Measurement of ϕ-meson photoproduction near production threshold by SPring8/LEPS [1]

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Abstract. Decay asymmetry of ϕ meson (A_{ϕ}) with respect to the direction of photon polarization for the $\vec{\gamma}d \to \phi d$ reaction has been measured and compared with the $\vec{\gamma}p \to \phi p$ results. It was found that the decay asymmetry of the both reactions are positive, while the A_{ϕ} value of the deuteron reaction is about twice larger than that of the proton reaction.

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The gluonic aspect of quantum chromodynamics (QCD) has been of wide interest in hadron physics. It has been suggested that there is a connection between the glueball Regge trajectory ($J^{PC} = 2^{++}, 4^{++}...$) and the Pomeron trajectory [1]. The diffractive photoproduction of ϕ-mesons has been used to study the Pomeron exchange process [2] and to look for a exotic daughter Pomeron trajectory associated with a glueball ($J^{PC} = 0^{++}$) [3, 4]. This is because the baryon and meson exchange amplitudes in the s- and t-channels are suppressed by the Okubo-Zweig-Iizuka (OZI) rule. However, isovector π exchange still contribute to the ϕ photoproduction which makes extraction of the true exotic channel difficult. One of the possible solution to eliminate the contribution of these π-exchange precess is to use an isoscalar target such as deuteron. Here, we present a new measurement of decay asymmetry of ϕ meson with respect to the direction of photon polarization for the $\vec{\gamma}d \to \phi d$ reaction. The experiment was performed at the SPring8 facility by using linearly polarized photons in conjunction with the LEPS spectrometer system [5, 6], as shown in Fig.1. The design of the LEPS detector system is optimized for measuring ϕ mesons at forward angle by detecting K^+ and K^- from the $\phi \to K^+K^-$ decay. Comparing ϕ events with horizontally (HZ) and vertically (VT) polarized photons, the ϕ decay asymmetry was obtained by suppressing systematic errors due to detector acceptance distortions.

Photons with a maximum energy of 2.4 GeV were produced from backward-Compton scattering of 351-nm Ar laser off 8-GeV electrons in the SPring-8 storage ring. The photon energy was determined by analyzing momentum of the scattered electrons which were detected by a tagging counter system inside the ring. The photon polarization amounted 95% at the maximum photon energy and slightly decreased with decreasing the photon energy. The direction of the polarization was switched every 10 hours to reduce potential systematic effects. The ϕ mesons were produced by irradiating liquid-

[1] on behalf of the LEPS collaboration

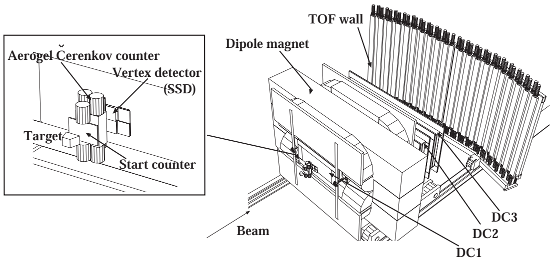

FIGURE 1. Schematic view of the LEPS detector configuration. Assembly details around the target system is shown in the inset.

deuterium target. Charged particles from the production target were tracked through a dipole magnet, and their momenta were analyzed using a silicon-strip vertex detector and three drift chambers. The momentum resolution for 1 GeV/c particles was achieved to be σ_p =6 MeV/c. Kaons were discriminated by calculating mass of the charged particles from the time-of-flight between TOF counters. Plastic scintillators located just behind the production target and an array of 40 plastic scintillators positioned 3m downstream from the magnet were used as TOF start and stop counters, respectively.

Specific cuts for the $d(\gamma,\phi)d$ selection are described below. Invariant mass of K^+ and K^- (M_{KK}) was required to be $1.009 < M_{KK} < 1.029$ GeV/c^2. The missing-mass $MM_{\gamma\phi}$ calculated by assuming the $d(\gamma,\phi)X$ kinematics was obtained, as shown in Fig. 2(a). Main background of this reaction is quasi-free $N(\gamma,\phi)N$ events. A Monte Carlo simulation for the $N(\gamma,\phi)N$ reaction was performed by taking into account Fermi motion and off-shell effect in deuteron system, as shown in Fig. 2(a) as dashed line. Fig. 2(b) shows the background-subtracted $MM_{\gamma\phi}$ distribution where peak position and peak width are consistent with deuteron rest mass and the expected value from the detector resolutions, respectively, indicating significant contribution from the $d(\gamma,\phi)d$ reaction in the data. Then, events with $MM_{\gamma\phi} < 1.9$ GeV/c^2 were selected, as shown in Fig. 2(a), while the quasi-free background events were still contained. Also, momentum transfer with $|t - t^d_{\rm min}| < 0.1$ GeV^2 was imposed to extract forward angle events, where $t^d_{\rm min}$ is the minimum momentum transfer allowed for the ϕ photoproduction.

The ϕ decay asymmetry, $A_\phi = \rho^1_{1-1} - {\rm Im}\rho^2_{1-1}$ value (see Ref. [8] for details), is introduced as an amplitude of the angular distribution of ϕ decay as [6, 7, 8], $W(\Phi) = 1 + P_\gamma A_\phi \cos 2\Phi$, where P_γ and Φ are magnitude of the photon polarization and K^+ emission angle with respect to the photon polarization direction, respectively. The ϕ photoproduction can be characterized as $A_\phi = 1$ for natural-parity exchange and -1 for unnatural-parity exchange. Here it should be noted that Pomeron and scalar meson contribute to the natural parity exchange, while pseudo-scalar mesons (π,η) contribute to unnatural-parity exchange [8].

The A_ϕ was determined as follows. The observed ϕ events (N) were separated into 8 regions by Φ with every $\pi/4$ step as,

$$[N(A)]_{pol} = \Omega(A) \cdot Y_{pol} \int_{\pi/4\cdot(A-1)}^{\pi/4\cdot A} W(\Phi) d\Phi \qquad (1)$$

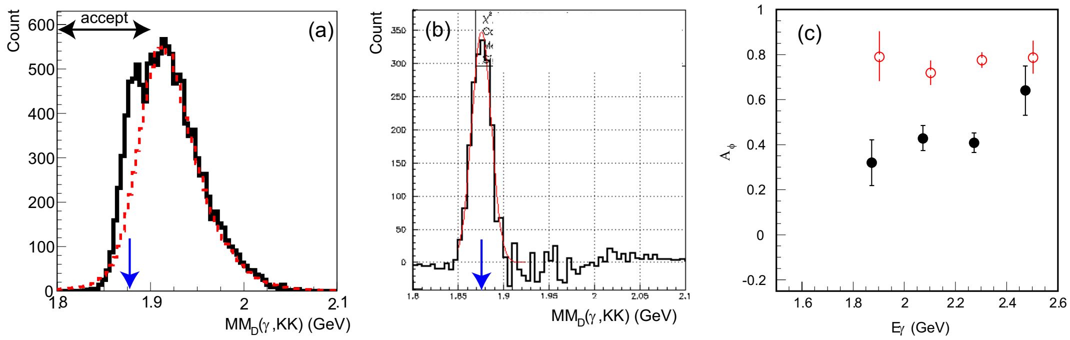

FIGURE 2. (a) is missing mass distribution for data (solid) and simulation with the quasi-free production(dashed). Missing mass subtracted the quasi-free events from the experimental sample is shown in (b). Arrows in (a) and (b) correspond to deuteron rest mass. (c) is ϕ decay asymmetry as a function of the photon energy for $d(\gamma,\phi)d$(open) and $p(\gamma,\phi)p$ (closed).

for $A = 1-8$, where Ω and Y denote the detector acceptance and the number of photons, respectively. *pol* corresponds to the photon polarization direction (HZ or VT). Here, double ratio quantities between the HZ and VT events were introduced as,

$$R_1 = [\frac{N(3)N(7)}{N(1)N(5)}]_{\mathrm{VT}}/[\frac{N(3)N(7)}{N(1)N(5)}]_{\mathrm{HZ}}, \quad R_2 = [\frac{N(2)N(6)}{N(4)N(8)}]_{\mathrm{VT}}/[\frac{N(2)N(6)}{N(4)N(8)}]_{\mathrm{HZ}}. \tag{2}$$

Then, error-weighted average of R_1 and R_2, R, was calculated. It should be noted Ω and Y are automatically canceled out. Substituting Eq.(1) into Eq.(2), A_ϕ was derived to be

$$A_\phi = \frac{1}{P_\gamma}\cdot\frac{\pi}{2}\cdot\frac{1-R^{1/4}}{1+R^{1/4}}, \tag{3}$$

where a factor of $\pi/2$ come from solid angle effect in the W integration.

The ϕ decay asymmetry of the $d(\gamma,\phi)d$ reaction was obtained as a function of the photon energy, as shown in Fig.2(c) as open circles. Also, using the same procedure, the decay asymmetry of the proton reaction, $p(\gamma,\phi)p$, was determined from liquid hydrogen target, as shown in Fig.2(c) as closed circle. It was found that the decay asymmetry of the both reactions are positive, while the A_ϕ value of the deuteron reaction is about twice larger than that of the proton reaction.

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