Status report on the beam asymmetry for the omega meson off bound proton

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November 3, 2016

This work is funded by NSF Grant: PHY-1615146

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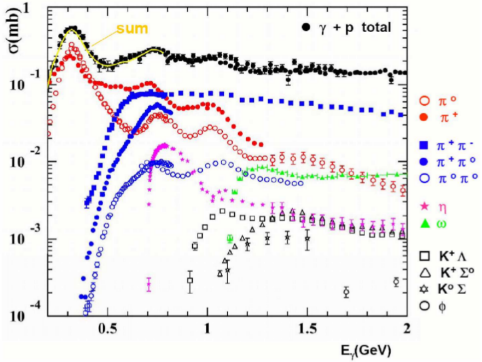
Motivation

- Baryon spectroscopy helps to understand the link between quark based models with QCD. Quark based models predict resonances that have not been experimentally observed.
- Studies of different channels should help in finding "missing resonances"
- Resonances are broad and overlap. Spin observables are necessary to differentiate between resonant contributions.



ω photoproduction off bound proton in previous experiments

- The study of bound proton can be studied in comparison with free proton data. (CLAS g8b and g9FROST)
- The way we handle bound proton will provide information on how to analyze bound neutrons

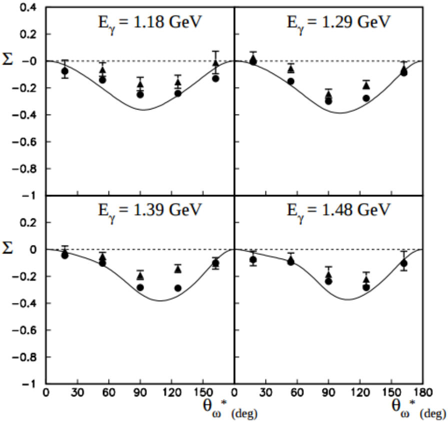
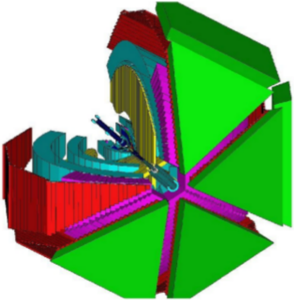
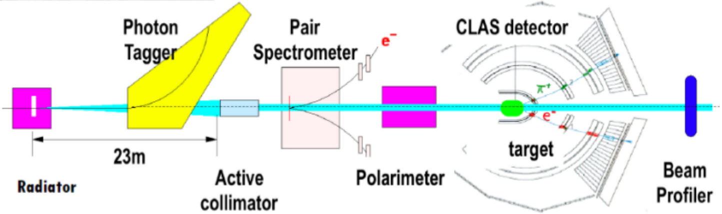


Figure: Data GRAAL 2015: Full circles, free proton. Full triangles, quasifree. (V. Vegna et al. PhysRevC.91.065207 (2015))

CEBAF: Continuous Electron Beam Accelerator Facility

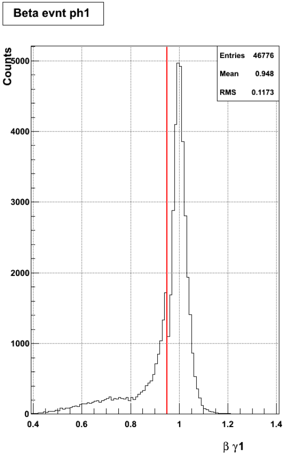
CLAS: CEBAF Large Acceptance Spectrometer

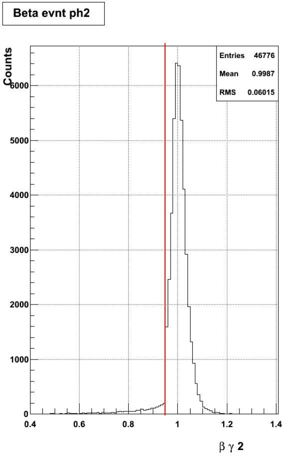




$\vec{\gamma}p(n) \to \omega p(n)$ with $\omega \to \pi^+\pi^-\pi^0$ and $\pi^0 \to \gamma\gamma$

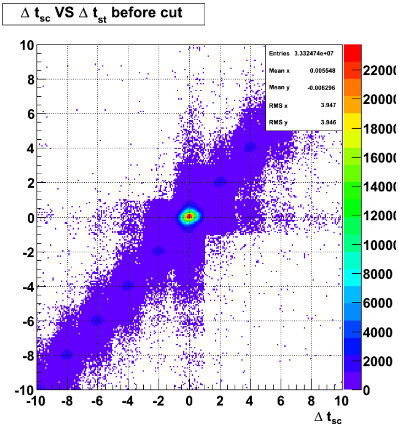
cut	description
PID charged particles	3σ for $\Delta\beta$ momentum dependent
PID photons	$\beta > 0.95$

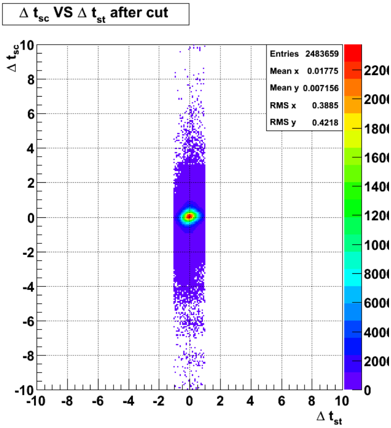




$$\vec{\gamma}p(n) \to \omega p(n) \text{ with } \omega \to \pi^+\pi^-\pi^0 \text{ and } \pi^0 \to \gamma\gamma$$

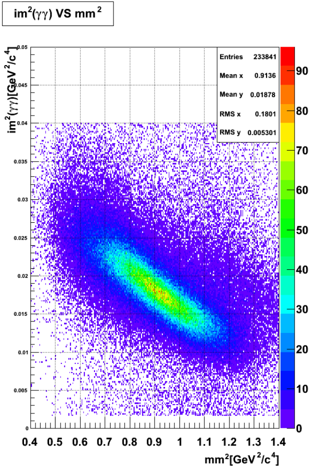
cut	description
tagged photon	$\Delta t_{\gamma\pi^-}$ $\leq$ 1ns
charged particles Δt	$\Delta t_{\pi^-\pi^+}$ and $\Delta t_{\pi^- p}$ $\leq$ 1ns

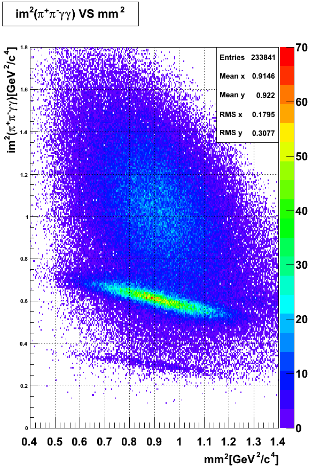




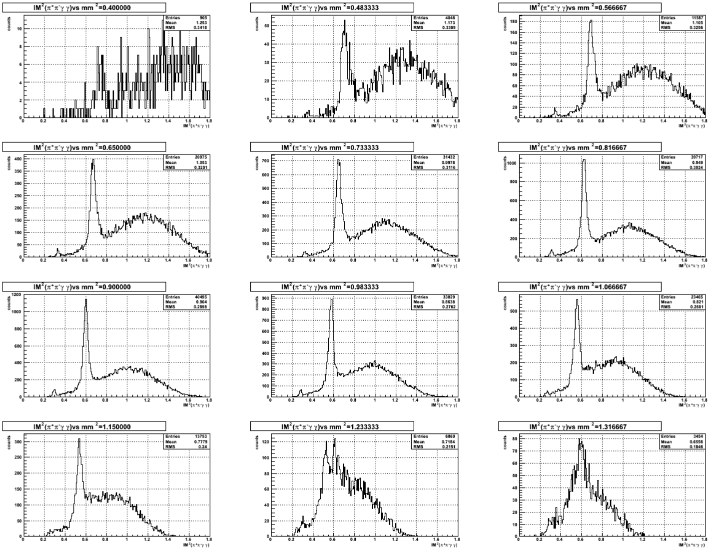
$\vec{\gamma}p(n) \rightarrow \omega p(n)$ with $\omega \rightarrow \pi^+\pi^-\pi^0$ and $\pi^0 \rightarrow \gamma\gamma$

cut	description
π^0 reconstruction	$3\sigma$for $M^2(\gamma\gamma)$
Missing momentum	$p_X < 0.2 \frac{\mathrm{GeV}}{c}$
other cuts	fiducial, momentum and energy corrections





$\vec{\gamma}p(n) \to \omega p(n)$ with $\omega \to \pi^+\pi^-\pi^0$ and $\pi^0 \to \gamma\gamma$



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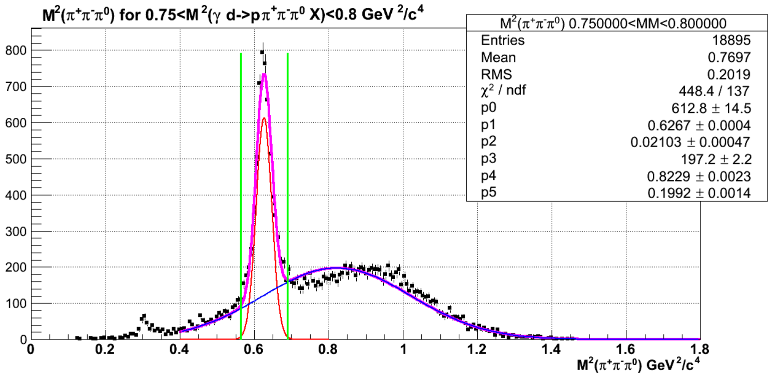

Figure: Example. Invariant mass squared of the three pions for missing mass squared $0.75 < M_X^2(\vec{\gamma}d \to p\pi^+\pi^-\pi^0 X) < 0.8\text{GeV}^2/c^4$. 3σ cut around the ω peak for missing mass squared. Shift in the peak due to calorimeter resolution and was reproduced via Toy Monte Carlo

$$\frac{(\frac{dN}{d\phi})^{\perp} - (\frac{dN}{d\phi})^{\parallel}}{(\frac{dN}{d\phi})^{\parallel} + (\frac{dN}{d\phi})^{\perp}} = \frac{1 - F_R + \frac{F_R P_R + 1}{P_R + 1} 2\bar{P}\Sigma \frac{\sin\Delta\phi}{\Delta\phi} \cos(2(\phi - \phi_0))}{1 + F_R + \frac{F_R P_R - 1}{P_R + 1} 2\bar{P}\Sigma \frac{\sin\Delta\phi}{\Delta\phi} \cos(2(\phi - \phi_0))} \quad (1)$$

with the flux ratio $F_R = \frac{F^{\perp}}{F^{\parallel}}$, polarization ratio $P_R = \frac{P^{\parallel}}{P^{\perp}}$, average of the polarization $\bar{P} = \frac{P^{\parallel} + P^{\perp}}{2}$, $\frac{\sin\Delta\phi}{\Delta\phi}$ correction for the bin width $\Delta\phi$ and ϕ_0 is the offset of the photon polarization vector [1]. We fix all but one variable in the fit, Σ.

- P_R and $\bar{P}$ are found using the polarization tables.

[1] Ref. N. Zachariou PhysRevC.91.055202 (2015)

$$\frac{(\frac{dN}{d\phi})^{\perp}-(\frac{dN}{d\phi})^{\parallel}}{(\frac{dN}{d\phi})^{\parallel}+(\frac{dN}{d\phi})^{\perp}}=\frac{1-F_R+\frac{F_R P_R+1}{P_R+1}2\bar{P}\Sigma\frac{\sin\Delta\phi}{\Delta\phi}\cos\left(2(\phi-\phi_0)\right)}{1+F_R+\frac{F_R P_R-1}{P_R+1}2\bar{P}\Sigma\frac{\sin\Delta\phi}{\Delta\phi}\cos\left(2(\phi-\phi_0)\right)} \quad (1)$$

with the flux ratio $F_R=\frac{F^{\perp}}{F^{\parallel}}$, polarization ratio $P_R=\frac{P^{\parallel}}{P^{\perp}}$, average of the polarization $\bar{P}=\frac{P^{\parallel}+P^{\perp}}{2}$, $\frac{\sin\Delta\phi}{\Delta\phi}$ correction for the bin width $\Delta\phi$ and ϕ_0 is the offset of the photon polarization vector [1]. We fix all but one variable in the fit, Σ.

- P_R and $\bar{P}$ are found using the polarization tables.
- Calculate F_R based on a fit over the (1) integrated over all the $\cos\theta$ bins.

$E_\gamma(GeV)$	P_R	$\bar{P}$
1.1-1.3	0.88	0.754
1.3-1.5	1.01	0.782
1.5-1.7	0.96	0.750
1.7-1.9	0.94	0.676
1.9-2.1	0.99	0.730
2.1-2.3	1.02	0.695

[1] Ref. N. Zachariou PhysRevC.91.055202 (2015)

$$\frac{(\frac{dN}{d\phi})^{\perp} - (\frac{dN}{d\phi})^{\parallel}}{(\frac{dN}{d\phi})^{\parallel} + (\frac{dN}{d\phi})^{\perp}} = \frac{1 - F_R + \frac{F_R P_R + 1}{P_R + 1} 2\bar{P}\Sigma \frac{\sin\Delta\phi}{\Delta\phi}\cos(2(\phi - \phi_0))}{1 + F_R + \frac{F_R P_R - 1}{P_R + 1} 2\bar{P}\Sigma \frac{\sin\Delta\phi}{\Delta\phi}\cos(2(\phi - \phi_0))} \quad (1)$$

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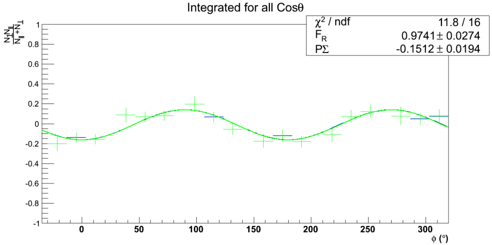

Figure: Example of fit for $1.7 < E_\gamma < 1.8$GeV

[1] Ref. N. Zachariou PhysRevC.91.055202 (2015)

$$\frac{(\frac{dN}{d\phi})^{\perp} - (\frac{dN}{d\phi})^{\parallel}}{(\frac{dN}{d\phi})^{\parallel} + (\frac{dN}{d\phi})^{\perp}} = \frac{1 - F_R + \frac{F_R P_R + 1}{P_R + 1} 2\bar{P}\Sigma \frac{\sin\Delta\phi}{\Delta\phi} \cos(2(\phi - \phi_0))}{1 + F_R + \frac{F_R P_R - 1}{P_R + 1} 2\bar{P}\Sigma \frac{\sin\Delta\phi}{\Delta\phi} \cos(2(\phi - \phi_0))} \quad (1)$$

with the flux ratio $F_R = \frac{F^{\perp}}{F^{\parallel}}$, polarization ratio $P_R = \frac{P^{\parallel}}{P^{\perp}}$, average of the polarization $\bar{P} = \frac{P^{\parallel} + P^{\perp}}{2}$, $\frac{\sin\Delta\phi}{\Delta\phi}$ correction for the bin width $\Delta\phi$ and ϕ_0 is the offset of the photon polarization vector [1]. We fix all but one variable in the fit, Σ.

- P_R and $\bar{P}$ are found using the polarization tables.
- Calculate F_R based on a fit over the (1) integrated over all the $\cos\theta$ bins.
- $\phi_0 = 0$ as suggested by large statistics channel study

E_γ(GeV)	F_R	χ^2/NDF
1.1-1.3	0.485 ± 0.015	1.098
1.3-1.5	1.024 ± 0.015	1.325
1.5-1.7	1.198 ± 0.014	1.358
1.7-1.9	0.914 ± 0.009	0.875
1.9-2.1	1.056 ± 0.011	0.677
2.1-2.3	1.058 ± 0.012	0.727

[1] Ref. N. Zachariou PhysRevC.91.055202 (2015)

$$\frac{(\frac{dN}{d\phi})^{\perp} - (\frac{dN}{d\phi})^{\parallel}}{(\frac{dN}{d\phi})^{\parallel} + (\frac{dN}{d\phi})^{\perp}} = \frac{1 - F_R + \frac{F_R P_R + 1}{P_R + 1} 2\bar{P}\Sigma \frac{\sin\Delta\phi}{\Delta\phi} \cos(2(\phi - \phi_0))}{1 + F_R + \frac{F_R P_R - 1}{P_R + 1} 2\bar{P}\Sigma \frac{\sin\Delta\phi}{\Delta\phi} \cos(2(\phi - \phi_0))} \quad (1)$$

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Is the background polarized?

- The first approach is to take all the events in the background region and calculate the angular asymmetry Σ.
- The events selected where those with $M^2(\pi^+\pi^-\pi^0) \geq 3\sigma_i$ (where i denotes the ith bin in missing mass squared $M_X^2(\vec{\gamma}p \rightarrow p\pi^+\pi^-\pi^0 X)$ and σ_i is the value of σ for a gaussian fit around the ω peak).
- A 2nd-degree polynomial fit is applied to these points.

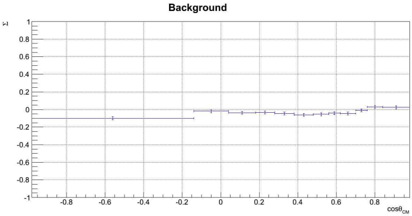


Figure: Example for $E_\gamma = 2.3$ GeV

Dilution Factor

- Asymmetry for the background region around zero.
- Dilution factor approach

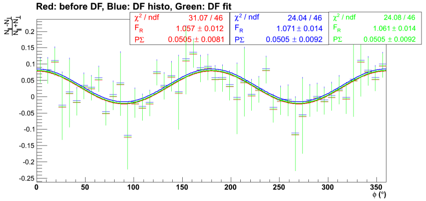
$$F = \frac{\sum_i (A_{tot} - A_{bkg})_i}{\sum_i (A_{bkg})_i}$$

$$\left(\frac{dN}{d\phi}\right)^{\parallel(\perp)}_{signal} = F^{\parallel(\perp)} \left(\frac{dN}{d\phi}\right)^{\parallel(\perp)}_{peak}$$

signal $\rightarrow \mu_i - 3\sigma_i \leq M^2(\pi^+\pi^-\pi^0) \leq \mu_i + 3\sigma_i$

- A_{peak} can be calculated integrating the model or integrating the histogram

E_γ(GeV)	$DF^{\parallel}_{HISTO}$	$DF^{\parallel}_{FIT}$	$DF^{\perp}_{HISTO}$	$DF^{\perp}_{FIT}$
1.1-1.3	0.571	0.679	0.603	0.657
1.3-1.5	0.606	0.619	0.611	0.621
1.5-1.7	0.601	0.606	0.605	0.607
1.7-1.9	0.661	0.661	0.661	0.660
1.9-2.1	0.730	0.736	0.736	0.738
2.1-2.3	0.779	0.776	0.769	0.773



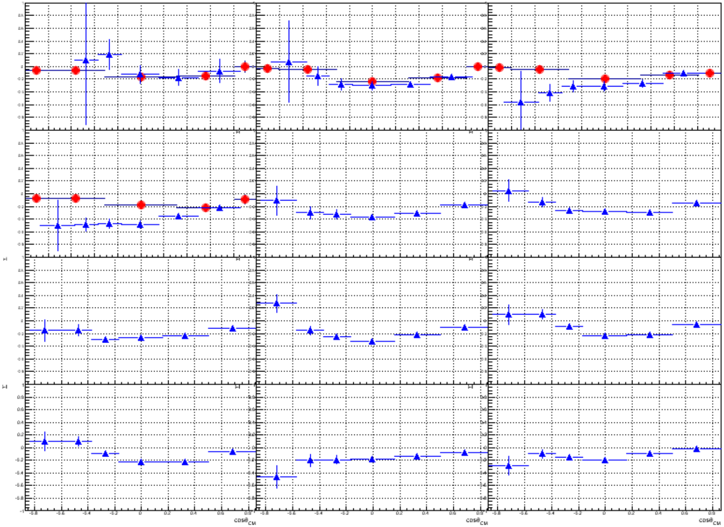


Figure: Preliminary result Beam Spin Asymmetry for $1.1 < E_\gamma < 2.3$GeV in energy bins of $\Delta E_\gamma = 100$MeV. Blue triangles this work, red circles GRAAL 2015

Future work

* Preliminary results are shown for the observable Σ for energies between $1.1\text{GeV} \leq E_\gamma \leq 2.3\text{GeV}$. Agreement with GRAAL (2015) only for low energy bins.
* The effects of a restrained phase space for the omega has to be studied.
* Systematic uncertainties are being studied (binning, different model for the background, fixed parameter dependency)
* Dependency of the observables as a function of p_X in order to compare with free proton.

THANK YOU!