ω Photoproduction at the CBELSA/TAPS Experiment

Andrew Wilson
For the CBELSA/TAPS Collaboration

Florida State University

May 17-20, 2011
NStar 2011 Jefferson Lab Newport News, VA
Outline

1. Motivation
2. CBELSA/TAPS Experimental Setup
3. $\gamma p \rightarrow p\omega$
   - Reconstruction
   - Differential Cross Sections
4. CLAS/CBELSA $\eta$ Disagreement
5. Summary and Outlook
Outline

1. Motivation
2. CBELSA/TAPS Experimental Setup
3. $\gamma p \rightarrow p\omega$
   - Reconstruction
   - Differential Cross Sections
4. CLAS/CBELSA $\eta$ Disagreement
5. Summary and Outlook
Motivations for Studying $\omega$ Photoproduction

- Find resonances that couple to $\omega$ mesons.
- Improve on the forward angle scattering cross sections.
- Help resolve the CLAS/CBELSA $\eta$ photoproduction discrepancy.
Motivations for Studying $\omega$ Photoproduction

- Find resonances that couple to $\omega$ mesons.
- Improve on the forward angle scattering cross sections.
- Help resolve the CLAS/CBELSA $\eta$ photoproduction discrepancy.

The PDG(2010) currently lists 4 $N^*$ resonances that couple to the $\omega$ meson.

$N(1710)^{***}$  $N(1900)^{**}$  $N(2080)^{**}$  $N(2190)^{****}$
Motivations for Studying $\omega$ Photoproduction

- Find resonances that couple to $\omega$ mesons.
- Improve on the forward angle scattering cross sections.
- Help resolve the CLAS/CBELSA $\eta$ photoproduction discrepancy.
Motivations for Studying $\omega$ Photoproduction

CLAS $\omega$ Photoproduction Cross Section


Forward and backward angles → background processes and high spin resonances.
Motivations for Studying $\omega$ Photoproduction

- Find resonances that couple to $\omega$ mesons.
- Improve on the forward angle scattering cross sections.
- Help resolve the CLAS/CBELSA $\eta$ photoproduction discrepancy.
Motivations for Studying $\omega$ Photoproduction

Single $\eta$ Photoproduction Cross Section

CBELSA/TAPS(09)  CBELSA(05)  CLAS(09)  CLAS(02)  LEPS(09)

no stat errors
no errors
Motivations for Studying $\omega$ Photoproduction

Single $\eta$ Photoproduction Cross Section Ratio

Normalization?
Motivations for Studying $\omega$ Photoproduction

- Find resonances that couple to $\omega$ mesons.
- Improve on the forward angle scattering cross sections.
- Help resolve the CLAS/CBELSA $\eta$ photoproduction discrepancy.

At CBELSA/TAPS, the same photon flux is used for reactions $\pi^0, \eta$ and $\omega$. Can use $\pi^0$ and $\omega$ cross sections study differences in normalization.
Outline

1. Motivation
2. CBELSA/TAPS Experimental Setup
3. $\gamma p \rightarrow p \omega$
   - Reconstruction
   - Differential Cross Sections
4. CLAS/CBELSA $\eta$ Disagreement
5. Summary and Outlook
CBELSA/TAPS Experiment (2002)

- Located in Bonn, Germany at the ELSA facility.
- Nearly a $4\pi$ detector optimized to detect photons.
- Has scintillators to detect the presence of charged particles.
- CB (1290 CsI Crystals) TAPS (528 BaF$_2$ Crystals)
Outline

1. Motivation

2. CBELSA/TAPS Experimental Setup

3. $\gamma p \rightarrow p \omega$
   - Reconstruction
   - Differential Cross Sections

4. CLAS/CBELSA $\eta$ Disagreement

5. Summary and Outlook
Outline

1 Motivation

2 CBELSA/TAPS Experimental Setup

3 $\gamma p \rightarrow p\omega$
   - Reconstruction
   - Differential Cross Sections

4 CLAS/CBELSA $\eta$ Disagreement

5 Summary and Outlook
Data Set

- Data taken October 2002 - November 2002
- Unpolarized photon beam up to 3.2 GeV
- Unpolarized liquid hydrogen target

**Kinematic Cuts**

\[ p \omega \rightarrow p(\pi^0 \gamma) \rightarrow p(\gamma \gamma) \gamma \rightarrow 3/4 \text{ particles} \]

- Transverse momentum cut $\pm 30$ deg
- Timing cuts (relative to the timing calibration)
  - Uncharged time $\pm 3$ ns
  - Charged time $\{-5,+15\}$ ns
Kinematic Fitting

\( \omega \) meson

\( m = 782.65 \text{ MeV}, \Gamma = 8.49 \text{ MeV} \)

→ Cannot kinematically fit to \( p\omega \)

Fit to \( p_{\text{missing}}\pi^0\gamma \)

Confidence Level Cut

\[ CL_{p\pi^0\gamma} > 0.01 \]

\( \sim 440,000 \) events left

Andrew Wilson  Omega Photoproduction
Qvalue Background Subtraction

Idea: Weight each event with its probability to be a true $\rho\omega$ event.

(M. Williams, M. Bellis, C.A. Meyer, JINST 4:P10003, 2009.)

Events in $\rho\omega$ Phase Space

$(E_\gamma, \cos \theta_P^{\text{cms}})$
Qvalue Background Subtraction

Idea: Weight each event with its probability to be a true $p\omega$ event.

Events in $p\omega$ Phase Space

$(E_{\gamma}, \cos \theta^\text{cms}_p)$
Q-value Background Subtraction

Idea: Weight each event with its probability to be a true $p\omega$ event.

Nearest Neighbor Events

$x_1$  \hspace{1cm}  $x_2$
Qvalue Background Subtraction

Idea: Weight each event with its probability to be a true $p\omega$ event.

Plot and Fit of Nearest Neighbor Events

Voigt function (peak) with 2nd degree chebychev polynomial (background)
Unbinned maximum likelyhood fit
Qvalue Background Subtraction

Idea: Weight each event with its probability to be a true $p\omega$ event.

\[
\text{probability fraction (Qvalue)} = \frac{s}{s+b}
\]

Repeat for each event

Advantage: Only have to fit once to produce different distributions of the data.

Disadvantage: Huge amounts of processing time. (one fit per event in analysis)
Outline

1. Motivation
2. CBELSA/TAPS Experimental Setup
3. $\gamma p \rightarrow p\omega$
   - Reconstruction
   - Differential Cross Sections
4. CLAS/CBELSA $\eta$ Disagreement
5. Summary and Outlook
Motivation  CBELSA/TAPS Experimental Setup  $\gamma p \rightarrow p\omega$  Reconstruction  Differential Cross Sections

ω Photoproduction Differential Cross Sections

CBELSA/TAPS  CLAS

$\omega$ cm  $\theta_{cm}$  $d\sigma/d\Omega$


2100-2150 MeV  2150-2200 MeV  2200-2250 MeV  2250-2300 MeV  2300-2350 MeV

2350-2400 MeV  2400-2450 MeV  2450-2500 MeV  2500-2550 MeV

Andrew Wilson  Omega Photoproduction
Photoproduction Differential Cross Sections

\[ \frac{d\sigma}{d\theta} \]

\( \omega \) cm

\( \theta \) sr

mb

Preliminary
Photoproduction Differential Cross Sections

CBELSA/TAPS vs. CLAS

Motivation CBELSA/TAPS Experimental Setup $\gamma p \to p\omega$ Reconstruction Differential Cross Sections

---

Andrew Wilson Omega Photoproduction
Outline

1. Motivation
2. CBELSA/TAPS Experimental Setup
3. $\gamma p \rightarrow p \omega$
   - Reconstruction
   - Differential Cross Sections
4. CLAS/CBELSA $\eta$ Disagreement
5. Summary and Outlook
Reaction by Reaction Comparison

- $\pi^0$ Photoproduction
- $\omega$ Photoproduction
- $\eta$ Photoproduction
Reaction by Reaction Comparison

π⁰ Photoproduction Cross Section

CBELSA/TAPS     CB-ELSA(07)     CLAS(07)

N. Sparks
Parallel session II-A
(under collaboration review)
Reaction by Reaction Comparison

- $\pi^0$ Photoproduction
- $\omega$ Photoproduction
- $\eta$ Photoproduction
Reaction by Reaction Comparison

$\omega$ Photoproduction Cross Section

CBELSA/TAPS  CLAS

$E_\gamma$ [GeV]  $d\sigma [\mu b/str]$
Reaction by Reaction Comparison

- $\pi^0$ Photoproduction
- $\omega$ Photoproduction
- $\eta$ Photoproduction
Reaction by Reaction Comparison

η Photoproduction Cross Section

CBELSA/TAPS(09)  CB-ELSA(05)  CLAS(09)  LEPS(09)
Reaction by Reaction Comparison

- $\pi^0$ Photoproduction
- $\omega$ Photoproduction
- $\eta$ Photoproduction

- Could be normalization.
- The $\eta$ photoproduction discrepancy is present above 1.8 GeV photon energy and occurs at all angles.
- Corresponds to about a factor of $\sim 2$ difference at 2.5 GeV photon energy.
Outline

1. Motivation
2. CBELSA/TAPS Experimental Setup
3. $\gamma p \rightarrow p\omega$
   - Reconstruction
   - Differential Cross Sections
4. CLAS/CBELSA $\eta$ Disagreement
5. Summary and Outlook
Summary

- Showed the reconstruction and differential cross sections for $\omega$ photoproduction.
- Analyzed the CBELSA/CLAS $\eta$ differential cross section disagreement.
Finalize the $\omega$ photoproduction analysis.
Continue with the analysis of $\pi^0\omega$ photoproduction.
Continue work on a phenominological model to describe $\omega$ and $\pi^0\omega$ photoproduction.

$\pi^0\omega$ Analysis: $\pi^0\gamma$ Invariant Mass

$\sim 17,000 \ p\pi^0\omega$ events.