Studies of Λn Interaction Through Polarization Observables for Final-State Interactions in $\gamma d \rightarrow K^+ \Lambda n$

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for the CLAS Collaboration

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Introduction

YN interaction not well known

- not all free parameters of the YN potential can be obtained from the NN potential via flavor SU(3) symmetry
- example: large uncertainties of YN scattering lengths:

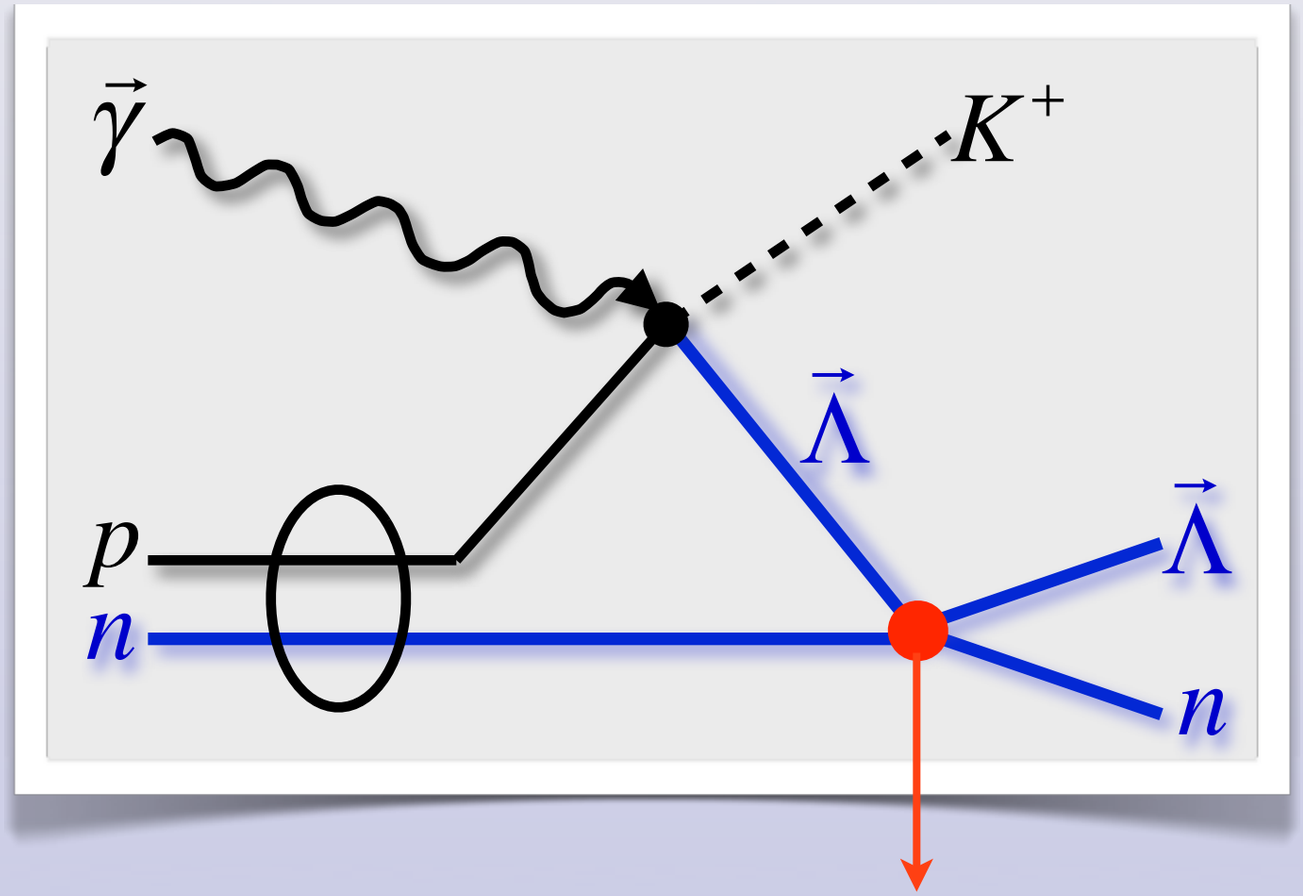
  $a(^1S_0) = -0.7 - -2.6$ fm,

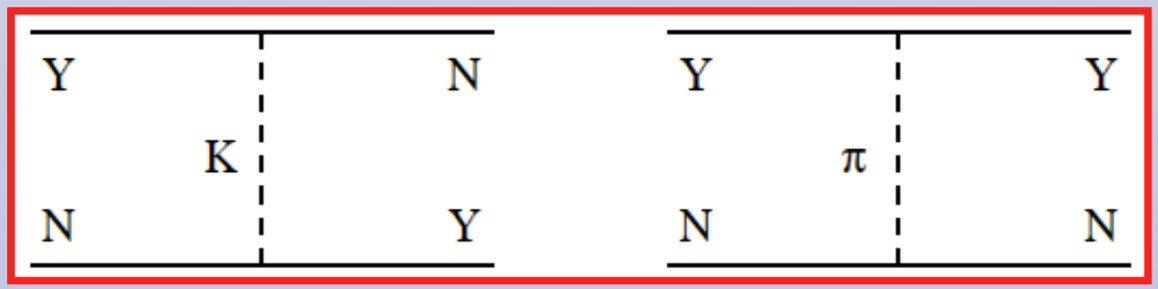
  $a(^3S_1) = -1.7 - 2.15$ fm
- YN elastic scattering database poor
- alternative approaches:
  - hypernuclear spectroscopy
  - studies of FSI in production reactions:

$$\gamma d \to K^+ \Lambda n \qquad pp \to K^+ \Lambda p$$

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

YN Interaction and Exclusive Hyperon Photoproduction off Deuteron





Nucleus used as a laboratory

- Hyperon Beam produced in first step
- Hyperons scatter off neutrons in a second step

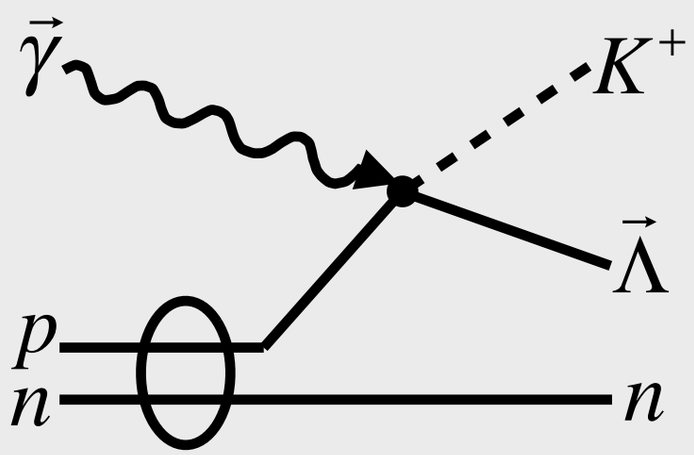
Theoretical Studies

- Observables sensitive to YN potentials at certain kinematics at a level of ~10% (K. Miyagawa et al., Phys. Rev. C **74**, 034002 (2006); A. Salam et al., Phys. Rev. C **74**, 044004 (2006); H. Yamamura et al., Phys. Rev. C **61**, 014001 (1999))
- A combination of $^1S_0$ and $^3S_1$ scattering lengths can be extracted from data close to threshold (A.Gasparian et al., Phys. Rev. C 69, 034006 (2004))

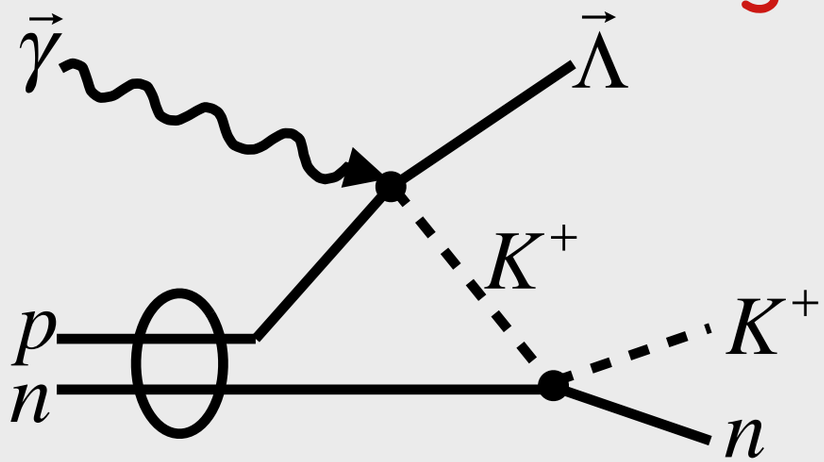
Exclusive Hyperon Photoproduction off Deuteron

Background Mechanisms

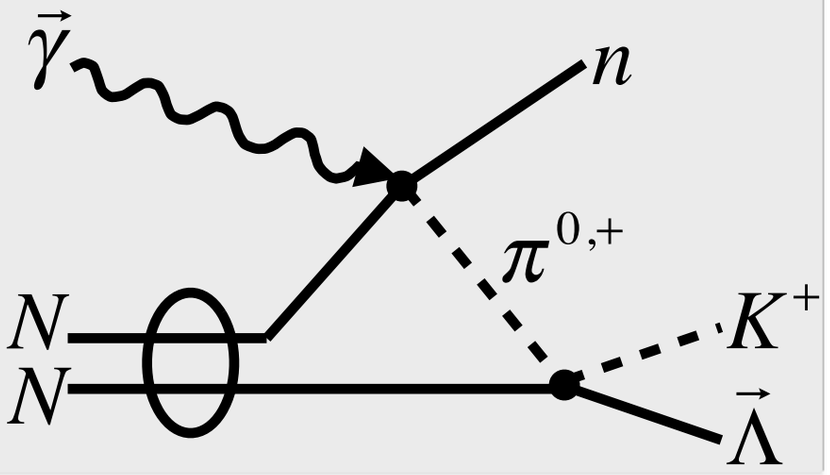
Quasi-Free



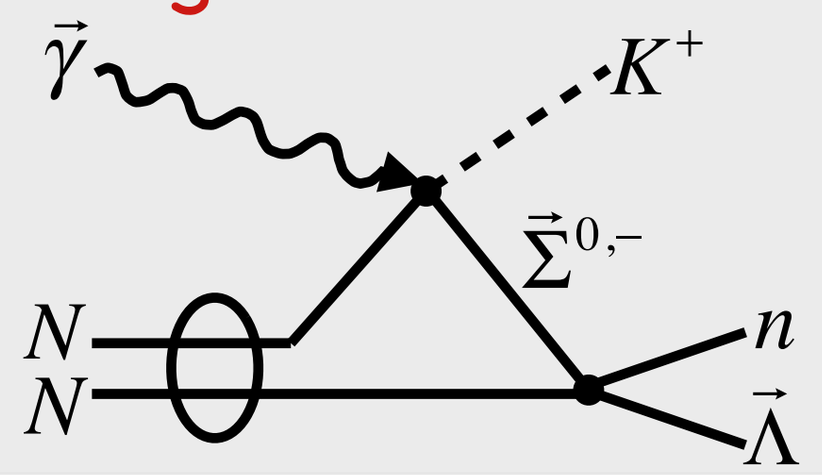
Kaon Rescattering



Pion Mediated



Sigma Mediated



Exclusive Hyperon Photoproduction off Deuteron

Polarization Observables

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_0}\left[1 - P_{lin}\Sigma\cos 2\varphi - \alpha\cos\theta_x(P_{lin}O_x\sin 2\phi + P_{circ}C_x) - \alpha\cos\theta_z(P_{lin}O_z\sin 2\phi + P_{circ}C_z) + \ldots\right]$$

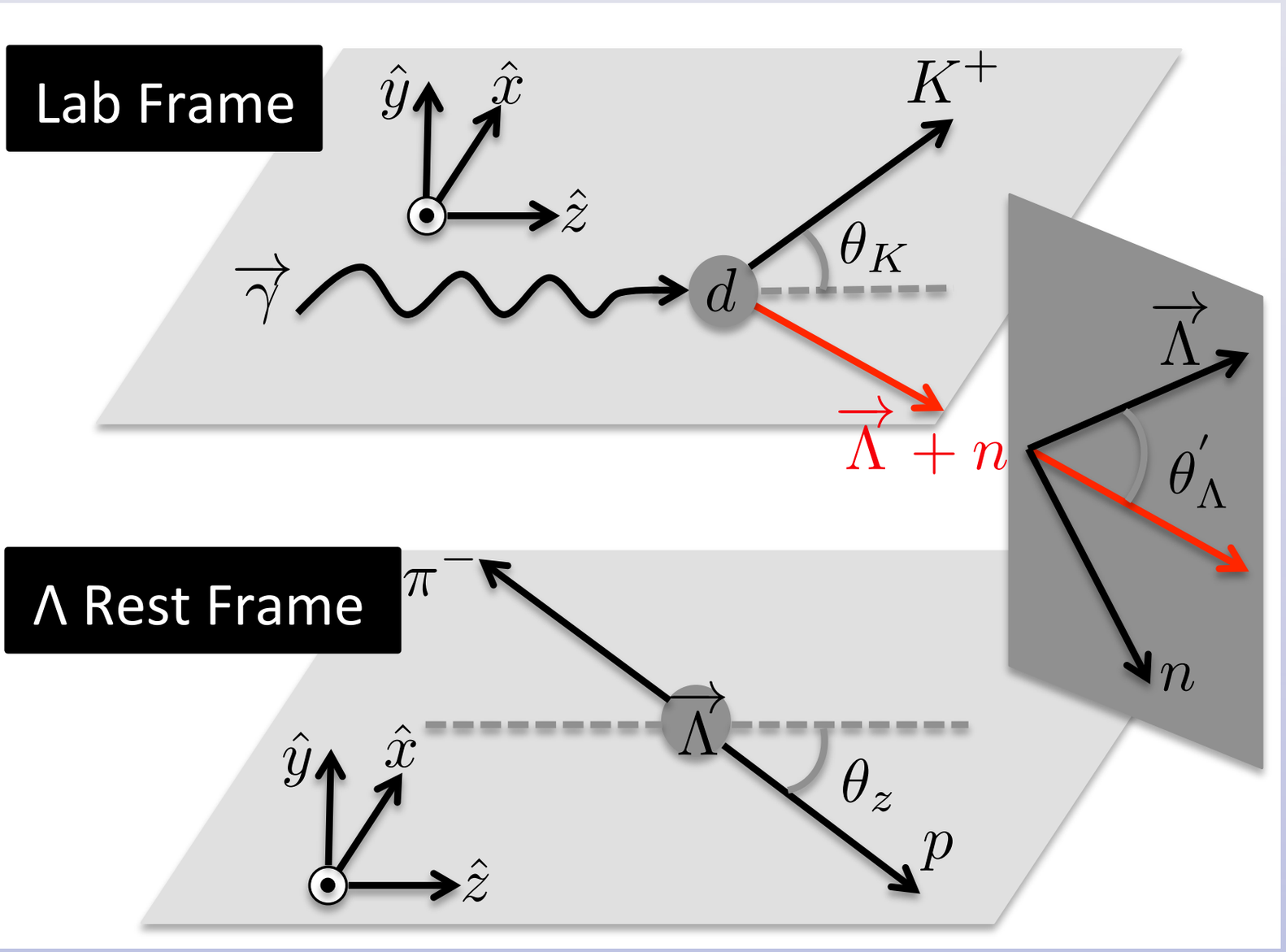


Figure from Tongtong Cao

Λ self-analysing power:

$\alpha = 0.642 \pm 0.013$

Relevant Kinematic Variables:

- From $\Lambda n \to \Lambda n$: θ_Λ', $W_{\Lambda n} \equiv IM_{\Lambda n}$
- From $\gamma p \to K^+\Lambda$: E_γ, p_K, θ_K

$\Sigma(E_\gamma, p_K, \theta_K, \theta_\Lambda', W_{\Lambda n})$

$C_x(E_\gamma, p_K, \theta_K, \theta_\Lambda', W_{\Lambda n})$

$C_z(E_\gamma, p_K, \theta_K, \theta_\Lambda', W_{\Lambda n})$

…

Experimental Facility: CLAS at Jefferson Lab

Experiment E06-103 (g13)

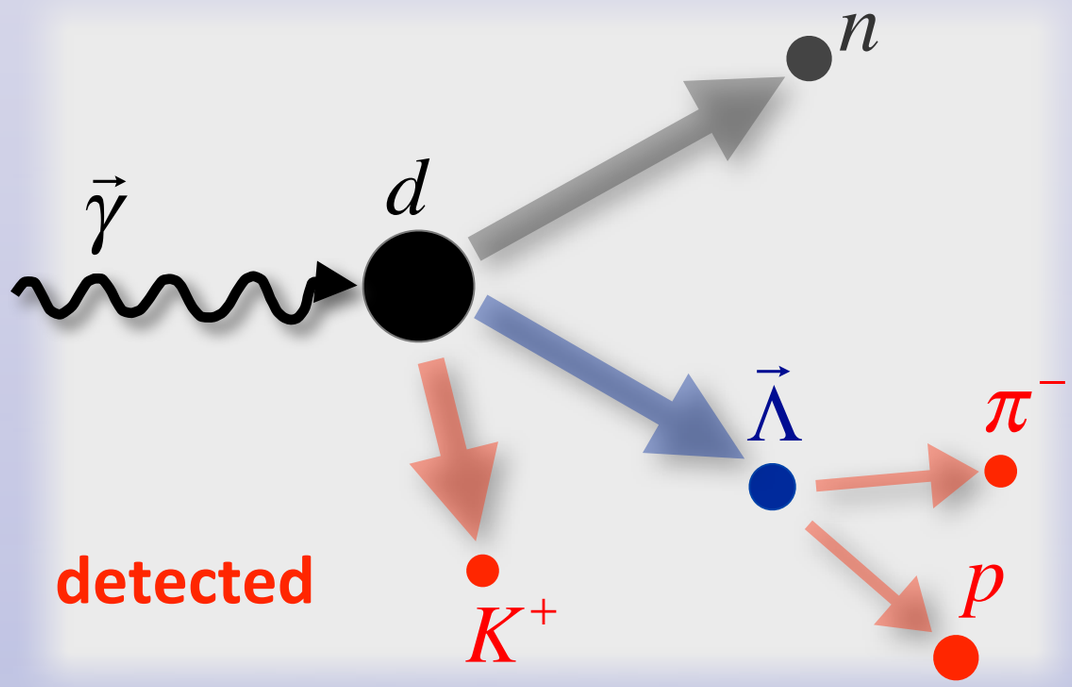
Circularly Polarized Photons (g13a)

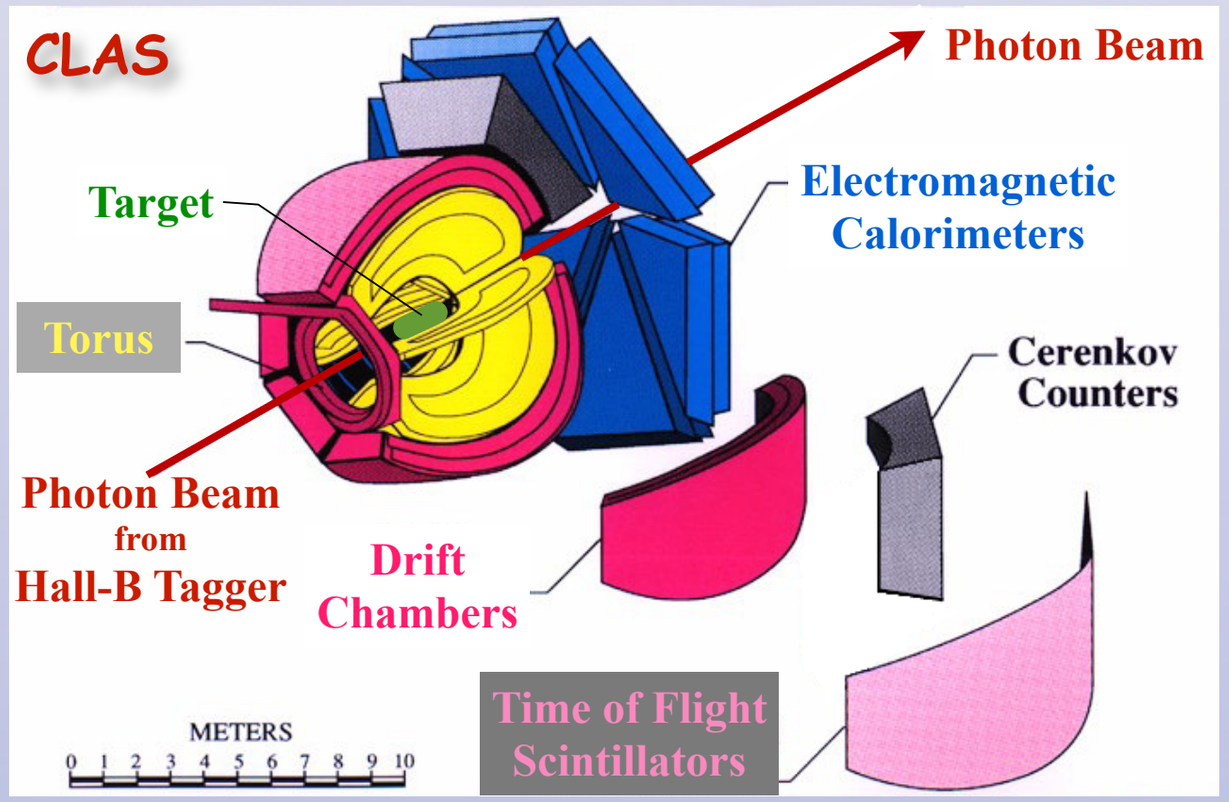
- E_e = 2 GeV; 2.65 GeV
- electron polarization: ~ 80%
- triggers: ~20×10^9 triggers

Linearly Polarized Photons (g13b)

- E_e = 3.3 - 5.2 GeV
- coherent edge at: 1.3, 1.5, 1.7, 1.9, 2.1, 2.3 GeV
- $P\gamma$ = 70% - 90%
- ~30×10^9 triggers

Fully Exclusive Measurement



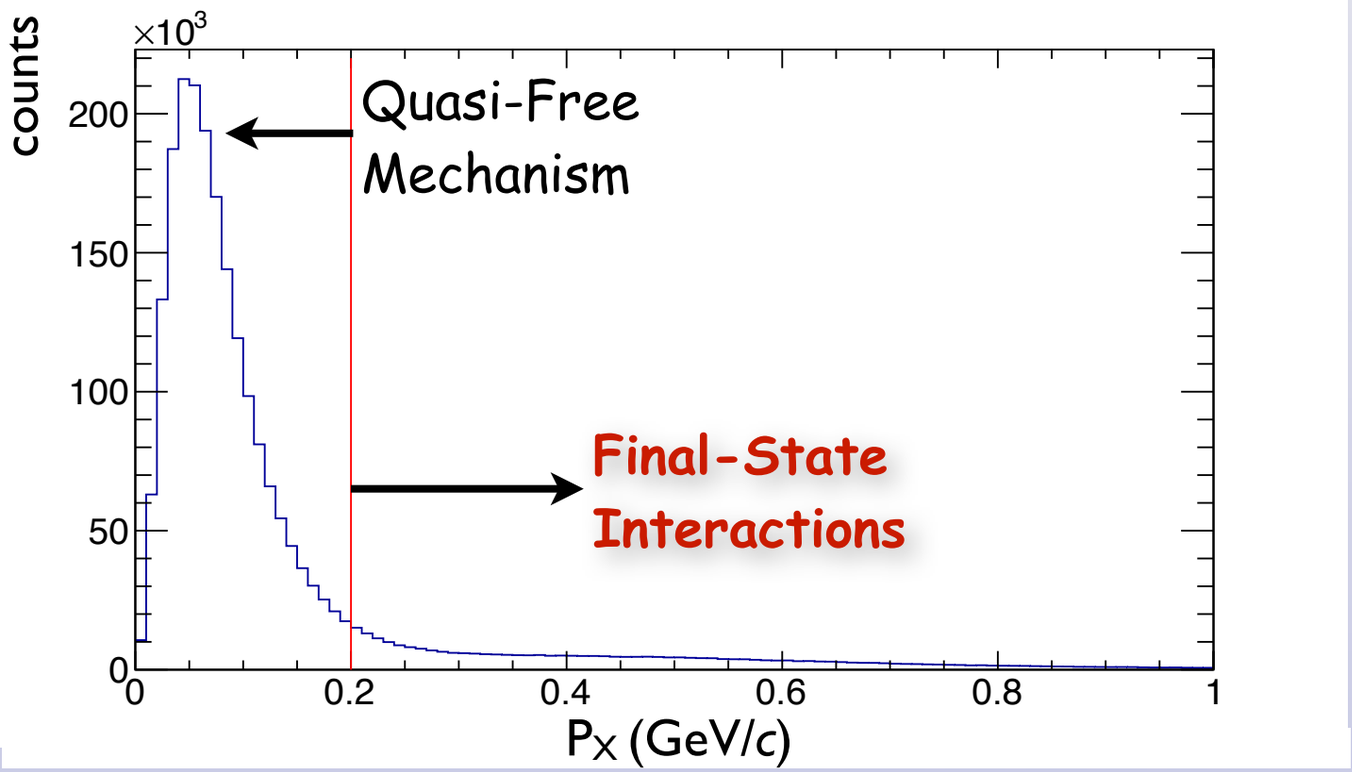


P. Nadel-Turonski, B. Berman, YI, D. Ireland, A. Tkabladze et al., E06-103: "Kaon Production on the Deuteron Using Polarized Photons"

Suppression of Quasi-Free Mechanism

Event Distribution over Missing Momentum

$P_x \ (\gamma d \to K^+ \Lambda X)$



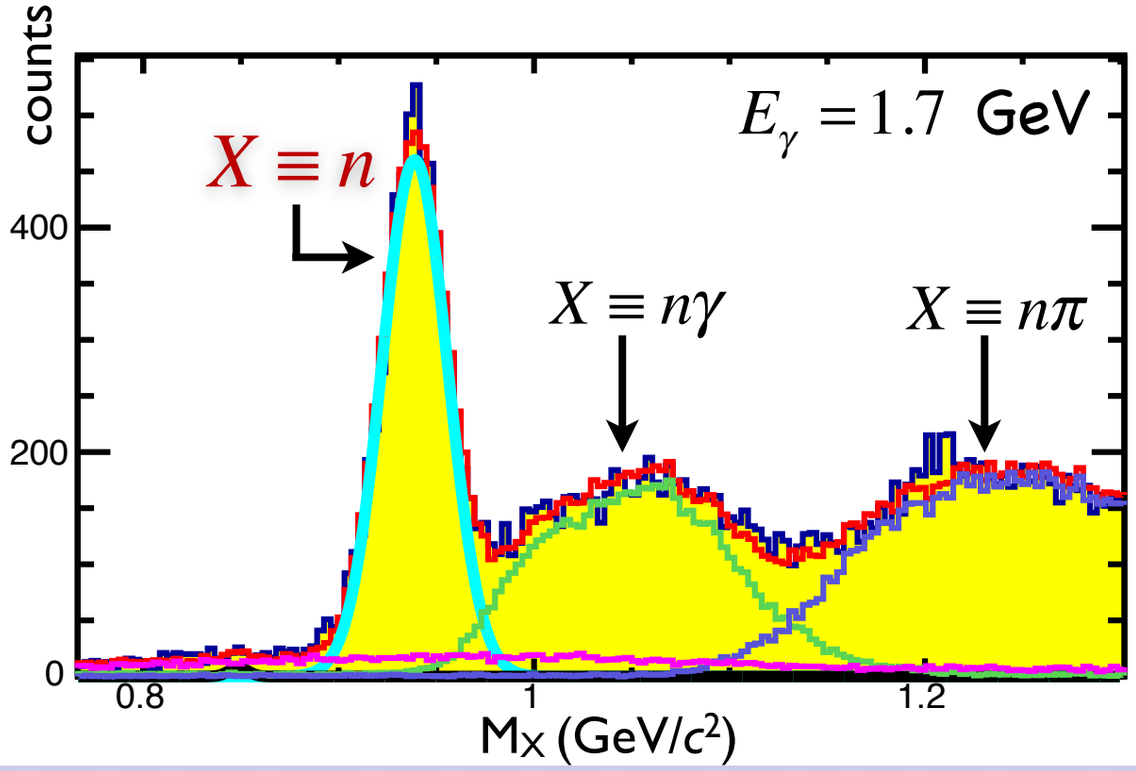
The removal of events with Px < 0.2 GeV/c provides a sample that is by far dominated by FSI events. Standard analysis procedure.

Figure from Tongtong Cao

Selection of Exclusive Events

Event Distribution over Missing Mass

$M_x \ (\gamma d \to K^+ \Lambda X)$



Removal of physics background based on realistic simulation of reactions, detector, and accidentals, followed by histogram or event-by-event fits for each kinematic bin.

Figure from Nick Zachariou

Exclusive Hyperon Photoproduction off Deuteron

Polarization Observables: Beam-Spin Asymmetry

Linearly Polarized Photons: $\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_0}\left[1 - P_{lin}\Sigma\cos 2\varphi + \ldots\right]$

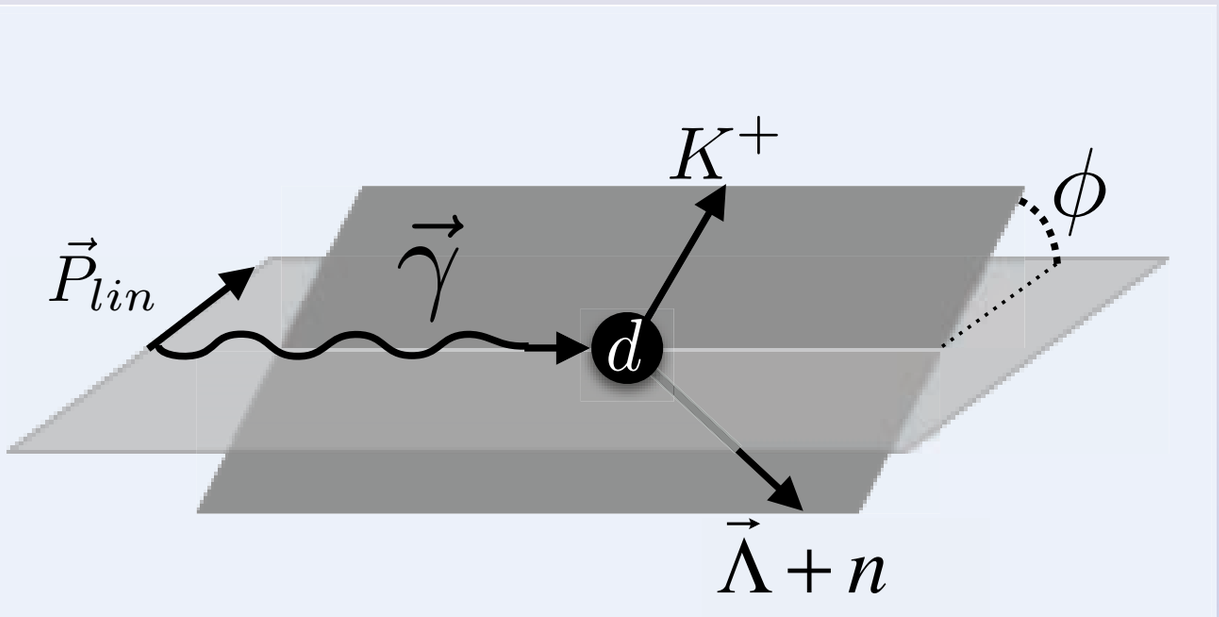
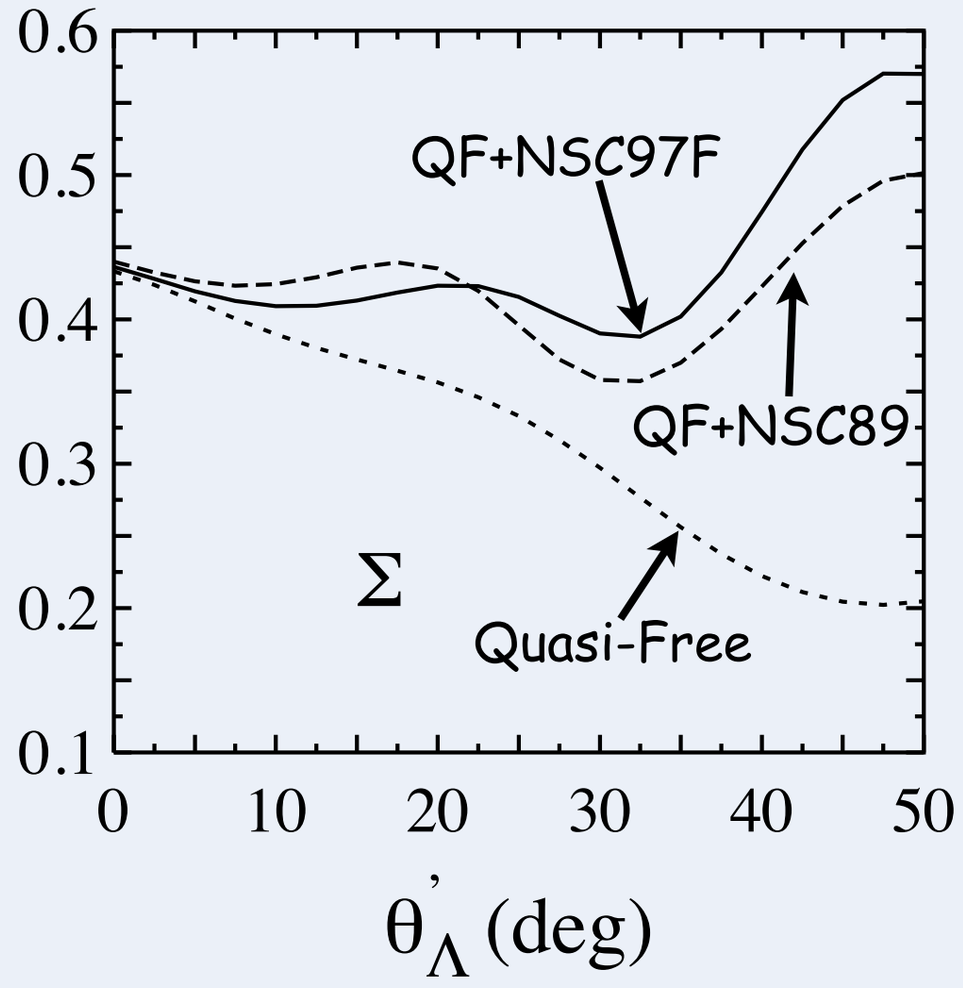


Figure from Nick Zachariou

- Single-polarization observable, i.e. smallest statistical uncertainties
- For the $K^+\Lambda n$ final state, ϕ is not uniquely defined: ϕ_K, ϕ_Λ, ϕ_n, $\phi_{K\Lambda}$, $\phi_{\Lambda n}$, ϕ_{Kn}
- Observable can be used as a probe for dominance of various FSI mechanisms

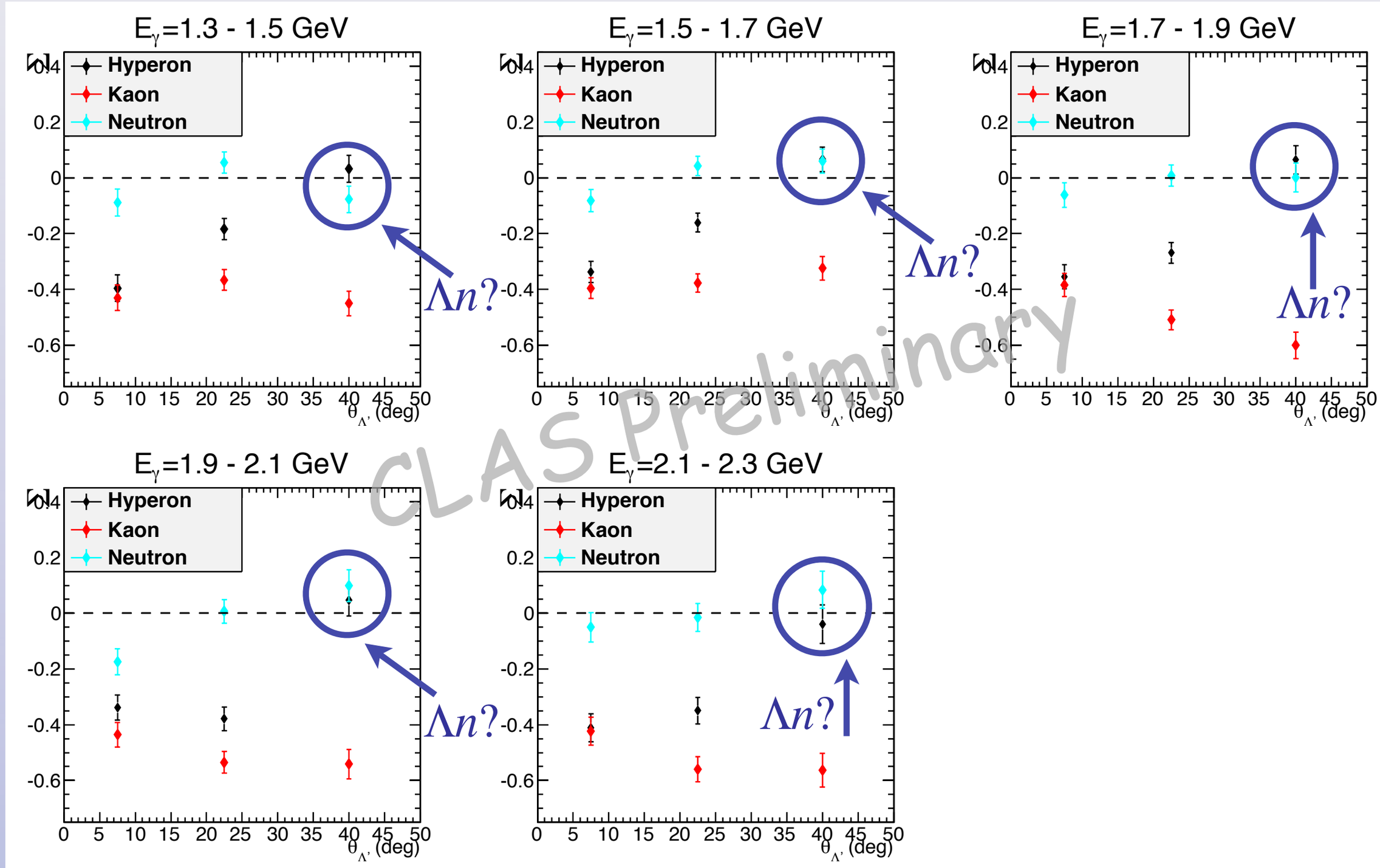
Theoretical Prediction



K. Miyagawa et al., Phys. Rev. C 74, 034002 (2006);

Preliminary Results: Beam Spin Asymmetry

Work by Nick Zachariou

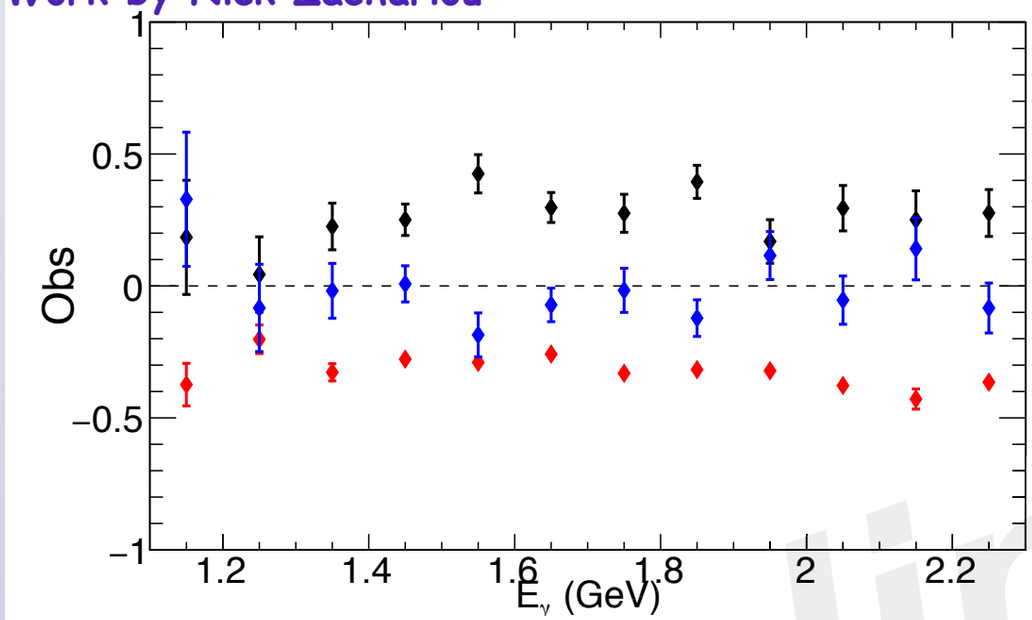


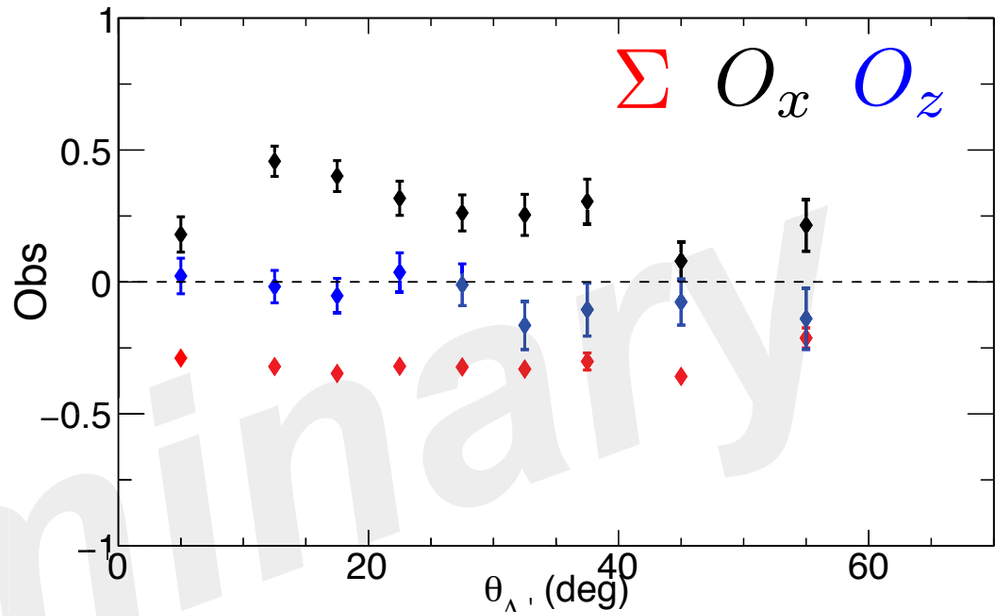
Preliminary Results

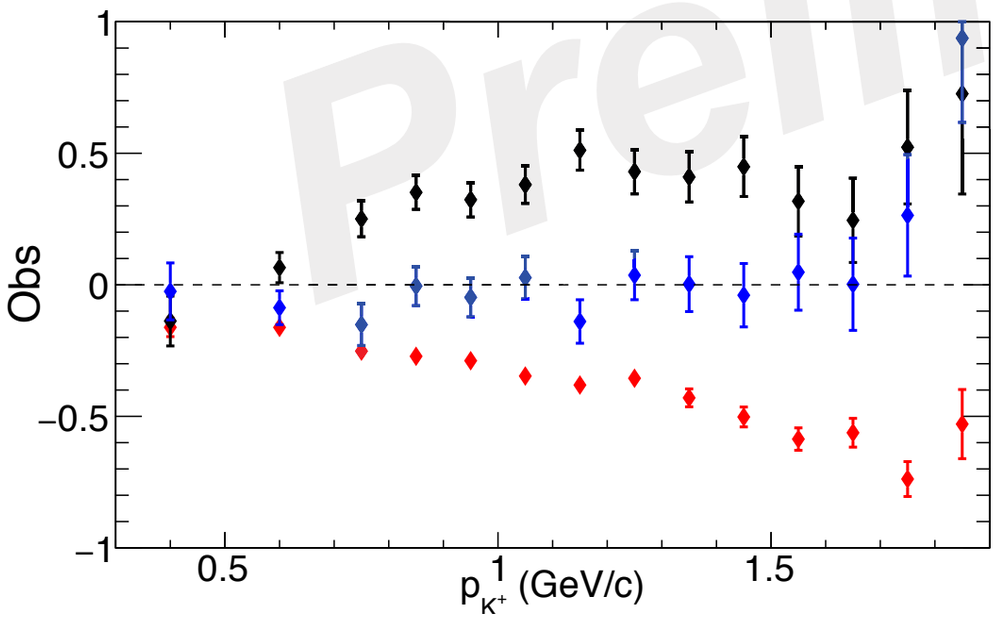
Observables for Linearly-Polarized Photons

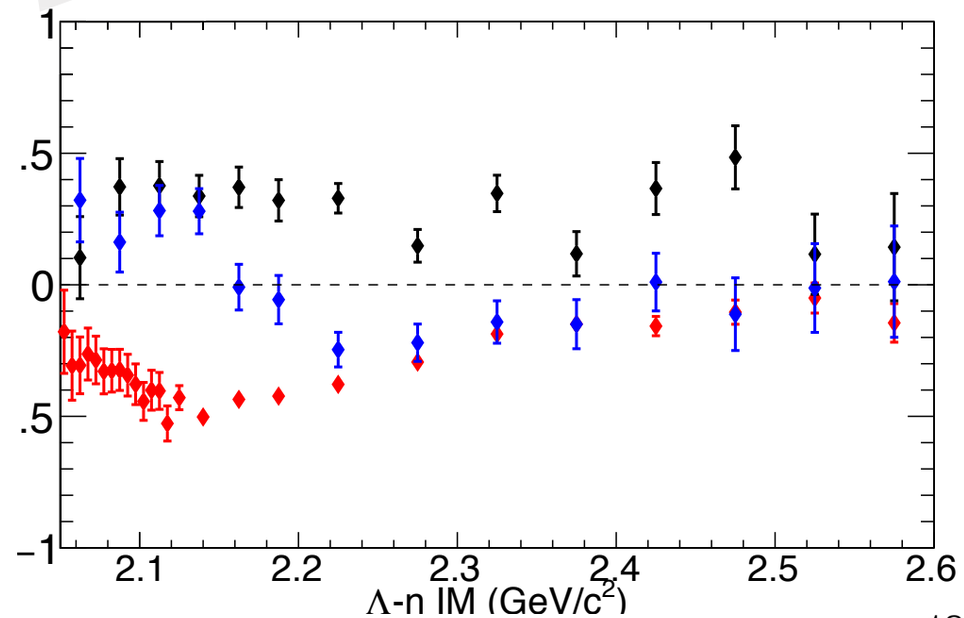
$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_{unp}}\left[1 - P_{lin}\Sigma\cos 2\varphi - P_{lin}O_x\alpha\cos\theta_x - P_{lin}O_z\alpha\cos\theta_z + \ldots\right]$$

Work by Nick Zachariou







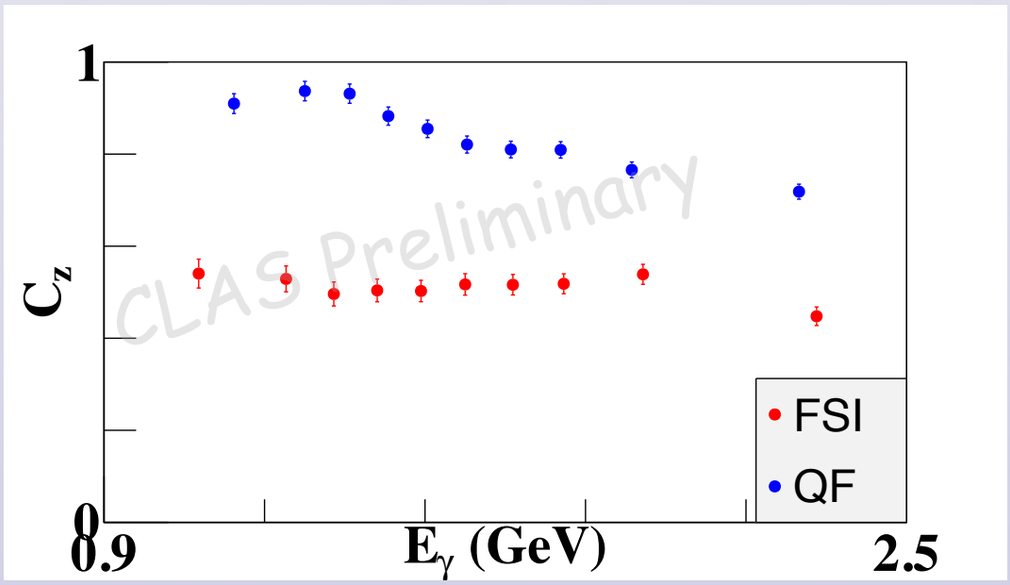


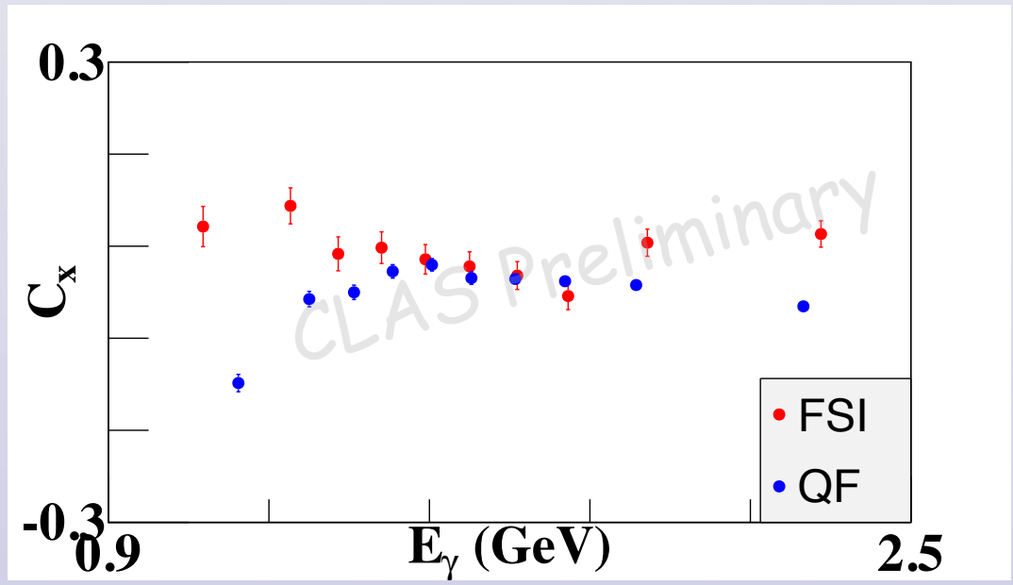
Preliminary Results

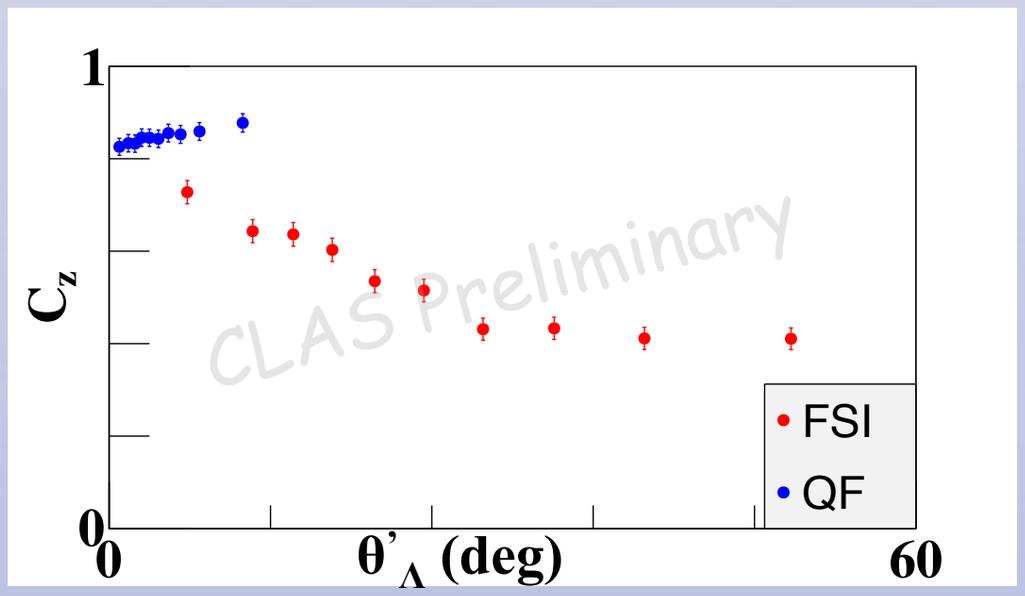
Observables for Circularly-Polarized Photons

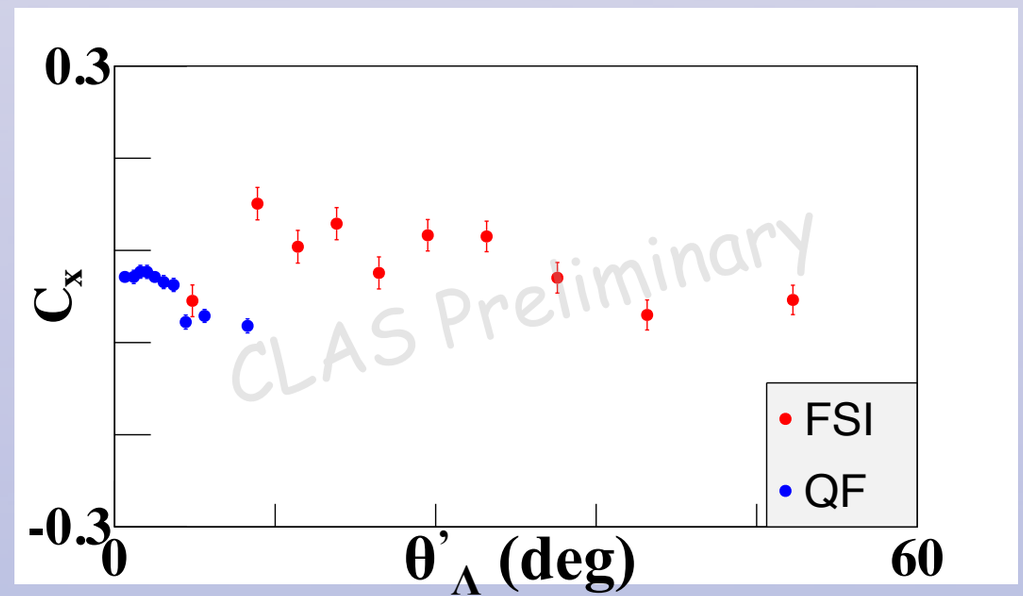
$$\frac{d\sigma^{\pm}}{d\Omega} = \frac{d\sigma}{d\Omega_{unp}}\left[1 \pm P_{circ}C_x\alpha\cos\theta_x \pm P_{circ}C_z\alpha\cos\theta_z + \alpha P_y\cos\theta_y \ldots\right]$$

Work by Tongtong Cao



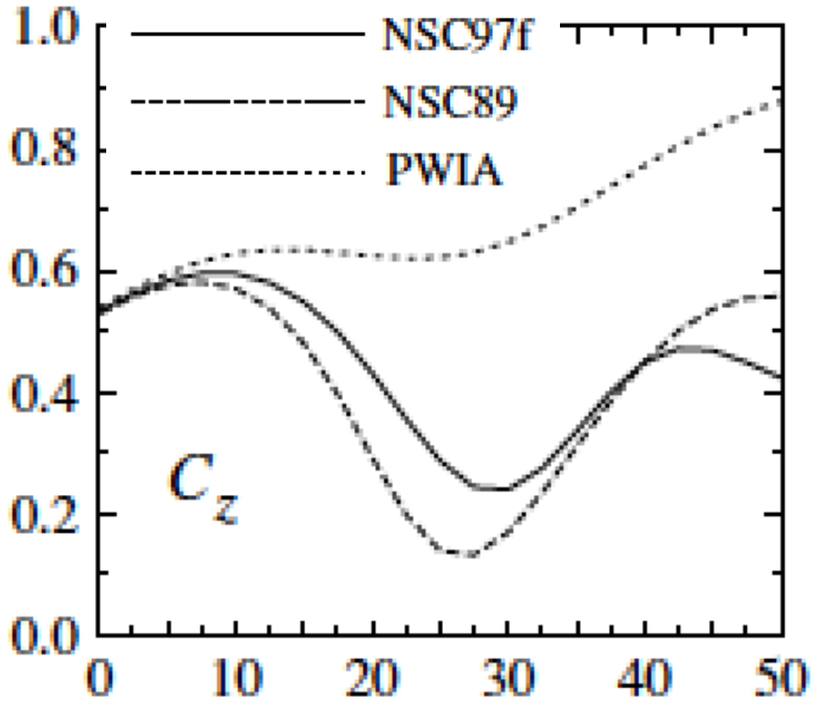


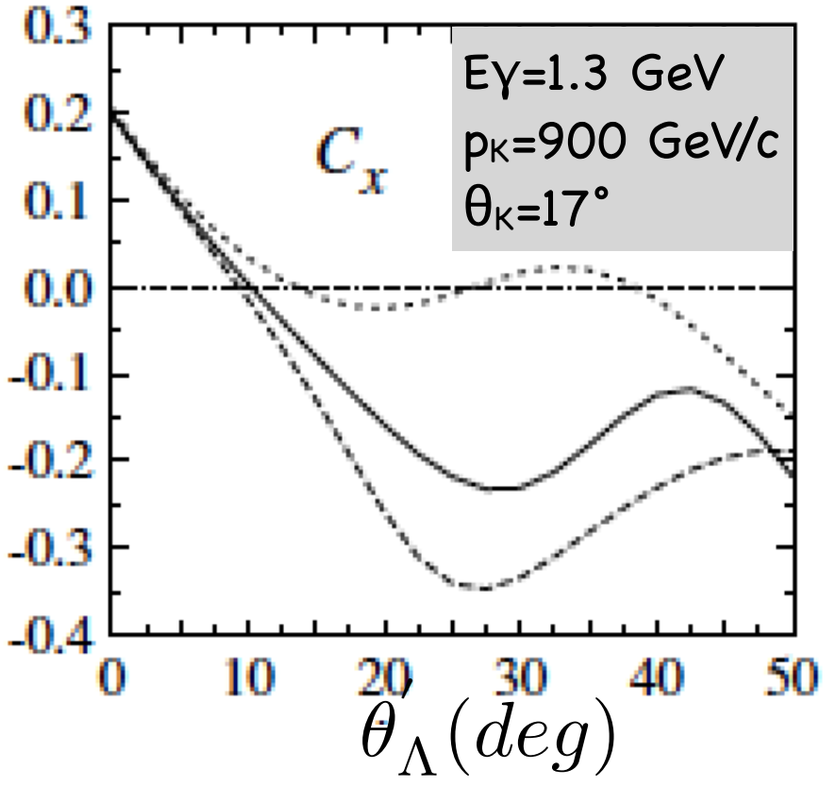




Model Comparison: Perspectives

K. Miyagawa et al., Phys. Rev. C 74, 034002 (2006)





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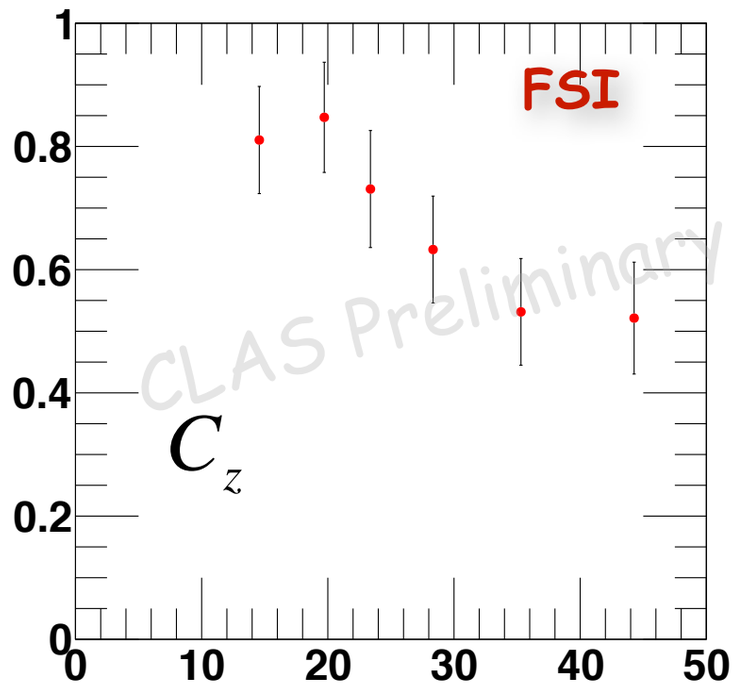
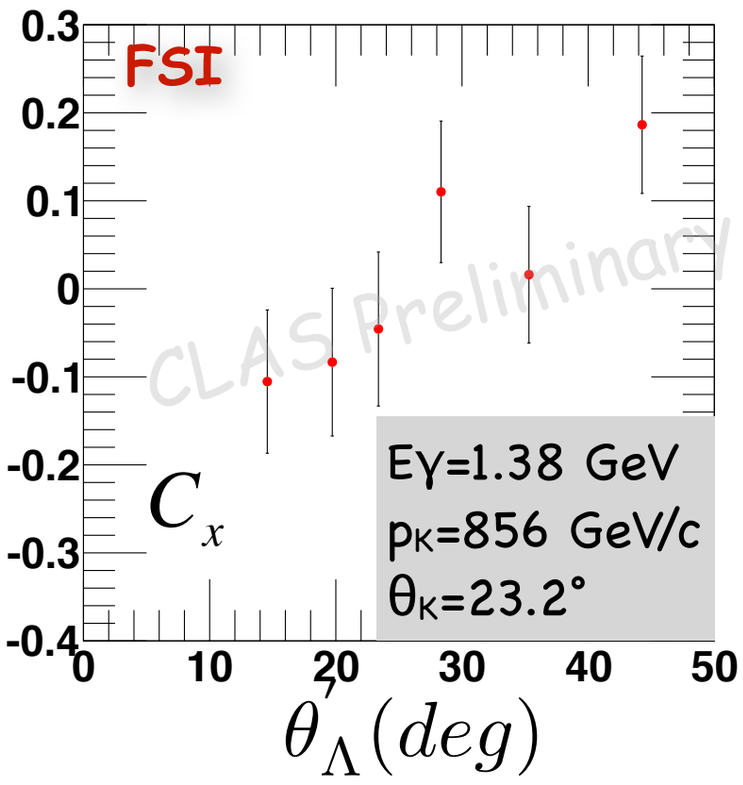
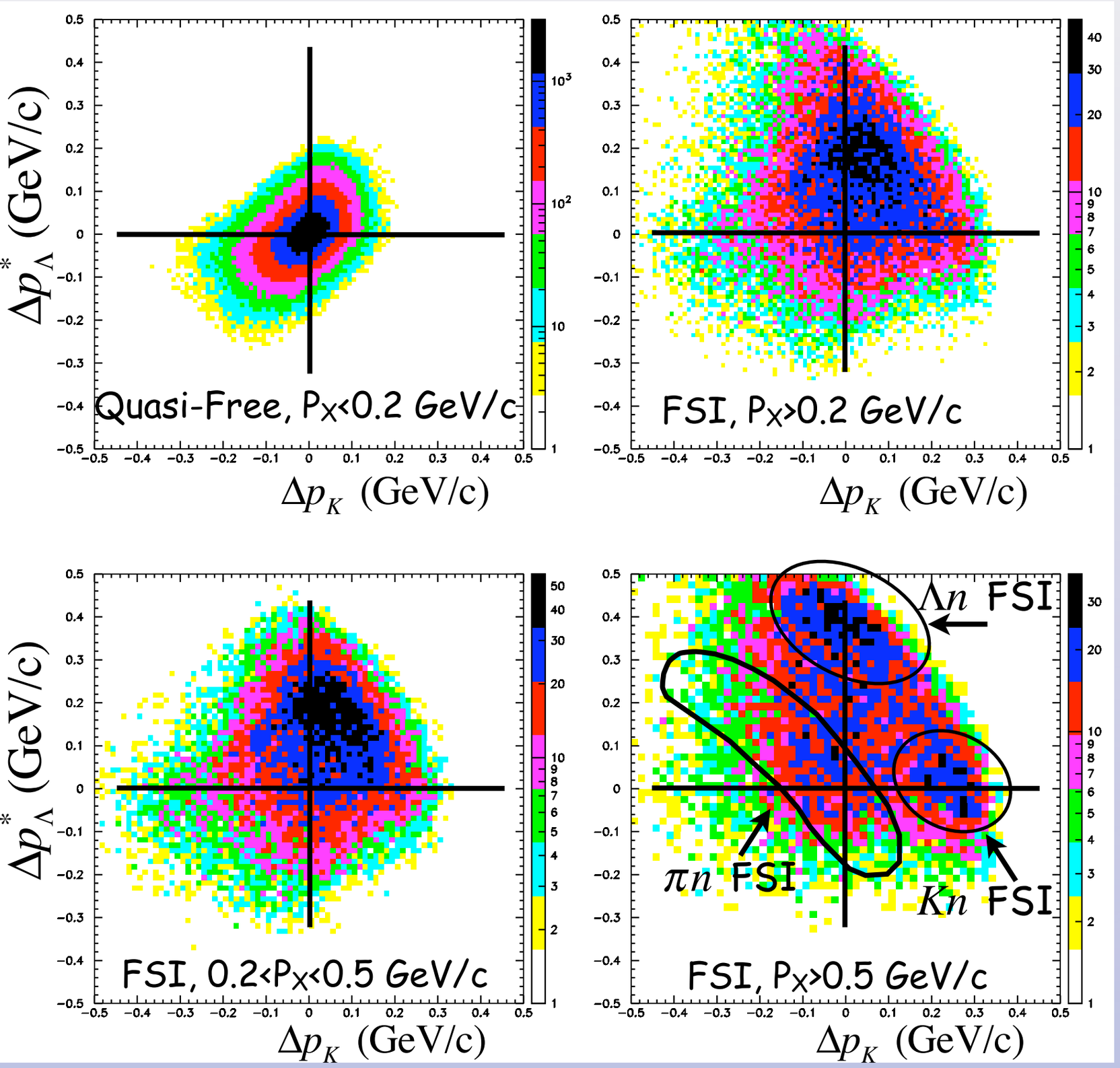




- one-, ..., four-fold differential observables will be extracted
- experimental observables are integrated over the CLAS acceptance
- direct comparison with models is not trivial
  - collaboration with theorists
  - use the model as event generator and process through CLAS simulation
  - provide a sample of FSI events that can be binned in any way

Suppression of Background Mechanisms



Assumption: The sequential 2→2 scatterings occur on a nucleon at rest

Strategy: Test if the 3-vector of each particle obeys 2-body kinematics at first step:

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

$$\Delta p^*_\Lambda = p^{CM-K\Lambda}_{\Lambda,meas} - p^{CM-K\Lambda}_{\Lambda,2body}$$

$$p^{CM-K\Lambda}_{\Lambda,2body} = F(E_\gamma, m_p, m_\Lambda, m_K)$$

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

$$\Delta p_K = p^{LS}_{K,meas} - p^{LS}_{K,2body}$$

$$p^{LS}_{K,2body} = F(E_\gamma, \theta^{LS}_{meas})$$

Summary

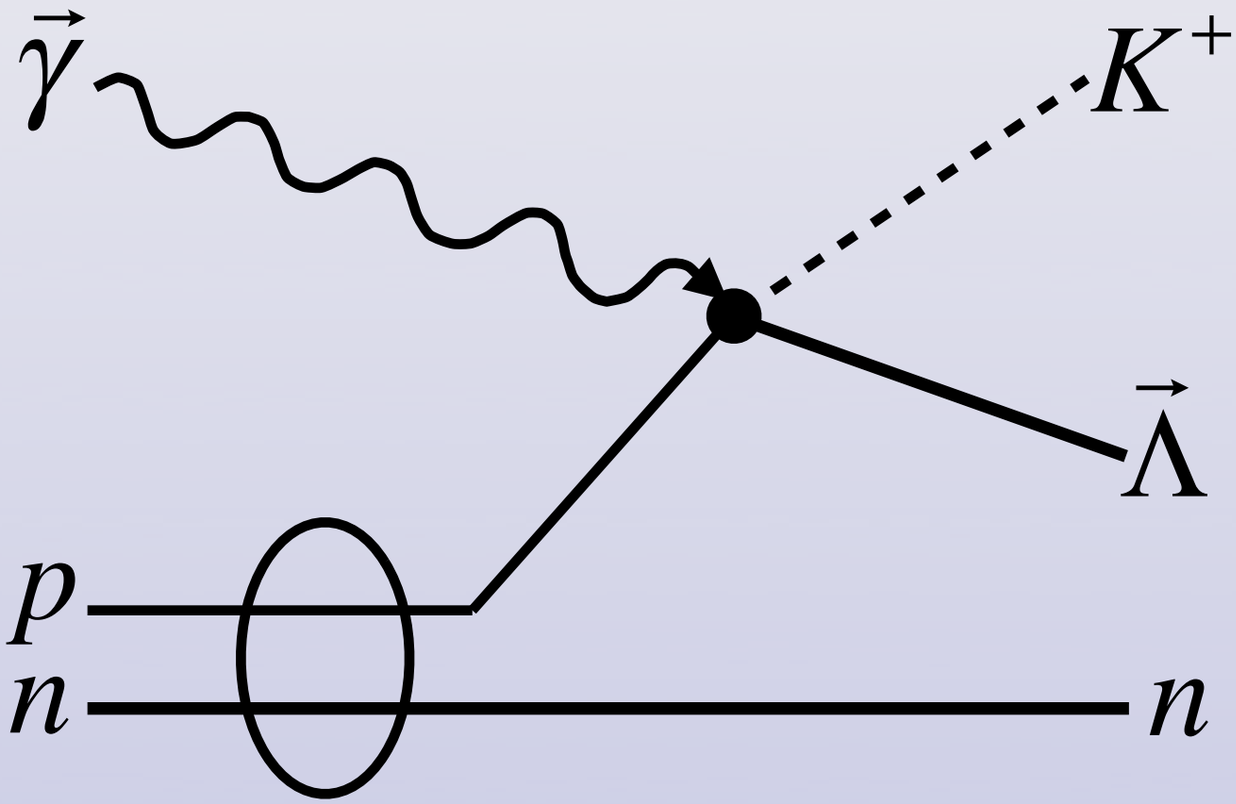
First estimates of a large set of polarization observables for FSI in the reaction $\gamma d \rightarrow K^+ \Lambda n$ have been obtained from JLab g13 experiment.

- One-, two-, three-, and four-fold differential estimates can be obtained with adequate statistical uncertainty.
- Beam-spin asymmetry provides indication that $\Lambda n \rightarrow \Lambda n$ mechanism may be dominant at large θ_Λ'.
- Beam-spin asymmetry can be binned sufficiently fine at low $W_{\Lambda n}$ to be suitable for extraction of the Λn scattering length.
- Extraction of helicity asymmetries and Λ induced polarization is underway.
- Data have sufficient coverage and statistical significance to impact YN.
- Work in progress on data interpretation (YN interaction).

The End

Exclusive Hyperon Photoproduction off Deuteron

Background Mechanisms



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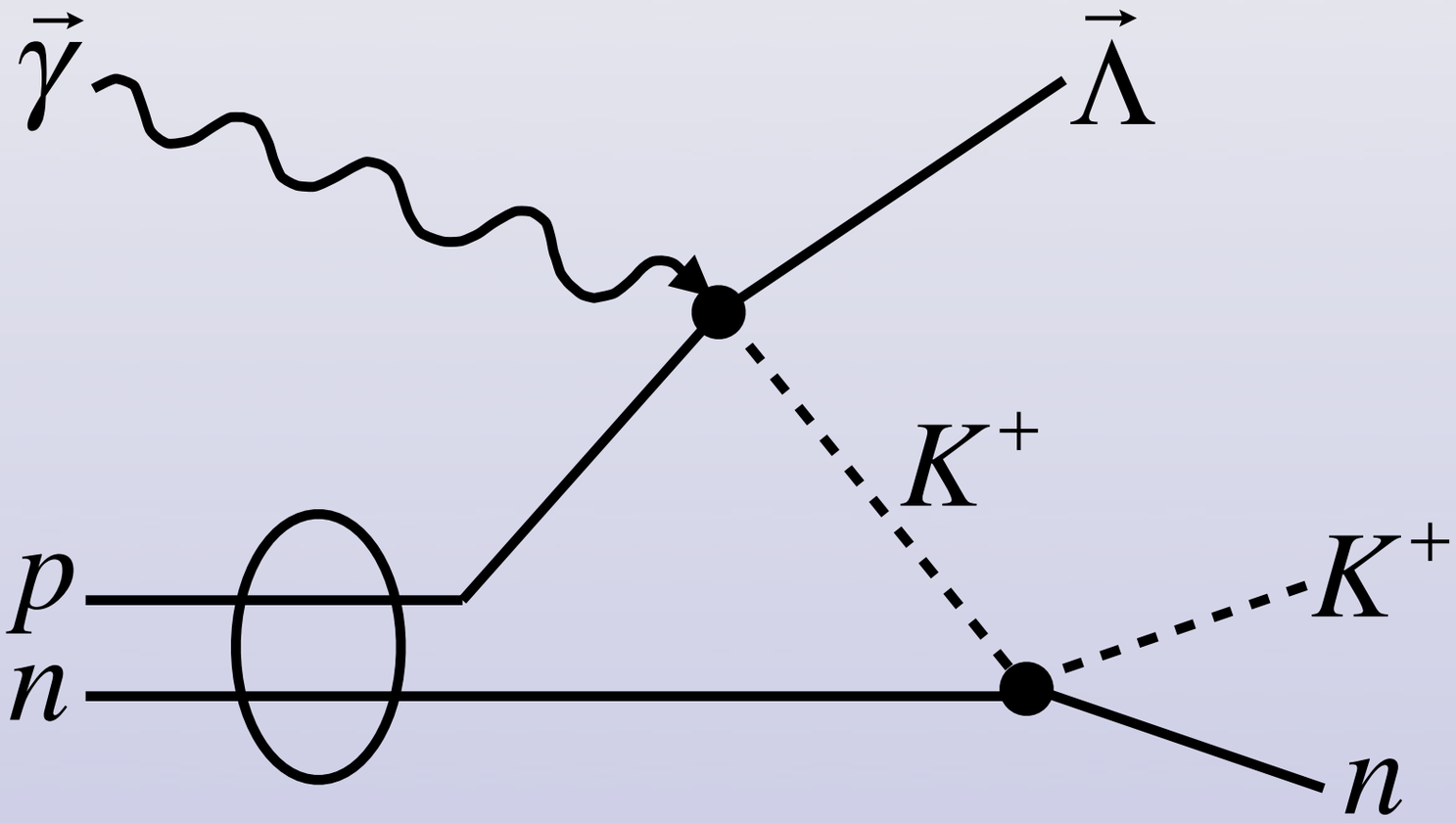

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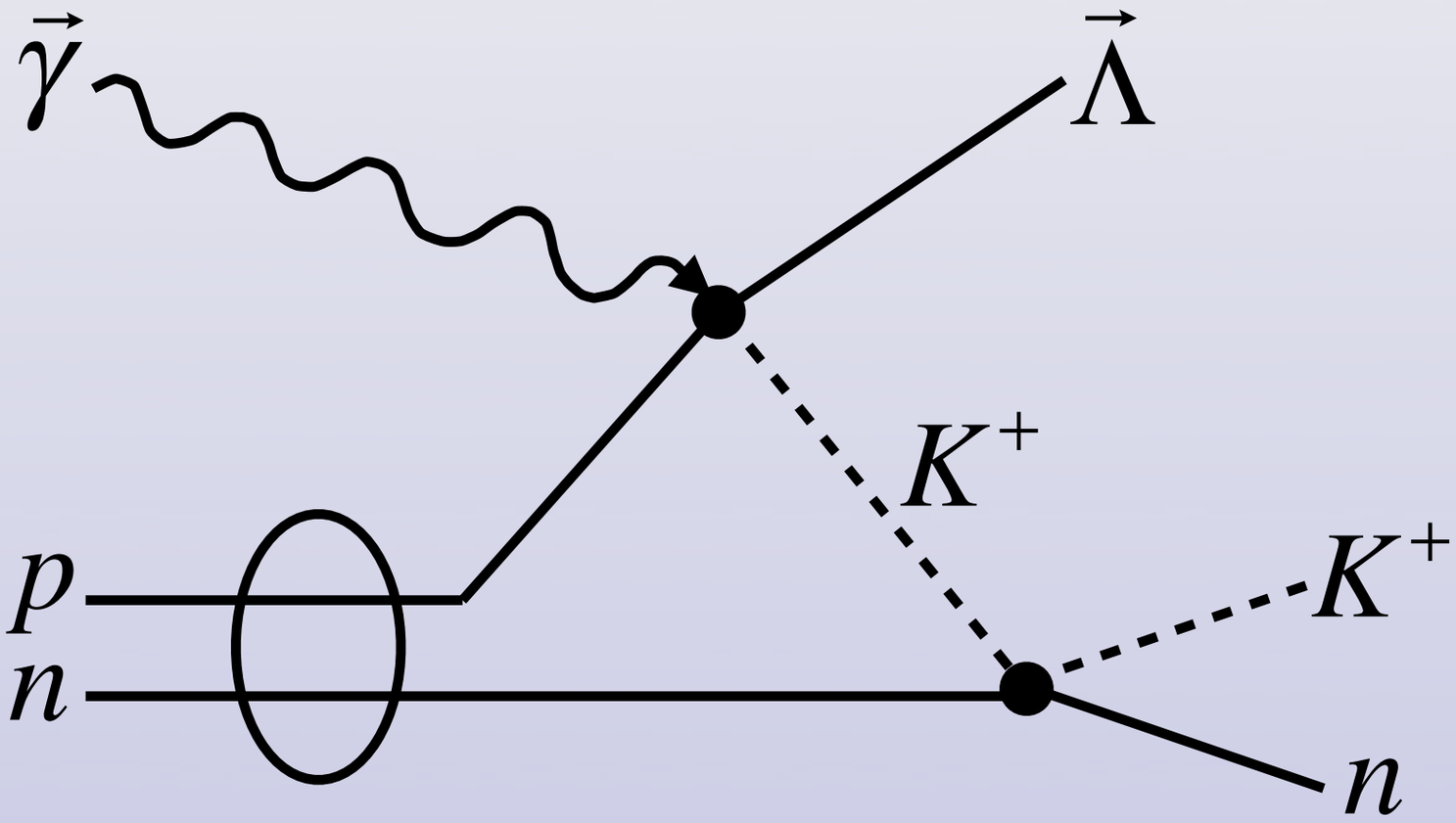

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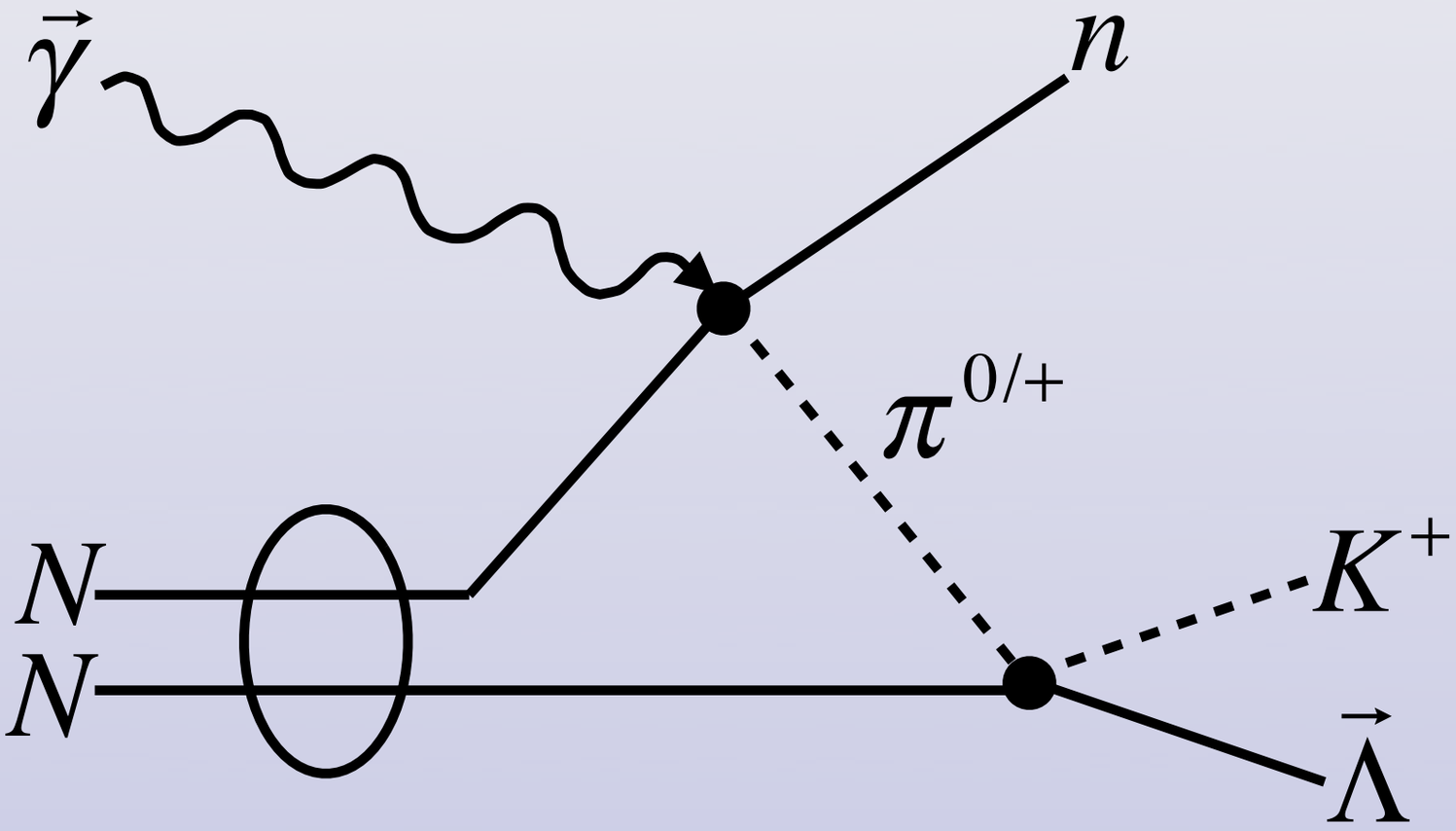

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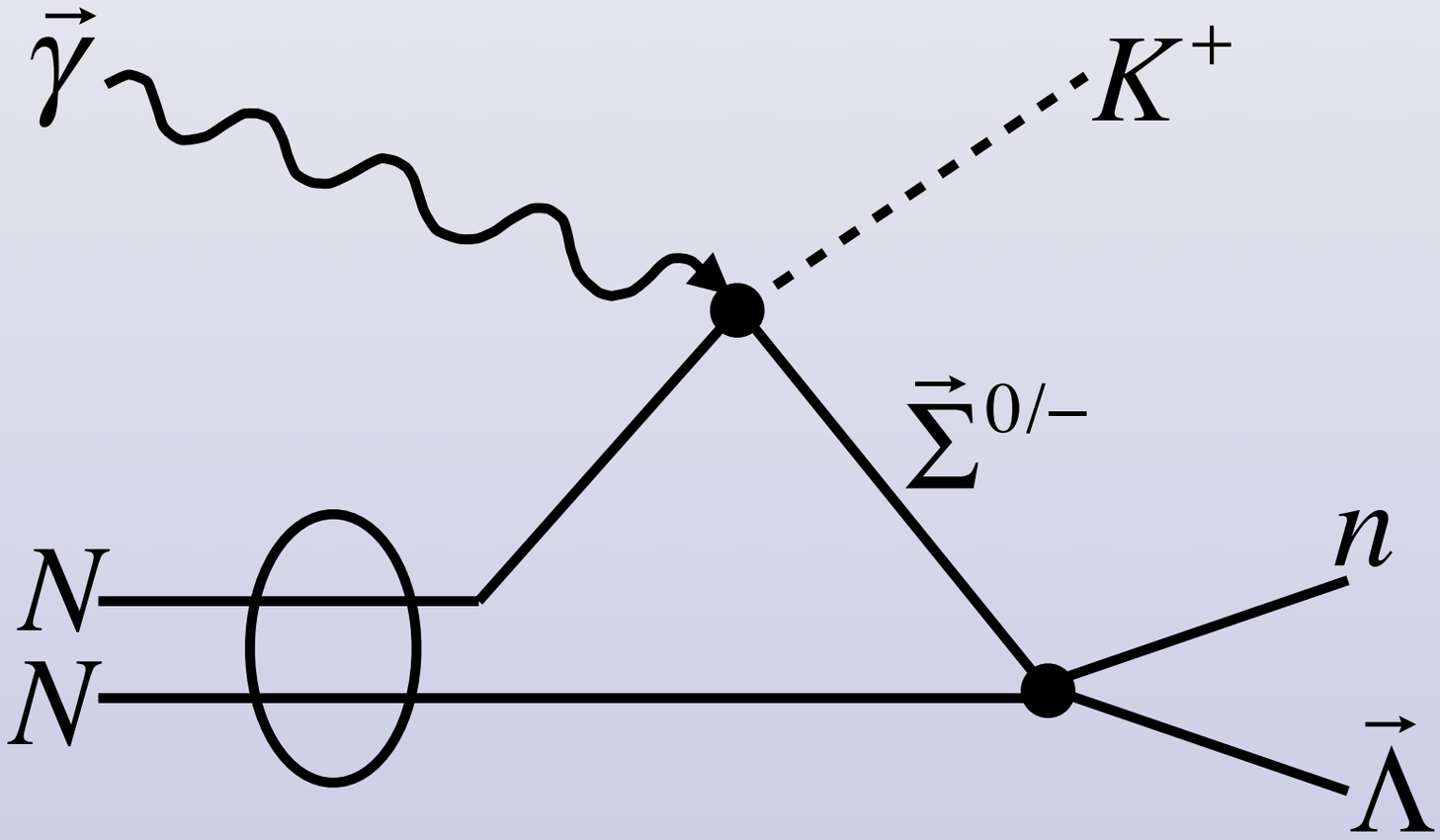

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Polarization Observables

Linearly Polarized Photons:

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_{unp}}\left[1 - P_{lin}\Sigma\cos 2\varphi - P_{lin}O_x\alpha\cos\theta_x - P_{lin}O_z\alpha\cos\theta_z - \alpha\cos\theta_y(P_y + P_{lin}T\cos 2\phi) + \ldots\right]$$