Coherent φ-Meson Photoproduction from Deuterium

The common behavior of high-energy diffractive processes of hadron-hadron and photon-hadron interactions is traditionally interpreted as the exchange of a Pomeron. The physical particles responsible for Pomeron exchange have not been conclusively identified, but such particles can exist in the strong interaction as glueballs, composite particles of gluons. The behavior of Pomeron exchange at low energies is not well understood because meson-exchange processes appear and become comparable near threshold.

A particularly interesting and unique way of studying the possible Pomeron exchange is φ(1020)-meson photoproduction from hadrons. In this reaction pseudo-scalar π-meson exchange is suppressed. Furthermore, with the use of an iso-scalar deuteron target, the coupling between iso-vector π-mesons and deuterons is forbidden due to iso-spin conservation. Accordingly, the coherent photoproduction of φ mesons from deuterons, $\gamma d \rightarrow \phi d$, becomes an excellent source of information for Pomeron dynamics at low energies.

We measured the differential cross sections and decay asymmetries of coherent φ-meson photoproduction from liquid deuterium target near threshold in the very forward direction with linearly polarized photons using the LEPS spectrometer in **BL33LEP**. Highly polarized photons were produced by backward Compton scattering with an ultra-violet Ar laser from 8 GeV electrons in the storage ring of SPring-8. The photon energy was determined by measuring the recoil electrons with a tagging spectrometer event by event. A liquid deuterium target with an effective length of 16 cm was employed. Charged particles produced at the targets were detected at forward angles with the LEPS spectrometer which consisted of a dipole magnet, a silicon-strip vertex detector, three multi-wire drift chambers, a plastic scintillator behind the target, and a time-of-flight hodoscope placed downstream of the tracking detectors.

The production of φ mesons was identified via the charged kaon decay mode with the detection of K^+ and K^- in the final state. A clear signal of φ mesons was seen in the invariant mass of K^+K^- pairs, for photon energy of 1.5-2.4 GeV as shown in Fig. 1(a). The separation of coherent ($\gamma d \rightarrow \phi d$) and incoherent ($\gamma d \rightarrow \phi pn$) interactions could not be performed on an event-by-event basis. Instead, the individual yields were disentangled by fitting the distributions of missing mass where the reaction of coherent production from deuterons, $\gamma d \rightarrow \phi d$, has a structure peaking at the mass of deuterons 1.875 GeV/c^2, as shown in Fig. 1(b). This distribution is nicely reproduced by the sum of individual ones generated by Monte Carlo simulations.

The cross section of coherent production at zero degree shows a strong increase with photon energy. A very large decay asymmetry of 0.48±0.07(stat)±0.07(sys) was observed, contrasting with a value of 0.2 from the proton. Within errors, our measurement reaches the maximum boundary corresponding to a pure natural-parity exchange process, showing that coherent φ-meson production from deuterons is predominantly from natural-parity processes. It is found that deduced $\gamma N \rightarrow \phi N$ cross sections for isoscalar t-channel exchange at zero

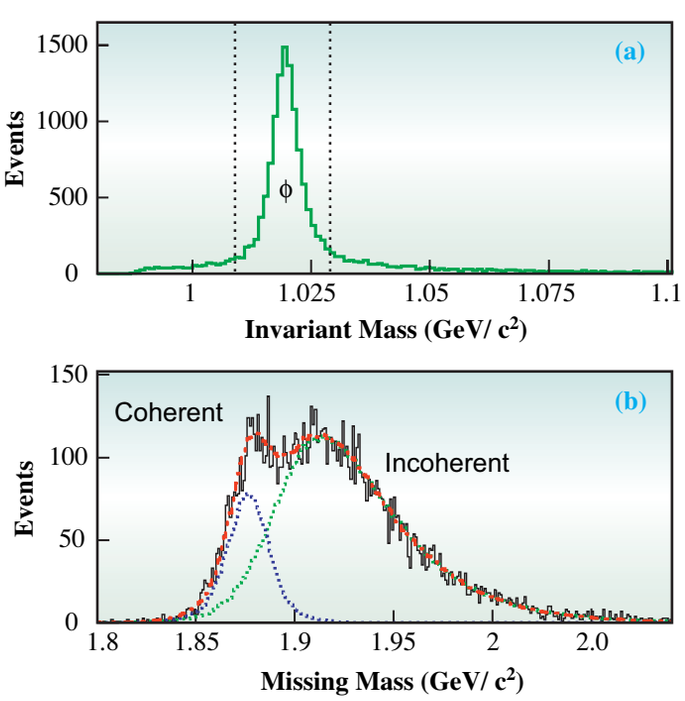

Fig. 1. **(a)** The distributions of invariant mass for the events with a K^+K^- pair. The two dashed lines on the distribution of invariant mass show the final cut to select the φ-meson events. **(b)** The missing mass spectrum together with fit of Monte-Carlo-simulated coherent and incoherent components.

degree as a function of beam energy were not consistent with the prediction of the conventional Pomeron model, shown in Fig. 2. Either a modified energy dependence for the Pomeron trajectory or additional natural-parity processes beyond Pomeron exchange in the near-threshold region would be compatible with our measurement. This measurement will serve as an important constraint on the theoretical modeling of Pomeron trajectory and additional exotic channels in the low-energy regime and help to understand the strong coupling region of Quantum Chromodynamics.

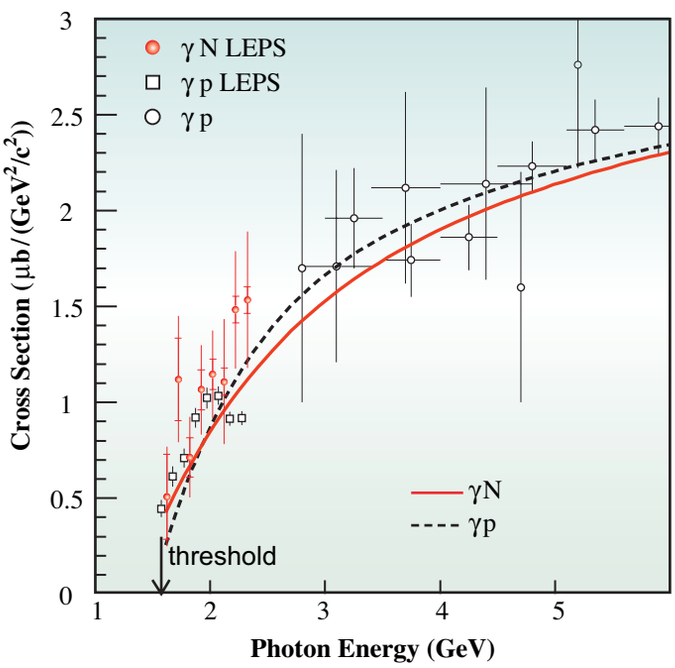

Fig. 2. Data of the cross section of ϕ-meson photoproduction from nucleons by iso-scalar t-channel exchange processes deduced from coherent production from deuterons in this work and the existing data of γp→ϕp up to photon energy equal to 6 GeV. The solid and dashed lines represent the predictions of conventional theoretical model including Pomeron and π-η exchange processes.

Wen-Chen Chang for the LEPS Collaboration

Institute of Physics, Academia Sinica, Taiwan

E-mail: changwc@phys.sinica.edu.tw

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[1] *W.C. Chang, K. Horie, S. Shimizu, M. Miyabe, D.S. Ahn, J.K. Ahn, H. Akimune, Y. Asano, S. Daté, H. Ejiri, S. Fukui, H. Fujimura, M. Fujiwara, S. Hasegawa, K. Hicks, T. Hotta, K. Imai, T. Ishikawa, T. Iwata, Y. Kato, H. Kawai, Z.Y. Kimi, K. Kino, H. Kohri, N. Kumagai, P.J. Lin, S. Makino, T. Matsuda, T. Matsumura, N. Matsuoka, T. Mibe, Y. Miyachi, M. Morita, N. Muramatsu, T. Nakano, M. Niiyama, M. Nomachi, Y. Ohashi, H. Ohkuma, T. Ooba, D.S. Oshuev, C. Rangacharyulu, A. Sakaguchi, T. Sasaki, P.M. Shagin, Y. Shiino, A. Shimizu, H. Shimizu, Y. Sugaya, M. Sumihama, Y. Toi, H. Toyokawa, A. Wakai, C.W. Wang, S.C. Wang, K. Yonehara, T. Yorita, M. Yoshimura, M. Yosoi, R.G.T. Zegers: Phys. Lett. B* ***658*** *(2008) 209.*