Measuring the Target Asymmetry in $p\pi^0\eta$ Photoproduction

Andrew Wilson

Florida State University
Tallahassee, Florida

Collaboration Meeting

July 2, 2009
Outline

1. Target Asymmetry $P_z$

2. Calculating $P_z$ for $\gamma p \rightarrow p\pi^0\eta$
   - Selecting the Reaction $\gamma p \rightarrow p\pi^0\eta$
   - Factoring in Target Polarization
   - Photon Flux
   - Results

3. Things to Improve
Target Asymmetry $P_z$

1. **Target Asymmetry $P_z$**

2. **Calculating $P_z$ for $\gamma p \rightarrow p\pi^0\eta$**
   - Selecting the Reaction $\gamma p \rightarrow p\pi^0\eta$
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   - Results

3. **Things to Improve**
Polarization Observables (November 2007 Beamtime)

November 2007 Beamtime
Circularly Polarized Photons, Longitudinally Polarized Target

Polarization Observables possible
(Two Mesons in the final state)

\[
\frac{\partial \sigma}{\partial x_i} = \frac{\partial \sigma_0}{\partial x_i} \left( 1 + \Lambda_z P_z + \delta_\odot I_\odot + \delta_\odot \Lambda_z E \right)
\]

Ultimate Goal \(\Rightarrow\) E
First Attempt \(\Rightarrow\) \(P_z\)
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3. Things to Improve
Calculating $P_z$

After Solving for $P_z$: ($\Rightarrow$ means Positive Target Polarization)

$$\rightarrow P_z(x_i) = \frac{1}{2 \Lambda_z} \frac{\frac{\partial \sigma \Rightarrow}{\partial x_i} - \frac{\partial \sigma \Leftarrow}{\partial x_i}}{\frac{\partial \sigma \Rightarrow}{\partial x_i} + \frac{\partial \sigma \Leftarrow}{\partial x_i}} = \frac{1}{2} \frac{\frac{N \Rightarrow}{\text{Flux} \Rightarrow} - \frac{N \Leftarrow}{\text{Flux} \Leftarrow}}{\frac{N \Rightarrow}{\text{Flux} \Rightarrow} + \frac{N \Leftarrow}{\text{Flux} \Leftarrow}}$$

**Need**

- Number of Reconstructed $p\pi^0\eta$ events under each polarization.
- Photon Flux under each polarization.
- Target Polarization for each event.

Only binning in CM Energy
(Integrating over all other Kinematic Variables)
Target Asymmetry $P_z$  

Calculating $P_z$ for $\gamma p \rightarrow p \pi^0 \eta$  

Selecting the Reaction $\gamma p \rightarrow p \pi^0 \eta$  

Factoring in Target Polarization  

Photon Flux  

Results  

Things to Improve  

$$P_z = \frac{1}{2} \left( \frac{N\Rightarrow}{\Lambda_Z\Rightarrow} \frac{1}{\text{Flux}\Rightarrow} - \frac{N\Leftarrow}{\Lambda_Z\Leftarrow} \frac{1}{\text{Flux}\Leftarrow} \right)$$
## Reaction Selection Cuts

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles</td>
<td>1 charged, 4 uncharged</td>
</tr>
<tr>
<td>$\pi^0$ mass</td>
<td>{110,160} MeV</td>
</tr>
<tr>
<td>$\eta$ mass</td>
<td>{500,600} MeV</td>
</tr>
<tr>
<td>Missing Mass (proton)</td>
<td>{750,1150} MeV</td>
</tr>
<tr>
<td>Coplanarity</td>
<td>$\pm 20^\circ$</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>{-5,5} ns</td>
</tr>
</tbody>
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$\Rightarrow 12,155$ events

### $\pi^0$ Mass

- **Invariant Mass**
  - Entries: 12155
  - Mean: 134.7
  - RMS: 11.79

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\[ \Rightarrow 12,155 \text{ events} \]

**\( \eta \) Mass**

![\( \eta \) Invariant Mass](image.png)

**Meson2InvariantMass**
- Entries: 12155
- Mean: 546.1
- RMS: 24.56
Calculating $P_z$ for $\gamma p \rightarrow p\pi^0\eta$

**Things to Improve**

Selecting the Reaction $\gamma p \rightarrow p\pi^0\eta$

Factoring in Target Polarization

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**Reaction Selection Cuts**

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$\Rightarrow$ 12,155 events

**Missing Mass (Proton)**

![Missing Mass (Proton) Graph](image)

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⇒ 12,155 events

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**Reaction Time**

![Reaction Time Histogram](histogram.png)

- **Entries**: 12,155
- **Mean**: -0.4439
- **RMS**: 1.879

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Measuring the Target Asymmetry in $p\pi^0\eta$ Photoproduction
Reconstructed $p\pi^0\eta$ Events

Positive Target Polarization ($N\Rightarrow$)

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Entries</th>
<th>Mean</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1400</td>
<td>20</td>
<td>175</td>
<td>20</td>
</tr>
<tr>
<td>1600</td>
<td>50</td>
<td>180</td>
<td>30</td>
</tr>
<tr>
<td>1800</td>
<td>80</td>
<td>185</td>
<td>40</td>
</tr>
<tr>
<td>2000</td>
<td>100</td>
<td>190</td>
<td>50</td>
</tr>
<tr>
<td>2200</td>
<td>120</td>
<td>195</td>
<td>60</td>
</tr>
<tr>
<td>2400</td>
<td>150</td>
<td>200</td>
<td>70</td>
</tr>
</tbody>
</table>

3406 events

$p\pi^0\eta$ Threshold $\approx$ 1620 MeV (red line)

Negative Target Polarization ($N\Leftarrow$)

<table>
<thead>
<tr>
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<th>RMS</th>
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8749 events
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3. Things to Improve

$$P_z = \frac{1}{2} \frac{\Lambda_{\leftarrow} \leftarrow Flux\Rightarrow}{\Lambda_{\rightarrow} \rightarrow Flux\Rightarrow} - \frac{\Lambda_{\rightarrow} \rightarrow Flux\Leftarrow}{\Lambda_{\leftarrow} \leftarrow Flux\Leftarrow}$$
Target Asymmetry $P_z$ Calculating $P_z$ for $\gamma p \rightarrow p\pi^0\eta$ Things

Selecting the Reaction $\gamma p \rightarrow p\pi^0\eta$

Factoring in Target Polarization

Target Polarization

<table>
<thead>
<tr>
<th>Target_pol</th>
</tr>
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<tbody>
<tr>
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Unequal Beamtime from each Target Polarization Setting
Things to Improve
Selecting the Reaction $\gamma p \rightarrow p \pi^0 \eta$

Factoring in Target Polarization

Histograms filled with each event divided by its degree of polarization.
Target Asymmetry $P_z$

Calculating $P_z$ for $\gamma p \rightarrow p\pi^0\eta$

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Photon Flux

Results

Things to Improve

$$P_z = \frac{1}{2} \left( \frac{N_{\Rightarrow Flux}}{\Lambda_Z} - \frac{N_{\Leftarrow Flux}}{\Lambda_Z} \right) + \left( \frac{N_{\Rightarrow Flux}}{\Lambda_Z} - \frac{N_{\Leftarrow Flux}}{\Lambda_Z} \right)$$
Photon Flux Quick Fix

Need a Normalization Factor

Perfect world $\rightarrow$ Photon Flux.
My World $\rightarrow$ Total Events Recorded.

Total Events Recorded

Dominated by 2 body final state reactions and unpolarized events (unpolarized nucleons).
Largely invariant to change in target polarization.
Target Asymmetry $P_z$ Calculating $P_z$ for $\gamma p \rightarrow p\pi^0\eta$ Things

Selecting the Reaction $\gamma p \rightarrow p\pi^0\eta$ Factoring in Target Polarization

Total Events Recorded

<table>
<thead>
<tr>
<th>Events (x10^6)</th>
<th>Positive Polarization</th>
<th>Negative Polarization</th>
</tr>
</thead>
<tbody>
<tr>
<td>350</td>
<td>1.20 x 10^8 events</td>
<td>3.23 x 10^8 events</td>
</tr>
<tr>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>250</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
</tr>
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Mathematical Expression:

$$P_z = \frac{1}{2} \left( \frac{N \rightarrow \Lambda_Z}{\text{Flux}} \frac{1}{\text{Flux}} - \frac{N \leftarrow \Lambda_Z}{\text{Flux}} \frac{1}{\text{Flux}} \right)$$
Numerator

\[ \text{Numerator} = \frac{N_{\rightarrow}}{\Lambda_{\rightarrow}} \frac{1}{\text{Flux}_{\rightarrow}} - \frac{N_{\leftarrow}}{\Lambda_{\leftarrow}} \frac{1}{\text{Flux}_{\leftarrow}} \]
Denominator

\[ \text{Denominator} = \frac{N_{\rightarrow}}{\text{Flux}_{\rightarrow}} + \frac{N_{\leftarrow}}{\text{Flux}_{\leftarrow}} \]
Target Asymmetry $P_z$ Calculating $P_z$ for $\gamma p \rightarrow p \pi^0 \eta$ Things

Selecting the Reaction $\gamma p \rightarrow p \pi^0 \eta$ Factoring in Target Polarization

$$P_z = \frac{1}{2} \left( \frac{N_{\rightarrow}}{\Lambda_{\rightarrow}} \frac{1}{\text{Flux}_{\rightarrow}} - \frac{N_{\rightarrow}}{\Lambda_{\rightarrow}} \frac{1}{\text{Flux}_{\rightarrow}} \right) + \frac{N_{\rightarrow}}{\Lambda_{\rightarrow}} \frac{1}{\text{Flux}_{\rightarrow}}$$

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3. Things to Improve
Work to be done

- Include the Correct Photon Flux
- Improve the Reconstruction Efficiency
- Include the Summer? 2009 Data
- Include Acceptance and Efficiency Effects
- Incorporate Beam Polarization to Calculate the Helicity Difference ($E$)