THE PHOTOPRODUCTION CROSS SECTIONS OF $\Lambda(1520)$ AND $\bar{\Lambda}(1520)$

SIGUANG WANG
On behalf of the HERMES collaboration
School of physics, Peking University, Beijing 100871, China
E-mail: siguang@hep.pku.edu.cn

In this paper partial cross sections for photoproduction of the hyperons $\Lambda(1520)$ and $\bar{\Lambda}(1520)$, with longitudinal momentum along the beam axis $P_z > 6\,\mathrm{GeV}$, were presented separately using pK^- and $\bar{p}K^+$ decay mode. The results obtained by the HERMES spectrometer show that $\sigma_{\Lambda(1520)} = 65.3 \pm 8.8(stat) \pm 6.9(syst)$ nb and $\sigma_{\bar{\Lambda}(1520)} = 9.8 \pm 2.6(stat) \pm 0.9(syst)$ nb, giving the cross sections ratio between $\bar{\Lambda}(1520)$ and $\Lambda(1520)$ of $\frac{\sigma_{\bar{\Lambda}(1520)}}{\sigma_{\Lambda(1520)}} = 0.15 \pm 0.05(stat) \pm 0.02(syst)$.

1. Introduction

Recently, there has been a lot of interest in the resonance $\Lambda(1520)$, which has a mass close to the mass of the exotic Θ^+. Results of the LEPS experiment point to similar production mechanism for Θ^+ and $\Lambda(1520)$ [1]. Moreover, theorists are interested in the ratio of antihadron and hadron's cross sections, which could help understanding the Θ^+ production mechanism [2,3].

In HERMES, a search of Θ^+ via the decay $\Theta^+ \to pK_S^0 \to p\pi^+\pi^-$ with deuterium target resulted in 59 ± 16 Θ^+ candidate at the mass of $1528 \pm 2.6(stat)$ MeV [4], but evidence for its antiparticle($\bar{\Theta}^+ \to \bar{p}K_S^0 \to \bar{p}\pi^+\pi^-$) has not yet been seen. The resulting spectrum of the invariant mass of the $p\pi^+\pi^-$ with Θ^+ resonance is displayed in Fig. 1 while the spectrum of the $\bar{p}\pi^+\pi^-$ for its antiparticle is shown in Fig. 2. The event numbers under the bumps around 1530MeV on both invariant mass spectra of $p\pi^+\pi^-$ and $\bar{p}\pi^+\pi^-$ systems are from fits to the data of a Gaussian plus a third-order polynomial function. For the fit on $\bar{p}\pi^+\pi^-$, the width σ is constant and the value fixed according to the result of the fit to $p\pi^+\pi^-$ system. The number of events under the broad peak around 1530 MeV of 3 ± 6 indicates no evidence of $\bar{\Theta}^+$.

Based in the assumption that $\Lambda(1520)$ and θ^+ have the same production mechanism, the ratio between events number of $\bar{\Lambda}(1520)$ and $\Lambda(1520)$ can be helpful to estimate the number of $\bar{\Theta}^+$ candidate that HERMES should see with the number of Θ^+ candidate seen.

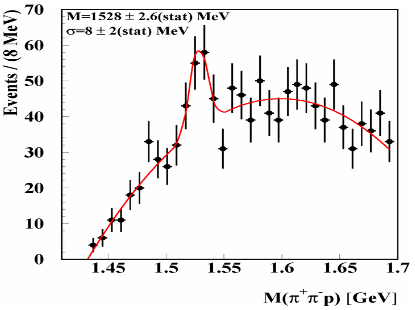

Figure 1. Invariant mass spectrum of $p\pi^+\pi^-$ system with evidence of Θ^+ resonance around 1528 MeV. Experimental data are represented by filled circles with statistical error bars. A fit to the data of a Gaussian plus a third-order polynomial function is shown with smooth curve.

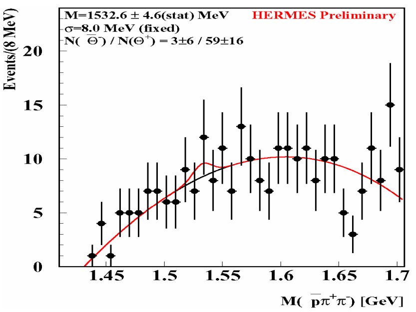

Figure 2. Similar spectrum as Fig. 1 but for $\bar{p}\pi^+\pi^-$ system in $\bar{\Theta}^+$ searching. A fit to the data of a Gaussian, with constant σ same as Θ^+ peak, plus a third-order polynomial function is shown.

2. Experiment

HERMES is an internal target experiment using the 27.5 GeV electron or positron beam at HERA storage ring in DESY [5]. The data for the photoproduction cross sections were obtained with a deuterium target and an integrated luminosity of $209pb^{-1}$. The number of inclusive photoproduction candidates of the $\Lambda(1520)$ and $\bar{\Lambda}(1520)$ were reconstructed via the decay $\Lambda(1520) \to pK^-$ and $\bar{\Lambda}(1520) \to \bar{p}K^+$, separately. Selected events contained at least two oppositely charged hadron tracks where one of them was identified as kaon and the other as proton. Particle identification(PID) was provided by a leadglass calorimeter, a preshower detector consisting of two radiation lengths of lead followed by a plastic scintillator hodoscope, a transition radiation detector consisting of six identical modules and a Ring-Imaging Cherenkov(RICH) detector, which provided separation of pion, kaon and proton over most of the kinematics acceptance of the spectrometer. In order to keep the contaminations for kaons and protons at negligible levels, protons were restricted to a momentum range of $4-9$GeV and kaons to a range of $2-15$ GeV where the RICH worked well.

In order to maximize the yield of the $\Lambda(1520)$ while minimizing its background, restrictions on the event topology pK^- system were applied. Based on the intrinsic tracking resolution, it was required a minimum distance of approach between the kaon and proton tracks less than 0.6 cm, a radial distance of the secondary vertex (cross point of kaon and proton) from HERA beam axis less than 0.4 cm, and a decay length of $\Lambda(1520)$ less than 5 cm due to the short life-time of the particle($c\tau \approx 12.6$ fm according to the full width of PDG value $\Gamma = 15.6$ MeV) and the tracking resolution of around 3 cm along beam direction. Mis-identified protons (actually kaons) were rejected by the reconstruction of a $\Phi(1020)$ with the K^- in pK^- pairs taking the p as K^+.

A similar method of event selection was applied on the invariant mass spectrum of $M_{\bar{p}K^+}$ system for observing the $\bar{\Lambda}(1520)$ resonance.

3. Results and Conclusion

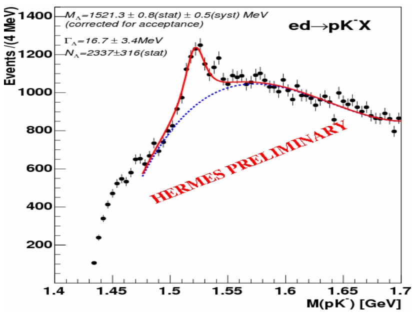

Figure 3. Spectrum of invariant mass of pK^- system with $\Lambda(1520)$ peak. A fit to the data of a BreitWigner function convoluted with a Gaussian plus a third-order polynomial is shown. The labeled position of the peak has been corrected from the effect of HERMES spectrometer acceptance.

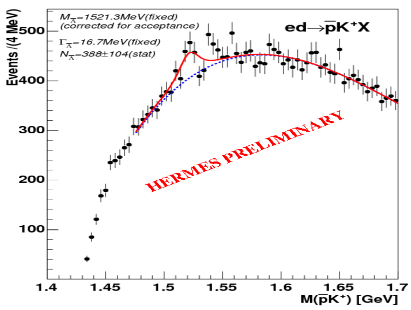

Figure 4. Similar spectrum as Fig. 3 except for $\bar{p}K^+$ system with $\bar{\Lambda}(1520)$ peak. The width and position of the $\bar{\Lambda}(1520)$ are fixed during fitting.

The invariant mass M_{pK^-} spectrum with $\Lambda(1520)$ peak and a spectrum of $M_{\bar{p}K^+}$ with $\bar{\Lambda}(1520)$ are shown in Fig. 3 and Fig. 4, respectively. The numbers of $\Lambda(1520)$ and $\bar{\Lambda}1520$ events labeled on the plots were obtained from fits to the data using a Breit-Wigner convoluted with a Gaussian function to describe the peak around 1520 MeV and with a third-order polynomial for the background description. Here Γ represents the intrinsic width of the hyperon's decay and σ for the intrinsic resolution of the HERMES spectrometer. According to Monte Carlo (MC) simulations, $\sigma = 4$ MeV for both pK^- and $\bar{p}K^+$ system . The peak position, the intrinsic width, and the number of $\Lambda(1520)$ were obtained with the fixed σ to fit the pK^- spectrum. Then the number of $\bar{\Lambda}(1520)$ events was extracted after performing another fit on the $\bar{p}K^+$ system assuming the peak position and the intrinsic width of $\bar{\Lambda}(1520)$ being same as those of $\Lambda(1520)$.

For the cross section calculations, the geometrical and kinematical acceptance of the HERMES spectrometer for pK^- and $\bar{p}K^+$ system was obtained from MC simulations. Here, the momentum distribution from Pythia was used with the requirement that the longitudinal momentum P_z of $\Lambda(1520)$ and $\bar{\Lambda}(1520)$ along z axis (along the beam direction) must be greater than 6 GeV. Both particles were assumed to be unpolarized.

The partial cross sections($P_z \geq 6$ GeV) were measured as: $\sigma_{\Lambda(1520)} = 65.3 \pm 8.8(stat) \pm 6.9(syst)$ nb and $\sigma_{\bar{\Lambda}(1520)} = 9.8 \pm 2.6(stat) \pm 0.9(syst)$ nb, giving the cross sections ratio between $\Lambda(\bar{1}520)$ and $\Lambda(1520)$ was $\frac{\sigma_{\bar{\Lambda}(1520)}}{\sigma_{\Lambda(1520)}} = 0.15 \pm 0.05(stat) \pm 0.02(syst)$. The systematic uncertainty of the acceptance was evaluated by MC, studying the effect on acceptance from differences in the initial momentum distributions. Monte Carlo results also showed the acceptance for both pK^- and $\bar{p}K^+$ system increases slowly and continually with the increasing of invariant mass in the interested region. Moreover the positions of peaks were shifted due to peak shape distorted by the change of acceptance.

The number of $\bar{\Theta}^+$ candidates that should be seen in HERMES based on assumption of the same production mechanism for $\Lambda(1520)$ and Θ^+, and on assumption of $\frac{N_{\bar{\Theta}^+}}{N_{\Theta^+}} = \frac{N_{\bar{\Lambda}}}{N_{\Lambda}}$ was estimated as: $10 \pm 4(stat)$, which agreed with experiment result, $3 \pm 6(stat)$, within statistical errors.

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