Study of the Initial and Final State Effects through Polarization Observables

Nicholas Zachariou, *for the CLAS collaboration*

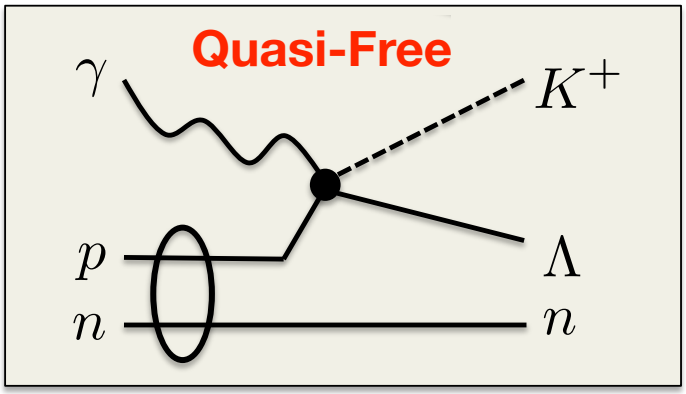
Outline

$$\vec{\gamma} d \rightarrow K^{+} \vec{\Lambda}(n)$$

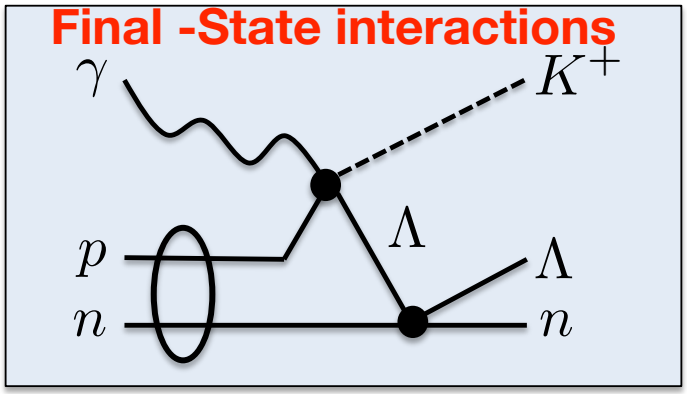
- Initial and final state effects in Exclusive reactions
- Jefferson Lab and the CEBAF Large Acceptance Spectrometer
- Results on polarization observables

Exclusive Reactions

$$\vec{\gamma} d \rightarrow K^+ \vec{\Lambda}(n)$$



- Neutron targets—> Important information for the search of missing resonances
- Information inferred from bound neutron targets



- Final State Interaction—> Important information for the Hyperon nucleon interaction

Polarization observables allows us to reduce model dependence on the interpretation of QF and FSI results

Motivation

- Final State Effects:

  Study Hyperon-Nucleon Interaction

The understanding of both *nucleon-nucleon (NN)* and *hyperon-nucleon (YN)* potentials is necessary in order to have a comprehensive picture of the strong interaction

- Understand the composition of neutron stars
- Understand hyper-nuclear structure and hyperon matter
- Extend *NN* to a more unified picture of the baryon-baryon interaction

HOW?

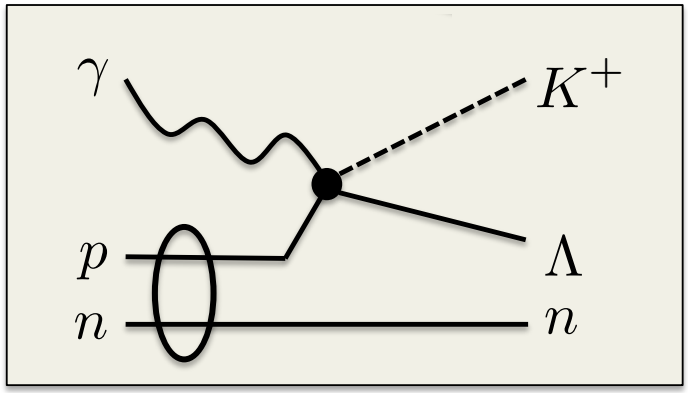
- Elastic *YN* Scattering

  poor database

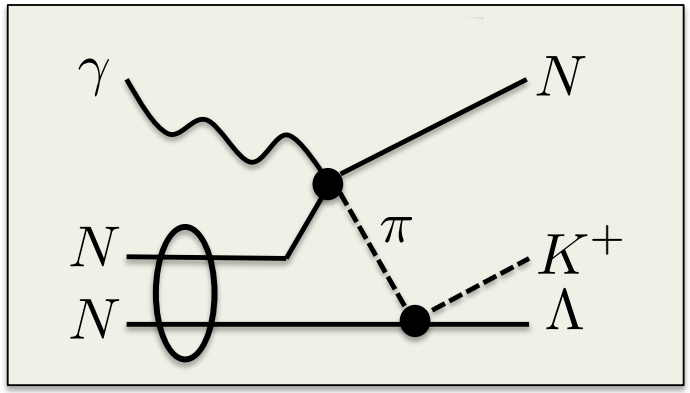
- **Final State Interactions (FSI) in Hyperon Production**

QF and FSI in Exclusive Λ Photoproduction off the deuteron

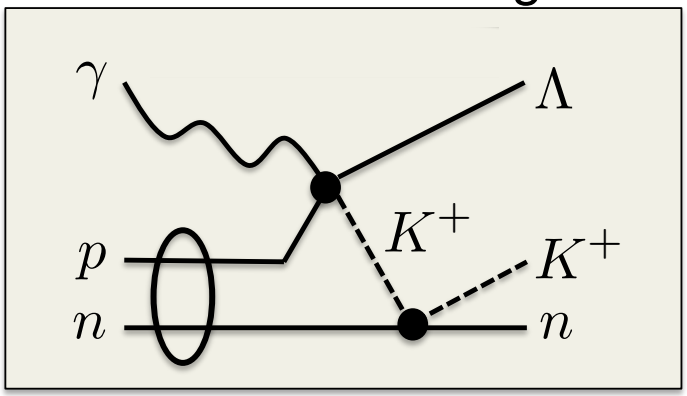
Quasi-free



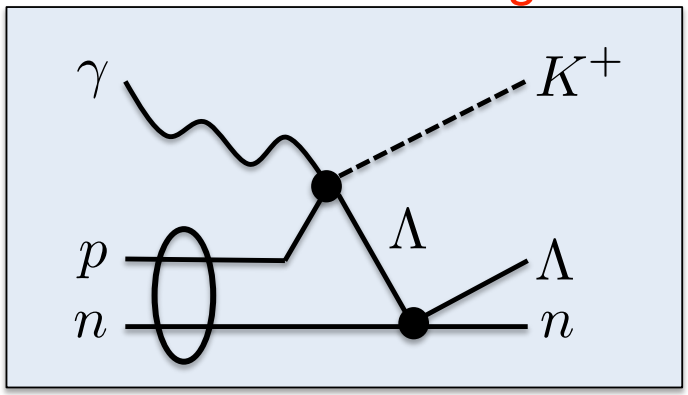
π-mediated



K^+n rescattering



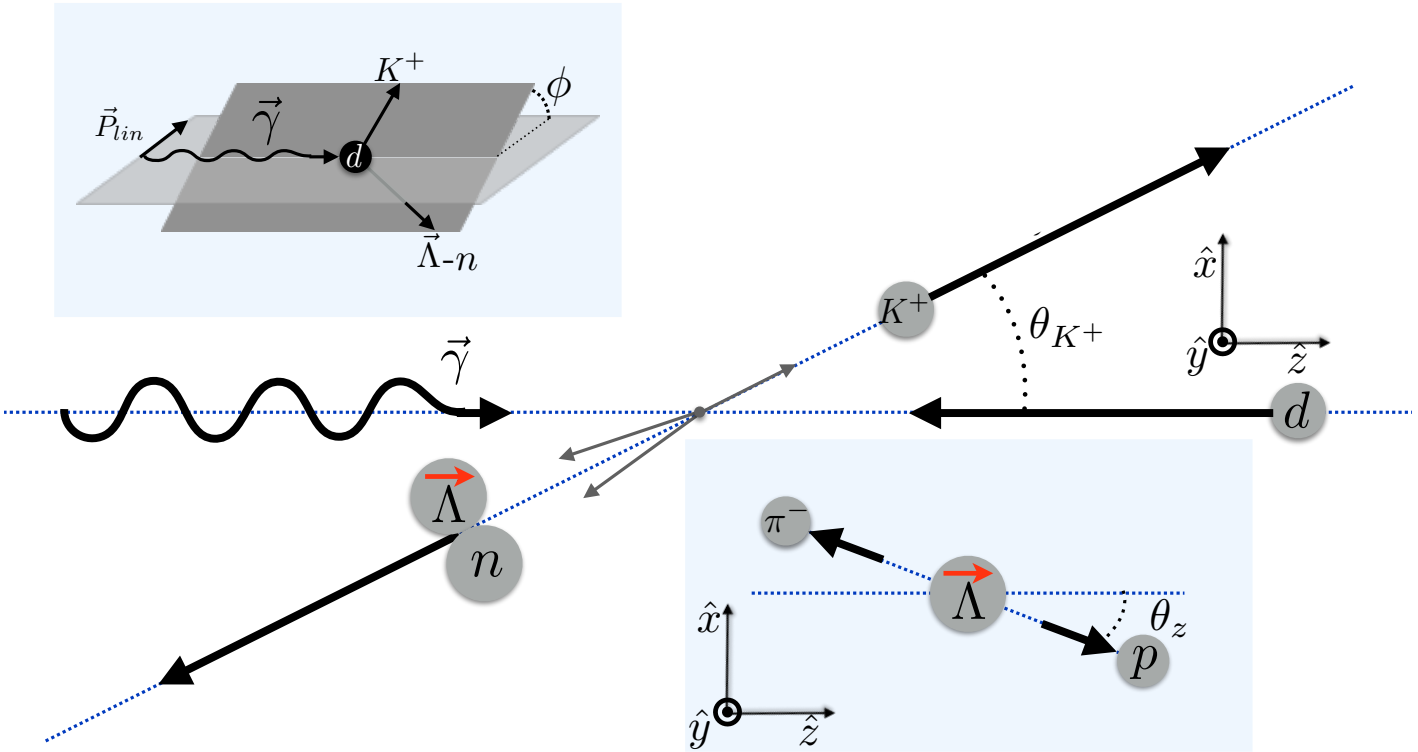
Λn rescattering



The QF events can be significantly reduced or enhanced experimentally, through kinematic constraints

Experimentally Accessible Observables

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



Beam Polarization

linearly polarized γ beam

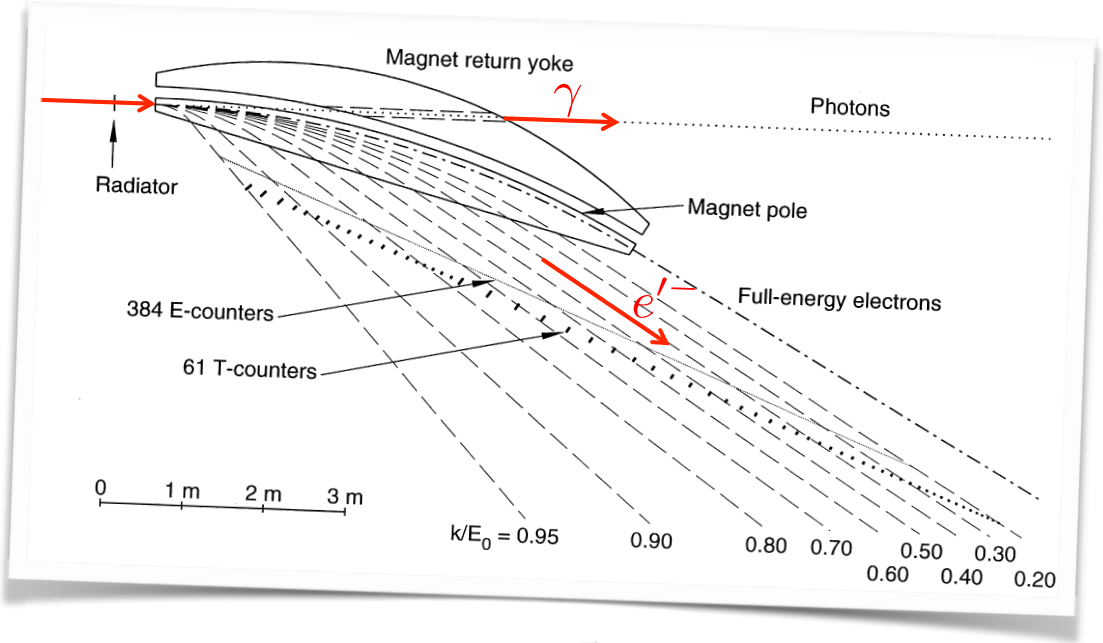
circularly polarized γ beam

Λ Recoil Polarization

self-analyzing power

α =0.642

Jefferson Lab and Hall B



Angular Coverage

$8^\circ < \theta < 140^\circ$

$\phi \sim 1.7\pi$

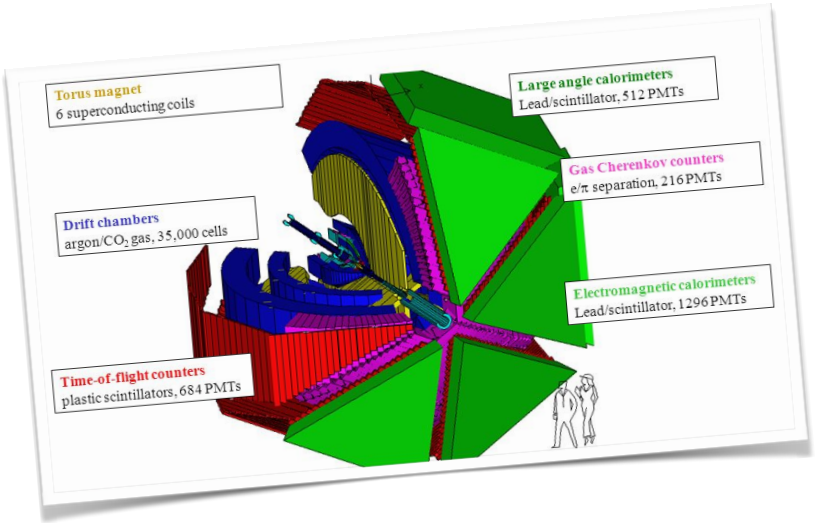
Angular Resolution

$\sigma_\theta \sim 1$ mrad

$\sigma_\phi \sim 4$ mrad

Momentum Resolution

$\sigma_p/p \sim 1\%$



Efficient detection of charged particles over a large fraction of the full solid angle.

E06-103 Experiment

- Liquid Deuterium Target (40 cm long)
- Tagged photon beam (linearly and circularly polarized)
- Collected data over a large fraction of the full solid angle using CLAS (2007)

- Current 10 nA
- Eight e-beam energies between 3.30 and 5.16 GeV
- ~2 mm collimator
- Two orientations of linear polarization (*Para* & *Perp*)
- Data obtained at photon energies between 1.1 and 2.3 GeV
- ~30 billion events collected

- Current 40 nA
- Two e-beam energies (1.99 and 2.66 GeV)
- Two orientation of circular polarization (+/- *helicities*)
- Data obtained at photon energies between 0.4 and 2.6 GeV
- ~20 billion events collected

$$\overline{P}_e = 80\% \rightarrow \overline{P}_{circ} = 32\% - 80\%$$

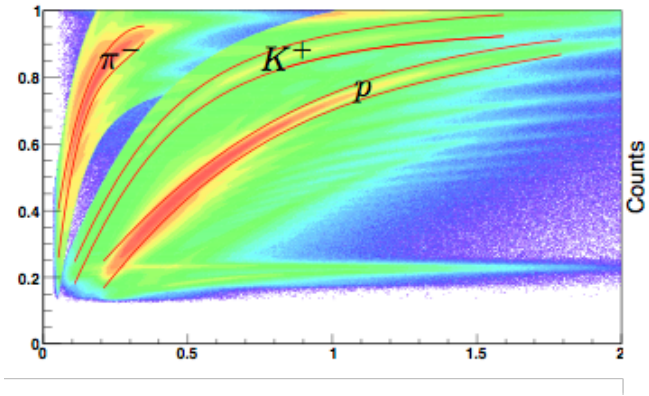
Analysis

Analysis of $\vec{\gamma}d \to K^+\vec{\Lambda}(n)$

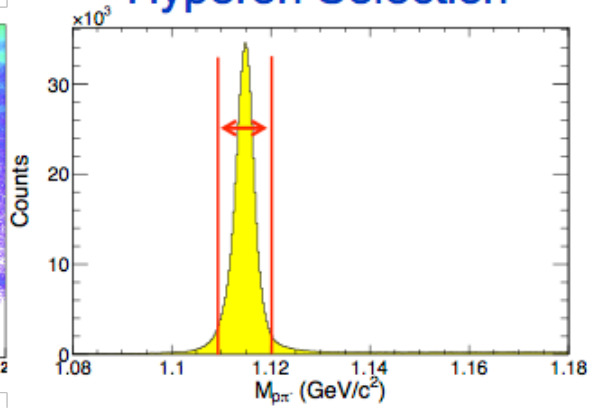
$\hookrightarrow p\pi^-$

(Branching ratio 63.9%)

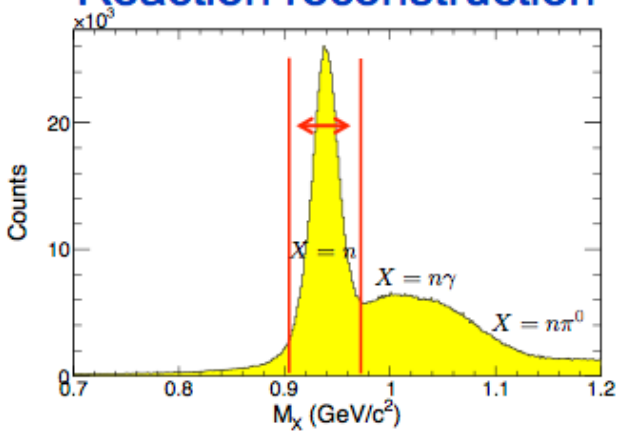
Particle Identification

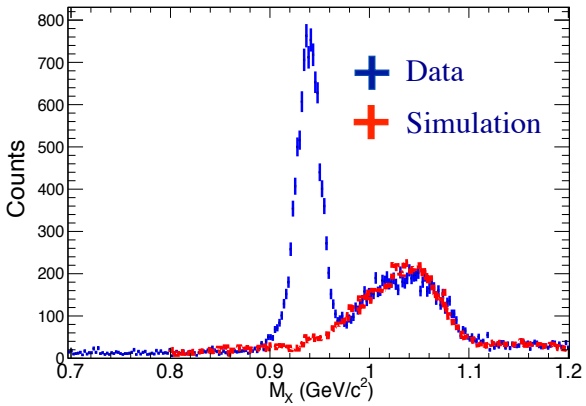


Hyperon Selection



Reaction reconstruction





$\gamma d \to K^+\Lambda X$

Generated Background Reactions

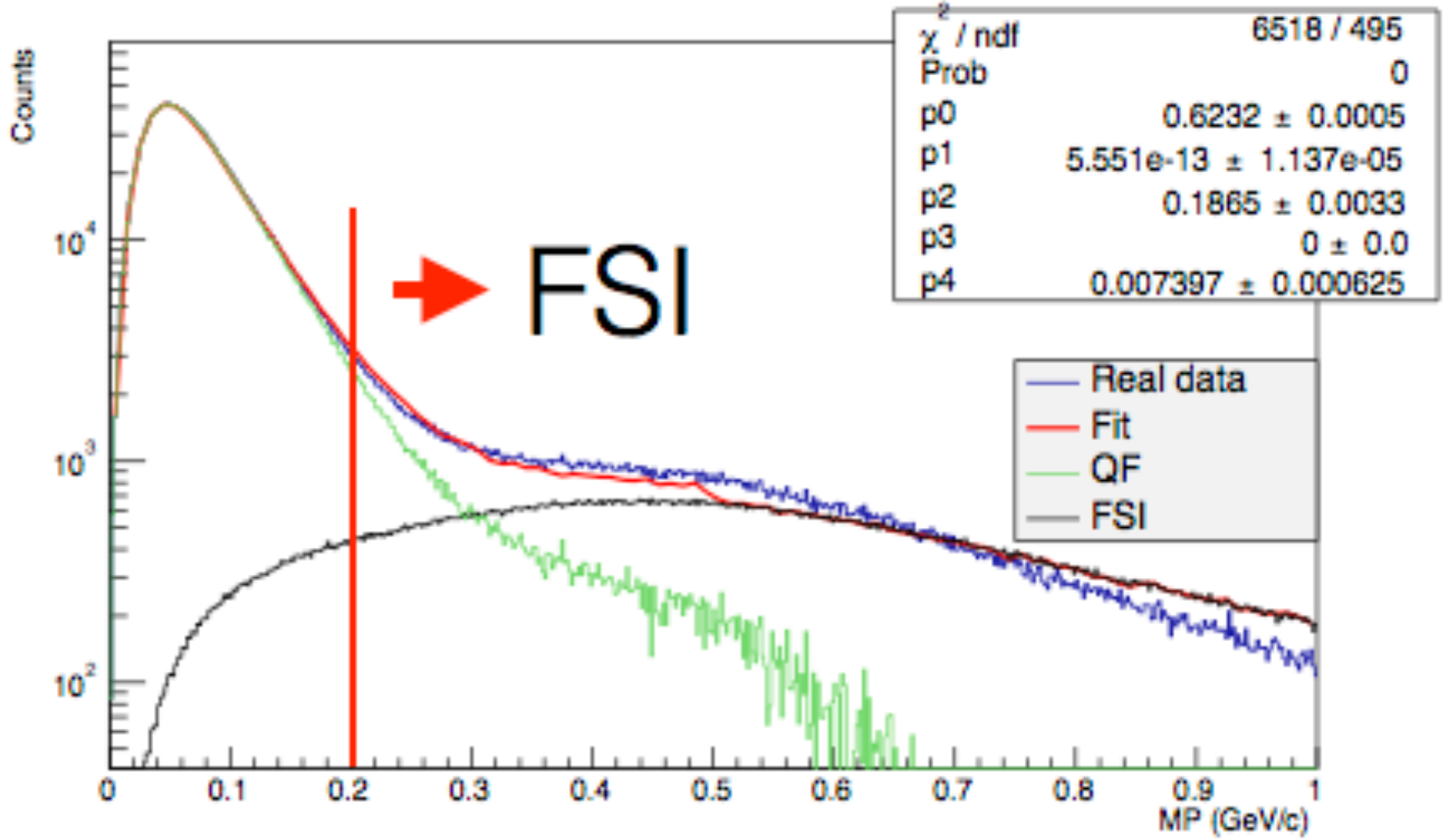
$\gamma n \to \pi^0 n$	$\pi^0 p \to \Lambda K^+$
$\gamma p \to \Lambda K^+$	$K^+ n \to K^+ n$
$\gamma p \to \Lambda K^+$	$\Lambda n \to \Lambda n$
$\gamma p \to \Sigma K^+$	$\Sigma n \to \Sigma n$
$\gamma p \to \pi^+ n$	$\pi^+ n \to \Lambda K^+$
$\gamma p \to K^+\Sigma^{*0}$	$\Sigma^{*0} \to \Lambda\pi^0$
$\gamma n \to K^+\Sigma^{*-}$	$\Sigma^{*-} \to \Lambda\pi^-$

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

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

Exclusivity of the Reaction

$$\gamma d \to K^+ \Lambda(n)$$

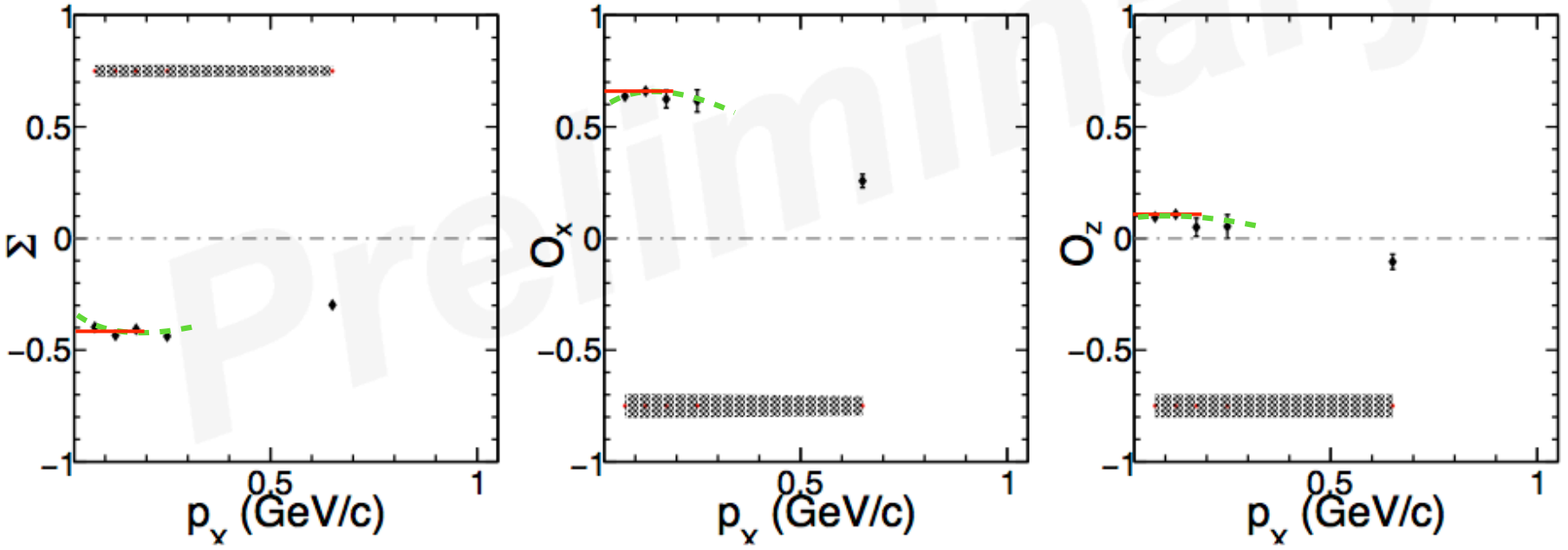


Initial State Effects

Analysis of $\vec{\gamma}d \to K^+\vec{\Lambda}(n)$

$\hookrightarrow p\pi^-$

(Branching ratio 63.9%)

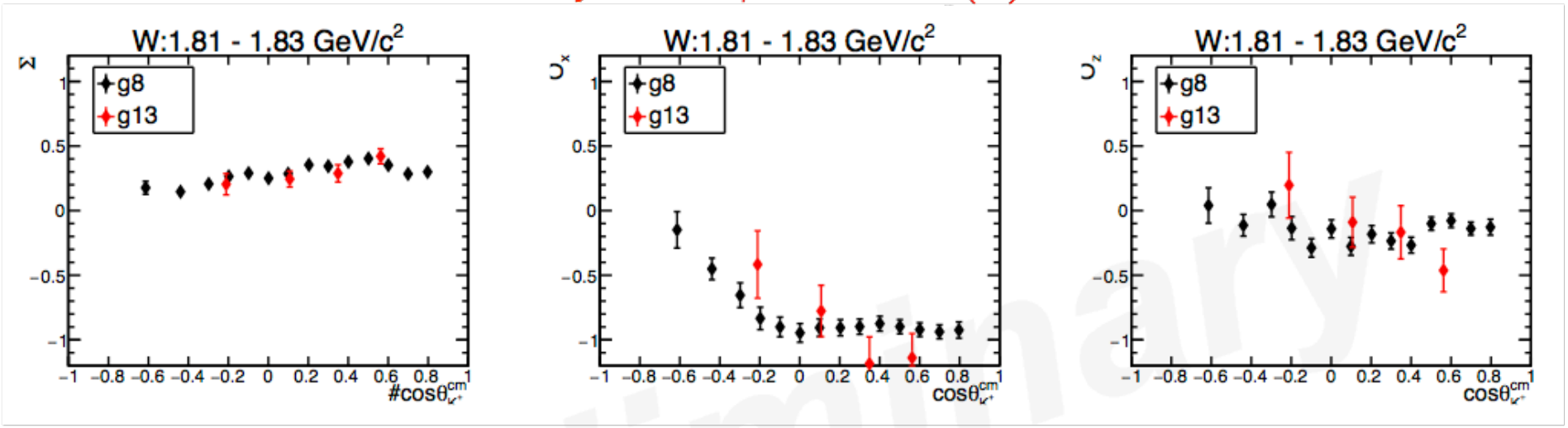


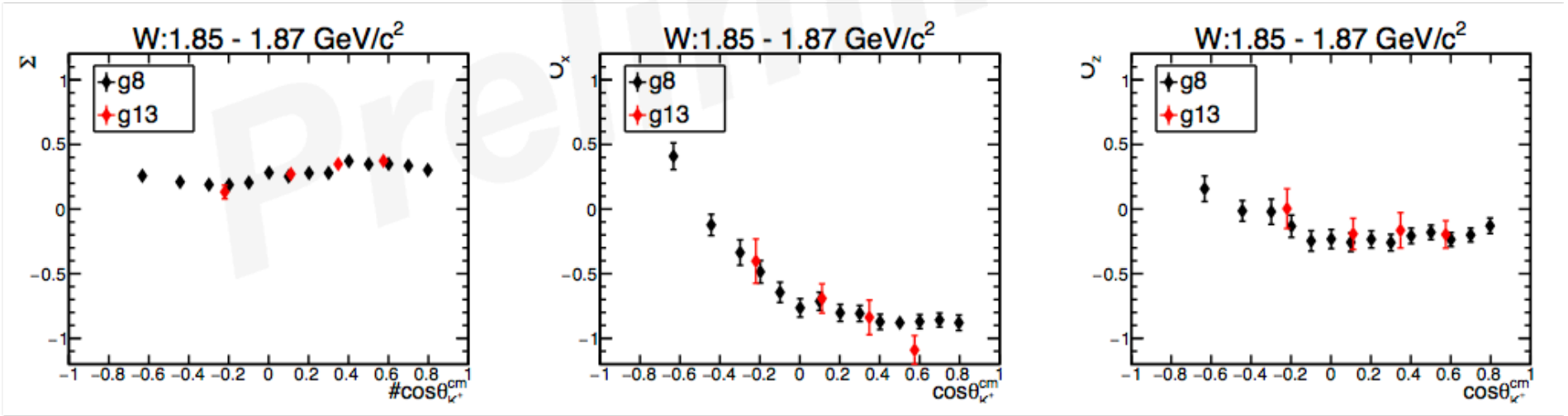
Initial State Effects

Free Proton target

Bound Proton Target

Analysis of $\vec{\gamma}d \to K^+\vec{\Lambda}(n)$

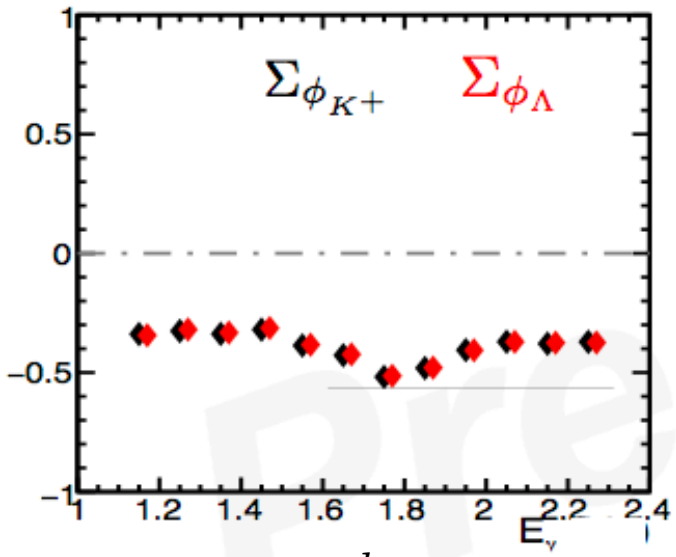




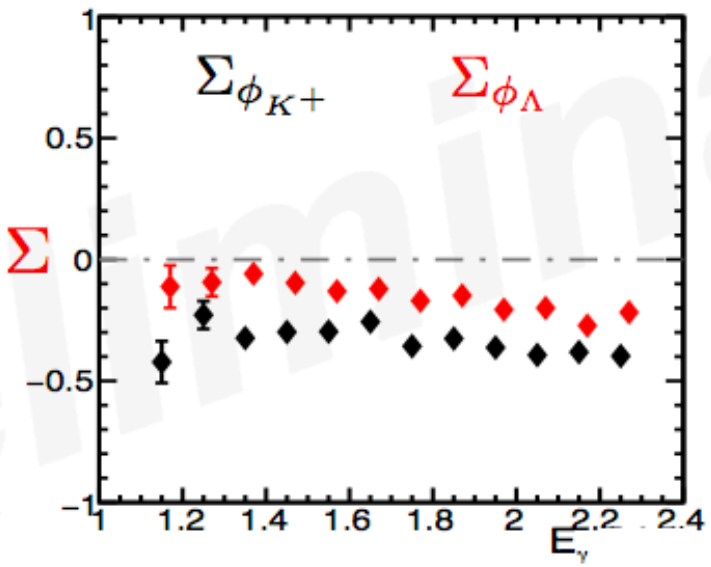
Final State Interactions

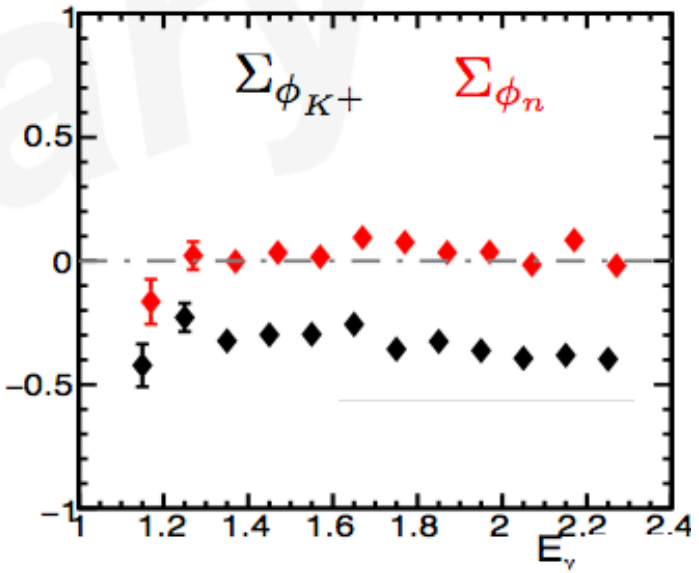
Study of the YN Interaction

QuasiFree data



FSI data



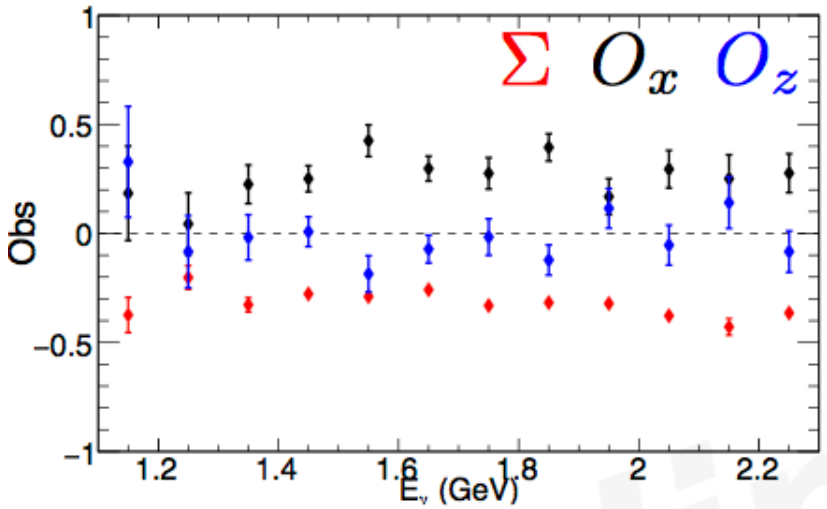


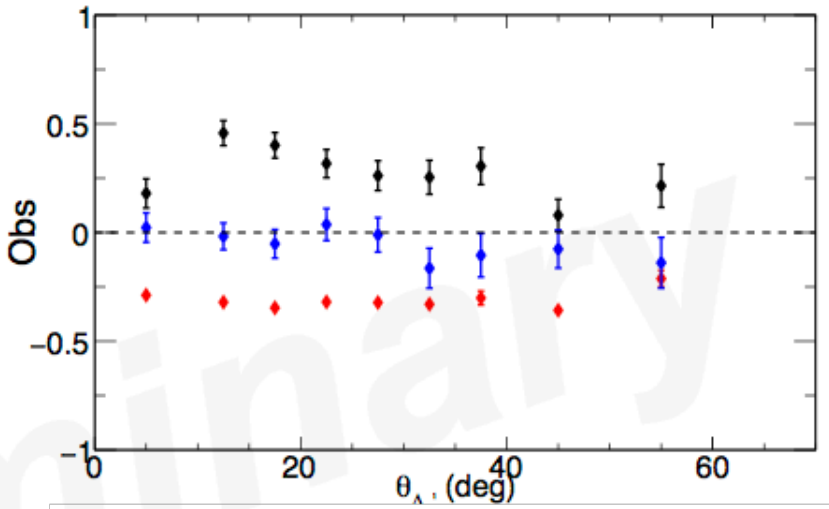
$$\frac{d\sigma}{d\Omega} = \sigma_0\{1 - P_{lin}\Sigma\cos 2\phi + \alpha\cos\theta_x(-P_{lin}O_x\sin 2\phi - P_{circ}C_x)$$
$$- \alpha\cos\theta_y(-P_y + P_{lin}T\cos 2\phi) - \alpha\cos\theta_z(P_{lin}O_z\sin 2\phi + P_{circ}C_z)\}$$

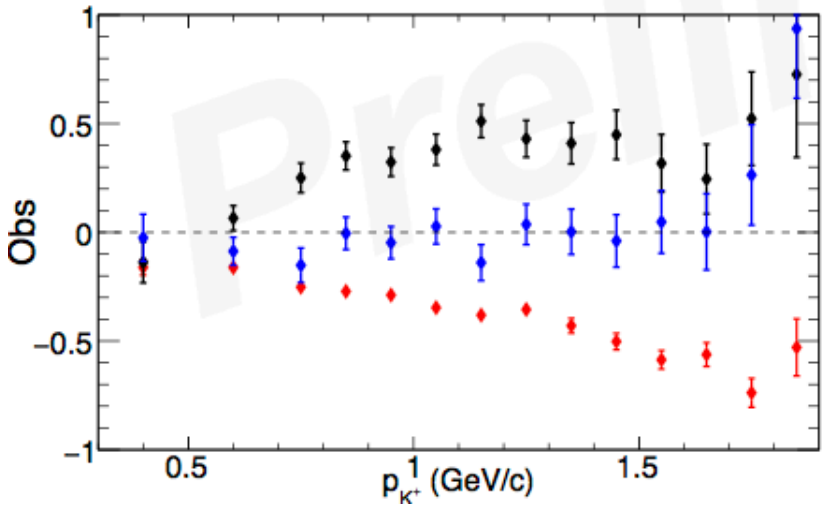
Final State Interactions

Study of the YN Interaction

FSI Results







Summary and Outlook

- Determination of observables in high-statistic exclusive reactions of bound nucleons allows us to obtain more accurate estimates for scattering off free nucleons by studying the evolution of the observable with the momentum of the spectator nucleon.

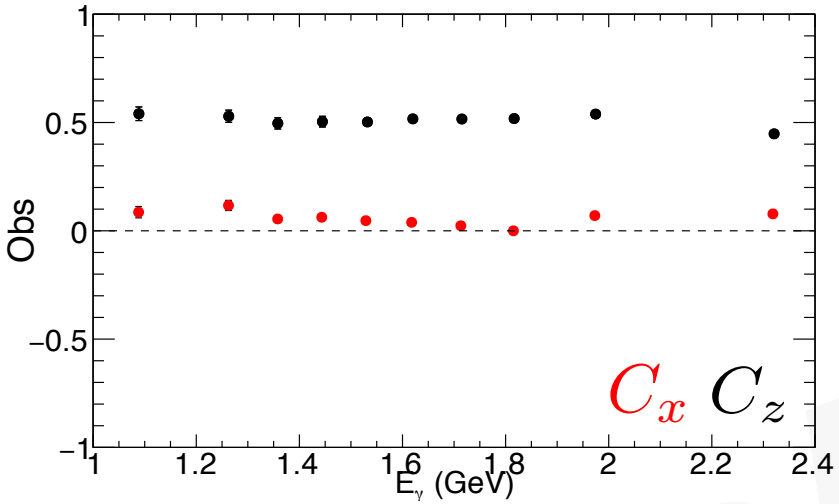
- Polarization observables play a crucial role in identifying the kinematics for specific mechanisms of interest in Final State Interactions; allowing us to study/access reaction processes that are otherwise difficult to perfom experimentally.

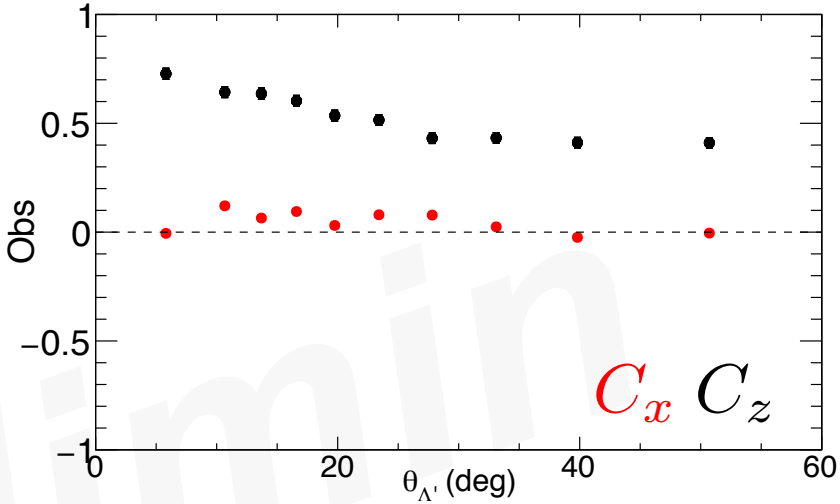
Thank you

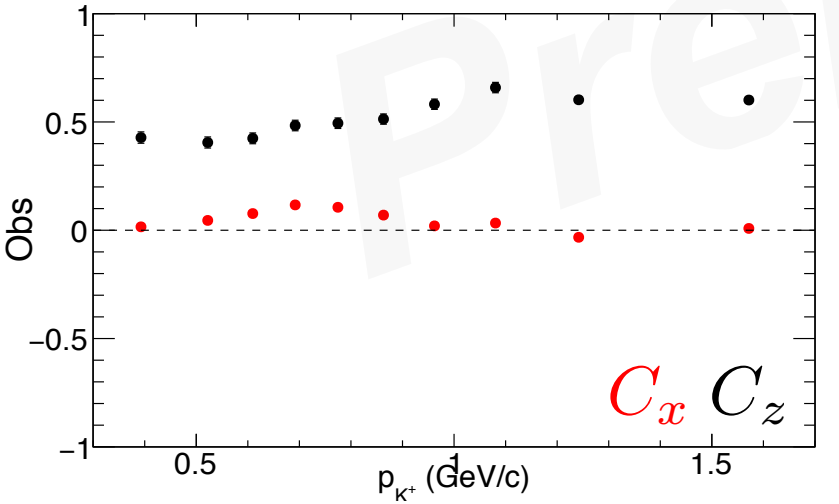
Final State Interactions

Study of the YN Interaction

*** PhD Study of Tongtong Cao**

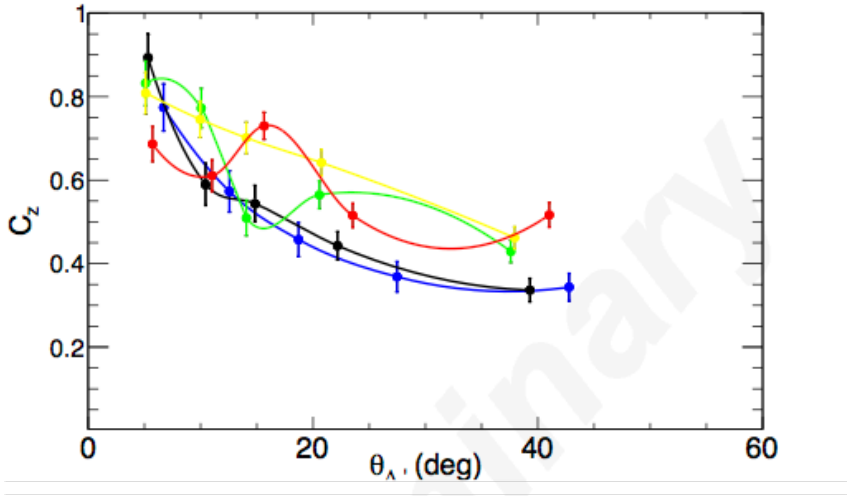


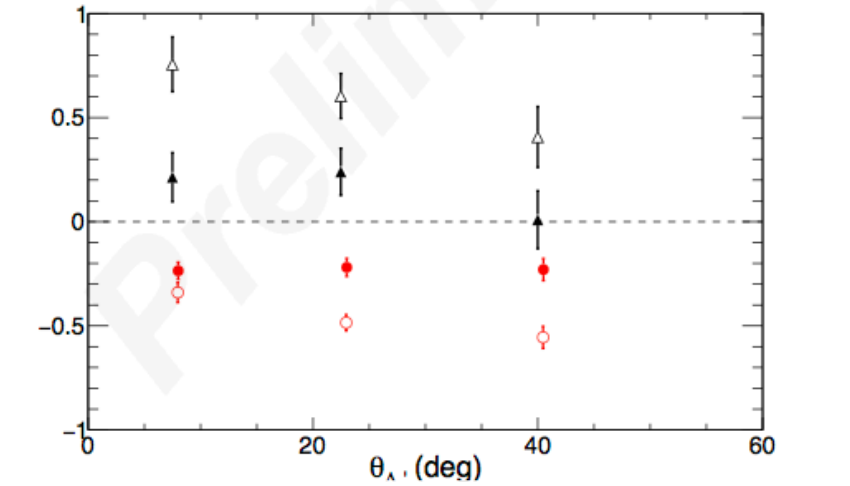




Final State Interactions

Study of the YN Interaction





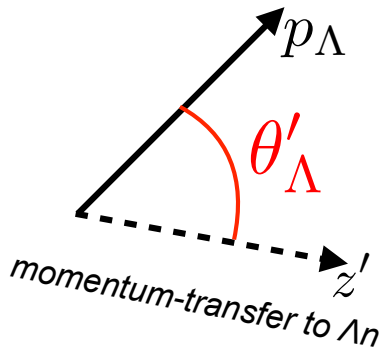
- Adequate statistics for extracting observables 2-fold and 3-fold differential
- Goal is to better tune the free parameters of YN potentials
- Work with theorists to interpret the data

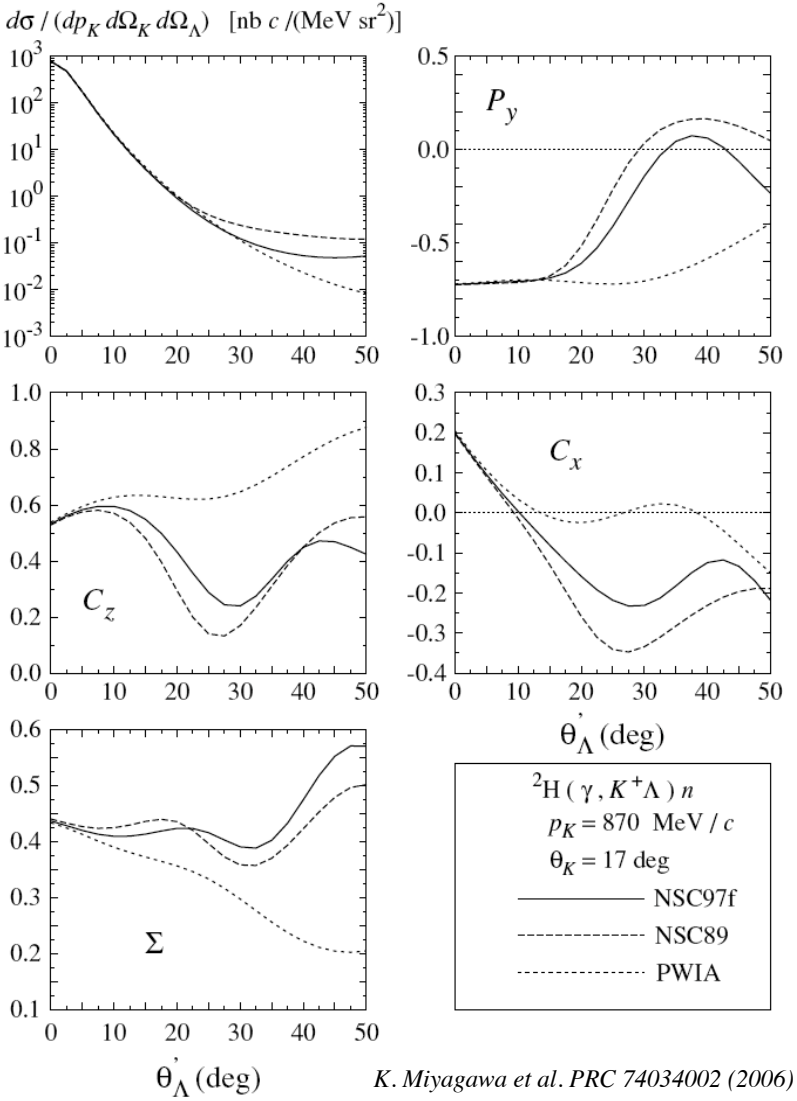
Theoretical Studies

- Existing *YN* models allow the calculation of single and double polarization observables
- Two *YN* potentials (NSC97F and NSC89) give the correct hypetrition binding energy
- NSC97F and NSC89 lead to very different predictions of polarization observables at some kinematics

$$\hat{z}' = \frac{\vec{p}_\gamma - \vec{p}_{K+}}{|\vec{p}_\gamma - \vec{p}_{K+}|}$$

$$\hat{y}' = \frac{\hat{z}' \times \vec{p}_{K+}}{|\hat{z}' \times \vec{p}_{K+}|}$$





K. Miyagawa et al. PRC 74034002 (2006)

Polarization observables are sensitive to θ'_Λ and p_{K+}

How can we study the *YN* interaction?

- Extending *NN* to *YN* potentials using SU(3) symmetry
  free parameters remain
- Elastic *YN* Scattering
  poor database
- Study of Hypernuclei
  no direct access on bare *YN* interaction
- **Final State Interactions (FSI) in Hyperon Production**
  simple target
  sufficient counting rates in modern accelerators
  model-dependent data interpretation

$$\vec{\gamma} d \rightarrow K^{+} \vec{\Lambda}(n)$$