Evidence for the $\kappa(800)$ meson exchange in $\gamma p \rightarrow K^{*0}\Sigma^{+}$ reaction at $E_{\gamma} = 1.85\text{–}3.0$ GeV

In the simplest quark model, the lightest meson octet has 3 mesons with no strange quark, 4 mesons containing either a strange quark (s) or a strange antiquark ($\bar{s}$), and one meson with a dominant $s\bar{s}$ content. The ground-state pseudoscalar meson octet is well-established, and consists of three pions, four kaons, and an eta-meson. However, for the higher-mass mesons, the assignments are not clear. For example, the Particle Data Group (PDG) states that identification of the scalar mesons is "a long-standing puzzle." In particular, the κ-meson (presumed to be part of the lowest-mass scalar meson octet) with a resonance pole at about 800 MeV is seen in many phenomenological analyses, yet its existence is still controversial.

The quantum numbers of the κ-meson are $J^P = 0^+$ and I = 1/2. The κ is considered to be the scalar partner to the kaon in an analogous way as the σ-meson (also called the $f_0(600)$) is the scalar partner to the η-meson. Definitive evidence for the σ or κ-mesons would provide a significant advance in the understanding of possible multi-quark states. Here, we report on the linear polarization observables for K^* photoproduction measured using a proton target [1]. These observables, the spin-density matrix elements, have been shown to be sensitive to κ-meson exchange. In particular, Ref. [2] predicts that the $\kappa(800)$ contributes to K^* photoproduction through t-channel exchange, which dominates at forward scattering angles.

The parity spin asymmetry [2], given in terms of the spin density matrix elements by $P_\sigma = 2\rho^1_{1-1} - \rho^1_{00}$, is shown in Ref. [1] to be particularly sensitive to the role of κ-exchange, especially at forward angles. In the case of scalar κ exchange, the parity spin asymmetry is positive, whereas calculations without the κ (with pseudoscalar kaon exchange only) have negative parity spin asymmetry. The present data provide the first-ever reported parity spin asymmetry for K^{*0} photoproduction.

The experiment was carried out using the LEPS detector at beamline **BL33LEP**. The photon beam was produced by the laser backscattering technique [3] using a 275 nm laser, with wavelengths in the deep-UV region, to produce Compton-scattered photons in the range of 1.5 to 2.96 GeV. The laser light was linearly polarized with an average polarization of 98%. The photon beam was incident on a 15 cm liquid hydrogen target, where K^+ and π^- particles were produced and then passed through the LEPS spectrometer [4]. The invariant mass spectrum, calculated from the measured 4-vectors of detected K^+ and π^-, are shown in Fig. 1.

The decay angular distribution can be expressed in terms of nine spin-density matrix elements and linear polarization of the photon beam energy. We extracted the spin-density matrix elements using an unbinned extended maximum likelihood fit (see [5] for details) in the helicity frame and the beam energy region from 1.85 (threshold for $K^*\Sigma$ production) to 2.96 GeV. The K^* production angle $\cos\theta_{K^*}$ ranges from 0.6 to 1.0 and its average value is 0.9115.

Figure 2 shows decay angular distributions for a sum of horizontal and vertical beam polarizations with only a single variable, $\cos\theta_{K^+}$, ϕ_{K^+}, $(\phi - \Phi)_{K^+}$ and Φ_{K^+}, in the helicity frame [6]. Black histograms indicate the estimated Y^* background in the reconstructed Monte Carlo distribution.

The parity spin asymmetry ($P_\sigma = 2\rho^1_{1-1} - \rho^1_{00}$) is estimated to be 0.758±0.123 in the helicity frame over the angular range shown by the horizontal error bar in Fig. 3. The large positive asymmetry shows that the natural parity exchange is the dominant process at forward angles. The dashed (solid) line in Fig. 3 is the result with Model I (Model II) of Ref. [1] at E_γ = 2.5 GeV. The data clearly favors Model II, which includes a substantial contribution from natural-parity κ-exchange. The mass and width of the κ-meson are parameters of the theoretical model, and are not directly measured by the present data.

In summary, the photoproduction of the $\gamma p \rightarrow K^{*0}\Sigma^+$ reaction was measured at the LEPS detector at

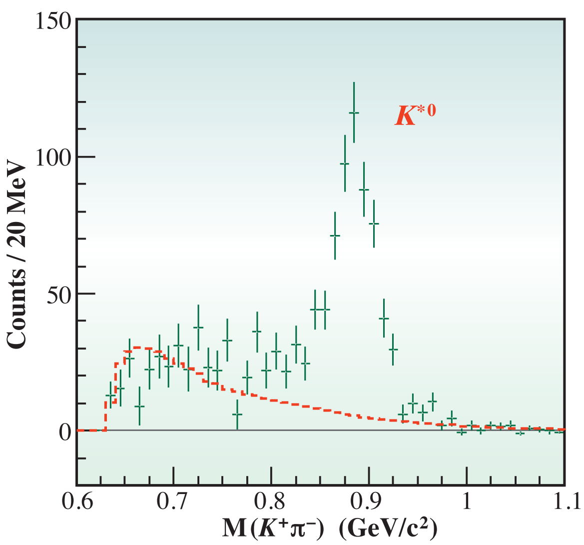

Fig. 1. The invariant mass distribution with a cut on the Σ^+ peak, and the overlaid dashed line shows the estimated Y^* background.

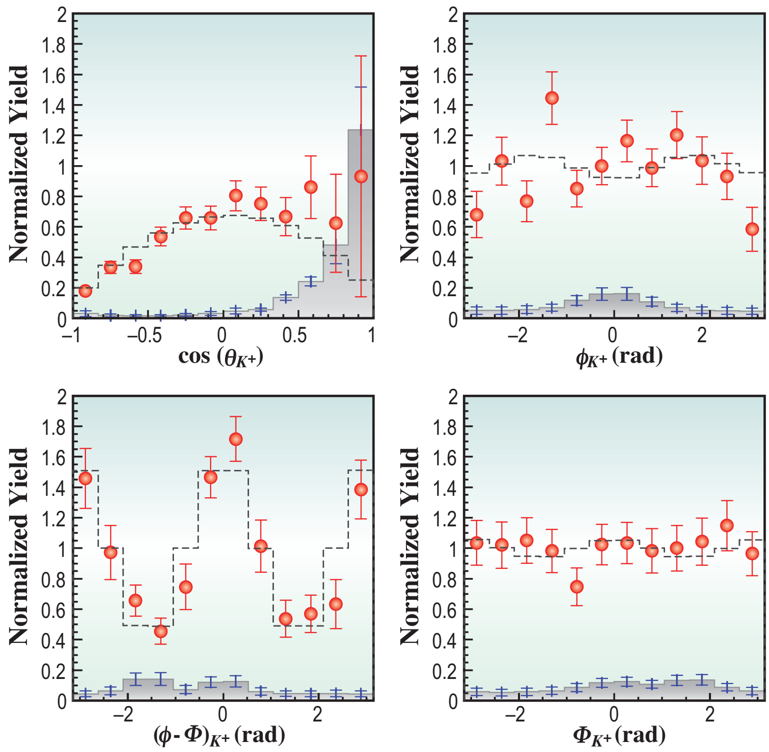

Fig. 2. Decay angular distributions of $\cos\theta_{K^+}$, ϕ_{K^+}, $(\phi - \Phi)_{K^+}$, and Φ_{K^+} in the helicity frame. The dashed line shows Monte-Carlo data using the measured spin-density matrix elements, while the overlaid grey histogram indicates the Y^* background yield from a Monte-Carlo simulation.

forward production angles and energies from 1.85 to 2.96 GeV, using a linearly polarized photon beam at BL33LEP. The parity spin asymmetry ($P_\sigma = 2\rho^1_{1-1} - \rho^1_{00}$) has a large positive value, showing that natural-parity exchange is dominant at forward angles for $K^{*0}\Sigma^+$ photoproduction. A natural explanation for the natural-parity exchange would be t-channel exchange of a scalar meson with strangeness, which is consistent with the κ-meson. The existence of this meson would be a good candidate to complete the lowest-mass scalar meson octet.

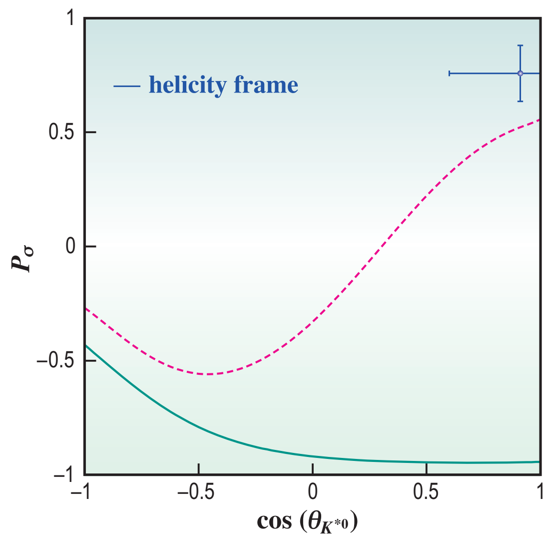

Fig. 3. Parity spin asymmetry ($P_\sigma = 2\rho^1_{1-1} - \rho^1_{00}$) in the helicity frame. The solid (dashed) line is the result of Model I (Model II) of Ref. [1] at E_γ = 2.5 GeV. Model I has almost no contribution from κ-exchange, whereas Model II includes substantial κ-exchange.

Jung Keun Ahn for the LEPS Collaboration

Dept. of Physics, Pusan National University, Korea

E-mail: ahnjk@pusan.ac.kr

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