Determination of the Hyperon Induced Polarization and Polarization–Transfer Coefficients for Quasi–Free Hyperon Photoproduction off the Bound Neutron

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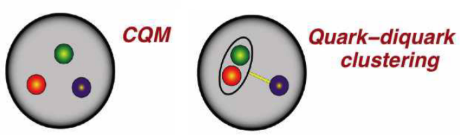
Overview

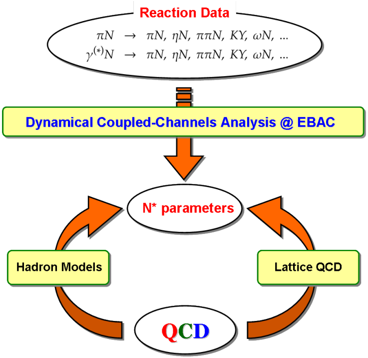
- Baryon Spectroscopy and Jefferson Lab
- Strangeness ($K\Lambda$) photoproduction
- Preliminary results for $\vec{\gamma} d \to K^0 \vec{\Lambda}(p)$
  1. Comparison to theoretical predictions
  2. Comparison to free proton data
  3. Dependence on the neutron momentum

Baryon Spectroscopy

Provides a way to measure the excited nucleon (N*) spectrum

- Excited nucleon states → understanding of nucleon
- Map N* spectrum to learn about the internal structure of nucleons
- Goal is to provide information about the underlying degrees of freedom in the non–perturbative regime



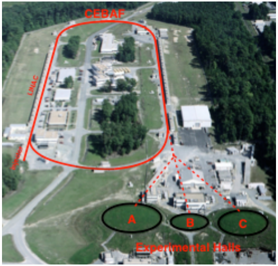


http://ebac-theory.jlab.org/

Constituent quark models three valence quarks
Di-quark models bound quark pair → less degrees of freedom
Lattice QCD numerical solution to QCD

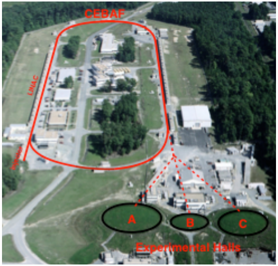
Many other approaches...

Jefferson Lab, Hall B, and CLAS



- CEBAF accelerated e up to 6 GeV

Jefferson Lab, Hall B, and CLAS

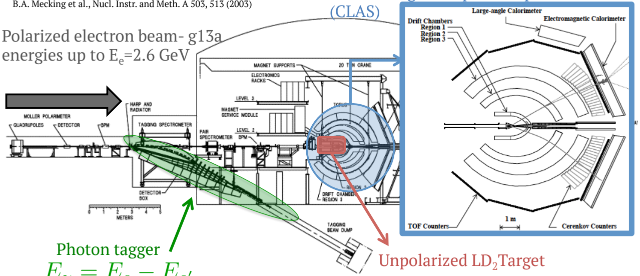


B.A. Mecking et al., Nucl. Instr. and Meth. A 503, 513 (2003)

- CEBAF accelerated e up to 6 GeV
- Located in Hall B is the CLAS
- g13a run group
  - E_e up to 2.6 GeV
  - circularly polarized photons
  - 40 cm long LD_2 target

CEBAF Large Acceptance Spectrometer (CLAS)

Polarized electron beam- g13a energies up to E_e=2.6 GeV



Photon tagger
$E_\gamma = E_e - E_{e'}$

Unpolarized LD_2Target

- $\approx 80\%$ e polarization
- $P_\gamma \approx 20 - 95\% P_e$
- $0.9 < E_\gamma < 2.55$ GeV

Motivation for $\vec{\gamma} d \to K^0 \vec{\Lambda}(p)$

- Need more data
  - Majority of data is πN scattering or final state
  - Some resonances couple weakly to these channels while having significant branching ratios to $K\Lambda$
- Most strangeness data from free proton
  - $\gamma p \to K^+\Lambda$ moving $N(1900)\frac{3}{2}^+$ from $\star\star$ to $\star\star\star$
  - $\gamma n \to K^0\Lambda$ sensitive to $\star\star\, N(2150)\frac{3}{2}^-$ and $\star\star\star N(1875)\frac{3}{2}^-$
- How do data from the proton and bound neutron compare to each other?

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

K.A. Olive et al., Review of Particle Physics

Polarization Observables in $K\Lambda$ Photoproduction

- Can't "bump hunt" on the energy evolution of the cross–section
- 16 Polarization observables are derived from the matrix elements of the scattering matrix

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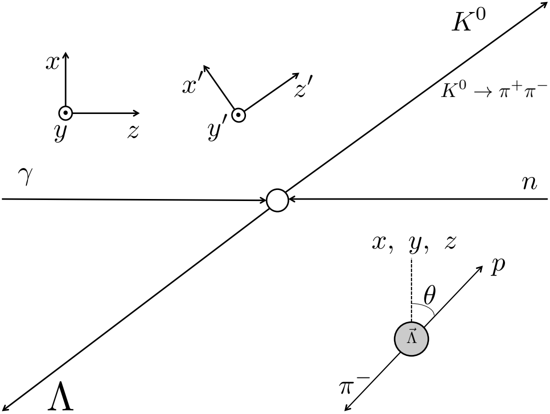
Unpolarized Cross Section	σ_0			
Single		P	Σ	T
Beam-Recoil	C_x	C_z	O_x	O_z
Target-Recoil	T_x	T_z	L_x	L_z
Beam-Target	E	F	G	H

- 8 carefully chosen observables are needed to determine the full scattering amplitude

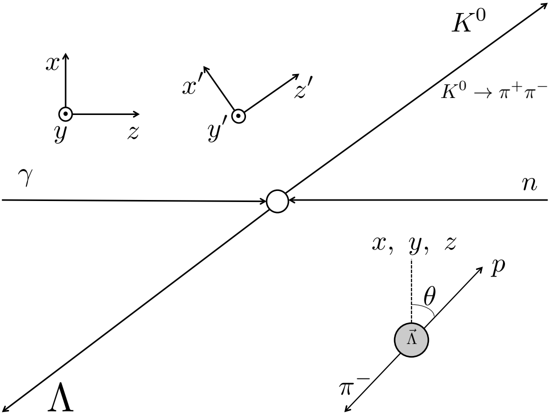
$$\frac{d\sigma}{d\Omega} = \sigma_0[1 - P_{lin}\Sigma\cos 2\phi - \alpha\cos\theta_x(P_{lin}O_x\sin 2\phi + P_{circ}C_x) - \alpha\cos\theta_y(-P + P_{lin}T\cos 2\phi) - \alpha\cos\theta_z(P_{lin}O_z\sin 2\phi + P_{circ}C_z)]$$

Axis Conventions for $\gamma n \rightarrow K^0 \Lambda$



1. $\vec{\gamma} n \rightarrow N^*$

Axis Conventions for $\gamma n \to K^0\Lambda$



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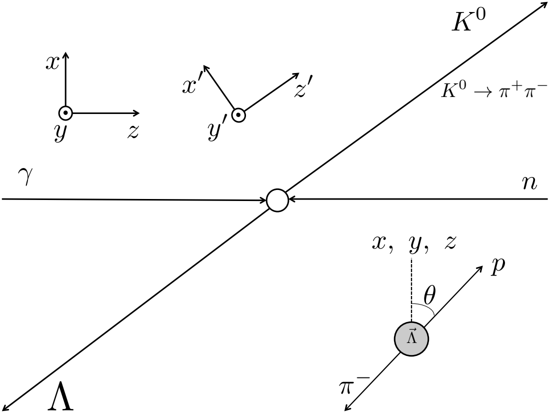

1. $\vec{\gamma} n \to N^*$
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3. $K^0 \to \pi^+\pi^-$ and $\Lambda \to p\pi^-$

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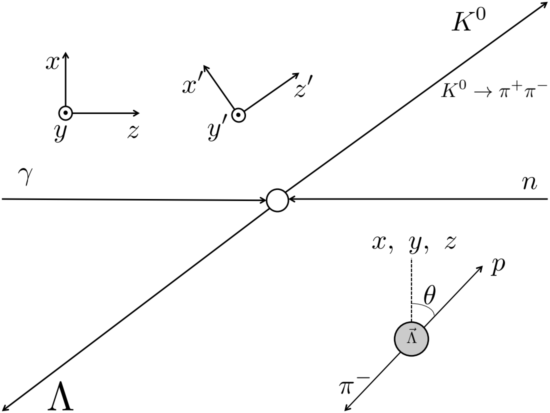


1. $\vec{\gamma} n \to N^*$
2. $N^* \to K^0\Lambda$
3. $K^0 \to \pi^+\pi^-$ and $\Lambda \to p\pi^-$
4. Using information about θ, we can calculate the polarization transfer from $\vec{\gamma}$ to Λ

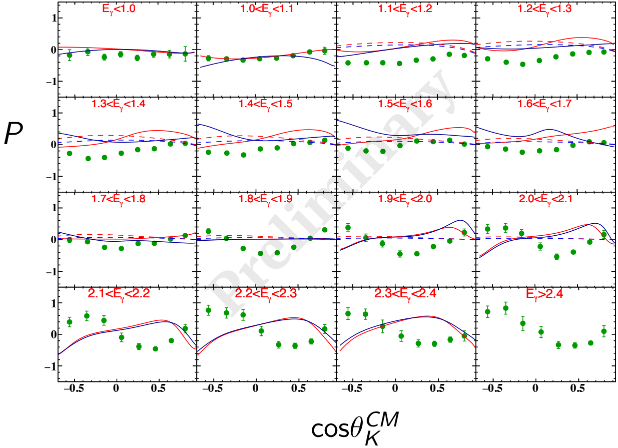
$$\frac{d\sigma}{d\Omega} = \sigma_0[1 - \alpha \cos\theta_{x'} P_{circ} C_{x'} + \alpha \cos\theta_{y'} P - \alpha \cos\theta_{z'} P_{circ} C_{z'}]$$

Preliminary Results

Will present and discuss the first (preliminary) estimates for C_x and C_z for $\vec{\gamma} d \rightarrow K^0 \vec{\Lambda}(p)$

1. Compare to models using the primed axis convention (z along K^0 momentum).
2. Compare to data off the free proton in the unprimed axis convention (z along γ momentum).
3. Dependence on the momentum of the bound neutron.

Comparison to Models–P



Two Models

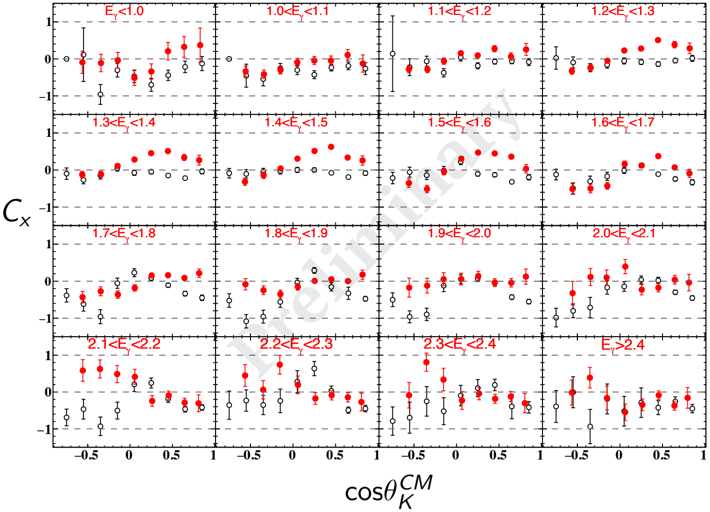
1. Waluyo (solid), CCA
2. Kaon–MAID (dashed), PWA

- No D13(1900)
- With D13(1900)

1) A. Waluyo, Ph.D. Thesis, The George Washington University, (2005).

2) F.X. Lee, T. Mart, C. Bennhold, H. Haberzettl, L.E. Wright, Nucl. Phys. A695 (2001) 237

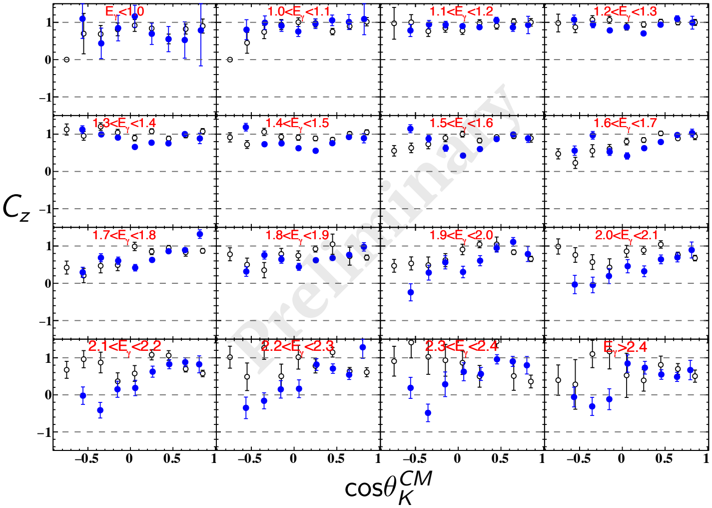
C_x: Comparison of $\gamma d \to K^0\Lambda(p)$ to $\gamma p \to K^+\Lambda$



$\gamma d \to K^0\Lambda(p)$
$\gamma p \to K^+\Lambda$

R. K. Bradford et al. (CLAS Collaboration), Phys. Rev. C 75, 035205

C_z: Comparison of $\gamma d \to K^0\Lambda(p)$ to $\gamma p \to K^+\Lambda$

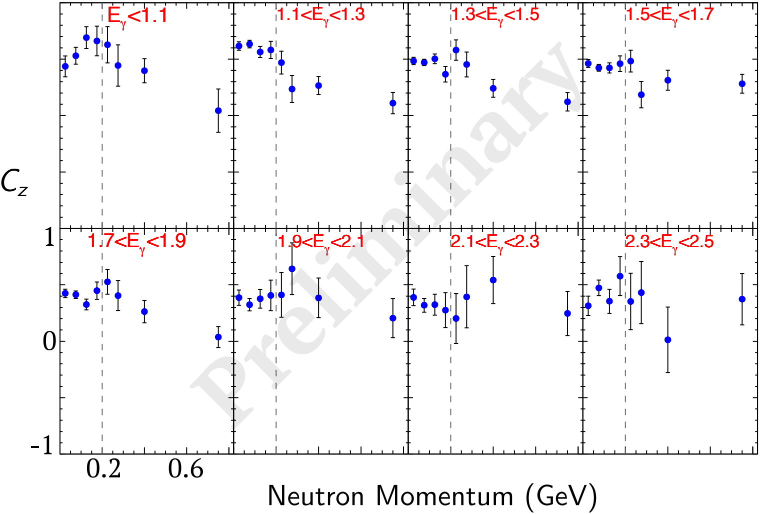


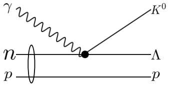
$\gamma d \to K^0\Lambda(p)$

$\gamma p \to K^+\Lambda$

R. K. Bradford et al. (CLAS Collaboration), Phys. Rev. C 75, 035205

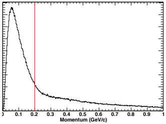
Dependence on Neutron Momentum–C_z



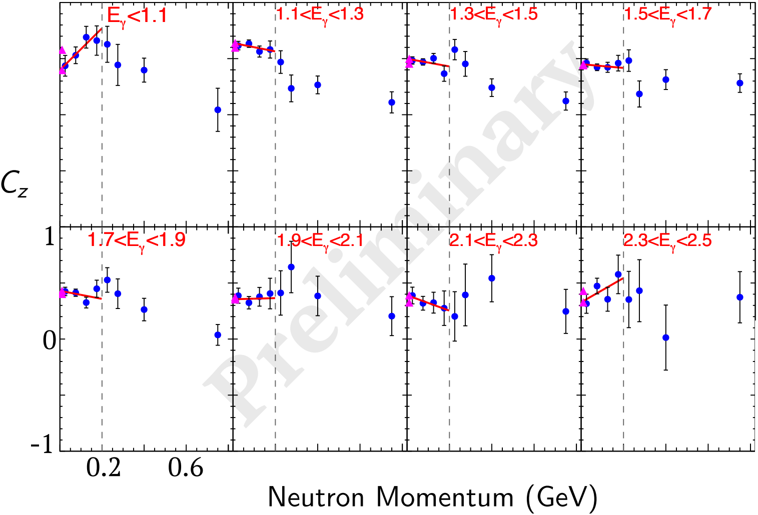


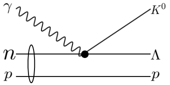
- Neutron is not free
- Need free neutron for CCA
- How well do the observables represent the free neutron?

Neutron Momentum



Dependence on Neutron Momentum–C_z





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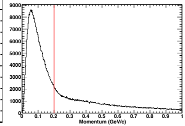
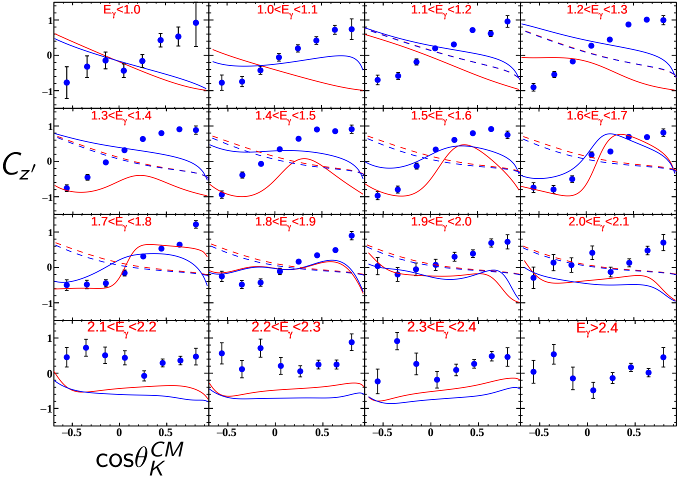


Conclusion

- Many resonant states predicted by constituent quark models have yet to be observed
- Hyperon channels have a strong coupling to some of these resonances
- Very first (preliminary) estimates of polarization observables for data off the bound neutron have been obtained.
- **Differences with model calculations from are observed. Data are expected to have an impact.**
- **Differences between data off free proton and quasi–free neutron are observed that could be due to reaction dynamics or other resonances.**
- C_z **is dependent on the neutron momentum, but below 0.2 GeV it is mostly constant.**

Comparison to Models–$C_{z'}$



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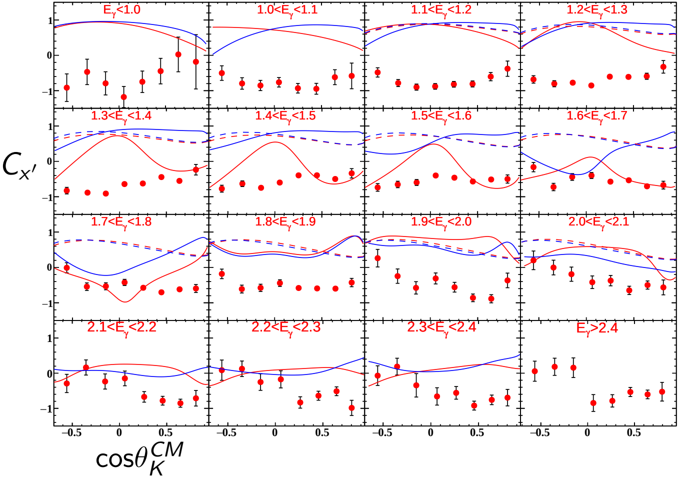
Comparison to Models–$C_{x'}$



Two Models

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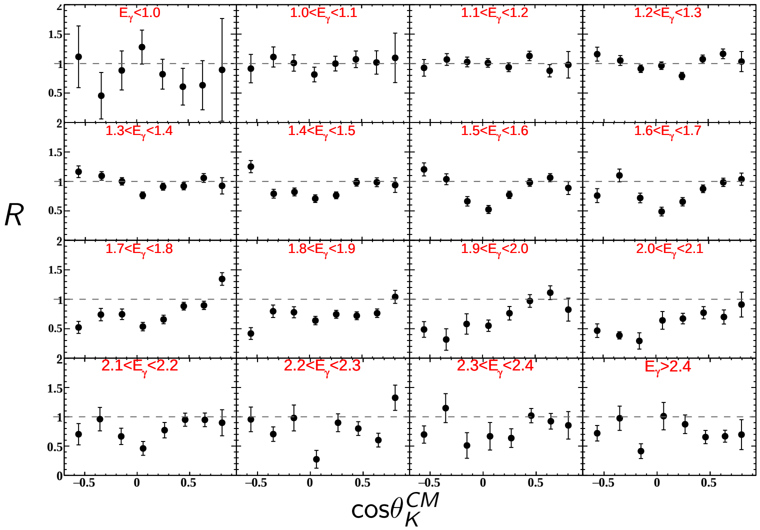
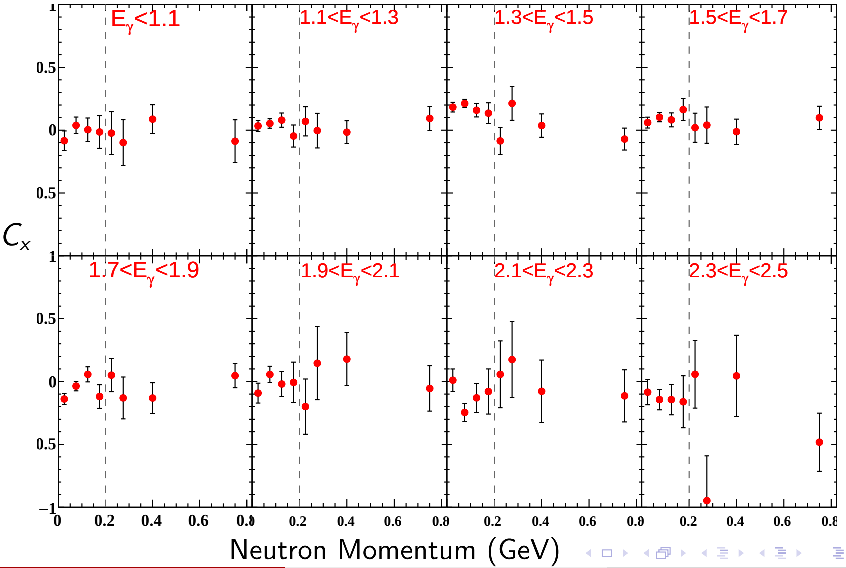
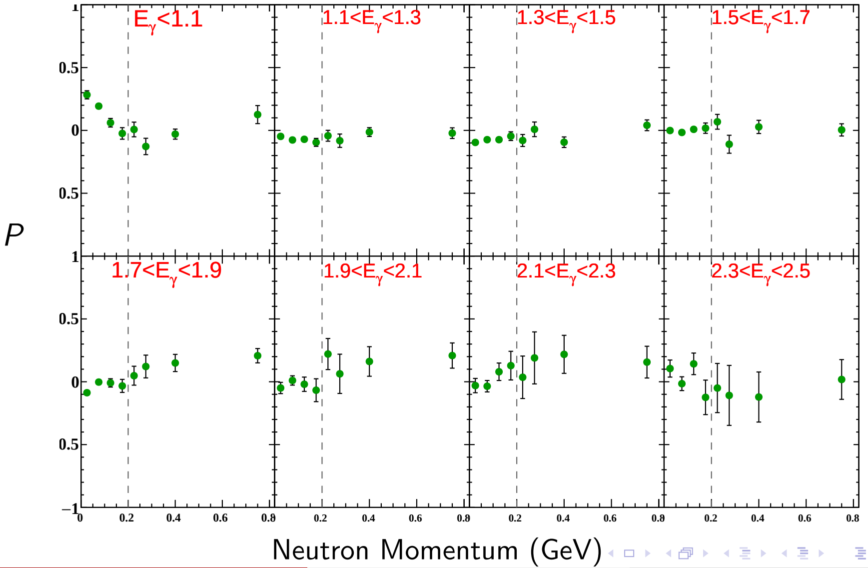
$R = \sqrt{C_x^2 + C_z^2 + P^2} \leq 1$–Total Polarization Transfer



Dependence on Neutron Momentum–C_x

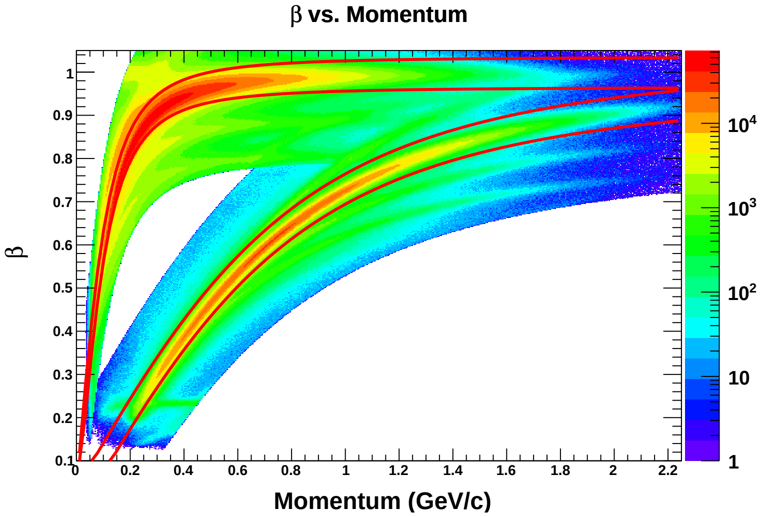


Dependence on Neutron Momentum–P



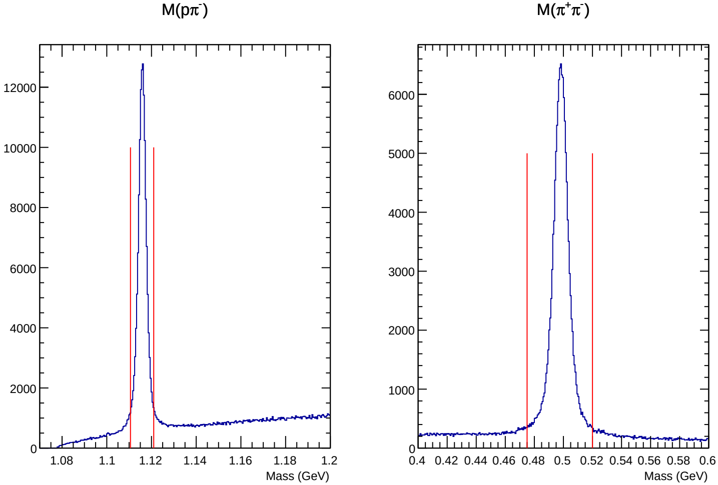
Particle Identification

Particles are identified based off their β and momentum in CLAS



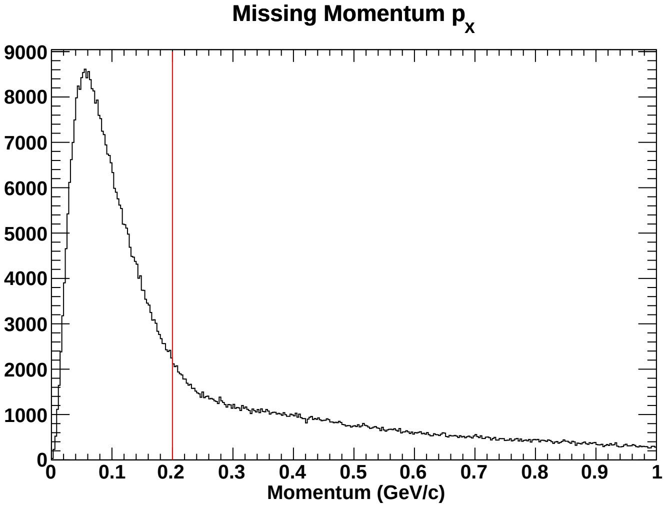
Reaction Identification

The Λ and K^0 need to be reconstructed since $\Lambda \to p\pi^-$ and $K^0 \to \pi^+\pi^-$



Quasi–free Selection

The neutron momentum can be reconstructed



Final–state Identification

The missing proton is reconstructed