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POLARIZATION OBSERVABLES FROM THE PHOTOPRODUCTION OF ω-MESONS USING LINEARLY POLARIZED PHOTONS

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We report on the extraction of Polarization Observables Spin Density Matrix Elements (SDMEs), and Beam Asymmetry Σ, for the ω meson using a beam of linearly polarized photons in the photon energy region of E_γ = 1.3 to 1.7 GeV, by means of the angular distributions of the daughter pions from ω decay. These preliminary results are from the summer 2005 g8b dataset, which were collected with the CLAS detector in Hall B of Jefferson Lab.

Keywords: polarization observables; linearly polarized photons; angular distributions.

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1. Introduction

Polarization observables are necessary for delineating the underlying processes in the photoproduction of ω mesons. Spin-Density Matrix Elements (SDMEs) are formed of bilinear combinations of the helicity amplitudes, and serve as a parity filter for understanding the nature of the t-channel exchange, i.e. whether the exchange is from either pseudoscalar or scalar mesons or even perhaps a combination thereof. The angular distributions of the daughter pions from ω decay give us access to these SDMEs. Since the ω is an isoscalar, it may only couple to N^* states, i.e. $I = \frac{1}{2}$. This eliminates Δ resonance production and makes for cleaner data samples. We expect that a precise measurement of the for SDMEs for the reaction $\vec{\gamma}p \to \omega p$ will shed light on the spin-parity of the underlying baryon resonances and will further help in disentangling the overlapping N*s.

The photon asymmetry Σ and parity asymmetry Σ_p observables can be decomposed into several spin-density matrix elements and as such set constraints on these SDMEs.

2. G8b experiment

The photoproduction of ω mesons off the proton was achieved by using CEBAF (Continuous Electron Beam Accelerator Facility) and the CLAS (CEBAF Large Acceptance Spectrometer) detector at Thomas Jefferson National Accelerator Facility during the g8b run period which took place in the summer of 2005. CEBAF produces an electron beam with end point energy: 4.544 GeV, that impinges upon a diamond radiator to produce linearly polarized photons by bremsstrahlung and by tuning the angle of the diamond radiator in such way that coherent light is obtained from a set of lattice vectors, taking advantage of the crystal structure of the diamond [2]. The remaining incoherent light is emitted at large angles compared to the polarized part, which is emitted very forward, thus making possible to remove this part from the coherent one, by using a collimator with a stacking arrangement of thirteen nickel diskettes with a small aperture (r =1mm) at the center (the distance from the goniometer is 23 meters, therefore it subtends an angle of 43 μrad) [3] that allow the polarized part of the photon spectrum to pass through, removing 80% of the background and enhancing the quality of the polarization.

3. SDMEs

Spin Density Matrix Elements $\rho^{\alpha}_{i,j}$ (SDMEs) are to be extracted for two orientations of the polarization vector ($\vec{E}$), by checking the angular distribution of the decay pions, which in turn are parametrized in terms of these SDMEs [4] such that:

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

with,

$$\begin{aligned}
W^0(\cos\theta,\phi) &= \frac{3}{4}\Big[\frac{1}{2}\left(1-\rho^0_{00}\right)+\frac{1}{2}\left(3\rho^0_{00}-1\right)\cos^2\theta-\sqrt{2}Re\rho^0_{10}\sin 2\theta cos\phi \\
&\quad -\rho^0_{1-1}\sin^2\theta cos2\phi\Big] \\
W^1(\cos\theta,\phi) &= \frac{3}{4}\left[\rho^1_{11}\sin^2\theta+\rho^1_{00}\cos^2\theta-\sqrt{2}\rho^1_{10}\sin 2\theta cos\phi-\rho^1_{1-1}\sin^2\theta cos2\phi\right] \\
W^2(\cos\theta,\phi) &= \frac{3}{4}\left[\sqrt{2}Im\rho^2_{10}\sin 2\theta\sin\phi+Im\rho^2_{1-1}\sin^2\theta\sin 2\phi\right]
\end{aligned}$$

Σ and Σ_p will be used as a constraint for these SDME's, since:

$$\Sigma = P_\gamma\frac{2(\rho^1_{11}+\rho^1_{1-1})}{1-\rho^0_{00}+2\rho^0_{1-1}}$$

and

$$\Sigma_p = 2\rho^1_{1-1}-\rho^0_{00}$$

If helicity is conserved in the s-channel, then, only two of the SDMEs [5] are nonzero: $\rho^1_{1-1} = 0.5$ and $Im\rho^2_{1-1} = -0.5$, hence $\Sigma = 1$ when P_γ is 1 [6] (with θ and ϕ determined in the helicity frame). Any deviation from this value is an indication that non-diffractive processes are present. Assuming natural parity, $\rho^1_{1-1} = 0.5$, $\rho^1_{00} = 0$, and $\Sigma_p = 1$. For unnatural parity, $\rho^1_{11} = -0.5$, $\rho^1_{00} = 0$ and $\Sigma_p = -1$.

The SDMEs extraction proceeds by obtaining the following angular distributions:

$$\begin{aligned} W(\cos\theta) &= N[\frac{1}{2}(1-\rho^0_{00})\sin^2\theta + \rho^0_{00}\cos^2\theta] \\ W(\phi) &= N[1-\rho^0_{1-1}\cos 2\phi] \\ W(\phi-\Phi) &= N[1+2P_\gamma\rho^3\cos 2(\phi-\Phi)] \\ W(\phi+\Phi) &= N[1+2P_\gamma\rho^4\cos 2(\phi+\Phi)] \end{aligned}$$

with $\rho^3 = \frac{1}{2}(\rho^1_{1-1} - Im\rho^2_{1-1})$ and $\rho^4 = \frac{1}{2}(\rho^1_{1-1} + Im\rho^2_{1-1})$. The data was divided in 5 $|t - t_{min}|$ bins, 54 bins in ϕ_{hel} and 50 MeV wide E_γ bins.

4. Beam Asymmetry Σ

For this calculation different angular regions of CLAS were studied. We separated CLAS into 10 $\cos\theta_{CM}$ bins and 36 bins in ϕ_{lab}, as well as a 50 MeV E_γ bin around the coherent peak. The Beam Asymmetry parameter Σ is determined by fitting the ratio $\frac{PERP-PARA}{PERP+PARA}$ for each $\cos\theta_{CM}$ bin and E_γ bin, to a $\cos 2\phi$ like function:

$$\begin{aligned} \sigma_\perp &= \sigma_0(1+P_\perp\Sigma\cos 2\phi) \\ \sigma_\parallel &= \sigma_0(1+P_\parallel\Sigma\cos 2\phi+\pi) \\ \sigma_\parallel &= \sigma_0(1-P_\parallel\Sigma\cos 2\phi) \end{aligned}$$

$$\frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel} = \frac{(\frac{N_\perp}{N_\parallel} - 1) - (\frac{N_\perp}{N_\parallel}P_\perp + P_\parallel)\Sigma\cos(2(\phi))}{(\frac{N_\perp}{N_\parallel} + 1) - (\frac{N_\perp}{N_\parallel}P_\perp - P_\parallel)\Sigma\cos(2(\phi))}$$

5. Preliminary Results

The following are samples of the angular distributions needed to extract the SDMEs and beam asymmetry Σ polarization observables for a particular bin out of 10 $\cos\theta_{CM}$ bins, 36 ϕ_{lab} bins, 5 $|t - t_{min}|$ bins, 54 ϕ_{hel} bins, 54 $(\phi_{hel} \pm \Phi)$ bins and a single E_γ bin that are possible.

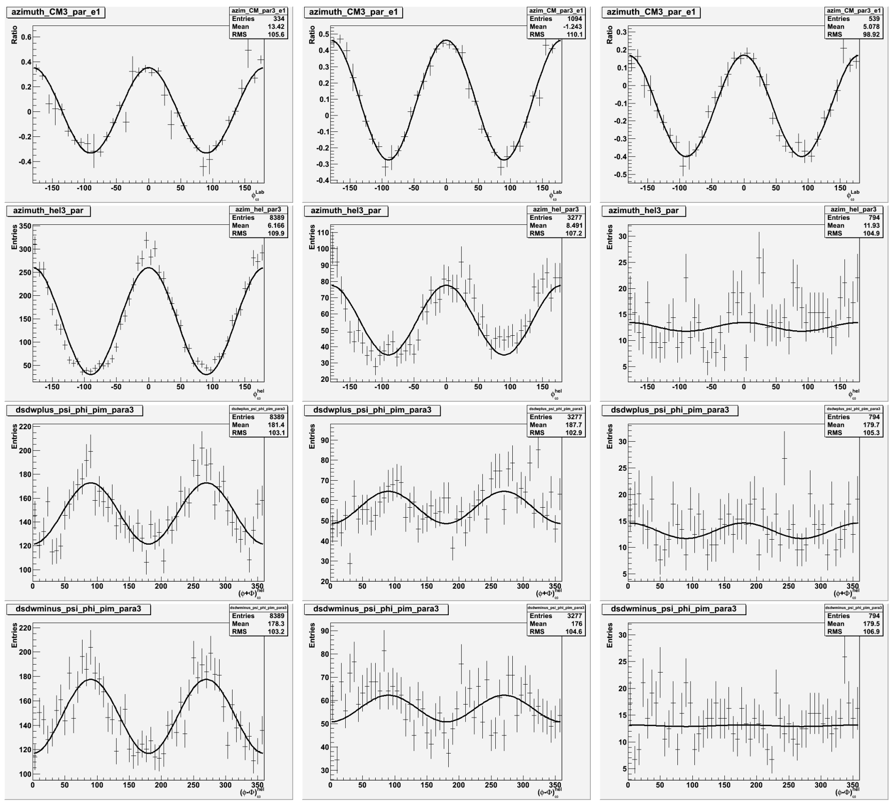

Fig. 1. Top to bottom (for a specific E_γ bin): ratio $\frac{PERP-PARA}{PERP+PARA}$ for a $\cos\theta_{CM}$ bin, ϕ_{hel}, $\phi+\Phi$ and $\phi-\Phi$ for a $|t-t_{min}|$ bin. Left to right: 1.3, 1.5 and 1.7 GeV energy set.

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