A PWA of $p\pi^+\pi^-$ in Photoproduction Using CLAS

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M. Bellis  Z. Krahn  C. Meyer  M. Williams
for the CLAS Collaboration

Department of Physics
Carnegie Mellon University

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Outline

1 Introduction

2 CLAS/g1c Dataset

3 $\gamma p \rightarrow p\pi^+\pi^-$ Analysis
CMU PWA program is focused on the missing baryon issue

- Many states predicted by *Constituent Quark Model* are not experimentally observed. Have we looked in the right places?

Where we’re looking (using CLAS):
- $\gamma p \rightarrow p\pi^+\pi^- (\Delta^{++}\pi^-, \Delta^0\pi^+, p\rho^0)$
- $\gamma p \rightarrow n\pi^+$
- $\gamma p \rightarrow p\pi^0$
- $\gamma p \rightarrow p\omega$
- $\gamma p \rightarrow p\eta$
- $\gamma p \rightarrow p\eta'$
- $\gamma p \rightarrow \Lambda K^+$
- $\gamma p \rightarrow \Sigma^0 K^+$
- $\gamma p \rightarrow \Sigma^+ K^0$
CMU PWA program is focused on the missing baryon issue.

Many states predicted by Constituent Quark Model are not experimentally observed. Have we looked in the right places?

Where we’re looking (using CLAS):

- \( \gamma p \rightarrow p\pi^+\pi^- \) (\( \Delta^{++}\pi^- \), \( \Delta^0\pi^+ \), \( p\rho^0 \)) this talk
- \( \gamma p \rightarrow n\pi^+ \)
- \( \gamma p \rightarrow p\pi^0 \)
- \( \gamma p \rightarrow p\omega \) Mike Williams
- \( \gamma p \rightarrow p\eta \) Zeb Krahn
- \( \gamma p \rightarrow p\eta' \) Zeb Krahn
- \( \gamma p \rightarrow \Lambda K^+ \)
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## Predictions - Capstick and Roberts (1993)

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The **CLAS** detector is a large acceptance spectrometer located in Hall-B at Jefferson Lab in Newport News, Va.

Our data comes from the \(g1c\) 2.445 \(E_{\text{electron}}\) run period.

- Data taken Oct.-Nov. 1999
- Tagged photon beam \((0.5 < E_\gamma < 2.3\text{GeV})\)
- Liquid \(H_2\) target
- Single charged track trigger
  - \((\approx 10^9\) triggers)
Selecting $\gamma p \rightarrow p\pi^+\pi^-$ events

- Selecting $\gamma p \rightarrow p\pi^+\pi^-$ events
  - Require detection of the $p\pi^+\pi^-$ and kinematic fit to the exclusive hypothesis.
  - Make a 10% confidence level cut.
  - 4-constraint fit is very clean!
- Our PWA is mass-independent and binned in 10 MeV $W(\sqrt{s})$ bins.
- 50k-150k events/bin after fiducial cuts.

Missing mass squared off of $p\pi^+\pi^-$

Red events passing C.L. cut.
Blue events failing C.L. cut
Total cross section has been measured by previous experiments.
\( \gamma p \rightarrow p\pi^+\pi^- \)

- Missing resonances should lie above 1800 MeV/c\(^2\).
\[ \gamma p \rightarrow p\pi^+\pi^- \]

- Missing resonances should lie above 1800 MeV/c².
- \(\rho\)-production turns on at 1700 MeV/c², possibly significant \(t\)-channel contribution (Pomeron exchange).
Missing resonances should lie above 1800 MeV/c^2.

*ρ*-production turns on at 1700 MeV/c^2, possibly significant *t*-channel contribution (Pomeron exchange).

For now, this analysis focuses on region below 1600 MeV/c^2 in an effort to describe known physics as a test of procedure.
\[ \gamma p \rightarrow p \pi^+ \pi^- \]

- So what lives below 1600 MeV/c\(^2\)?
\[ \gamma p \rightarrow p\pi^+\pi^- \]

So what lives below 1600 MeV/c^2?

- s-channel resonances
  - \( P_{11}(1440) \)
  - \( D_{13}(1520) \)

Shapes and strengths of terms in cross section are for reference only!
$\gamma p \rightarrow p\pi^+\pi^-$

So what lives below 1600 MeV/c$^2$?

- $s$-channel resonances
  - $P_{11}(1440)$
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- Non-resonant terms
  - Contact (Kroll-Ruderman) term (dominant?)

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- So what lives below 1600 MeV/c^2?

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    - \( \pi \)-exchange (\( t \)-channel)
    - \( p \)-exchange (\( u \)-channel)
$\gamma p \rightarrow p\pi^+\pi^-$

So what lives below 1600 MeV/c²?

- $s$-channel resonances
  - $P_{11}(1440)$
  - $D_{13}(1520)$

- Non-resonant terms
  - Contact (Kroll-Ruderman) term (dominant?)
  - $\pi$-exchange ($t$-channel)
  - $p$-exchange ($u$-channel)
  - Off-shell proton ($s$-channel)

Shapes and strengths of terms in cross section are for reference only!
\( \gamma p \rightarrow p\pi^+\pi^- \)

Shapes and strengths of terms in cross section are for reference only!

- Initial goal is to try to describe the physics with these processes in a single \( W \)-bin.
- Fit using an event based, Maximum Likelihood Method.
- Repeat this for each bin.
- We do not put in Breit-Wigner shapes for the \( s \)-channel terms.
- We put in quantum numbers for \( J^P \) and look for evidence of resonances in intensity and phase motion from bin to bin.
- We can fix the couplings for the non-resonant terms, which should be \( W \)-indepedant.
Our code allows us to write these diagrams using the Rarita-Schwinger formalism.

- We constrain isospin of our $J^P$ states at fit time.
  - Lock down ratio of decay to $\Delta^{++}$ and $\Delta^0$.
- Contact term (Kroll-Ruderman)
  - Should be able to lock this term down from calculations (discussions with Simon Capstick and Alvin Kiswandhi)
- $t, u$-channel terms
  - Can also get a handle on this from theory.
Determining goodness of fit

We look at projections of the data which preserve correlations. Dalitz plot ($W=1600-1610$ MeV/c$^2$).

First plot is data, second plot is accepted MC.
Determining goodness of fit

We look at projections of the data which preserve correlations. Dalitz plot (W=1600-1610 MeV/c²).

First plot is data, second plot is accepted MC *weighted by the results of a fit*. Goal is to develop a quantifiable test of goodness of fit. $\chi^2$ over Dalitz plot? Kolmogorov test?
So let’s try a real fit!

Put in some reasonable physics and compare with other experiments.

- Contact term (fixed from theory)
- $N^*_{\frac{3}{2}^-}$
  - $\Delta \pi$ decay
  - $p\rho$ decay
  - Motivated by $D_{13}(1520)$
- $N^*_{\frac{1}{2}^+}$
  - $\Delta \pi$ decay
  - Motivated by $P_{11}(1440)$
- $\pi$ production from $t$-channel?
  - Not yet tried... but is probably somewhat significant
\[ \gamma p \rightarrow p\pi^+\pi^- \]

Can compare measured differential yields. **PRELIMINARY!**

**Black** is SAPHIR and **blues** are CLAS.

\[ W = 1416-1480 \text{ Mev}/c^2 \quad W = 1542-1603 \text{ Mev}/c^2 \]

\[ \frac{\text{yield}}{dt} t(\gamma - (\pi^+\pi^-)) \]

Our binning is finer and we get pretty good agreement.
Where are we?
- Attacking $p\pi^+\pi^-$ channel with Rarita-Schwinger formalism
- Allows more direct input/comparison from theoretical models.
- Putting in contact term by hand.
- Constraining isospin of $s$-channel waves.
  - Differential cross sections are in rough agreement

Work ahead
- Extract consistent differential cross sections.
- Extract total cross sections from known $N^*$ contributions.
- Extend to higher $W$ where missing resonances possibly lurk.

We have a consistent and flexible framework that allows for a more direct comparison between models and data.

Optimistic that this is the experimental tool to use when attacking this difficult channel.