Preliminary Results of $T$ and $F$ Asymmetries for $\eta$ Photoproduction from the Proton

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Motivation: Understand Nucleon Resonance Spectrum

- Quark models and lattice QCD simulations generally predict more resonances than experimentally observed
- Untangling baryon resonance spectra is nontrivial
  - Many broad overlapping states
  - Cross sections are not enough
- Wish to know which resonances participate in the reactions we study
- $\gamma p \rightarrow p\eta\ (I = 1/2) \rightarrow$ isospin filter: no contribution from $\Delta$ resonances
Polarization Observables

For single pseudoscalar meson photoproduction:

- 8 helicity states: 4 initial $\times$ 2 final $= 8$ complex amplitudes
- Parity symmetry $\rightarrow$ 4 complex numbers
- Turns out that we need 8 measurements
- “Complete” measurement requires double-polarization observables from multiple groups (target+recoil, etc)
- Our setup can obtain a “nearly complete” measurement
The $T$ and $F$ observables may be obtained with circularly polarized photon beam on a transversely polarized target. The cross section for these conditions is

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 \left(1 + P_t T \sin\phi + P_t P_\gamma F \cos\phi\right)$$

where

- $\left(\frac{d\sigma}{d\Omega}\right)_0$ = unpolarized cross section,
- $P_t$ = transverse target polarization,
- $P_\gamma$ = circular beam polarization, and
- $\phi$ = angle between target polarization and reaction plane.
Tagged polarized photon beams are produced at Jefferson Lab’s Hall B facility from the CEBAF electron beam. \((e^-\) polarization ~87%)
Large acceptance detector designed for variously polarized targets.

- good tracking of charged particles
- efficient identification of neutral particles via missing mass
Butanol ($\text{C}_4\text{H}_9\text{OH}$) primary target
Helium dilution refrigerator holds at $\approx 25\text{ mK}$
Average polarization $\approx 85\%$
Depolarization rate $\leq 1\%$ per day

Carbon secondary target
For flux estimation

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Cuts:

- Reaction cut: required detection of recoil proton.
- When pions were detected, cut on them to reduce background.
- Required one tagged photon in coincidence with event

Bound-nucleon and other background was parameterized with a third-order polynomial

To estimate relative photon flux, we took all events from the carbon target

Performed modified $\varphi$-bin analysis on normalized yield to extract $T$ and $F$ for each energy and $\cos \theta_{cm}$ bin
All $\gamma \, p \rightarrow p \, (\eta)$

$Y_\eta : 554394 \pm 4099$

Preliminary

missing mass $\frac{\text{MeV}}{c^2}$
W=1599 MeV \cos(\theta)=-0.5

\varphi: -8 9 52 69 112 129 172 189 232 249 292 309

missing mass \frac{\text{MeV}}{c^2}

P_t P_t\gamma

- -
- +
+ -
+ +
$T$ for $\gamma p \rightarrow p (\eta)$

\begin{align*}
W = 1550 \text{ MeV} & \quad \text{Preliminary} \\
W = 1600 \text{ MeV} & \quad \text{Preliminary} \\
W = 1650 \text{ MeV} & \quad \text{Preliminary} \\
W = 1700 \text{ MeV} & \quad \text{Preliminary} \\
W = 1750 \text{ MeV} & \quad \text{Preliminary} \\
W = 1800 \text{ MeV} & \quad \text{Preliminary}
\end{align*}

\[ \cos(\theta_{\eta}^{\text{cm}}) \]
$F$ for $\gamma p \rightarrow p (\eta)$

$\eta p (\rightarrow p \gamma$ for $F$

$\eta_{cm} \cos(\theta_{\eta^{cm}})$
Polarization observables are an important tool for understanding baryon resonance spectra.

I have presented preliminary data of the $T$ and $F$ asymmetries for $\eta$ meson photoproduction from the proton.

$W$ beginning at 1550 MeV to 1700 MeV.

Where comparisons are possible, they look reasonable.

When complete, will extend coverage of world database for these reactions.

Inclusion of our data should improve understanding of resonances.