Double-Pion Photoproduction Analysis with Linearly Polarized Photons on FROST (g9b Run)

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Outline

Motivation

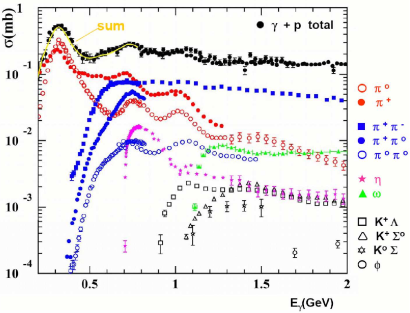
Objective: to extract spin observables for the $\vec{\gamma}\vec{p} \rightarrow p\pi^+\pi^-$ (1.6 < W < 2.1 GeV).

$\pi^+\pi^-$ photoproduction advantages -

- biggest contributor to total photoabsorption cross section for W > 1.7 GeV.
- higher mass resonances likely to undergo sequential decay.

  e.g., $\gamma p \rightarrow N^* \rightarrow \Delta\pi \rightarrow p\pi^+\pi^-$

  $\gamma p \rightarrow N^* \rightarrow p\rho \rightarrow p\pi^+\pi^-$



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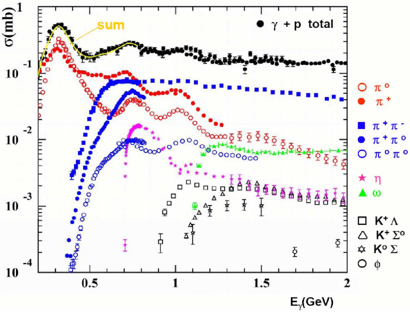
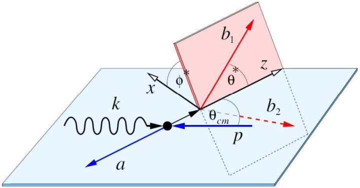


Spin Observables and cross section will give complete information about the scattering amplitudes and assist in isolating resonant contributions to the N* parameters.

Spin Observables for $\vec{\gamma}\vec{p} \rightarrow p\pi\pi$



5 independent kinematic variables needed -
E_γ, $\phi^*_{\pi^+}$, $\cos(\theta^*_{\pi^+})$, $\cos(\theta^{c.m.}_p)$, $m_{\pi^+\pi^-}$

For $p\pi\pi$ state, w/o measuring polarization of recoiling p, reaction rate I-

$$\mathrm{I} = \mathrm{I}_0\{(1 + \vec{\Lambda}_i \cdot \vec{\mathrm{P}})$$

W. Roberts *et al.*, Phys. Rev. C **71**, 055201 (2005)

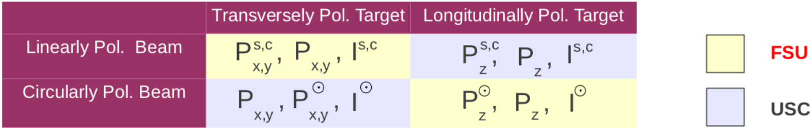
$$+\delta_\odot(\mathrm{I}^\odot + \vec{\Lambda}_i \cdot \vec{\mathrm{P}}^\odot)$$
$$+\delta_l[\sin 2\beta(\mathrm{I}^s + \vec{\Lambda}_i \cdot \vec{\mathrm{P}}^s) + \cos 2\beta(\mathrm{I}^c + \vec{\Lambda}_i \cdot \vec{\mathrm{P}}^c)]\}$$

	Transversely Pol. Target	Longitudinally Pol. Target
Linearly Pol. Beam	$P^{s,c}_{x,y}$, $P_{x,y}$, $I^{s,c}$	$P^{s,c}_{z}$, P_{z}, $I^{s,c}$
Circularly Pol. Beam	$P_{x,y}$, $P^{\odot}_{x,y}$, $I^{\odot}$	$P^{\odot}_{z}$, P_{z}, $I^{\odot}$

Spin Observables for $\vec{\gamma}\vec{p} \rightarrow p\pi\pi$

Present Status of the database-

- Published results on $I^{\odot}$ [1,2] and on helicity dependent cross section difference [3].
  [1] S.Strauch *et al.* Phys. Rev. Lett. **95**, 162003 (2005)
  [2] D. Krambrich *et al.* Phys. Rev. Lett. **103**, 052002 (2009)
  [3] J. Ahrens *et al.* Eur. Phys. J. **A34**, 11 (2007)
- Preliminary results from the FROST expt. on $I^{s,c}$, $I^{\odot}$, $P_z^{\odot}$, P_z, $P_z^{s,c}$.



	Transversely Pol. Target	Longitudinally Pol. Target
Linearly Pol. Beam	🟨 $P^{s,c}_{x,y}$, $P_{x,y}$, $I^{s,c}$	🟦 $P^{s,c}_{z}$, P_{z}, $I^{s,c}$
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🟨 FSU
🟦 USC

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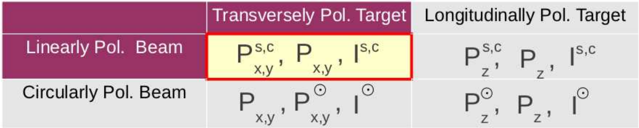


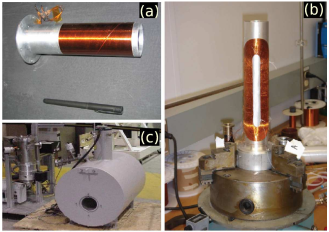
	Transversely Pol. Target	Longitudinally Pol. Target
Linearly Pol. Beam	$\mathrm{P}_{x,y}^{s,c}$, $\mathrm{P}_{x,y}$, $\mathrm{I}^{s,c}$	$\mathrm{P}_{z}^{s,c}$, P_{z}, $\mathrm{I}^{s,c}$
Circularly Pol. Beam	$\mathrm{P}_{x,y}$, $\mathrm{P}_{x,y}^{\odot}$, $\mathrm{I}^{\odot}$	$\mathrm{P}_{z}^{\odot}$, P_{z}, $\mathrm{I}^{\odot}$

- In this analysis - linearly pol. beam, transversely pol. target; **access to 8 spin observables** → getting very close to the complete set of spin observables for beam-target polarizations.

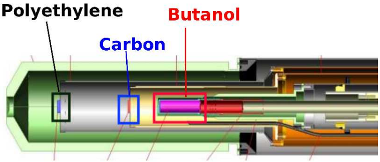
Outline

1. Motivation
2. The FROST Experiment g9b Run
3. Event Selection
4. Outlook

The FROST Experiment g9b Run



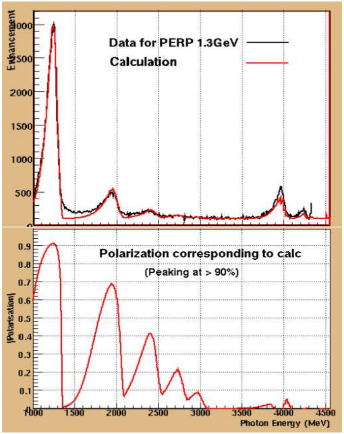
CLAS detector- charged particles detection, almost 4π coverage

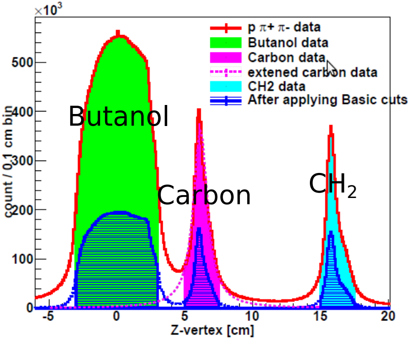


FROzen Spin Target (FROST) g9b-
Linearly/circularly polarized photons,
Transversely polarized protons in butanol

The FROST Experiment g9b Run

Example plot (CLAS -g8)





In this analysis-

Linearly pol. beam, transversely pol. target

Coherent edge - 0.9 to 2.1 GeV

(in steps of 0.2 GeV)

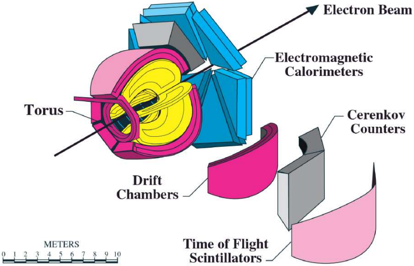
Outline

Topology Cut

Topologies considered for $p\pi^+\pi^-$ final state -

$\vec{\gamma}\vec{p} \rightarrow p\pi^+$ (missing π^-)
$\vec{\gamma}\vec{p} \rightarrow p\pi^-$ (missing π^+)
$\vec{\gamma}\vec{p} \rightarrow p\pi^+\pi^-$

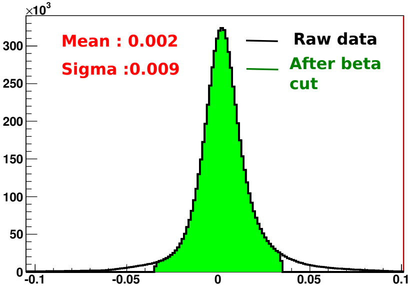
Particle id determined using $\vec{v}$ & $\vec{p}$ information from drift chamber, start counter and time of flight.



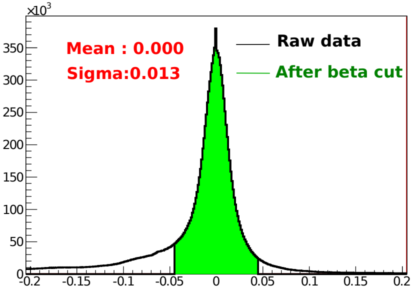
Proton and Pions Selection

- The beta cut :- $\Delta\beta < 3\sigma$
- $\Delta\beta = \beta_1 - \beta_2, \beta_1 = \frac{v}{c}, \beta_2 = \frac{p}{\sqrt{p^2+m^2}}$

proton beta difference



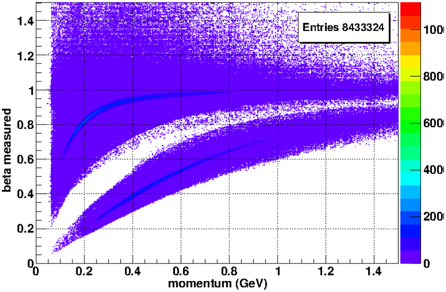
pi beta difference



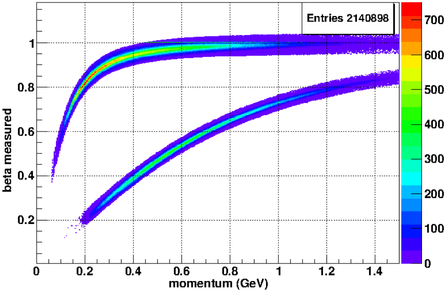
Proton and Pions Selection

- Beta cut : identifying pions and protons
- $\Delta\beta = \beta_1 - \beta_2, \beta_1 = \frac{v}{c}, \beta_2 = \frac{p}{\sqrt{p^2+m^2}}$

Before beta cut



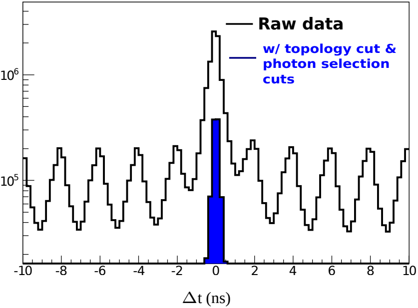
After beta cut



Photon Selection

2 ns photon bunches. Many candidate photons per event.

Δt $=$ t(event vertex time) - t(candidate photon at the vertex).



Photon selection cuts-

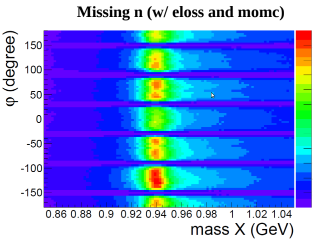
- ◇ 1 photon for each final state particle.
- ◇ All final state particles originated from the same incident photon.
- ◇ $|\Delta t| < 1$ ns after applying the above cuts.

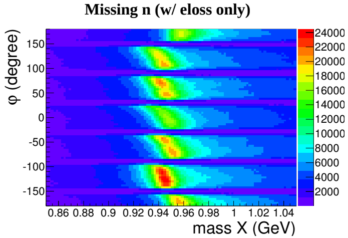
Eloss and Momentum Corrections

Eloss correction- corrects for E lost by the particles while traveling to the DCs.

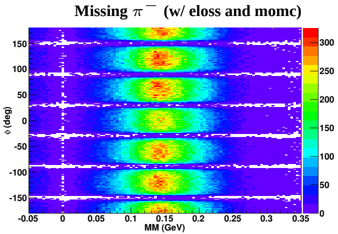
Momentum magnitude corrections for-

- p and π^+ - by Mike Dugger for g9b.
- π^- - at FSU using kinematic fitting and Mike's corrections.


Missing n (w/ eloss and momc)

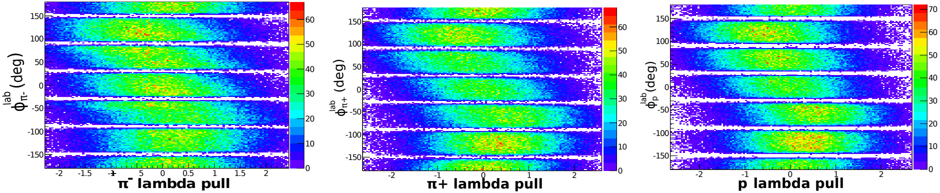

Missing n (w/ eloss only)

M. Dugger, P. Roy, N. Walford, CLAS-note (under review)

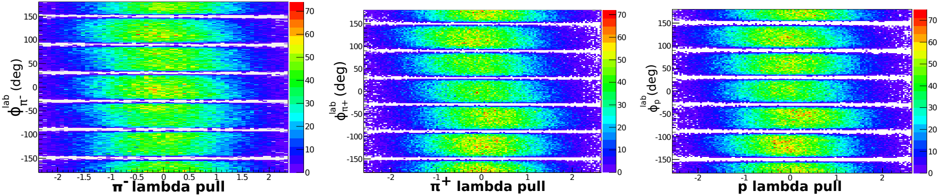

Missing π^- (w/ eloss and momc)

Lab ϕ Corrections for Proton and Pion Momenta

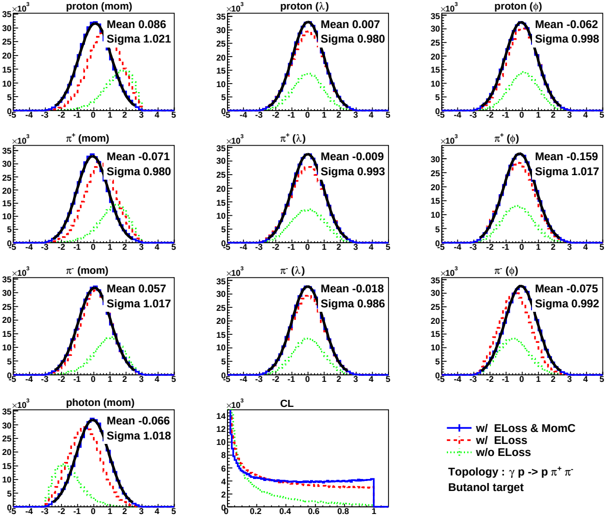
Before :



After :



Confidence Level and Pull Distributions

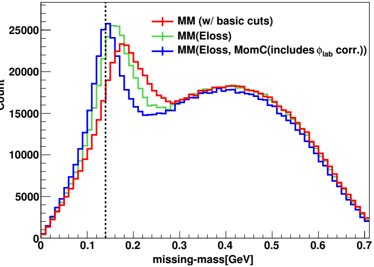


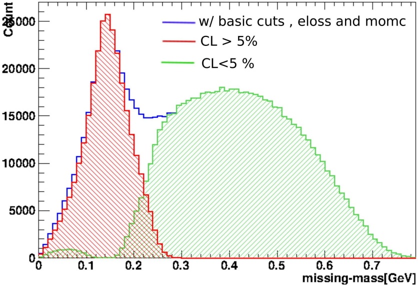
Select events above 5 % confidence level.

Missing Mass Plots

Pion invariant mass = 139.6 MeV.

$\gamma \ p \rightarrow p \ \pi^{+}$ (Missing π^{-})

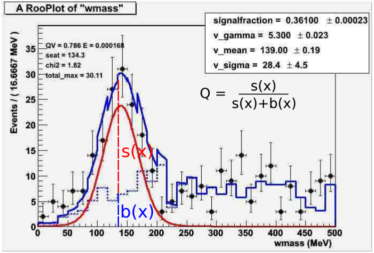


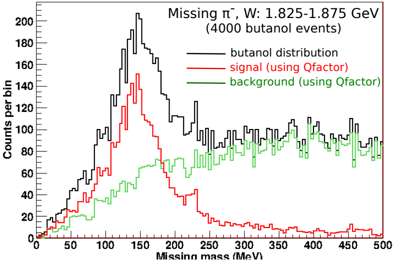


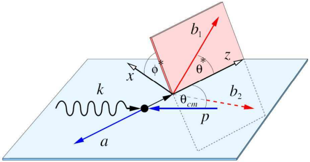
Kinematic fitter doesn't distinguish between events originating from free protons and bound nucleons → need event based quality factor technique.

Event-Based Quality Factor Method

Event based Q-factor techniue assigns a chance to each event that it came from the signal distribution.







Event-based Qfactor method advantages -

- plotting asymmetries in different dimensions w/o finding an overall dilution factor each time.
- Event-based Partial Wave Analysis possible.

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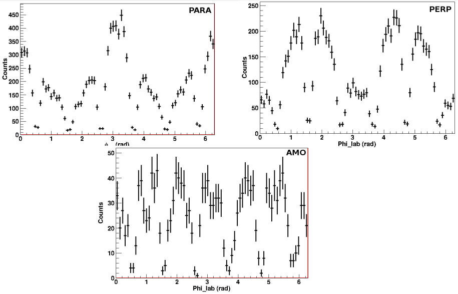
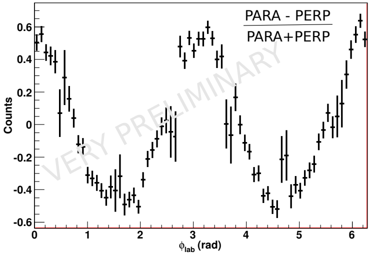
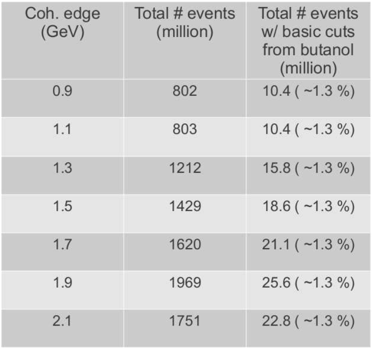
Data Analysis and Event Statistics







Coh. edge (GeV)	Total # events (million)	Total # events w/ basic cuts from butanol (million)
0.9	802	10.4 (~1.3 %)
1.1	803	10.4 (~1.3 %)
1.3	1212	15.8 (~1.3 %)
1.5	1429	18.6 (~1.3 %)
1.7	1620	21.1 (~1.3 %)
1.9	1969	25.6 (~1.3 %)
2.1	1751	22.8 (~1.3 %)

Av. # of events for :
PARA beam pol. : 46 %
PERP beam pol. : 44 %
AMO beam pol. : 10 %

Ultimate goal - extract amplitudes using spin obervables and cross section data to better understand systematics of the baryon spectrum.

- Interpretation of spin observables -
  Model based interpretation - W. Roberts, A. Fix, (V. Mokeev ?)
  Dynamical coupled channel approach -
  Nakayama (Jülich-Athens/GA-Washington/DC Collaboration)
- Extraction of $\pi^+\pi^-$ cross section using g12 data (A. Zulkaida @ FSU)

Thank You !