Determination of the Polarization Observables $C_{x'}$, $C_{z'}$, and $P_{y'}$ for $\vec{\gamma}\mathrm{d} \rightarrow K^0\vec{\Lambda}(p)$ From g13 Data

CLAS Collaboration Meeting

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Overview

1. Overview and g13 data set
2. Selection of $K^0\Lambda$
3. Extraction of $C_{x'}$, $C_{z'}$, and $P_{y'}$
4. Very preliminary results
   - 1d fits
   - 2d fits
   - Maximum likelihood method (addition of $P_{y'}$)

Motivation

- Understanding the N^* spectrum is a major part of the research program at Jefferson Lab
- Recently, there has been significant work done on pseudo-scalar meson channels to understand the N^* spectrum
- For KY, largest contribution is from the proton where progress has been made ($\gamma p \rightarrow K^+\Lambda$ $N(1900)3/2+$)
- Main goal of the g13 proposal: provide 7 observables ($\frac{d\sigma}{d\Omega}$, P_y, Σ, $O_{x'/z'}$, $C_{x'/z'}$) on $\gamma n \rightarrow K^0\Lambda$ ($\star\star$ $N(2080)3/2-$)
- Current $K^0\Lambda$ studies in g13: **Charles Taylor** and **Nick Compton** are working on cross-sections, **Derek Glazier** working on linearly polarized photon data (Neil Hassal's PhD project)

		Status			Status as seen in —						
Particle	J^P	overall	πN	γN	$N\eta$	$N\sigma$	$N\omega$	ΛK	ΣK	$N\rho$	$\Delta\pi$
N	$1/2^+$	****									
$N(1440)$	$1/2^+$	****	****	****		***				*	***
$N(1520)$	$3/2^-$	****	****	****	***					***	***
$N(1535)$	$1/2^-$	****	****	****	****					**	*
$N(1650)$	$1/2^-$	****	****	***	***			***	**	**	***
$N(1675)$	$5/2^-$	****	****	***	*			*		*	***
$N(1680)$	$5/2^+$	****	****	****	*	**				***	***
$N(1685)$	$?^?$	*									
$N(1700)$	$3/2^-$	***	***	**	*			*	*	*	***
$N(1710)$	$1/2^+$	***	***	***	***		**	***	**	*	**
$N(1720)$	$3/2^+$	****	****	***	***			**	**	**	*
$N(1860)$	$5/2^+$	**	**							*	*
$N(1875)$	$3/2^-$	***	*	***			**	***	**		***
$N(1880)$	$1/2^+$	**	*	*		**		*			
$N(1895)$	$1/2^-$	**	*	**	**			**	*		
$N(1900)$	$3/2^+$	***	**	***	**		**	***	**	*	**
$N(1990)$	$7/2^+$	**	**	**					*		
$N(2000)$	$5/2^+$	**	*	**	**			**	*	**	
$N(2040)$	$3/2^+$	*									
$N(2060)$	$5/2^-$	**	**	**	*				**		
$N(2100)$	$1/2^+$	*									
$N(2150)$	$3/2^-$	**	**	**				**			**
$N(2190)$	$7/2^-$	****	****	***			*	**		*	
$N(2220)$	$9/2^+$	****	****								
$N(2250)$	$9/2^-$	****	****								
$N(2600)$	$11/2^-$	***	***								
$N(2700)$	$13/2^+$	**	**								

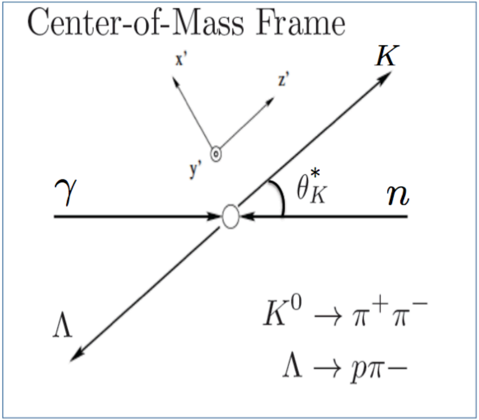
g13 Experiment

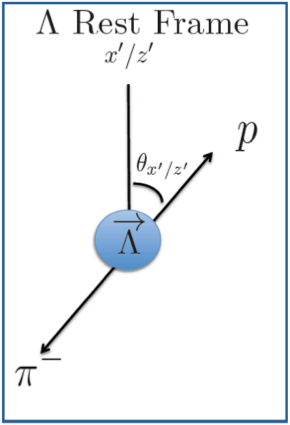
- Data for experiment E06–103 (g13) was taken at Jefferson Lab in 2006–2007
- g13a: circularly–polarized, g13b: linearly–polarized
- Both used a 40-cm long unpolarized LD_2 target
- e^- beam energies of 2.0 and 2.6 GeV for g13a

Person	Channel	Observable
Tongtong Cao	$\vec{\gamma}d \to K^+\vec{\Lambda}n)$	C_x, C_z, P_y
Nick Compton and Charles Taylor	$\gamma d \to K^0\Lambda(p)$	$\frac{d\sigma}{d\Omega}$
Olga Cortes	$\vec{\gamma}d \to \omega(n)$ and $\vec{\gamma}d \to \omega(p)$	Σ, ...
Derek Glazier (Neil Hassal)	$\vec{\gamma}d \to K^0\vec{\Lambda}(p)$	Σ
Paul Mattione	$\gamma d \to K^{*0}\Lambda(p)$ and $\gamma d \to K^+\Sigma^{*-}(p)$	$\frac{d\sigma}{d\Omega}$
Daria Sokhan	$\vec{\gamma}d \to p\pi^-(p)$	Σ
Nicholas Zachariou	$\vec{\gamma}d \to K^+\vec{\Lambda}n$	Σ, O_x, O_z

Observables for $\vec{\gamma} d \to K^0 \vec{\Lambda}(p_s)$

$$\frac{d\sigma}{d\Omega}^{\pm} = \sigma_0 (1 \pm \alpha \cos\theta_{x'} P_{circ} \mathbf{C_{x'}} \pm \alpha \cos\theta_{z'} P_{circ} \mathbf{C_{z'}} + \alpha \mathbf{P_{y'}} \cos\theta_{y'})$$

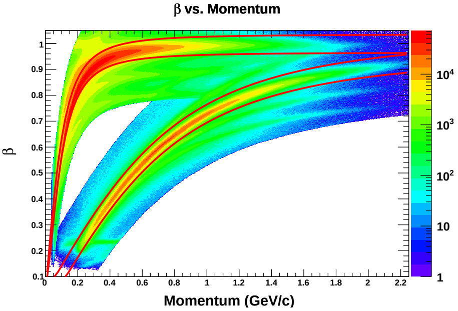




Analysis Overview: $\vec{\gamma} d \rightarrow K^0 \vec{\Lambda}(p)$

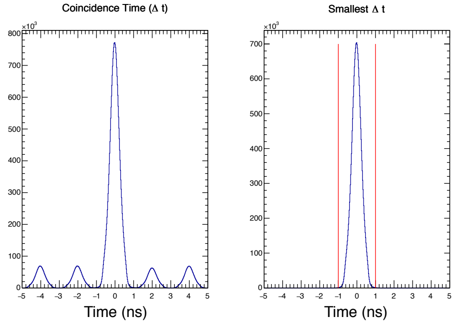
- $K^0 \rightarrow \pi^+\pi^-$ and $\Lambda \rightarrow p\pi^-$
- Select events which have 2 positive and 2 negative tracks

Particle Identification



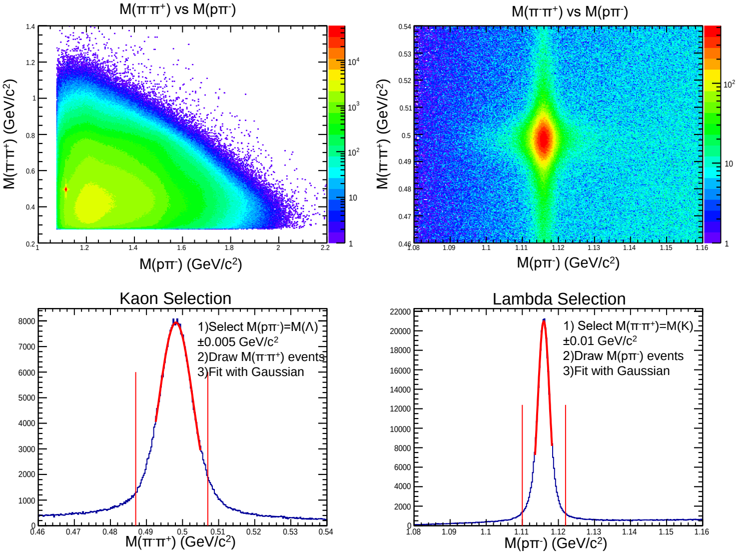
Particles were identified based on their velocity and momentum in CLAS ($\Delta\beta$ cut)

Photon Selection

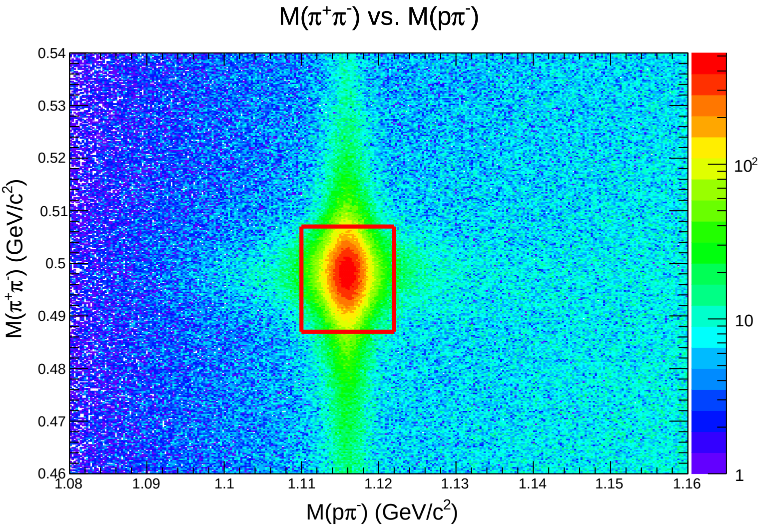


$\Delta t = t_v - t_\gamma$ where t_v is the reconstructed event vertex time using the trajectory in CLAS of the fastest particle and t_γ is the time that the photon arrived at the event location

Selection of K^0 and Λ



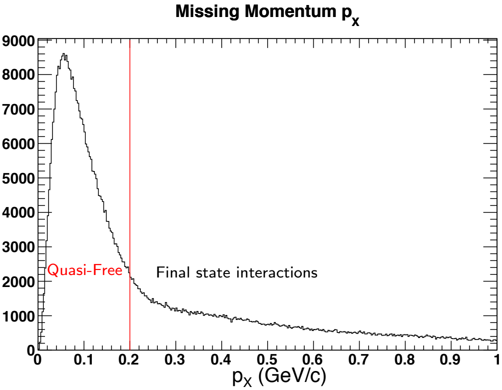
Selection of K^0 and Λ



Quasi-Free Event Selection: $\vec{\gamma}d \rightarrow K^0\vec{\Lambda}(p_s)$

- The reaction of interest is $\gamma(n_s) \rightarrow K^0\Lambda$
- QF events: the momentum of the final state proton should be small (consistent with the Fermi momentum of the n_s)
- For the reaction $\gamma d \rightarrow K^0\Lambda X$, we calculate the missing momentum, $\tilde{p}_X$

$$\tilde{p}_X = \tilde{p}_\gamma + \tilde{p}_d - \tilde{p}_p - \tilde{p}_{\pi^+} - \tilde{p}_{\pi^-} - \tilde{p}_{\pi^-}$$

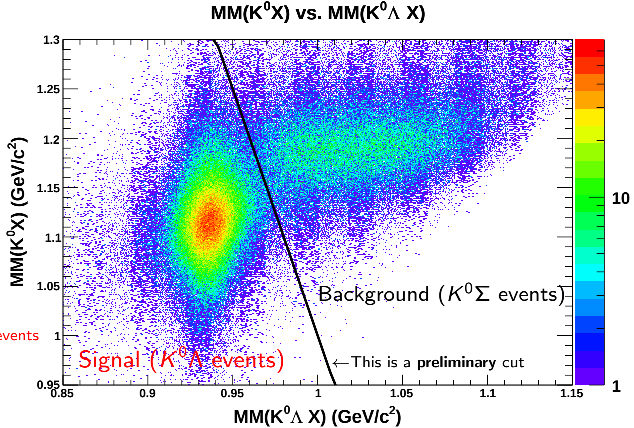


Selection of the $K^0\Lambda(p_s)$ Final State

The $K^0\Lambda$ final state was identified using the missing mass (MM) technique
Two MM's were calculated and used in cutting away large portion of background events

1. $MM(K^0X)$: $\gamma n \rightarrow K^0X$ where $M_X = \sqrt{(\tilde{p}_\gamma + \tilde{p}_n - \tilde{p}_{K^0})^2}$ and $X = \Lambda$ OR $X = \Sigma \rightarrow \Lambda\gamma \rightarrow \gamma p \pi^-$
2. $MM(K^0\Lambda X)$: $\gamma d \rightarrow K^0\Lambda X$ where $M_X = \sqrt{(\tilde{p}_\gamma + \tilde{p}_d - \tilde{p}_{K^0} - \tilde{p}_\Lambda)^2}$ and $X = p$ OR $X = \gamma p$

225,330 $K^0\Lambda(p_s)$ events



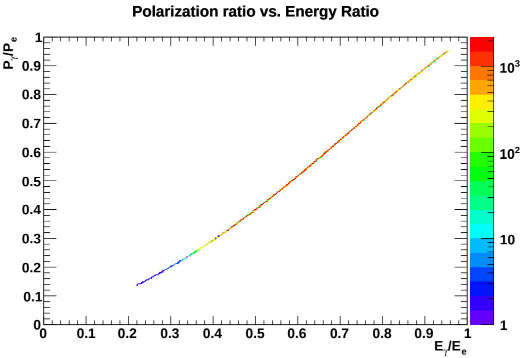
Beam Polarization

In order to determine the polarization observables, the polarization of the photon beam needs to be determined

- e^- polarization (P_e) measured using a Moller polarimeter in Hall B

Run Number	Average % e^- Polarization
53164-53532	84.97±0.28
53538-53547	80.60±0.18
53550-53862	78.47±0.18
53998-54035	84.11±1.11

- $P_{circ} = \frac{E_\gamma (E_e + \frac{1}{3}E')}{E_e^2 + E'^2 - \frac{2}{3}E_e E'} P_e$
- $E' = E_e - E_\gamma$
- Data in the table is from the work done by Tongtong Cao

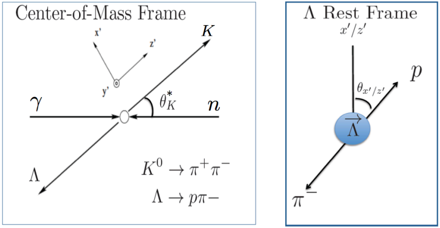


Extraction of $C_{x'}$, $C_{z'}$, and $P_{y'}$

From the equation for the polarized cross section of $K\Lambda$ photoproduction, the experimental asymmetry, A, can be derived:

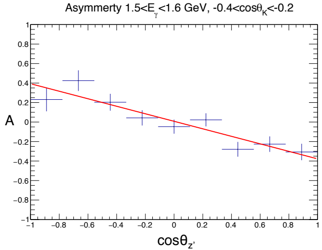
1. $A = \frac{N^+ - N^-}{N^+ + N^-} = \alpha P_{circ} C_{z'} \cos\theta_{z'}$
2. $A = \alpha P_{circ}(C_{z'} \cos\theta_{z'} + C_{x'} \cos\theta_{x'})$ ← Simultaneous fit to $\cos\theta_{z'}$ and $\cos\theta_{x'}$
3. PDF: $1 \pm \alpha P_{circ} C_{x'} \cos\theta_{x'} \pm \alpha P_{circ} C_{z'} \cos\theta_{z'} + \alpha P_{y'} \cos\theta_{y'}$

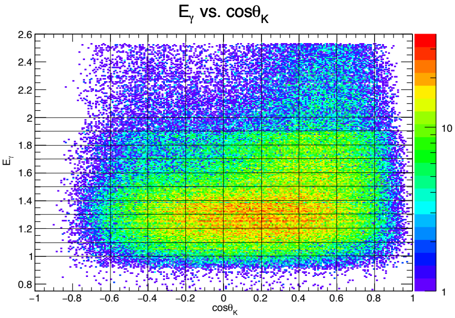
- $N^+(N^-)$ is the number of events with $+(-)$ helicity
- $\alpha = 0.642 \pm 0.013$, is the self-analyzing power of Λ

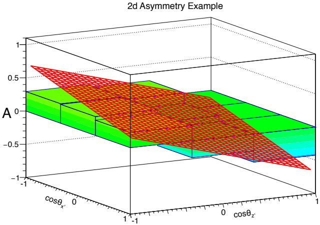


E_γ and $\cos\theta_K$ bins

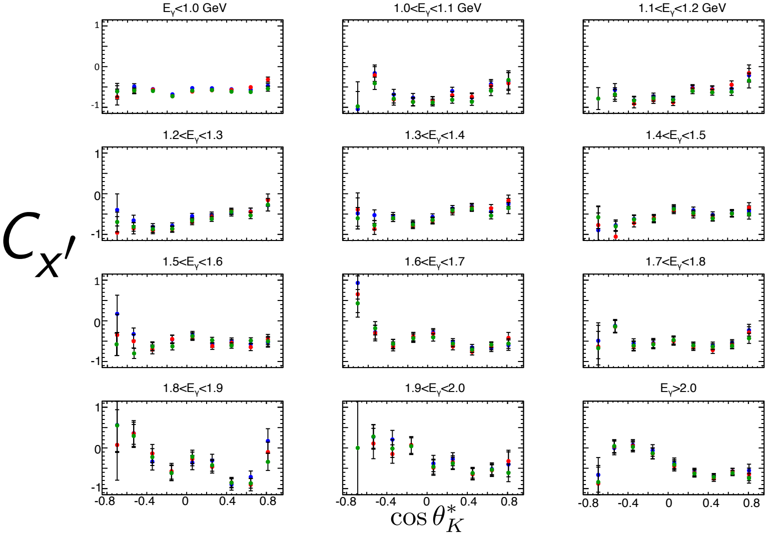
- An A is calculated for each kinematic bin
- 12 E_γ bins, 9 $\cos\theta^*_K$ bins



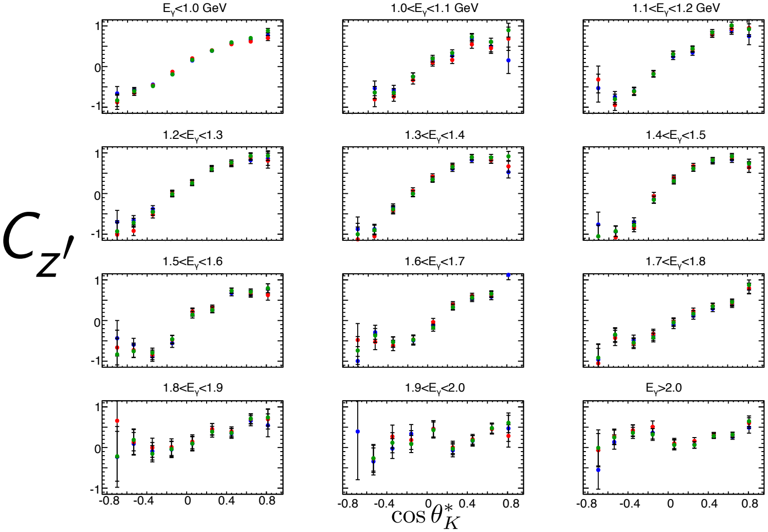




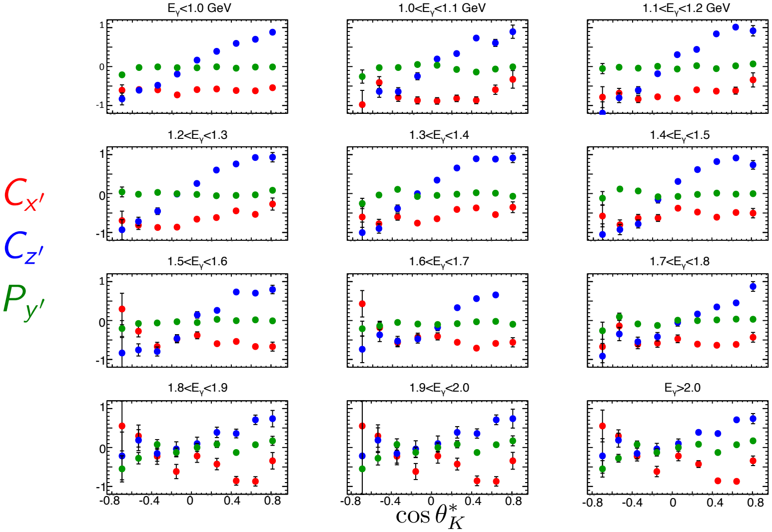
$C_{X'}$ Comparison for 1d, 2d, Maximum Likelihood



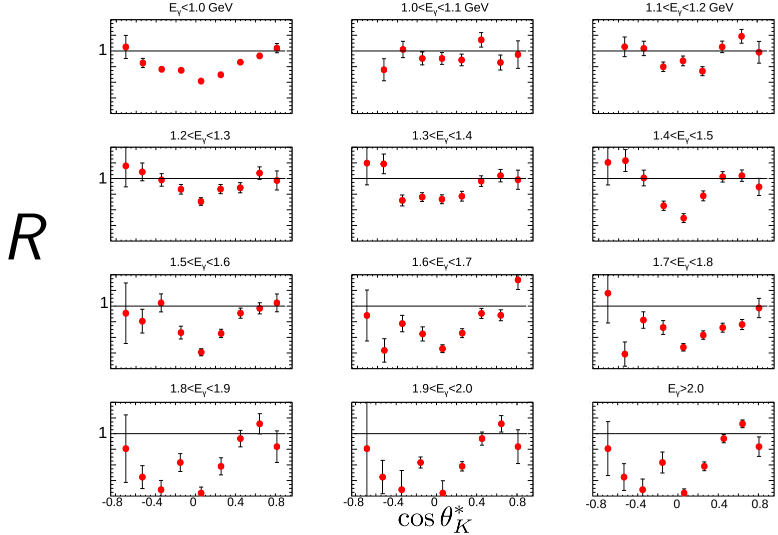
$C_{z'}$ Comparison for 1d, 2d, Maximum Likelihood



Maximum Likelihood Estimates for $C_{x'}$, $C_{z'}$, $P_{y'}$



$$R = \sqrt{C_{x'}^2 + C_{z'}^2 + P_{y'}^2}$$



Conclusions

- This work aims to provide polarization observables for $K\Lambda$ photoproduction off the bound neutron
- Preliminary estimates of $C_{x'}$, $C_{z'}$ were extracted with 3 different methods, and $P_{y'}$ with the maximum likelihood method
- As of now, all three methods provide similar estimates
- The maximum likelihood method will be used to extract final results
- Work is in progress to understand background contributions