The Photoproduction of Strangeness in $\gamma p \rightarrow \Lambda K^+ \pi^+ \pi^-$ with CLAS at Jefferson Lab and Construction of Time of Flight Detector at FSU

Prospectus Defense
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Objectives

- INTRODUCTION
- MOTIVATION
- CLAS g12 EXPERIMENT
- ANALYSIS
- GLUEX
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Introduction

- Quantum Chromodynamics And The Quark Model
- Excited Strange Mesons
Quantum Chromodynamics and The Quark Model

- Quarks are elementary particles, fermions, that make up all matter. Gluons are exchange particles, or gauge bosons, for the color force between quarks.
- Baryons are half integer spin particles (fermions), while mesons are integer spin particles (bosons).
- In the constituent Quark Model, a meson is made up of a quark-antiquark pair. A baryon is made up of three quarks.

A Meson in the Quark Model

A Baryon as “seen” by QCD
Excited Strange Mesons

- Free quarks and gluons haven’t been seen in nature due to the confinement of quarks.
- Different meson and baryon states are represented according to their total angular momentum $J$, the parity $P$, and the charge conjugation $C$.

\[
J = L + S \\
P = (-1)^{L+1} \\
C = (-1)^{L+S}
\]

allowed $J^{PC} = 0^{++}, 0^{+-}, 1^{--}, 1^{+-} \ldots$

- QCD also predicts meson states that are beyond the constituent quark model (hybrids, glueballs, multi-quark states), these are called “Exotic Mesons”.

exotic $J^{PC} = 0^{-+}, 0^{+-}, 1^{-+}, 2^{+-} \ldots$
In this research, we are looking for excited strange states through photoproduction. In particular the excited Kaon states.
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- CLAS g12 Experiment
- Analysis
- GLUEX
Motivation

- The $\gamma p \rightarrow p K^+ \pi^+ \pi^- [\pi^-]$ reaction is an opportunity for searching for excited strange mesons.

  - Understand the photoproduction of a strange meson off a $\Lambda$ strange baryon.

  - Preliminary results predict two decaying modes in the $(K^+ \pi^+ \pi^-)$ system, that will be presented later on in this talk.
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- Jefferson Lab hosts CEBAF (Continuous Electron Beam Accelerator Facility) that delivers up to a 5.5 GeV photon beam to three halls: A, B and C.

- Hall B hosts the CEBAF Large Acceptance Spectrometer (CLAS).
The CLAS g12 experiment was primarily approved for exotic mesons and excited cascade states studies.

- Up to a 5.5 GeV photon beam incident on a LH$_2$ target.

- 26.2 billion triggers (68 Pb$^{-1}$, 126 TB) of various topologies.

- About $25\times10^6$ $\gamma p \rightarrow p K^+ \pi^+ \pi^- \pi^-$ events.
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- The $\gamma p \rightarrow p K^+ \pi^+ \pi^- [\pi^-]$ events are selected from all the available data files.

- About 24M $\gamma p \rightarrow p K^+ \pi^+ \pi^- [\pi^-]$ events.

<table>
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<th>Description</th>
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<td>$\Lambda$ Selection</td>
<td>71488</td>
</tr>
<tr>
<td>$</td>
<td>t'</td>
</tr>
</tbody>
</table>
Missing Pion Selection

- Corrections applied in this part include: beam energy loss, particle energy loss and momentum corrections.
Selection of the Missing Pion and Kinematic Fitting

- The missing mass is fit to a pion.
- 5% confidence level cut is applied on the data.
Beta is the velocity of the particle. \[ \beta = \frac{P}{E} \]
Selection of Λ

Entries 186158
Entries 71488

Selected Λ Events

Entries 186158
Entries 71488

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Intermediate States in the \((K^+ \pi^+ \pi^-)\) System

Selected Events from the \((K^+ \pi^-)\) System

Selected Events from the \((\pi^+ \pi^-)\) System
Reduction of Baryon Background with $t'$ Cut

Select events of $t' < 0.5 \text{ GeV}^2/\text{c}^4$
(K⁺ π⁺ π⁻) System Study

Selected Events from the (K⁺ π⁺ π⁻) System 1.6 GeV

Entries 14980
Entries 6740

Dalitz Plot of the (K⁺ π⁺ π⁻) System for Range 1 – 1.6 GeV/c²

Entries 6740

Selected Events from the (K⁺ π⁺ π⁻) System 1.6-2.2 GeV

Entries 14980
Entries 8212

Dalitz Plot of the (K⁺ π⁺ π⁻) System for Range 1.6– 2.2 GeV/c²

Entries 8212
What’s next?

- Understand the baryon background and possibly including it in PWA.
- Determine the cross section of $$(\Lambda K^+ \pi^+ \pi^-)$$ and its upper limit.
- A total of 15K Events were finally Selected, ready for PWA.

Partial wave analysis of the $$(K^+ \pi^+ \pi^-)$$ System will use decay amplitudes $A_\alpha(\tau)$ to study the contribution of various spin-parity states.

$$I(\tau) = \sum_\alpha |V_\alpha|^2 |A_\alpha(\tau)|^2$$

$$A_\alpha(\tau) \equiv A_\alpha(\Omega_X, \Omega_Y) A_\alpha(m_Y)$$
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GlueX Experiment At Jefferson Lab

- An experiment targeted to search for exotic mesons.
- Detector will be hosted in Hall D at Jefferson Lab, Virginia.
- Expected to start taking data by 2014.

Fig 19. 12 GeV Upgrade to CEBAF.

Fig 20. The GlueX detector.
The GlueX detector is made of 6 sections: Superconducting solenoid, Start Counter, Barrel Calorimeter (BCAL), Central Drift Chamber (CDC), Forward Drift Chamber (FDC), and the Time of Flight (TOF), detector.
- The time of flight detector is important for particles identification.
- The Time of Flight section will be built here at FSU.
- Consists of two planes of scintillator paddles each of which consists 44 bars per plane.
- Each paddle is 2.5 m long, 6 cm wide, and 2.5 cm thick and is mounted by photomultipliers on opposite sides.
- Scintillators and photomultipliers were tested.
- Prototype modules were made.
- A prototype was constructed.
Conclusion and Future Plans

- The chosen channel has shown to be convenient for studying the photoproduction of strange mesons.
- All data files have been processed and all corrections were performed.
- The final decay modes of the \((K^+ \pi^+ \pi^-)\) system are expected to be the \((K^* \pi^+)\) and the \((\rho K^+)\).
- Partial Wave Analysis will start shortly.
- Study the Cross Section of the \((\Lambda K^+ \pi^+ \pi^-)\) System.
- Construct the final TOF modules.
Thank You!