Photoproduction of $\Lambda^*$ Resonances at CLAS

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Missing baryon resonances play important role to explore the fundamental degrees of freedom inside hadrons.

Study of quark dynamics to determine properties of hadrons that are responsible for spectrum of hadrons.
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Study of quark dynamics to determine properties of hadrons that are responsible for spectrum of hadrons.
Motivation
\( \gamma + p \rightarrow K^+ + \Lambda^* \)

\( \Lambda^* \rightarrow \Sigma^+ + \pi^- \)

\( \Lambda^* \rightarrow \Sigma^- + \pi^+ \)

- Photo-production off a proton creates a \( K^+ \)-meson and a \( \Lambda^* \).
- \( \Lambda^* \) decays by \( \Sigma\pi \) channel. \( \Sigma^+ \) gives off a n & \( \pi^+ \), \( \Sigma^- \) gives off a n & \( \pi^- \).
- The final particles detected are \( K^+ \), \( \pi^+ \) & \( \pi^- \).
The g12 experiment

- $E_{\text{beam}}$ of photon: 5.715 GeV
- Beam Polarization: Circular
- $e^-$ Current: 60–65 nA
- Tagger Range: 5% - 95% of $e^-$ energy
- Tagger Trigger Range: 3.6–5.441 GeV
- Torus Magnet: $\frac{1}{2} B_{\text{max}}$ (1930 A)
- Target Length: 40 cm
- Target Center ($z$ location): –90 cm
- Target Material: $^{6}\text{LiH}_2$
- Target Polarization: None
- Start Counter Offset: 0 cm
- Radiator Thickness: $10^{-4}$ radiation lengths
- Collimator Radius: 6.4 mm
## Outline (Cuts)

- Photon selection → 1 and 2 photon case (Photon Multiplicity)
- PID → $K^+$, $\pi^+$, $\pi^-$. Straight cuts of 1 ns on Momentum Vs Timing plots were made for particle identification.
- Trigger Correction was applied creating trigger efficiency map using the g12 trigger configuration.
- The g12 standard data analysis procedure was followed for Vertex, Fiducial & Paddle Cuts.
- A series of Missing Mass cut was followed to obtain the nature of $\Lambda^*$ resonances.
- Further analysis includes an appropriate binning and fitting scheme to obtain yield and acceptances for differential cross-section.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.9 \leq MM(K^+\pi\pi) \leq 1$</td>
<td>Select neutron events</td>
</tr>
<tr>
<td>$0.48 \leq IM(\pi^+\pi^-) \leq 0.51$</td>
<td>Remove n$K^0$ channel</td>
</tr>
<tr>
<td>$1.15 \leq MM(K^+\pi^-) \leq 1.25$&lt;br&gt;$1.15 \leq MM(K^+\pi^+) \leq 1.25$</td>
<td>Select $\Sigma^+$ and $\Sigma^-$ events for exclusive $\Sigma\pi$ channels</td>
</tr>
</tbody>
</table>
| $1.44 \leq MM(K^+) \leq 1.6$<br>$1.62 \leq MM(K^-) \leq 1.76$ | Fitting Range $\Lambda$(1520)  
| | Fitting Range $\Lambda$(1670) & $\Lambda$(1690) |
| $2.15 \leq W \leq 2.95$ GeV<br>$-0.9 \leq \cos\theta_{cm}^{K^+} \leq 0.9$ | Kinematic Ranges |
Data: select \( n \) events

<table>
<thead>
<tr>
<th>MM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entries</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Std Dev</td>
</tr>
</tbody>
</table>

\[
\gamma + p \rightarrow K^+ + \Lambda \ (1520)
\]

\[
\Sigma^+ + \pi^- \quad \sim 14\%
\]

\[
\Sigma^- + \pi^+ \quad \sim 14\%
\]

\[
n + \pi^+ \quad \sim 48\%
\]

\[
n + \pi^- \quad \sim 100\%
\]

0.9 < MM\((K^+\pi\pi)\) < 1.0 \ [GeV]

Data: remove nK\(^0\) channel

\[
K^0 \text{ remove}
\]

\[
\pi^+ \pi^-
\]

\[
\pi^+ \pi^-
\]
\[ \Sigma^+ + \Lambda(1520) \rightarrow \Sigma^+ + \pi^- \]

Cuts

\[ \Lambda(1405) \rightarrow \Sigma^- + \pi^+ \]

\[ \Lambda(1670,1690) \]
Global spectrum integrated over all angles leads towards fitting the Λ(1520) peak with a Lorentzian function that rests on a smooth quadratic background.
Differential Cross-section: \( \Lambda(1520) \)

\[
\frac{d\sigma}{d\cos\theta_{K^*}} = \frac{Y_d}{\tau \Delta \cos\theta_{K^*}} A L(W)
\]

\( \tau = \text{Branching ratio} \)
\( Y_d = \text{Signal Yield} \)
\( A = \text{Acceptance} \)
\( \Delta \cos\theta_{K^*} = \text{Width of } \cos\theta \text{ bin} \)
\( L(W) = \text{Luminosity} \)

\[
L(E_W) = \frac{\rho_p N_A l_t}{A_p} N_\gamma(W)
\]

- \( l_t = 40 \text{ cm} \)
- \( \rho_p = 0.07114 \text{ g/cm}^3 \)
- \( A_p = 1.00794 \text{ g/mol} \)
- \( N_A \) is Avogadro’s number

\( \Lambda(1520) \) dcs for \( \Sigma^+\pi^- \) & \( \Sigma^-\pi^+ \) channels with g11 CLAS results
Λ(1670) & Λ(1690)

<table>
<thead>
<tr>
<th>Particle</th>
<th>$J^P$</th>
<th>PDG rating</th>
<th>$N\bar{K}$</th>
<th>$\Lambda\pi$</th>
<th>$\Sigma\pi$</th>
<th>Other Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Λ(1405)</td>
<td>1/2-</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Λ(1520)</td>
<td>3/2-</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td></td>
<td>Λππ, Λγ</td>
</tr>
<tr>
<td>Λ(1670)</td>
<td>1/2-</td>
<td>****</td>
<td>****</td>
<td>Forbidden</td>
<td>****</td>
<td>Λη</td>
</tr>
<tr>
<td>Λ(1690)</td>
<td>3/2-</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td></td>
<td>Λππ, Σππ</td>
</tr>
</tbody>
</table>

Not well investigated using photoproduction data.

Same final state particles: $K^+, \pi^+, \pi^-$

Partial Wave Analysis will be employed.

Data: $\Lambda^* (\Sigma^*\pi^-$ channel)

Data: $\Lambda^* (\Sigma^*\pi^+)$ channel
### Signal Fitting: \( \Lambda(1670) \& \Lambda(1690) \)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( \Lambda(1670) )</th>
<th>( \Lambda(1690) )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Peak</strong></td>
<td>1660 – 1680 (MeV)</td>
<td>1685 – 1695 (MeV)</td>
</tr>
<tr>
<td><strong>Width</strong></td>
<td>25 – 50 (~35 MeV)</td>
<td>50 – 70 (~60 MeV)</td>
</tr>
</tbody>
</table>

### Data: \( \Lambda(1670) \& \Lambda(1690) \) (\( \Sigma^- \pi^+ \) channel)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entries</td>
<td>1142730</td>
</tr>
<tr>
<td>Mean</td>
<td>1.682</td>
</tr>
<tr>
<td>Std Dev</td>
<td>0.03746</td>
</tr>
<tr>
<td>( \chi^2 / \text{ndf} )</td>
<td>147.7 / 91</td>
</tr>
<tr>
<td>( p_0 )</td>
<td>5280 ± 185.2</td>
</tr>
<tr>
<td>( p_1 )</td>
<td>290.2 ± 4.0</td>
</tr>
<tr>
<td>( p_2 )</td>
<td>−1452 ± 61.1</td>
</tr>
<tr>
<td>( p_3 )</td>
<td>92.07 ± 2.13</td>
</tr>
<tr>
<td>( p_4 )</td>
<td>0.05 ± 0.00</td>
</tr>
<tr>
<td>( p_5 )</td>
<td>1.661 ± 0.001</td>
</tr>
<tr>
<td>( p_6 )</td>
<td>50.61 ± 4.56</td>
</tr>
<tr>
<td>( p_7 )</td>
<td>0.05525 ± 0.00281</td>
</tr>
<tr>
<td>( p_8 )</td>
<td>1.685 ± 0.001</td>
</tr>
</tbody>
</table>
Signal Fitting: $\Lambda(1670) \& \Lambda(1670)$ $\Sigma^-\pi^+$ channel (W bins)

Data: $\Lambda(1670) \& \Lambda(1690)$ (2.35 < W < 2.45)

Data: $\Lambda(1670) \& \Lambda(1690)$ (2.45 < W < 2.55)

Data: $\Lambda(1670) \& \Lambda(1690)$ (2.55 < W < 2.65)
Next

- The $\Lambda(1520)$ cross section matched with the CLAS g11 data.
- $\Lambda(1520)$ cross sections for higher $W$ value will be obtained.
- First attempt at $\Lambda(1670)$ & $\Lambda(1690)$ peaks show need for better understanding of the background function.
- Simulation are ongoing to study the nature of the peaks.
- Further Analysis of higher mass resonances, ie, $\Lambda(1670)$ & $\Lambda(1690)$, using partial wave analysis will be done.