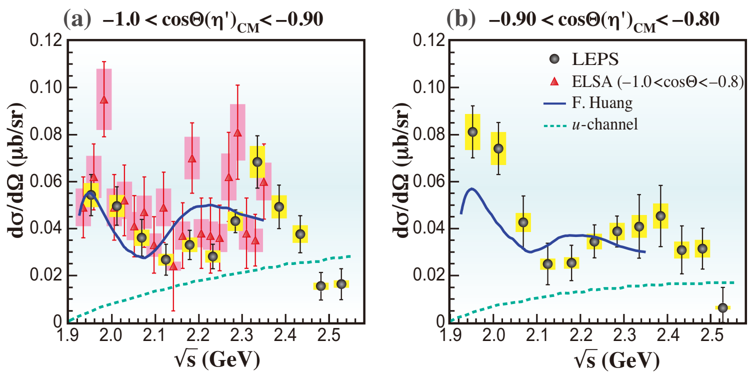

Fig. 2. Differential cross sections for η' photoproduction as a function of $\sqrt{s}$. Shaded bars represent the systematic uncertainty. Black circles are the present results [1]. Red triangles are the CB-ELSA results [5]. Smooth lines represent the theoretical calculation by F. Huang [4]. Dotted lines represent the *u*-channel contribution in F. Huang [4].

Yuhei Morino for the LEPS Collaboration

Institute of Particle and Nuclear Studies, KEK

E-mail: ymorino@post.kek.jp

References

[1] *Y. Morino, Y. Nakatsugawa, M. Yosoi, M. Niiyama, M. Sumihama, T. Nakano, D.S. Ahn, J.K. Ahn, S. Ajimura, W.C. Chang, J.Y. Chen, S. Daté, H. Fujimura, S. Fukui, K. Hicks, T. Hiraiwa, T. Hotta, S.H. Hwang, K. Imai, T. Ishikawa, Y. Kato, H. Kawai, M.J. Kim, H. Kohri, Y. Kon, P.J. Lin, K. Mase, Y. Maeda, M. Miyabe, N. Muramatsu, H. Noumi, Y. Ohashi, T. Ohta, M. Oka, J.D. Parker, C. Rangacharyulus, S.Y. Ryu, T. Saito, T. Sawada, H. Shimizu, E.A. Strokovsky, Y. Sugaya, K. Suzuki, K. Tanida, A. Tokiyasu, T. Tomioka, T. Tsunemi, M. Uchida, R. Yamamura and T. Yorita: Prog. Theor. Exp. Phys. (2015) 013D01.*
[2] M. Williams *et al.*: Phys. Rev. C **80** (2009) 065208.
[3] A. Sibirtsev *et al.*: nucl-th/0202083.
[4] F. Huang *et al.*: Phys. Rev. C **87** (2013) 054004.
[5] V. Crede *et al.*: Phys. Rev. C **80** (2009) 055202.