Measurement of Polarization Observables for the reaction $\gamma p \rightarrow K^0\Sigma^+$

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Outline

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Why $\gamma p \rightarrow K^0\Sigma^+$?

- Photoproduction of neutral kaons offers advantage over charged ones since photons cannot couple directly to (vanishing) charge of the meson.
- Data on isospin related channels $K^0\Sigma^+$ and $K^+\Sigma^0$ allow for disentanglement of contributions from N and Δ resonances.

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- Data on isospin related channels $K^0\Sigma^+$ and $K^+\Sigma^0$ allow for disentanglement of contributions from N and Δ resonances.
- Hyperon decay allows measurement of asymmetries, which allow for the extraction of hyperon recoil polarization P.
- Trade-off however is low cross-sections, leading to less statistics.
- The determination of the polarization observables allows for an understanding of the intermediate steps involved in the reaction.

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- Weak decay violates parity, thus allowing for extraction of polarization P observable of Σ^+ from angular distribution of a decay product in Σ^+ rest-frame.
- These observables are sensitive to interference from different states.

Figure 1: Particle Data Group.

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The C_x and C_z double polarization observables allow for a characterization of the transferred polarization from incident beam to recoiling hyperon along the orthonormal axes in the scattering plane.

Spin-Dependent Cross-Section for K^0 + Photoproduction

$$_Y \frac{d}{d \quad _{K^+}} = \left(\frac{d}{d \quad _{K^+}}\right)_{unpol} f\, 1 + \quad _y P + P \quad (C_x \quad _x + C_z \quad _z) g$$

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$$P_{\overset{+}{x}} = P \quad C_x$$

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Transverse (induced) polarization $P_y^{\ +}$ is equivalent to P observable.

The $\hat{x}$ and $\hat{z}$ components of hyperon polarization are proportional to C_x, C_z via degree of beam polarization P .

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Scattering Frame

$$(k) + p(q_1) \; ! \quad K^0(q_2) + \quad {}^+(q_3);$$

$$\hat{y} = \frac{\vec{k} \quad \vec{q}_2}{j\vec{k} \quad \vec{q}_2 j}; \qquad \hat{z} = \frac{\vec{k}}{j\vec{k}j}; \qquad \hat{x} = \hat{y} \quad \hat{z}:$$

Figure 2: Scattering plane of $p\,!\ K^0\ ^+$.

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Figure 3: Hall B at JLab, home to the g12 experiment.

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g12 Data Cuts

- Vertex Cut: -110.0 cm< z-vertex< -70.0 cm.
- Timing Cut: $| \; _{TBID}| < 1$ ns.
- Particle ID Cut: $\; = | \; _{c} \; \; _{m}| \; \; 3 \;$.
- Fiducial Cut: nominal scenario.

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Missing Momentum

$$x = k + P \quad P_{i=1}^{2;3} p_i :$$

Missing Mass

$$m_X^2 = x \; x :$$

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- Q-factor used as event weight in order to determine signal contribution to physical distributions.
- Due to K^0 ! $^+$ and $^+$! $p\ {}^0$ correlation, reference quantity can be either invariant mass.

Figure 4: Left: Raw distribution of all g12 $^{+}$ ^{0} events. Right: Same invariant mass $^{+}$ after $^{+}$ mass-cut has been employed.

Figure 5: Left: Invariant $^{+}$ ^{0} mass vs. $^{+}$ mass for all g12 $^{+}$ ^{0} events. Right: Same invariant $^{+}$ mass distribution after the ! and $^{+}$ mass-cuts.

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- The invariant p ^{0} mass was used as the reference coordinate for the determination of the Q-value for the polarization observables.

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- The measurement of the $^+$ induced recoil polarization P was thus based on the asymmetry between the proton count rate above and below the reaction plane in the $^+$ rest-frame.
- P observable does not require beam's polarization data; P can be seen as the "C_y" observable.

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For the induced polarization, we integrate over all events above and below the reaction plane so that no direct angular dependence on the proton is needed for either observable C_x and C_z.

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Results already approved and included within analysis notes.

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  - One-dimensional t: Individually yields C_x or C_z.
  - Maximum-likelihood t: Simultaneous extraction of all observables P, C_x and C_z.

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$$A(\cos {}^{p}_{x=z}) = \frac{N_+ \quad N}{N_+ + N} = \quad P \; C_{x=z} \cos {}^{p}_{x=z} :$$

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Likelihood Function

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Single Event Probability Distribution Function

$$P(\cos{}^{p}_{x}; \cos{}^{p}_{z}; \cos{}^{p}_{y} | C_x; C_z; P) =$$

$$1 \quad P \quad (C_x \cos{}^{p}_{x} + C_z \cos{}^{p}_{z}) + \quad P \cos{}^{p}_{y}$$

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Probability Distribution Function

$$\log L = \sum_{i=1}^{N} w_i \log(P_i)$$

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- Double polarization observables C_x and C_z have never measured for the $K^0\Sigma^+$ channel.
- Current issue lies with the ML fit error bars; C_x/C_z observables appear to be consistent with zero. We seek to address what becomes of this "missing" polarization.

Thank you so much for your time!