Coherent $\omega$-Meson Photoproduction off Deuterium from CLAS

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Outline

➢ Motivation
➢ CLAS Detector
➢ Particle Identification
➢ Yield Extraction
➢ Preliminary Results
➢ Summary
Motivation

$\gamma d \rightarrow \phi d$

Single scattering

$\gamma$

$\phi$

$d$

$d$

$\gamma$

$\phi$

$d$

$d$

$\gamma$

$\phi$

$d$

$d$

$\gamma$

$\phi$

$d$

$d$

Double scattering

Mandelstam $t$:

$$t = (P_\gamma - P_\phi)^2 = (P_{d_i} - P_{d_o})^2$$

T. Mibe et al. PHYSICAL REVIEW C 76, 052202(R) (2007)
Motivation

Reaction of interest

\[ \gamma d \rightarrow \omega d \rightarrow \pi^+ \pi^- \pi^0 d \ (88.8\%) \]

Limited World Data

- Photoproduction of omega mesons off Deuteron: limited studies → limited world data.

Photon Coupling ratio of the vector mesons:

\[ \gamma_\rho \:: \gamma_\omega \:: \gamma_\phi = 1 : 3 : -\frac{3}{\sqrt{2}} \]

- Assuming SU(3) and SU(6) symmetry.

- The Coupling constants provide understanding for EM form factors of pseudo-scalar mesons and nucleons, EM meson decays, etc.

- Better understanding of the Current-field identity.
CLAS Detector

- JLAB: Newport News, VA;
- CEBAF: accelerated electrons up to 6 GeV;
- Experimental Halls: A, B, C and D;
- Hall B: electron or photon beam;
- Data from \textit{g10} run period (Spring, 2004);
- Target: 24 cm long liquid deuterium at \( Z = -25 \) cm;
- Electron beam energy 3.778 GeV;

Side view of CLAS detector:

Particle Identification

Data: $E_\gamma$

Data: $\pi^-$

Data: $\pi^+$

Data: $d$
Global Spectrum

\[ \gamma d \rightarrow \omega d \]

\[ \omega \rightarrow \pi^+ \pi^- \pi^0 \quad (88.8\%) \]
Cuts Applied

- Timing cuts made using momentum-dependent analysis
  - $-40 \text{ cm} < z_{\text{vertex}} < -10 \text{ cm}$
  - $-0.01 < MM^2 < 0.005 \ [\text{GeV}^2/c^4]$  
- Theta cut applied
- Fiducial cuts applied $\varphi = a e^{b \theta} + c$
- Paddle Cuts

<table>
<thead>
<tr>
<th>Particle</th>
<th>Sector 1</th>
<th>Sector 2</th>
<th>Sector 3</th>
<th>Sector 4</th>
<th>Sector 5</th>
<th>Sector 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi^+$</td>
<td>23, 27</td>
<td>$\geq 43$</td>
<td>$\geq 45$</td>
<td>11, 23, 31</td>
<td>$\geq 40$</td>
<td>23, 33, 35</td>
</tr>
<tr>
<td>$\pi^-$</td>
<td>23, 27</td>
<td>$\geq 41$</td>
<td>$\geq 41$</td>
<td>11, 15, 16, 23, 34-36</td>
<td>$\geq 41$</td>
<td>23, 27, 35</td>
</tr>
<tr>
<td>$d$</td>
<td>23, 27</td>
<td>$\geq 35$</td>
<td>$\geq 35$</td>
<td>11, 22, 23</td>
<td>$\geq 35$</td>
<td>23</td>
</tr>
</tbody>
</table>

- Energy range: $1.4 < E_y < 3.4 \ [\text{GeV}]$
Binning

$0.069 < MM(\gamma d,d') < 0.91 \ [GeV/c^2]$

<table>
<thead>
<tr>
<th>$E_{\text{photon}}$ [GeV]</th>
<th>$t$-bins</th>
<th>$-t_{\text{min}}$ [GeV$^2$]</th>
<th>$-t_{\text{max}}$ [GeV$^2$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4-1.8</td>
<td>8</td>
<td>2.0</td>
<td>0.3</td>
</tr>
<tr>
<td>1.8-2.2</td>
<td>6</td>
<td>1.5</td>
<td>0.3</td>
</tr>
<tr>
<td>2.2-2.8</td>
<td>6</td>
<td>1.5</td>
<td>0.3</td>
</tr>
<tr>
<td>2.8-3.4</td>
<td>5</td>
<td>1.5</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Yield Extraction

Yield is extracted by taking integral of the Voigt function
**Differential Cross-section**

Differential cross-section,

\[
\frac{d\sigma}{dt} = \frac{Yield}{(\delta t)\epsilon L(E_\gamma)}
\]

\[\epsilon \equiv \text{Detector Acceptance} \sim 0.17\]

Luminosity,

\[L(E_\gamma) = \frac{\rho_d N_A l_d}{M_d} N_\gamma(E_\gamma)\]

\[\rho_d = 0.169 \text{ g cm}^{-3}\]

\[l_d = 24 \text{ cm}\]

\[M_d = 2.014 \text{ g mole}^{-1}\]

\[N_\gamma = \text{Photon Flux}\]
**Summary**

- The cross-section data provides sensitivity to the nucleon-scattering data in the energy and momentum transfer range mentioned.

- First high statistics world data for the reaction: $\gamma d \rightarrow \omega d$

- Double scattering contribution.

- Next steps would include:
  - Study of systematic uncertainties.
  - Calculate the ratio of photon-vector meson coupling constant.
  - Comparison with a theoretical model.
Acceptance

$1.4 < E_\gamma < 1.8$

$2.2 < E_\gamma < 2.8$

$1.8 < E_\gamma < 2.2$

$2.8 < E_\gamma < 3.4$

Acceptance $\sim t [\text{GeV}^2/c^2]$
Acceptance

$1.0 < E_\gamma < 1.4$ excluded.
Need to investigate the unusual acceptance.

$1.0 < E_\gamma < 1.4$
## Previous Studies

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Gupta <em>et. al.</em> [SLAC]</td>
<td>5.5</td>
<td>-</td>
<td>Low statistics. No mass fit was possible</td>
</tr>
<tr>
<td>Phys. Rev. D 14, 42 (1976)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Morris <em>et. al.</em> [NINA]</td>
<td>3.9</td>
<td>-</td>
<td>*Total Cross-section measured: $1.4 \pm 0.5 \mu b$</td>
</tr>
<tr>
<td>Nuclear Physics B119 (1977)</td>
<td></td>
<td></td>
<td>*Coupling constant ratio (rho/omega) measured</td>
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