

Beam-Target Asymmetry for $\gamma n(p) \rightarrow \pi^- p(p)$ in N^* Resonance Region

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Outline

- 1 Introduction
- 2 Event Selection and Correction
- 3 Result

Motivation

- Meson photoproduction probes the N^* spectrum and tests models
- ≥ 8 observables are needed to determine the amplitudes
- Lots of new proton target data, but little neutron target data, and almost no spin dependent data

- electromagnetic interaction do not conserve isospin

$$A_{\gamma p \rightarrow \pi^+ n} = \sqrt{2} \left(A_p^{I=1/2} - \frac{1}{3} A^{I=3/2} \right)$$

$$A_{\gamma n \rightarrow \pi^- p} = \sqrt{2} \left(A_n^{I=1/2} - \frac{1}{3} A^{I=3/2} \right)$$

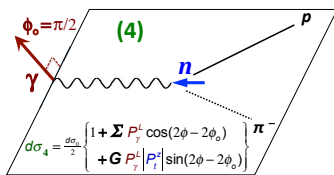
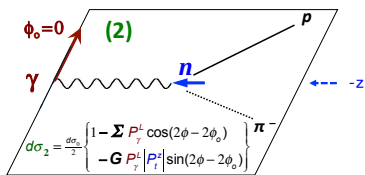
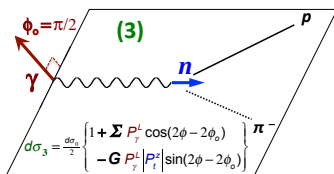
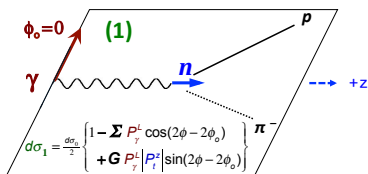
- both neutron and proton data are needed to separate the different $I = 1/2$ production amplitudes
- Results of circular polarized beam has been published at PRL 118,242002 (2017)

Single-Pion photo-production with HDIce target

- Reaction: $\gamma_L n(p) \rightarrow \pi^- p(p)$
- Linear polarized photon beams produced by the coherent bremsstrahlung of electrons in diamond, and up to 80%
- Three coherent-edge configurations: 1800, 2000, and 2200 MeV
- HDIce target: solid hydrogen-deuteride, with both hydrogen and deuterium nuclei polarized, and around 20 - 30%
- Two beam polarization planes and two directions of target polarization are utilized to extract beam asymmetry Σ and beam-target asymmetry G

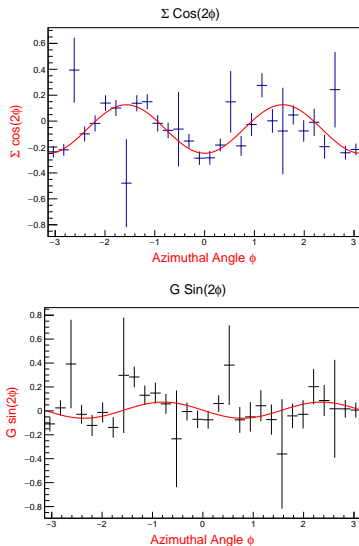
Configuration

Four Experimental Beam-Target Configurations



Separation

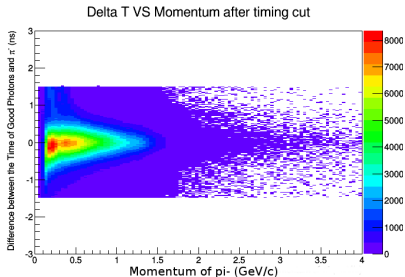
- Linear combinations of flux-normalized yield of the four configurations form: non-polarization term, Σ term, and G term.
- The ratio of Σ (G) to non-polarization term gives $\Sigma \cos 2\phi$ ($G \sin 2\phi$)
- Advantages:
 - detector acceptance drops out with cross section in the ratios
 - G is extracted without having to fit Σ and G together



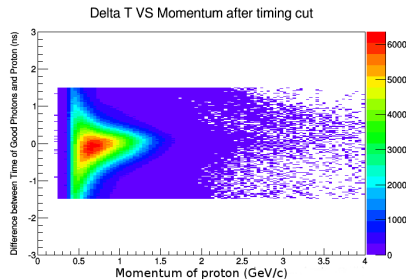
Overview of event selection

- Timing Cut: to select photons matching with proton and π^-
- Exclusivity Cut: to select the exclusive reaction
- Missing momentum Cut: to minimize non-quasi free events
- Vertex Cut: to eliminate reactions originating in the target windows
- Dilution Correction: to account for reactions with AI cooling wires within the target

Timing Cut



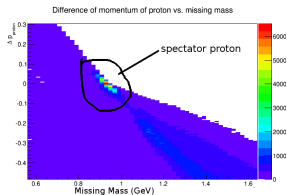
Time difference between
photons and π^-



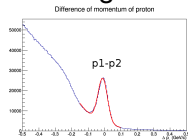
Time difference between
photons and proton

Exclusivity Cut

- Find the center-of-mass frame of the beam and the neutron target by taking the missing momentum into account
- Calculate the momentum (**p1**) of proton in the center-of-mass frame by assuming a two-body decay into $p\pi^-$
- Boost measured proton into this frame (**p2**) and calculate the momentum difference of **p1** and **p2**

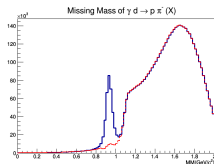


Difference of momentum VS missing mass

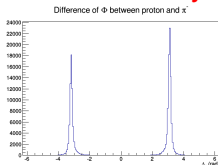


Events are selected within 3σ of the momentum difference peak

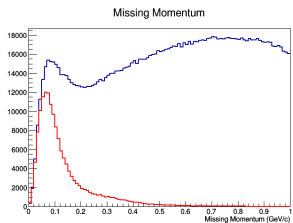
Effect of Exclusivity Cut



Missing mass **before** selection
and **cut away**



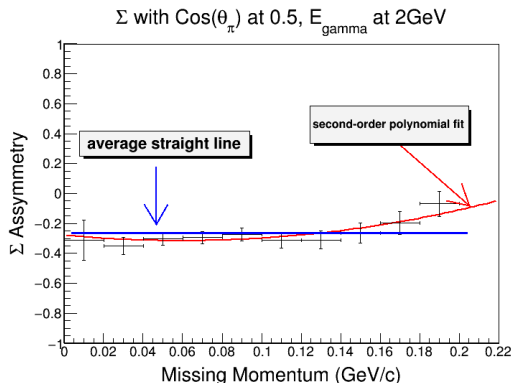
ϕ difference between p and π^-



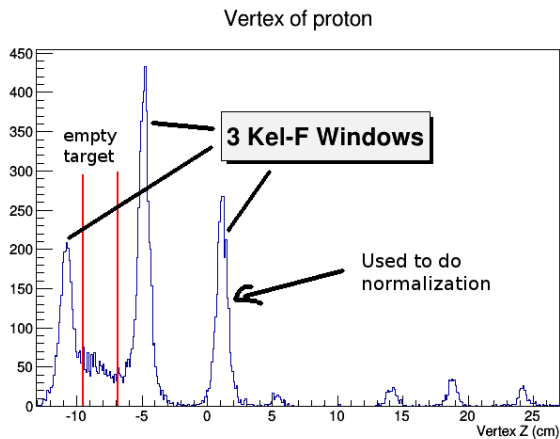
Missing momentum **before** and
after selection

Missing Momentum Cut

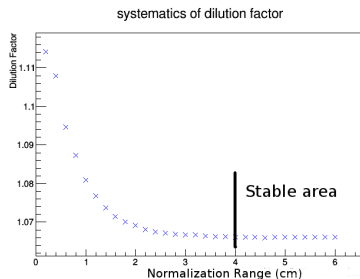
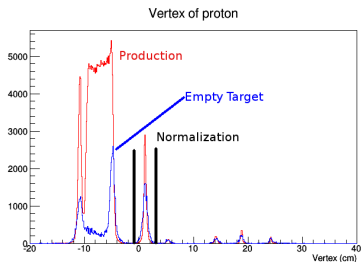
- Σ with different missing momentum
- **straight line**: the average
- **dotted second-order polynomial**: fit result used to study systematics



Vertex Cut

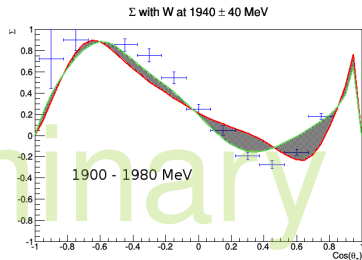
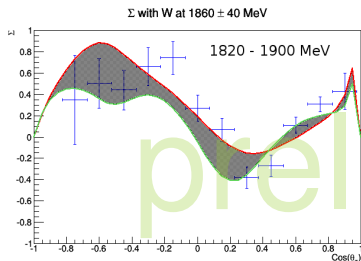


Dilution Factor



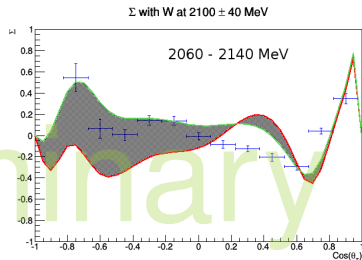
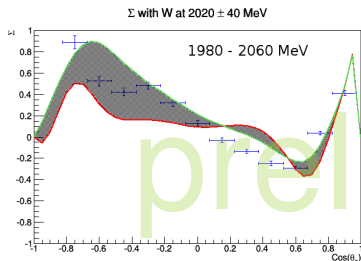
- the result is stable when the range is larger than 4 cm
- The final dilution factor is 1.066.

Σ Asymmetry



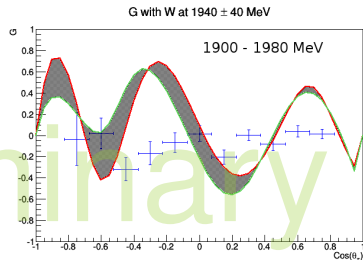
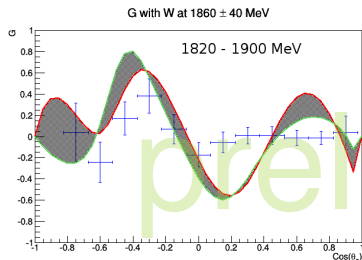
- Σ with error bar
- shaded area from latest SAID model fitted with $g_{14} E$ and $g_{13} \Sigma$
- upper W in red and lower in green.

Σ Asymmetry - cont.



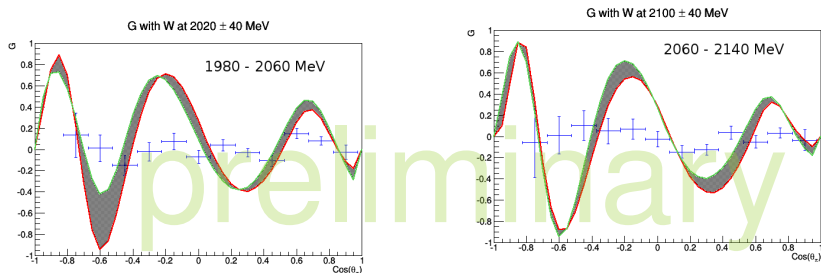
- Σ with error bar
- shaded area from latest SAID model fitted with g14 E and g13 Σ
- upper W in red and lower in green.

G Asymmetry



- G asymmetry with error bar
- shaded area from latest SAID model fitted with $g_{14} E$ and $g_{13} \Sigma$
- upper W in red and lower in green.

G Asymmetry - cont.



- G asymmetry with error bar
- shaded area from latest SAID model fitted with $g_{14} E$ and $g_{13} \Sigma$
- upper W in red and lower in green.

Summary

Summary

- quasi-free kinematics in $\vec{\gamma}_L \vec{D} \rightarrow \pi^- p(p)$ use to access $\vec{\gamma}_L \vec{n} \rightarrow \pi^- p$ asymmetries
- 2 combinations of linear photon polarization X 2 longitudinal target polarizations used to separate beam asymmetry Σ and beam-target asymmetry \mathbf{G}
- 1st results on the \mathbf{G} asymmetry for the $\vec{\gamma}_L \vec{n} \rightarrow \pi^- p$ reaction
- latest SAID PWA consistent with the beam asymmetry Σ results
- *preliminary* \mathbf{G} asymmetries are generally small in the 2 GeV invariant mass range, in contrast to expectations from SAID.
 ⇔ new PWA will be required