Photo-production of $\omega$ using CLAS at Jefferson Laboratory

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(CLAS Collaboration)

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Outline

• Background and Motivation
• CLAS Detector at JLAB
• CLAS-g12 and CLAS-FROST Experiment
• Data Analysis
• Preliminary Result and Discussion
• Summary
Background & Motivation

- The Principle Questions
- Baryon Resonances Spectrum
- Partial Wave Analysis (PWA)
- The Need of $\omega$ Photo-production
- Previous Study and Measurements
The principle questions

• The families of the fundamental Particles: Quark, Lepton, Gauge Boson.

• QCD governs the Strong interaction among quarks.

• Quarks/Antiquarks always form composite object called Hadrons.

Principle questions:

• How does the behaviors of quarks determine the properties of hadrons?

• How does the interactions among quarks give rise to the spectrum of hadrons?

• What are the fundamental degrees of freedom inside hadrons?
Baryon Resonances Spectrum

Some models:

Constituent Quark Model (CQM)
- Missing Baryon resonances from CQM (See Y16.0001: Recent progress in understanding the baryon resonances spectrum)
- The discovery of N(1900)3/2+ ruled out the static quark-diquark model.
- Mapping out the whole resonances spectrum is very important to test the models.

Hybrid Baryons

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Partial Wave Analysis (PWA)

- The overlapping nature among resonances.

- PWA requires Differential cross section and Polarization observables as inputs

Set of Particles and Resonances:

Nucleon resonances spectrum (courtesy of Mike Williams)
The need of $\omega$ Photo-production

**Why $\gamma p \rightarrow p\omega$?**

- The $N^*$ may couple stronger to photon.
- Vector meson and photon share the same quantum number ($J^{PC} = 1^- -$).
- Vector meson production channel ($p\omega$, $p\rho$, $p\varphi$) are under explored.
- The $\omega$ is an isospin filter.
- The $\omega$ has a lot of statistics.
- The $\omega$ threshold lies at the higher lying third resonance region.
- The relatively narrow width of the $\omega$ (8.5 MeV) enables a clean detection over background.
CLAS Detector at JLAB

Continuous Electron Beam Accelerator Facility (CEBAF)

CEBAF Large Acceptance Spectrometer (CLAS)
CLAS-g12 and CLAS-FROST (g9a) Experiment

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<th>g12:</th>
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<td><strong>Electron Energy</strong></td>
<td>Maximum at 2.4 GeV</td>
<td>5.7 GeV</td>
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<td><strong>Electron Polarization</strong></td>
<td>Maximum 84.8 %</td>
<td>67.2 %</td>
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<td><strong>Tagged Photon Energy</strong></td>
<td>0.3 - 2.4 GeV</td>
<td>1.1 – 5.45 GeV</td>
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<td><strong>Photon Polarization</strong></td>
<td>Circular and Linear</td>
<td>Circular</td>
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Data Analysis

• We choose the decay mode $\omega \rightarrow \pi^+\pi^0$.
• Hence, we are looking for all $\gamma p \rightarrow p\pi^+\pi^-(\pi^0)$ events.
• PID off $\gamma, p, \pi^+, \pi^-$ are reconstructed using the information from Start Counter, Drift Chamber, Time of flight and Tagger.
• $\pi^0$ is reconstructed using kinematic fitting.
• To isolate $\gamma p \rightarrow p\omega \rightarrow p\pi^+\pi^-(\pi^0)$ we apply event based Q-factor method.
Differential Cross Section & Polarization Observable $E$

The differential cross section

\[
\frac{d\sigma}{d\cos\theta_{\text{CM}}^\omega} = \left( \frac{A_{\text{target}}}{\rho_{\text{target}} \cdot l_{\text{target}} \cdot N_A \cdot \text{Flux}} \right) \frac{\sum_i^n Q_i}{\Delta \cos\theta_{\text{CM}}^\omega \cdot \varepsilon_{\text{MC}} \cdot BR}
\]

- The number of $\omega$ yields is the sum of $Q$-value.
- The detector acceptance is modelled using montecarlo simulation

The Polarization observable $E$

\[
E = -\frac{1}{\Lambda_{z} \delta_{o}} \left( \frac{N_+ - N_-}{N_+ + N_-} \right)
\]

- Polarization observable $E$ is the asymmetry between the $\omega$ produced when the polarization of the beam and target are parallel and antiparallel).
- Measured asymmetry is normalized by the product of beam and target polarizations,
Preliminary Results
& Discussion

1. Polarization Observable E along with Bonn-Gatchina PWA Fit:

- The figure shows the polarization observable E from CLAS-FROST at 1.1 – 2.3 GeV (red point) along with the Bonn-Gatchina PWA fit result (solid line), in comparison with the previous measurement from CBELSA/TAPS (blue point).
- The dominant contribution from $N(1720)$ 3/2+ is found.
- The background is dominated by the t-channel contributions (pomeron-exchange and a smaller π-exchange).
- The full description of the data need the contribution from:
  - $N(1680)$ 5/2+
  - $N(2000)$ 5/2+
  - $N(1895)$ 1/2−
  - $N(2100)$ 3/2−
The cross section behavior due to the $t$ channel pomeron exchange is expected to falling off exponentially at low $t$.

We see that the pomeron exchange contribution is more dominant when the energy is increasing.

But there are still significant contributions from non Pomeron exchange at the region $4.0 - 4.5$ GeV).
Summary

• $\gamma p \rightarrow p\omega$ is a great channel for Baryon resonances study.
• The high statistic of the differential cross section and the polarization observable $E$ have been measured at JLAB using CLAS-g12 and CLAS-FROST dataset.
• The Bonn-Gatchina PWA fit found some resonance contributions as well as the $t$-channel contributions from pomeron-exchange and a smaller $\pi$-exchange.
THANK YOU