Study of the Hyperon-Nucleon (YN) Interaction in Exclusive Λ Photoproduction off the Deuteron

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Abstract. This study aims to extract the polarization observables C_x, C_z, Σ, O_x, and O_z for final-state interactions (FSI) in $\vec{\gamma} d \to K^+ \vec{\Lambda} n$. The data were taken with the CEBAF Large Acceptance Spectrometer (CLAS) at the Thomas Jefferson National Accelerator Facility (JLab) during the E06-103 experiment. These are the very first results for FSI observables in hyperon photoproduction and are expected to constrain the free parameters of YN potentials. This work is funded in part by the U.S. NSF under grant PHY-125782.

1 Introduction

The YN interaction plays a key role in the understanding of hypernuclei and strange nuclear matter, and is an important part of the baryon-baryon interaction. While considerable progress has been made in the understanding of the nucleon-nucleon (NN) interaction, we are still far from a complete understanding of the YN interaction. Historically, a good NN potential is first constructed from meson-nucleon models, and then SU(3) symmetry is used to extend the NN potential to a YN potential. Due to the broken SU(3), there are free parameters in the YN potential, which must be obtained from fits to experimental data. Since experiments with hyperon beams or targets are difficult, high-statistics data on exclusive Λ photoproduction off the deuteron initiated with highly-polarized photons offer a unique opportunity to extract a large sample of polarization observables for FSI events, which can be used to constrain hyperon-nucleon potentials ([1] and references therein).

Exclusive hyperon photoproduction observables can be specifically used to extract a spin-averaged Λn scattering length from the Λn invariant-mass distribution by using the theoretical method of Ref. [2]. The method has been applied to inclusive K^+ hadro-production. Photoproduction data are expected to yield results with comparable systematic uncertainty.

While quasi-free (QF) Λ photoproduction is the main contributor to the cross section of the reaction $\vec{\gamma} d \to K^+ \vec{\Lambda} n$, exclusivity allows to reduce this contribution significantly by applying kinematic constraints, both in the data and in the theoretical models. This is expected to reduce the theoretical uncertainty in the interpretation of data.

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2 Experiment, Results, and Discussion

The data for this study were collected with the CLAS [3] at JLab. Both circularly- and linearly-polarized photon beams were generated during the E06-103 experiment [4]. The photons were incident on a 40-cm-long unpolarized liquid deuterium target. The self-analyzing power of the parity-violating Λ weak decay permits the determination of polarization transfers from the beam to the Λ [5]. Circularly-polarized photon beam, with polarization of 30% – 80%, gave access to C_x and C_z, while linearly-polarized photon beam, with polarization of 75%, gave access to Σ, O_x, and O_z.

After the reaction reconstruction, data were binned in different combinations of photon energy (E_γ), momentum of K^+ (p_K), polar angle of K^+ (θ_K), polar angle of Λ with respect to the momentum transferred to the Λn system (θ'_Λ), and invariant mass of Λn ($IM_{\Lambda n}$). Preliminary one- and multi-fold[1] differential estimates for FSI observables were determined. The one-fold differential estimates suggest that the observables are not sensitive to E_γ, but are sensitive to p_K, θ_K, and θ'_Λ. θ'_Λ dependent two-fold differential estimates for one bin in E_γ, p_K, and θ_K, respectively, are shown in Fig. 1, and clearly indicate that the available statistics is sufficient to produce meaningful results. Three- and four-fold estimates have also been extracted. These results will be fitted to theoretical models in order to constrain YN potentials. The distribution of each observable over $IM_{\Lambda n}$ can be used to extract the spin-averaged Λn scattering length [2]. These studies are in progress in collaboration with theorists.
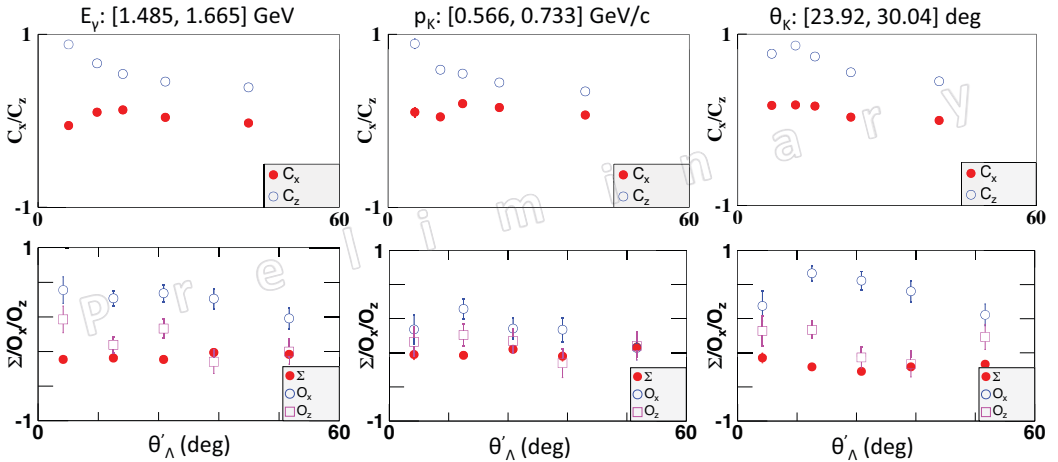

Figure 1. Preliminary two-fold differential estimates for FSI in the reaction $\vec{\gamma} d \to K^+ \vec{\Lambda} n$. The observables are shown as a function of θ'_Λ for fixed E_γ (left column), p_K (middle column), and θ_K (right column). The legend for the observables appears in the lower right corner of each panel.

References

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[1]N-fold estimate here means that data are binned simultaneously in N different kinematic variables