MEASUREMENTS OF $C_z$, $C_x$ FOR $K^+\Lambda$ AND $K^+\Sigma^0$ PHOTOPRODUCTION

ROBERT BRADFORD  
Department of Physics and Astronomy  
University of Rochester  
500 Wilson Boulevard  
Rochester, NY 14627-0171, USA  
E-mail: bradford@pas.rochester.edu

REINHARD SCHUMACHER  
Dept of Physics  
Carnegie Mellon University  
5000 Forbes Avenue  
Pittsburgh, PA 15213  
E-mail: schumacher@cmu.edu

FOR THE CLAS COLLABORATION.

The CLAS collaboration has recently completed first measurements of the double polarization observables $C_x$ and $C_z$ for the reactions $\gamma p \rightarrow K^+\Lambda$ and $\gamma p \rightarrow K^+\Sigma^0$. $C_x$ and $C_z$ are the beam-recoil polarization asymmetries measuring the polarization transfer from incoming circularly polarized photons to outgoing hyperons along two orthogonal directions in the production plane of the $K^+$-hyperon system. The $\Lambda$ is found to nearly maximally polarized along the direction of incident photon’s polarization for forward-going kaons. Polarization transfer to the $\Sigma^0$ is different from the $\Lambda$ case.

1. Introduction

Measurement of polarization observables have long been recognized as key to unraveling baryon production mechanisms. This work represents the first measurement of $C_x$ and $C_z$ for $\gamma p \rightarrow K^+\Lambda$ and $\gamma p \rightarrow K^+\Sigma^0$.

2. $C_x$ and $C_z$

$C_x$ and $C_z$ measure the polarization transfer from a circularly polarized incident photon beam to the recoiling $\Lambda$ or $\Sigma^0$ baryons along two orthogonal directions in the production plane of the $K^+$-hyperon system. The $\hat{x}$ and $\hat{z}$
directions are defined in the CM frame, with \( \hat{z} \) lying along the directions of the incident photon beam’s polarization. In this analysis, the polarization transfer was measured through the beam helicity asymmetry according to

\[
A_{x/z} (\cos \theta_p) = \frac{N^+ (\cos \theta_p) - N^- (\cos \theta_p)}{N^+ (\cos \theta_p) + N^- (\cos \theta_p)} = \alpha_{eff} \eta C_{x/z} \cos \theta_p
\]  

where \( \cos \theta_p \) is the direction of the proton from the hyperon’s decay measured in the hyperon rest frame with respect to the \( \hat{x} \) or \( \hat{z} \) axis. \( \eta \) is the polarization of the incident photon beam, \( N^+ (\cos \theta_p) \) and \( N^- (\cos \theta_p) \) are the beam helicity dependent hyperon yields in a given \( \cos \theta_p \) bin. \( \alpha_{eff} \) is the effective weak decay asymmetry parameter, and has a value of 0.642 for \( K^+ \Lambda \) and -0.165 for \( K^+ \Sigma^o \). The value of \( \alpha_{eff} \) for the \( \Sigma^o \) decay arises from our technique of measuring the proton distribution in the rest frame of the \( \Sigma^o \), not the \( \Lambda \); this dilutes its value to less than the nominal -0.642/3.

3. Experimental Setup and Analysis

The data were taken using the CLAS spectrometer in Hall B at Jefferson Lab. The experiment used a circularly polarized photon beam incident on a liquid hydrogen target. Data were taken with endpoint photon energies of 2.4 and 2.9 GeV. From this dataset, we also measured differential cross sections, which are currently available in preprint\(^1\).

All analyzed events were required to have explicit detection of the \( K^+ \) and proton. The \( \Lambda \) or \( \Sigma^o \) hyperons were identified in the \( p(\gamma, K^+) Y \) missing mass. The data were binned in beam helicity, the cosine of the kaon angle in the CM frame \( (\cos \theta_{KCM}) \), the cosine of the proton angle \( (\cos \theta_p) \) and photon energy \( (E_\gamma) \). Within kinematic each bin, yields were extracted by fitting a Gaussian peak to each hyperon in the missing mass spectrum. Backgrounds were modeled with a polynomial. The beam helicity asymmetry was plotted against \( \cos \theta_p \) and the slope of this distribution was extracted with a linear fit. Complete analysis details are available elsewhere\(^2\).

4. Results and Discussion

Sample results are presented in Figures 1 and 2. The data are plotted with predictions from the Kaon-MAID\(^4\) (solid line) and Janssen\(^3\) (dashed line) isobar models. The data plotted are for only a few representative bins in \( \cos \theta_{KCM} \). The full results include nine bins in \( \cos \theta_{KCM} \) for \( K^+ \Lambda \) and six bins for \( K^+ \Sigma^o \).
Figure 1. $C_x$ and $C_z$ for $K^+\Lambda$ in two different kaon-angle bins. Top: $\cos(\theta_K) = -0.75$, bottom: $\cos(\theta_K) = 0.25$. The data are a subset of the 2005 CLAS results. The curves are predictions from the Kaon-MAID (solid line, $^4$) and Janssen (dashed line, $^3$) isobar models.
Figure 2. $C_x$ and $C_z$ for $K^+\Sigma^0$ for $\cos(\theta_K) = 0.5$. The data are a subset the 2005 CLAS results. The curves are predictions from the Kaon-MAID (solid line, 4) and Janssen (dashed line, 3) isobar models.

The $\Lambda$ results show some $W$-dependent structure at backward kaon angles and then stabilize at more forward-going kaon angles. For this hyperon, $C_z$ is near one over most of the forward hemisphere of the kaon angle while $C_z$ is near zero for the same range.

The $K^+\Sigma^0$ results show no preferred direction for the polarization over the kaon angle range. The precision of these results here appears worse due to the small value of $\alpha_{eff}$.

Of the models shown, the Janssen does a good job of following the data. The MAID curve does not fair as well. This model has the oddity of predicting that $C_z$ saturates at -1 in $K^+\Lambda$ for forward-going kaons.

References
1. R. Bradford, et al. Preprint available at: nucl-ex/0509033. Submitted to Phys. Rev. C.
2. R. Bradford, Measurement of differential cross sections and $C_x$ and $C_z$ for $\gamma p \rightarrow K^+\Lambda$ and $\gamma p \rightarrow K^+\Sigma^0$ using CLAS at Jefferson Lab. Ph.D. thesis, Carnegie Mellon University, 2005, to be published. Available on-line at: http://www.jlab.org/Hall-B/general/thesis/bradford/index.html
3. S. Janssen, Strangeness production on the nucleon. Ph.D. thesis, University of Gent, 2002.
4. F.X. Lee, et al., Nucl. Phys. A 695, 237 (2001).