Study of two pion channel from photoproduction on the deuteron

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Hadron 2009

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• Physics Motivation
• CLAS Detector
• EG3 Data Set
• Analysis
• Outlook
Physics Motivation

- $2\pi$ data analysis is needed to improve our knowledge on $\pi\Delta$ and $\rho\pi$ hadronic couplings.

- Data on $1\pi$ and $2\pi$ non-resonant amplitudes are needed for $N^*$ studies in multi-channel analyses of meson photo/electro production within the framework of coupled channel approaches.

- Many higher-lying $N^*$s decay preferably into $N\pi\pi$ final states.
Resonant/non-resonant mechanism separation.

- full JM06 calculations
- non-resonant part
- resonant part

A model for $2\pi$ electroproduction has been produced with 1-diff. cross-sections allows us to isolate resonant/non-resonant parts, exploiting difference in shapes of their cross-sections.

9 single-differential cross sections for $2\pi$ final state.

Different W and $Q^2$ bins.

Photoproduction Needed!
• High lying ($W > 1.7$ GeV) nucleon resonances study.

Current study of low lying $W$ nucleon resonances (can compare).

• Extraction of **known resonances** with data extending to high energy range ($\sim 5.5$ GeV).

Existing published data is only up to $\sim 3.5$ GeV (that we know of).
Jefferson Lab (JLab)

(6 GeV)

(12 GeV)
CEBAF Large Acceptance Spectrometer
Particle production in CLAS

CLAS $4\pi$ detector

- toroidal magnetic field
  (provides good momentum resolution)
- 3 drift chamber regions
  (detect particle trajectories)
- time of flight
  (particle flight time)
- electromagnetic calorimeter
  (detect showering particles)
- cerenkov counter
  (electron detection)

- Electron beam energy 5.7 GeV
- Luminosity $10^{34}$ cm$^{-2}$ s$^{-1}$
- Momentum resolution < 1%
- Capability of detecting
- Multi-particle final states
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 \( \sim 2 \times 10^7 \text{sec}^{-1} \) tagged \( \gamma \)-rate.
- 40-cm long deuterium target achieving integrated luminosity of \( \sim 100 \text{ pb}^{-1} \) for active tagging range.
- Reversed magnetic field polarity to improve the acceptance for the negative tracks.
- Use 3-track trigger as the main trigger. Prescaled 2-track trigger.

Overall photon beam range from 1.1 to 5.5 GeV
Particle Identification

 Tau vs Momentum Positive

 Tau vs Momentum Negative

 Mass$^2$ Positive

 Mass$^2$ Negative

 Missing Mass$^2$ Neutron
First Look into Data

$\rho = 770 \text{ MeV}$

$\Delta^{++} = 1232 \text{ MeV}$

$N\pi = 1510 \& 1660 \text{ MeV}$

$\rho + \pi^-$
Possible 2π contributing channels only on proton (neutron spectator) are:

\[ \gamma d \rightarrow p \pi^+ \pi^- (n) \]

\[ \gamma d \rightarrow \Delta^{++} \pi^- \rightarrow p\pi^+ \pi^- (n) \]
\[ \gamma d \rightarrow \Delta^0 \pi^+ \rightarrow p\pi^- \pi^+ (n) \]
\[ \gamma d \rightarrow \rho p \rightarrow \pi^+\pi^- p (n) \]

We chose \(\Delta^{++}\) for first 2π channel analysis:

Experimental investigation is fairly straightforward since next state is far away.

Cross section is large for hadronic (\(\pi N\)) and electromagnetic (\(\gamma N\)) induced reactions.

Separated from any other observed or predicted resonance.
Data Fits with Corrections

- 44 Energy bins and fit with Convoluted Gauss Breit-Wigner.
- Cross Section Extracted for each fit energy bin.

\[ E_\gamma = 3.6 \text{ GeV} \]
\[ E_\gamma = 4.3 \text{ GeV} \]
Corrections

- **Missing Mass\(^2\) Cut** \(\rightarrow (.80 \text{ GeV}^2 < \text{MM2} < .97 \text{ GeV}^2)\)

- **Missing Momentum Cut** \(\rightarrow\) cuts away low momentum protons not coupling to \(\pi^+\)

- **450 MeV \(\rightarrow\) Proton Momentum Cut**

- **Timing Vertex Cuts** \(\rightarrow 2\text{ns}\)

- **Eloss Correction** \(\leftarrow\) energy charged particles lose passing through target

- **Fiducial Volume Cuts** \(\leftarrow\) areas that can be reproduced in target by GSIM

- **Photon Flux Normalization** \(\leftarrow\) accounts for the inefficiencies of detector due to deadtime

- **Acceptance (simulation)**

- **Untriggered Tagged Region** \(\leftarrow\) factor needed to bring untriggered region up to triggered

- **Trigger Efficiency Correction** \(\leftarrow\) efficiency of trigger of \(p\pi^+\pi^-\) channel
Cross Section Extraction

Yield of $\Delta^{++}$

Acceptance

Accepted Corrected Yield

After Acceptance

After Luminosity
Comparison of Preliminary Results

Color index: blue: G11 (5GeV), pink: EG3 data
Summary

• First results of $2\pi$ photoproduction by looking into the $\Delta^{++}$ reaction channel yields promising results to continue extraction of other reaction channels.

• Theoretical model incorporation and interpretations of photoproduction data must be implemented.

• Production of differential cross sections still to come and comparisons to existing published data.
Acknowledgements

EG3 Collaboration:
Kijun Park, Ralf Gothe, Haiyun Lu, Zhiwen Zhao, Elton Smith, Stepan Stepanyan, Paul Mattione and Hovanes Egiyan

CLAS Collaboration

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Back-Up Slides
Cuts

**PID:**

- 3-track Requirement
- Missing Mass\(^2\) Cut
  \((0.80 \text{ GeV}^2 < MM^2 < 0.97 \text{ GeV}^2)\)
- Skim Cut \((0.7 \text{ GeV} < M < 1.2 \text{ GeV})\)
- Proton Momentum – 450 MeV

**Timing:**

- Max. Vertex time between particles < 2ns
- Time difference of photon and fastest pion – 2ns.
Simulation

- Generated 10M $\Delta^{++}$ Events.
- Events Generated with same parameters as Data.
- 44 Energy bins and fit with Breit-Wigner.
- Yield Extracted for each Inv. Mass fit energy bin.

$E_\gamma = 2.6$ GeV

$E_\gamma = 4.3$ GeV
Acceptance Calculation

Acceptance = Reconstructed / Generated Events
Maximum Uncertainty for Comparison

<table>
<thead>
<tr>
<th>Data Sets (range)</th>
<th>Exclusive Channel $\Delta^{++}$</th>
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<tbody>
<tr>
<td>EG3/G11 (2 GeV – 5 GeV)</td>
<td>5.2%</td>
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<tr>
<td>EG3/G11 (2 GeV – 4.5 GeV)</td>
<td>5.9%</td>
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<tr>
<td>EG3/G11 (4.5 GeV – 5 GeV)</td>
<td>7.5%</td>
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<tr>
<td>EG3/SAPHIR</td>
<td>&lt; 1%</td>
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Overall uncertainties for the cross section data with an average fit for comparison of EG3 to G11 overall, from 2 - 4.5 GeV, and from 4.5 - 5 GeV, and also for EG3 to SAPHIR over the limited range that SAPHIR covers.
Quark Model Classification of N*

Particle Data Group
- ****
- ***
- **

\[ \frac{3}{2}, \frac{1}{2}, \frac{3}{2}, \frac{5}{2} \]

- \( \text{SU(6)xO(3) Symmetry} \)

Lowest Baryon Supermultiplets

- **Missing**
- \( P_{13}(1870) \)
- Capstick and Roberts

- \( D_{13}(1520) \)
- \( S_{11}(1535) \)
- \( \text{Capstick and Roberts} \)

- \( \text{Mart and Bennhold} \)

\( L_{3q} \)

- \( D(1232) \)
- \( Roper P_{11}(1440) \)

\[ \frac{3}{2}, \frac{1}{2}, \frac{3}{2}, \frac{5}{2} \]

\[ 0 \rightarrow \frac{3}{2}, \frac{1}{2}, \frac{3}{2}, \frac{5}{2} \]

\[ (1135 \text{ MeV}) \rightarrow (1545 \text{ MeV}) \rightarrow (1839 \text{ MeV}) \rightarrow (2130 \text{ MeV}) \]

\[ \text{N (Mass)} \]

\[ \text{+ } q^3g \]
\[ \text{+ } q^3q\bar{q} \]
\[ \text{+ N-Meson} \]
\[ \text{+ ...} \]

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Fit of single differential cross-sections from E93-006 experiment within the framework of JM-Model.

 Various theoretical models predict different pion production rates.

Several models of baryon decays have been developed:

- S. Capstick and W. Roberts, (Relativized $^3P_0$ model)
- Stancu and Stassart, (flux tube breaking)
- Graz group, (Modified $^3P_0$ model)
- R. Koniuk and N. Isgur, (pointlike coupling)
JM Mechanisms as Determined by the CLAS $2\pi$ Data

Each production mechanism contributes to all nine single differential cross sections in a unique way. Hence a successful description of all nine observables allows us to check and to establish the dynamics of all essential contributing mechanisms.
### Missing States

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<tr>
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<th>G(pN) (MeV)</th>
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<th>G(wN) (MeV)</th>
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From

S. Capstick and W. Roberts,
(Relativized $^3P_0$ model)
Questions?
Next Steps in Analysis!