Search for the $\Theta^+$ pentaquark in the $\gamma d\rightarrow\Lambda NK$ reaction with CLAS

S. Niccolai, IPN Orsay
for the CLAS collaboration
Search for the $\Theta^+$ pentaquark in the $\gamma d \rightarrow \Lambda NK$ reaction with CLAS
\[ \gamma d \rightarrow \Lambda \Theta^+: \text{the reaction} \]

- **Strangeness tagged** by \( \Lambda \): \( S=+1 \) both for \( nK^+ \) and \( pK^0 \)
- Unlike \( pK^+K^-n \) or \( pK^0K^-p \):
  - No possibility of **kinematical reflections** of mesons \( \rightarrow KK \)
    (only **one** \( K \), from \( \Theta^+ \) decay, in the final state)
  - “Clean” reaction: **no background channels** to remove
- **Model predictions**: \( \sigma \rightarrow \Gamma(\Theta^+) \) [Guzey, PRC 69, 065203 (2004)]
\[ \gamma d \rightarrow \Lambda \Theta^+ : \text{model prediction} \]

\[ \frac{d\sigma}{dt} \sim \Gamma(\Theta^+) \frac{d\sigma^{(p+n)}}{dt} S(t) \]

\[ \frac{d\sigma^{(p+n)}}{dt} \text{ interference of} \]

\[ \gamma p \rightarrow \Lambda(\Sigma^0)K^+ \text{ (exp. data)} \]

and \[ \gamma n \rightarrow \Lambda(\Sigma^0)K^0 \text{ (parametrization)} \]

\[ S(t) \text{ nuclear suppression factor} \]

\[ \frac{d\sigma}{dt} \text{ max for } E_\gamma = 1.2 \text{ GeV, } -0.2 < t < 0 \]

\[ \sigma_{\text{tot}} \approx 3 \text{ nb} \]

Cut \[ p_{n(p)} > 300 \text{ MeV/c} \text{ to remove N-spectator events – non resonant background} \]
\[ \gamma d \rightarrow \Lambda \Theta^+ : \text{CLAS G10 analysis} \]

CLAS is designed to measure exclusive reactions with multi-particle final states.

All G10 data analyzed
Both torus field settings
Higher statistics for low-field

10-20-2005

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\( \gamma d \rightarrow \Lambda \Theta^+ \): CLAS G10 analysis

Decay modes under study:

- \( \Lambda \rightarrow p\pi^- \quad \Theta^+ \rightarrow K^+ n \)

3 charged particles, 1 neutral in the final state

CLAS is designed to measure exclusive reactions with multi-particle final states
\[ \gamma d \rightarrow \Lambda \Theta^+ : \text{CLAS G10 analysis} \]

Decay modes under study:

- \( \Lambda \rightarrow p\pi^- \quad \Theta^+ \rightarrow K^+ n \)
- \( \Lambda \rightarrow p\pi^-, \Theta^+ \rightarrow K^0 p, K^0_s \rightarrow \pi^+ \pi^- \)

CLAS is designed to measure exclusive reactions with multi-particle final states.

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\[ \gamma d \rightarrow \Lambda \Theta^+: \text{CLAS G10 analysis} \]

**Decay modes under study:**
- \[ \Lambda \rightarrow p \pi^- \quad \Theta^+ \rightarrow K^+ n \]
- \[ \Lambda \rightarrow p \pi^-, \Theta^+ \rightarrow K^0 p, K^0_s \rightarrow \pi^+ \pi^- \]

5 charged particles in the final state

- **Possible to analyze 6 different exclusive topologies**
  1) All 5 particles detected
  2) Missing \( \pi^- \)
  3) Missing \( K^0 \)
  4) Missing \( p \)
  5) Missing \( \Lambda \)
  6) Missing \( \pi^+ \)
nK⁺ decay mode: data analysis

Channel ID:
- K⁺, p, π⁻ detected (PID+timing cuts)
- n identified by missing mass (3σ cut)
- Λ identified by pπ⁻ invariant mass (3σ)
nK⁺ decay mode: Σ⁻ background?

\[ \gamma d \rightarrow pK^+\Sigma^- \rightarrow pK^+n\pi^- \]

\[ \gamma d \rightarrow pK^+\Sigma^- \rightarrow pK^+n\pi^- \]

- pK⁺ missing mass before Λ cut
- pK⁺ missing mass after Λ cut
- No Σ⁻ background

LOW-FIELD G10 DATA

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\[ \chi^2/\text{ndf} \]

10-20-2005
nK$^+$ decay mode: mass spectra

- $M(nK^+)$ mass with and without **kinematic fit**
- 3 parallel independent analyses (Carman, Mirazita-Rossi, S.N.), **in agreement** (10%)
- no significant $\Theta^+$ **signal**, with and without **kinematic cuts** (Guzey)
- MC studies for acceptance underway, to extract **cross section upper limits**
nK⁺ decay mode: mass spectra

- M(nK⁺) mass with and without kinematic fit
- 3 parallel independent analyses (Carman, Mirazita-Rossi, S.N.), in agreement (10%)
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Model prediction

G10 low field
ΛK⁺(n), all Eγ
pK$^0$ mode – 1) all particles detected

2 protons, 2$\pi^-$, 1$\pi^+$
\[ p(p_1) > p(p_2), \; p(\pi^-_1) > p(\pi^-_2) \]

Channel ID cuts:
• $-0.01 < MM^2 < 0.005$ (GeV$^2$/c$^4$)
pK⁰ mode – 1) all particles detected

Channel ID cuts:
• -0.01<MM²<0.005 (GeV²/c⁴)
• M(pπ⁻) = M(L) ± 3σ
• M(π⁺π⁻) = M(K⁰) ± 3σ

4 combinations with 4 pK⁰ mass spectra that can be summed up
pK⁰ mode – 1) all particles detected

- 3 parallel independent analyses (Hicks-Mibe, Mirazita-Rossi, S.N.), cross checking
- no significant Θ⁺ signal in the pK⁰ invariant mass
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Very preliminary
pK⁰ mode – 1) all particles detected

- 3 parallel independent analyses (Hicks-Mibe, Mirazita-Rossi, S.N.), cross checking
- no significant Θ⁺ signal in the pK⁰ invariant mass
- MC studies for acceptance underway, to extract cross section upper limits
pK$^0$ mode – 2) missing $\pi^-$

2 protons, 1$\pi^-$, 1$\pi^+$

Channel ID cuts:
- $MM = M(\pi^-) \pm 3\sigma$

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pK⁰ mode – 2) missing π⁻

π⁺π⁻ invariant masses

pπ⁻ invariant masses

Channel ID cuts:
• MM = M(π⁻) ± 3σ
• IM(π⁺π⁻) = M(K⁰) ± 3σ
• IM(pπ⁻) = M(Λ) ± 3σ
pK$^0$ mode – 2) missing π$^-$

- 2 parallel independent analyses (Mirazita-Rossi, S.N.)

- no significant Θ$^+$ signal at 1.52$<$M(pK$^0$)$<$1.55 GeV/c$^2$ in any of the 4 spectra

- MC studies for acceptance underway, to extract cross section upper limits

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pK⁰ mode – 2) missing π⁻
pK^0 \text{ mode – 3) missing } K^0

2 \text{ protons, 1}\pi^-

Channel ID cuts:
- \text{MM} = M(K^0) \pm 3\sigma
- \text{IM}(p\pi^-) = M(\Lambda) = 3\sigma
pK^0 mode – 3) missing K^0

• 2 parallel independent analyses (Mirazita-Rossi, S.N.)

• no significant Θ^+ signal at 1.52<M(pK^0)<1.55 GeV/c^2 in any of the 2 spectra

• MC studies for acceptance underway, to extract cross section upper limits

Very preliminary
pK$^0$ mode – 3) missing K$^0$

- 2 parallel independent analyses (Mirazita-Rossi, S.N.)

- no significant $\Theta^+$ signal at 1.52<$M(pK^0)$<1.55 GeV/c$^2$ in any of the 2 spectra

- MC studies for acceptance underway, to extract cross section upper limits
Conclusions and outlook

• Search for $\Theta^+$ in the $\gamma d \rightarrow \Lambda N K$ reaction carried out using the high-statistics CLAS-G10 data set
• Both the $nK^+$ and $pK^0$ decay modes have been analyzed
• 4 parallel analyses are underway
• The $pK^0$ decay mode has been studied in 4 different topologies
• No statistically significant structure is observed in the NK invariant mass spectrum
• MC studies are underway to extract cross section upper limits