Transverse Polarization of $\Sigma^+(1189)$ in Photoproduction on a Hydrogen Target in CLAS

Hyperons produced in nuclear reactions were seen to be polarized normal to the production plane (a plane made by the momentum vector of the beam and the momentum vector of the hyperon, i.e., along $\hat{n}_z = \hat{p}_{\text{beam}} \times \hat{p}_{\text{hyperon}}/|\hat{p}_{\text{beam}} \times \hat{p}_{\text{hyperon}}|$) although neither the beam nor target were polarized. Based on a simple non-relativistic quark model, the ud quark-pair wave function in the Λ is anti-symmetric in both flavor and spin, and as a result, this quark pair does not carry a spin. Therefore, the Λ polarization is given by the strange quark. However, the ud quark pair in the Σ^0 is in a spin-1 state pointing in the direction of the Σ^0 spin. Then the spin $\frac{1}{2}$ of the Σ^0 is due to the opposite direction of the strange quark spin. The s quark is either produced polarized or else acquires it during recombination with the incident baryon fragments. Hence the polarization of the Λ and the Σ^0 should be similar in magnitude but opposite in direction. Recently, measurements of Λ and Σ^0 polarization with the highest statistical precision so far up to $\sqrt{s} \approx 2.84$ GeV have been completed using the CLAS detector at JLab [1, 2]. It shows that while this symmetry, $P_\Lambda \approx -P_{\Sigma^0}$, holds for backward production angles of the hyperon in the center-of-mass (c.m.) frame, it is broken for mid and forward hyperon production angles in the c.m. frame. Measurement of hyperon polarization is an important tool to understand the production mechanism of $s\bar{s}$ pair creation, including the s-quark polarization with subsequent polarization transfer to the produced hyperons.

We have measured the transverse polarization of the Σ^+ with the highest statistics so far in the photon energy range $E_\gamma = 1.0-3.5$ GeV ($\sqrt{s}$ range $1.66-2.73$ GeV) in photoproduction using data collected by the CLAS detector [3]. In this experiment both beam and target were unpolarized. The Σ^+ was reconstructed in the exclusive reaction $\gamma + p \rightarrow K^0_S + \Sigma^+$ via the $\Sigma^+ \rightarrow p\pi^0$ decay mode. The K^0_S was reconstructed in the invariant mass of two oppositely charged pions with the π^0 identified in the missing mass of the detected $p\pi^+\pi^-$ final state. We observed a large negative polarization of up to 95%, and the results are shown in Fig. 1. The trend of the polarizations near the resonance regime ($\sqrt{s} \approx 2.0$ GeV) and above the resonance regime ($\sqrt{s} \approx 2.5$ GeV) is different. Also, there is systematic differences of about 1 at $\sqrt{s} = 2$ GeV with the Σ^0 result [2]. The expectation, $P_\Lambda \approx -P_{\Sigma^+} \approx -P_{\Sigma^-} \approx -P_{\Sigma^0}$, based on SU(6) symmetry and the idea based on polarization of the s quark is broken in this case also. This difference in polarization might be due to the resonance effects of the different contributing s-channel states in these two mass ranges. For better understanding of the mechanism of polarization in the photoproduction process, and to understand the polarization mechanism at higher energy and at higher transverse momentum (p_T), measurements at even higher energies with good statistics are necessary. With the upgrade of CEBAF to 12 GeV, it is possible to address these questions with planned high statistics experiments at JLab.

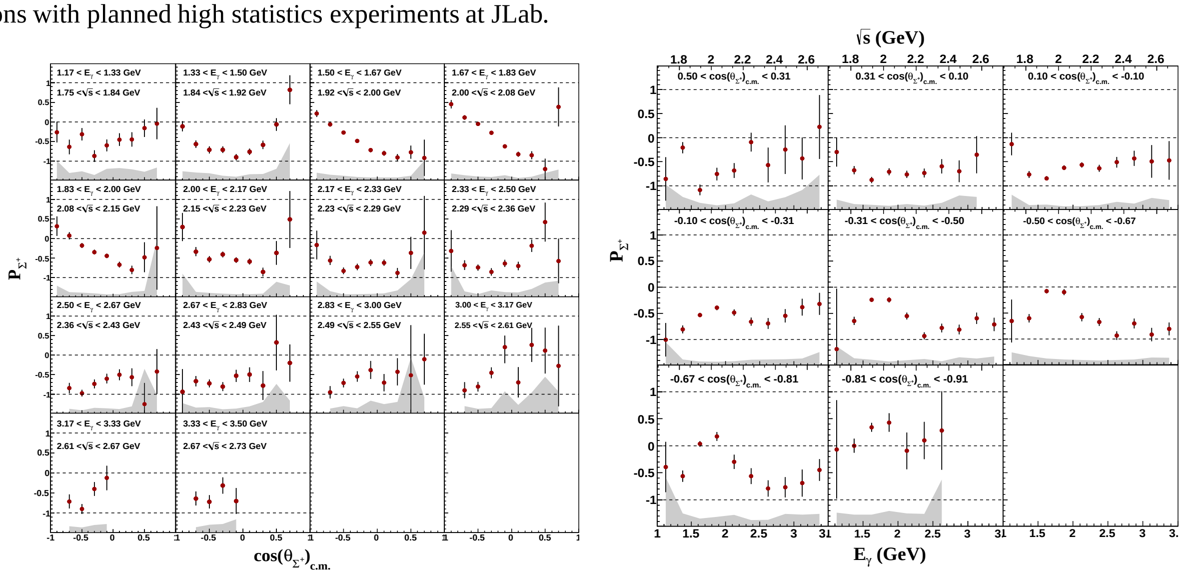

FIG. 1: Transverse polarization versus [a] $\cos(\theta_{\Sigma^+})_{\text{c.m.}}$ at different photon beam energy bins, [b] photon beam energy at different $\cos(\theta_{\Sigma^+})_{\text{c.m.}}$ bins. The bands on the horizontal axis are the systematic uncertainties.

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[2] B. Dey *et al.* [CLAS Collaboration], Phys. Rev. C **82**, 025202 (2010).
[3] C. S. Nepali *et al.* [CLAS Collaboration], Phys. Rev. C **87**, 045206 (2013).