Search for the $\Theta^+$ in photoproduction experiments at CLAS

APS spring meeting (Dallas)
April 22, 2006
Ken Hicks (Ohio University)
for the CLAS Collaboration
The CEBAF Large Acceptance Spectrometer

CLAS

Performance

- $L = 10^{34} \text{ cm}^2 \text{ s}^{-1}$
- $\int B \, dl = 2.5 \text{ T m}$
- $\Delta p/p \sim 0.5-1 \%$
- $\sim 4\pi$ acceptance
- Best suited for multiparticle final states
- Bremsstrahlung Photon Tagger ($\Delta E/E \sim 10^{-3}$)

April 22, 2005

K. Hicks, Ohio U.
“G10” run: March 13 - May 16, 2004

• Tagged photons in the energy range from 0.8 GeV to 3.59 GeV;
• Target - 24 cm long liquid deuterium at Z=-25cm;
• Trigger - two charged particles in CLAS.
• Data are taken at 2 settings of CLAS toroidal magnet.
• At each setting integrated luminosity (25pb^{-1}) is about 10 times higher than in published deuterium data.
Analysis strategy for the $\Theta^+$:

- Independent analysis of several reactions by different groups;

\[
\gamma + d \rightarrow p + K^- + K^+ + n; \Theta^+ \rightarrow nK^+ \\
\gamma + d \rightarrow \Lambda^0 + K^{+(0)} + n(p); \Theta^+ \rightarrow nK^+, pK_S^0 \\
\gamma + d \rightarrow p + \pi^+ + \pi^- + K^-; \Theta^+ \rightarrow pK_S^0; K_S^0 \rightarrow \pi^+ \pi^- \\
\gamma + "n" \rightarrow K^- + K^+ + n; \Theta^+ \rightarrow nK^+ \quad \text{Fermi momentum corrections}
\]

- Work on cross section upper limit estimate in other channels is in progress. Requires acceptance simulations for each final state.
Comparison: earlier data

- Restricted photon energy range
- Two distributions statistically consistent with each other:
  - 26% c.l. for null hypothesis from the Kolmogorov test (two histograms are compatible).
- G10 mass distribution can be used as a background for refitting the published spectrum.
Fit to the MM(pK⁻) distributions

- The same 3rd degree polynomial as a background in both fits (for g2a function was scaled by x5.9).
- For the fit to the g10 distribution Gaussian, the sigma was fixed to the known CLAS resolution (determined from MC and fits to other peaks).
Missing momentum (active neutron cut)

$g_{10}$: all photons $E_\gamma$

$g_{2a}$ cut

$0.2 > \text{GeV/c}$

neutron momentum (GeV/c)

low B-field (2250 A)  
high B-field (3375 A)

Events/5 MeV/c²

$M(nK^+)$ [GeV/c²]

$\frac{d\sigma}{dM} [\text{nb}/(\text{GeV/c})^2]$

$M(nK^+)$
$\gamma \ n \rightarrow \ p \ \pi^-$ cross section

- Consistency between high field and low field data.
- $g_{10}$ data agree with world data.
- 0.5% of statistics
Cross section upper limit

\[ \gamma d \rightarrow pK^-K^+n \]
upper limit from counts above BG (angle integrated).

Upper limit as a function of \( \Theta^+ \) angle for \( 1.52 < M < 1.56 \).

Same, for \( M = 1.54 \)
The elementary cross section: $\gamma n \rightarrow \Theta^+ K^-$

- A model for an energetic spectator: take the $\Lambda(1520)$ production as a guide.
- The symmetry of $\Lambda(1520)$ and $\Theta^+$ is seen below.
- Studies show the spectator cut reduces the cross section by a factor of about 10.
- Upper limit $\gamma n \rightarrow \Theta^+ K^-$ estimated at 3-6 nb.

$\Lambda(1520)$ is produced on the proton, neutron is a spectator.

$\Theta^+$ is produced on the neutron, proton is a spectator.
New subject: $\gamma d \rightarrow \Lambda \Theta^+$

- Two baryons in the final state:
  - simpler kinematics
  - no possibility of kinematic reflections
- $\Lambda \rightarrow p \pi^-$ is cleanly identified
  - many topologies: $\Theta^+ \rightarrow nK^+$ used here
  - neutron momentum should be significant
Mass Spectra (particle ID)

Missing mass (= neutron mass) for cut on \( \Lambda \) peak.

Invariant mass (= \( \Lambda \) mass) for cut on \( n \) peak.

high statistics!
nK+ mass spectrum

No signal for the $\Theta^+$ is evident in the full data.

These cuts were made to enhance $\Theta^+$ production.
Still no signal.
Cross section upper limit

Upper limit at a given mass (angle integrated).

Upper limit for masses (1.52<\(M<1.56\)) vs. momentum transfer \(t\).

Open/closed assume different models of \(\Theta^+\) production.

solid = phase spaced
open = Guzey et al.
Summary of Deuterium Data

• A search for the $\Theta^+$ in the photon-induced reactions using photons with energies up to 3.6 GeV has been carried out with the CLAS.

• The peak in the $M(nK^+)$ spectrum published earlier cannot be reproduced. Also, no peak is found in the full data set (all $E_\gamma$).

• The upper limit on the measured cross section in the reaction $\gamma d \to \Theta^+ pK^-$, with $P_p > 0.35$ GeV/c, is about 0.3 nb (95% CL). For the elementary (neutron) cross section, the limit is higher.

• A second search was done using the reaction $\gamma d \to \Lambda \Theta^+$, to the exclusive final state $p\pi^- K^+ n$, but no $\Theta^+$ peak is seen. Upper limit is model dependent, especially at forward angles.