POLARIZATION OBSERVABLES FROM THE PHOTOPRODUCTION OF $\omega$ MESONS USING LINEARLY POLARIZED PHOTONS

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There are many baryon resonances that decay through vector meson channel.

They overlap because of their broad widths (~150 MeV).
Models predict more resonances than the ones that have been measured.
Processes contributing to the reaction \( \gamma p \rightarrow \omega p \)
All models agree that:

π⁰ exchange (unnatural parity) in the t-channel plays a significant role in the cross section of the electro- and photoproduction of ω mesons.

Baryon resonances contribute significantly to both the total and differential cross section in ω electro- and photoproduction.

We urgently need polarized observables to disentangle which resonances and by how much these resonances contribute to the cross section.
CLAS: **Multi-layer** spherical array of detectors for charged and neutral particles.

Very **large angular coverage**: Near full coverage in azimuthal angle and from $8^\circ$ to $140^\circ$ in scattering angle.
CEBAF Large Acceptance Spectrometer

Torus magnet
6 superconducting coils

Liquid \( \text{D}_2 (\text{H}_2) \) target + \( \gamma \) start counter; e minitorus

Drift chambers
argon/\( \text{CO}_2 \) gas, 35,000 cells

Large angle calorimeters
Lead/scintillator, 512 PMTs

Gas Cherenkov counters
e/\( \pi \) separation, 216 PMTs

Electromagnetic calorimeters
Lead/scintillator, 1296 PMTs

Time-of-flight counters
plastic scintillators, 684 PMTs
G8b RUN

Target type: Liquid H2

Electron end-point energy: 4.544 GeV

<table>
<thead>
<tr>
<th>$E_\gamma$ at the coherent peak (GeV)</th>
<th>Events (billion)</th>
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<tbody>
<tr>
<td>1.3</td>
<td>1.5</td>
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<tr>
<td>1.5</td>
<td>1.5</td>
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<tr>
<td>1.7</td>
<td>1.5</td>
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<tr>
<td>1.9</td>
<td>1.0</td>
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<tr>
<td>2.1</td>
<td>1.0</td>
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<tr>
<td>Amorphous data</td>
<td>1.8</td>
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We start by requiring three particles in the final state: proton, $\pi^+$, and $\pi^-$. The PID process encompasses cuts on the values for mass, beta, time, momentum and TOF time to best identify good events.

A track in the drift chambers and a coincidence in the TOF detector are required flags to accept a candidate event.
The mass distribution as given by EVNT bank. Peaks correspond to pion, kaon and proton mass.
A comparison between $\pi^+$ and $\pi^-$ cut is seen.

Zooming on proton mass cut.
Cuts to the photon energy range are established for each data set.

The initial cuts for the data sets are:

- 1.3 GeV → 1.1 to 1.325 GeV
- 1.7 GeV → 1.3 to 1.525 GeV
- 1.7 GeV → 1.5 to 1.725 GeV
- 1.9 GeV → 1.7 to 1.925 GeV
- 2.1 GeV → 1.8 to 2.125 GeV

EXAMPLE
A loose cut between -1.5 and 1.5 ns is performed. The plot shows $\Delta t$ vs momentum.
A cut for $\Delta \beta$ (as given by EVNT bank - calculated $\beta$) is performed between -0.05 and 0.05.
To distinguish positively charged particles, i.e., proton and π⁺, a cut from -1 to 1 ns is performed. The clusters of events around (+-2,+-2), (+-4,+-4) are due to photons associated with the wrong RF bucket.
INITIAL CUTS/CORRECTIONS

- **Fiducial cuts (angular)**

- **Energy loss corrections** (by using `eloss` package written by Eugene Pasyuk)

- **Momentum corrections** are less than 1%, so for now they are neglected in the analysis.
A rough fit (Gaussian) to the $\pi^0$ mass peak, found by using missing mass technique, from which the 3 to 5 sigma cut is made.
EXTRA CUTS

- **Cos Θ cut for bad photons:**
  
  A cut of 0.01 for Cos θ distribution for π⁰ is done to ensure non-π⁰ misidentified events are ruled out of the analysis. Notice how at the most forward part there is an excess of events. These belong to the wrong photon assignation to a non-π⁰ event.

- **Vertex cuts**

Cos θ distribution after a 3 sigma cut on the π⁰ mass and the cut mentioned above.
The mass of the $\omega$ meson is obtained by using the 4-momentum of the detected $\pi^+$ and $\pi^-$, and also from the reconstructed $\pi^0$. 
Fitting function:

- **Voigtian function** for the \( \omega \) signal.
- **4th degree polynomial** for the background.
- No constraints to the parameters.
• 10 bins in $\cos \Theta$ and
• 18 bins in $\varphi$ are used.

The asymmetry parameter was checked for three $E_\gamma$ values, for future comparison with the data obtained by P. Collins.

• 27 MeV wide $E_\gamma$ bins. The $E_\gamma$ bin cuts are:

$$1.861 < E_\gamma < 1.888$$
$$1.834 < E_\gamma < 1.861$$
$$1.807 < E_\gamma < 1.834$$
The Beam Asymmetry is determined by fitting the ratio PERP-PARA/PERP+PARA for each Cos Θ and Eγ bin, to a cosine 2φ like function.

\[
\begin{align*}
\sigma_\perp &= \sigma_0 (1 + P_\perp \Sigma \cos 2\phi) \\
\sigma_\parallel &= \sigma_0 (1 + P_\parallel \Sigma \cos 2\phi + \pi) \\
\sigma_\parallel &= \sigma_0 (1 - P_\parallel \Sigma \cos 2\phi)
\end{align*}
\]

\[
\frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel} = \frac{\left(\frac{N_\perp}{N_\parallel} - 1\right) - \left(\frac{N_\perp}{N_\parallel} P_\perp + P_\parallel\right)\Sigma \cos(2(\phi))}{\left(\frac{N_\perp}{N_\parallel} + 1\right) - \left(\frac{N_\perp}{N_\parallel} P_\perp - P_\parallel\right)\Sigma \cos(2(\phi))}
\]
ω beam asymmetry
2σ cut

PRELIMINARY
ω beam asymmetry
2σ cut

PRELIMINARY
ω beam asymmetry
2σ cut

PRELIMINARY
\[ \Sigma \text{ vs } \cos \theta \text{ for } 1820.45, 1847.25, 1874.05 \text{ MeV} \]

- **Blue 1820.45 MeV**
- **Red 1847.25 MeV**
- **Green 1874.05 MeV**

**PRELIMINARY**
ω beam asymmetry
3σ cut
ω beam asymmetry
3σ cut

PRELIMINARY
ω beam asymmetry
3σ cut

PRELIMINARY
PRELIMINARY
• Extraction of $\Sigma$.
  
  We have determined $\Sigma$ through one technique.
  * $\phi$ binning method.
  
  And cross compared to:
  * Moments method (P. Collins).

  They agree → we have a good handle on our systematics.

  * Studies on the binning for both $\text{Cos } \Theta$ and $\phi$ are to be done.

  * Further studies have to be performed to reduce the background of the $\omega$ meson and thus clean up the signal.

  * 1.3, 1.5, and 1.7 data sets are yet to be studied.

  * 2.1 data set is currently being analyzed.
The first goal is to compare $\Sigma$ with more mature analysis (Patrick Collins).

Extraction of Spin Density Matrix Elements $\rho_{ij}^{\alpha}$ (SDME).

\[
W^L(\cos \theta, \phi, \Phi) = W^0(\cos \theta, \phi) - P_\gamma \cos 2\Phi W^1(\cos \theta, \phi) - P_\gamma \cos 2\Phi W^2(\cos \theta, \phi)
\]

with

\[
W^0(\cos \theta, \phi) = \frac{3}{4} \left[ \frac{1}{2} \left( 1 - \rho_{00}^0 \right) + \frac{1}{2} \left( 3\rho_{00}^0 - 1 \right) \cos^2 \theta - \sqrt{2} \text{Re}\rho_{10}^0 \sin 2\theta \cos \phi - \rho_{1-1}^0 \sin^2 \theta \cos 2\phi \right]
\]

\[
W^1(\cos \theta, \phi) = \frac{3}{4} \left[ \rho_{11}^1 \sin^2 \theta + \rho_{00}^1 \cos^2 \theta - \sqrt{2} \rho_{10}^1 \sin 2\theta \cos \phi - \rho_{1-1}^1 \sin^2 \theta \cos 2\phi \right]
\]

\[
W^2(\cos \theta, \phi) = \frac{3}{4} \left[ \sqrt{2} \text{Im}\rho_{10}^2 \sin 2\theta \sin \phi + \text{Im}\rho_{1-1}^2 \sin^2 \theta \sin 2\phi \right]
\]
Σ will be used as a constraint for this SDMEs, since:

\[
\Sigma = P_\gamma \frac{2(\rho_{11}^1 + \rho_{1-1}^1)}{1 - \rho_{00}^0 + 2\rho_{1-1}^0}
\]

If Helicity is conserved in the s-channel, then only two of the nine SDMEs are nonzero: \( \rho_{1-1}^1 = 0.5 \) and \( \text{Im}\rho_{1-1}^2 = 0.5 \), hence \( \Sigma = 1 \) when \( P_\gamma = 1 \) (with \( \theta, \phi \) determined in the helicity frame). Any deviation from this value is an indication that nondiffractive processes are present. If we assume natural parity as the production mechanism, then

\[
\rho_{1-1}^1 = 0.5, \quad \rho_{00}^1 = 0
\]

If unnatural-parity exchange dominates, then

\[
\rho_{1-1}^1 = -0.5, \quad \rho_{00}^1 = 0
\]