Search for $\Phi(1860)$ in CLAS

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for CLAS Collaboration
Outline of the Talk

- Physics Overview
- Objective of this experiment
- CLAS Data
- Summary
Introduction

- A number of experimental results suggest existence of $\Theta^+(1540)$ pentaquark state.
- Models predicted such a state as a part of pentaquark antidecuplet.
- 3 predicted states have predicted exotic quantum numbers.
- NA49 collaboration reported an observation of $\Xi_5^-(1860)$ ($\Phi(1860)$) states which they identified with two $I=3/2$ states of antidecuplet.
- Other experiments failed to confirm NA49 result.
## Status of $\Phi(1860)$ Search

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial state</th>
<th>$\Xi^-$</th>
<th>$\Xi(1530)$</th>
<th>$\Phi(1860)^-$</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA49</td>
<td>$pp$</td>
<td>1640</td>
<td>150</td>
<td>36</td>
</tr>
<tr>
<td>ALEPH</td>
<td>$e^+e^-$</td>
<td>3450</td>
<td>322</td>
<td>$&lt;24$</td>
</tr>
<tr>
<td>BaBar</td>
<td>$e^+e^-$</td>
<td>250000</td>
<td>24000</td>
<td>$&lt;133$</td>
</tr>
<tr>
<td>CDF</td>
<td>$pp$</td>
<td>35722</td>
<td>2182</td>
<td>$&lt;63$</td>
</tr>
<tr>
<td>COMPASS</td>
<td>$\mu^+A$</td>
<td>18000</td>
<td>1700</td>
<td>$&lt;79$</td>
</tr>
<tr>
<td>E690</td>
<td>$pp$</td>
<td>512850</td>
<td>70000</td>
<td>$&lt;200$</td>
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<tr>
<td>FOCUS</td>
<td>$\gamma p$</td>
<td>800000</td>
<td>59391</td>
<td>$&lt;170$</td>
</tr>
<tr>
<td>HERA-B</td>
<td>$pA$</td>
<td>12000</td>
<td>1400</td>
<td>$&lt;56$</td>
</tr>
<tr>
<td>HERMES</td>
<td>$e^+D$</td>
<td>450</td>
<td>35</td>
<td>$&lt;5$</td>
</tr>
<tr>
<td>WA89</td>
<td>$\Sigma^-A$</td>
<td>676000</td>
<td>60000</td>
<td>$&lt;760$</td>
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<tr>
<td>ZEUS</td>
<td>$e\gamma$</td>
<td>1561</td>
<td>192</td>
<td>$&lt;56$</td>
</tr>
</tbody>
</table>

Photo-Production Diagram

\[ \Phi^{--} \] is composed of (ssdd\bar{u}) quarks

\[ n \left\{ \begin{array}{c} ddu \\ \Sigma^- \end{array} \right\} K^+ \]

\[ \Phi^{--} \left\{ \begin{array}{c} u\bar{s} \\ \Sigma^- \end{array} \right\} K^+ \]

\[ \bar{u}d \left\{ \begin{array}{c} \pi^- \\ \Xi^- \end{array} \right\} \]

\[ \Phi^{--} \left\{ \begin{array}{c} ssd \end{array} \right\} \Xi^- \]
### Φ(1860) Decays

<table>
<thead>
<tr>
<th>Primary decay</th>
<th>Secondary decay</th>
<th>Tertiary decay</th>
<th>Mass Constr.</th>
<th>Q=0</th>
<th>Br.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Φ⁺⁻⁻ → π⁻⁻Ξ⁻ (0.5)</td>
<td>→ π⁻⁻(π⁻⁻Λ)</td>
<td>→ π⁻⁻π⁻⁻(π⁻⁻p)</td>
<td>Ξ⁻⁻, Λ</td>
<td></td>
<td>0.32</td>
</tr>
<tr>
<td>Φ⁻⁻⁻ → K⁻⁻Σ⁻ (0.5)</td>
<td>→ K⁻⁻(π⁻⁻n)</td>
<td></td>
<td>Σ⁻⁻, n</td>
<td></td>
<td>0.5</td>
</tr>
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<td>Φ⁻⁻ → π⁰⁻⁻Ξ⁻ (0.33)</td>
<td>→ π⁰⁻⁻(π⁻⁻Λ)</td>
<td>→ π⁰⁻⁻π⁻⁻(π⁻⁻p)</td>
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<td>π⁰</td>
<td>0.21</td>
</tr>
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<td>Φ⁻⁻ → π⁻⁻Ξ⁰ (0.17)</td>
<td>→ π⁻⁻(π⁰Λ)</td>
<td>→ π⁻⁻π⁻⁻(π⁻⁻p)</td>
<td>Ξ⁻⁻, Λ</td>
<td>π⁰</td>
<td>0.11</td>
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<tr>
<td>Φ⁻⁻ → K⁻⁻Σ⁻ (0.33)</td>
<td>→ K⁻⁻(γΛ)</td>
<td>→ K⁻⁻γ(π⁻⁻p)</td>
<td>Kₛ⁻⁻, Σ⁻⁻, π⁻⁻</td>
<td></td>
<td>0.06</td>
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<td>Φ⁻⁻ → K⁻⁻Σ⁻⁻ (0.33)</td>
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**Exotic States**
Role of CLAS

- Look for $\Phi(1860)$ in photo- and electro-production on neutron.
- CLAS allows simultaneous detection of multiple particles in the final state. In particular, channel
  \[ \gamma d \rightarrow (K^+K^+p_s) \Phi^{--} \rightarrow \\
  (K^+K^+p_s) \pi^-\Xi^- \rightarrow \\
  (K^+K^+p_s) \pi^-\pi^-\Lambda \rightarrow \\
  (K^+K^+p_s) \pi^-\pi^-\pi^-p \]
can be studied with CLAS.
- Directly reconstruct the $\Phi^-$ as a $p\pi^-\pi^-\pi^-$ system instead of using missing mass technique.
- Expected $\sim 45 \Phi^-$ events/nb in 40 days run.
Schematic of the Reaction

$\Xi^- \rightarrow \pi^- \Xi^-$

$\Xi^- \rightarrow \pi^- \Lambda$

$\Lambda \rightarrow \pi^- p$

$\gamma n \rightarrow K^+ K^+ \Xi^-\Xi^-$

1 cm

Production vertex and two decay vertices.

$\Xi^- \ c\tau = 4.9 \ cm$

$\Lambda \ c\tau = 7.9 \ cm$

Reconstruction of detached vertices can be very helpful.
EG3 Run Conditions

- Use CEBAF 5.7 GeV initial electron beam.
- Secondary tagged photon beam within a tagging range from 4.5-5.5 GeV at \(~2\times10^7\) sec\(^{-1}\) tagged $\gamma$-rate.
- 40-cm long deuterium target achieving integrated luminosity of \(~100\) pb\(^{-1}\) for active tagging range.
- Reversed magnetic field polarity to improve the acceptance for the negative tracks.
- Use 3-tracks trigger as the main trigger. Prescaled 2-track trigger.
- Collected total of 4 billion triggers (2 track + 3 track) in 40 calendar days.
Sample Event in CLAS
PID in CLAS

- Momentum determined from tracking in drift chambers.
- Timing determined from TOF system.
- Proton-pion separation is easy for $P<2.5$ GeV.
- $K^+$ and $K^-$ identification for $P<1.5$ GeV.
Kinematical Coverage

- Acceptance for $\pi^-$ is very good, from $8^\circ$ to $130^\circ$ due to reversed magnetic field.
- Forward-going protons are bent inward into the CLAS beam pipe.
- Forward kinematical coverage for $K^-$ will allow for $\Theta^+(1540)$ search in $\gamma d \rightarrow K^-p\Theta^+$ channel in both $\Theta^+ \rightarrow K^+n$ and $K^0p$ decay channels.
Reconstruction of Particles

$\Lambda(1116)$
Summary

EG3 run’s primary goal is to search for Φ(1860) pentaquark seen in NA49.
Used tagged photon beam on deuterium target.
The data taking was completed in Feb 2005, collected 4 billion triggers.
Calibrations are nearly complete, data processing will start very soon.
Need to developed a procedure for detached vertex reconstruction to identify Ξ−(1321) and Φ−(1860).
The data can be used for Θ+(1540) search as well.
Stay tuned for the results.
The End
The coverage for $K^-$ is better than for $K^+$. Cannot afford to tag strangeness with two $K^+$s. Still, can require one $K^+$ detection to clean up the data sample by losing 70% in statistics.