Measurements of spin observables in single pion photo-production from polarized neutrons in solid HD

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on behalf of CLAS collaboration

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(On behalf of CLAS collaboration)

1. Physics motivation: for missing resonances issue, measure 16 spin observables for neutron (little known)

Sandorfi –CIPANP'12

Photon beam		Target			Recoil			Target - Recoil								
					x'	y'	z'	x'	x'	x'	y'	y'	y'	z'	z'	z'
		x	y	z				x	y	z	x	y	z	x	y	z
unpolarized	σ_0		T			P		$T_{x'}$		$L_{x'}$		Σ		$T_{z'}$		$L_{z'}$
$P_L^\gamma \sin(2\phi_\gamma)$		H		G	$O_{x'}$		$O_{z'}$		$C_{z'}$		E		F		$-C_{x'}$	
$P_L^\gamma \cos(2\phi_\gamma)$	$-\Sigma$		$-P$			$-T$		$-L_{z'}$		$T_{z'}$		$-\sigma_0$		$L_{x'}$		$-T_{x'}$
circular P_c^γ		F		$-E$	$C_{x'}$		$C_{z'}$		$-O_{z'}$		G		$-H$		$O_{x'}$	

This talk

Full set of 16

status	*CLAS run period*	*beam*	*target*
complete	*g13*	$\vec{\gamma}_L$, $\vec{\gamma}_c$	LD_2
complete	*g14*	$\vec{\gamma}_L$, $\vec{\gamma}_c$	$H\vec{D}ice$ (Longitudinally polarized)

Sandorfi, Hoblit, Kumano, Lee, J.PHYS, G38 (2011)053001

2. Experimental apparatus

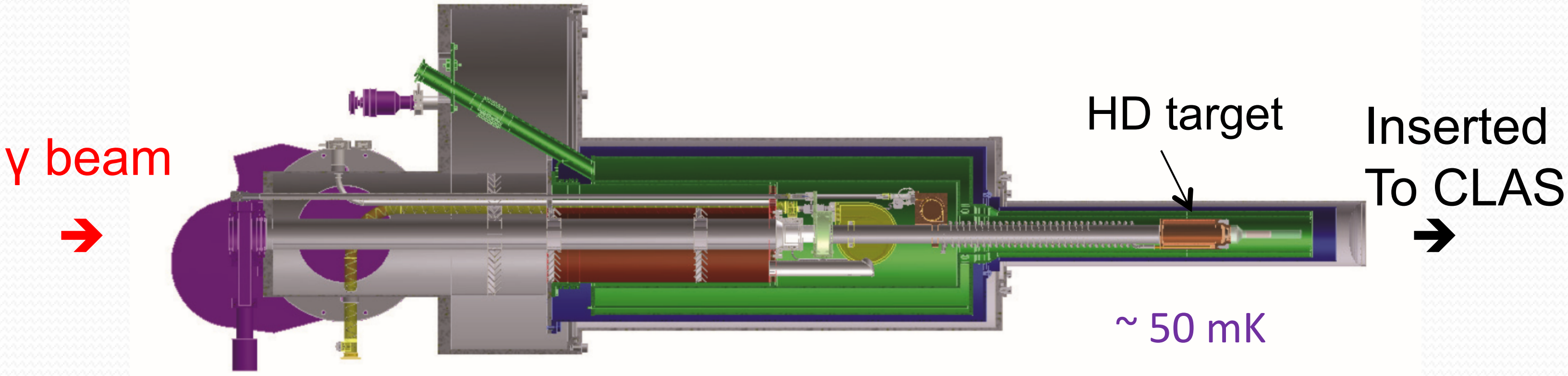
Circularly and linearly polarized photon beams

CLAS detectors and electron tagging system

Polarized neutron target (Solid HD) : newly installed

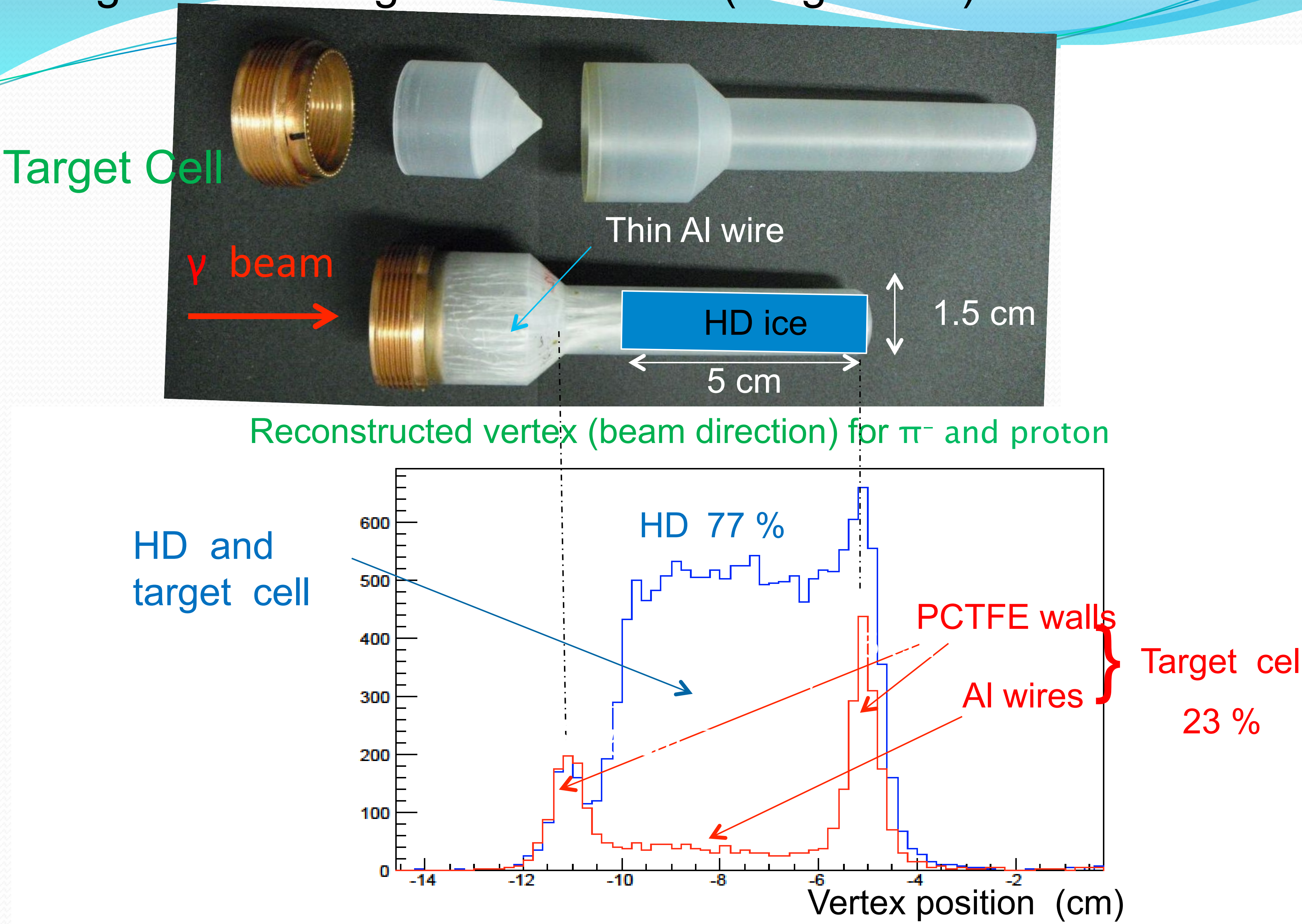
New longitudinally polarized target for this experiment

Frozen Spin Polarized solid HD target
Relaxation time > 1 year @ ~ 50 mK and 0.9 Tesla



* Horizontal Dilution Fridge (designed and constructed by HDice group at Jlab)
* 1 Tesla main Solenoid for longitudinal holding field
* Transverse field of 750 Gauss for field rotation (spin flip)
* NMR coil: polarization monitor during the run and spin transfer and H-spin flip, Birdcage coil

Target and background material (Target cell) subtraction



3. Experimental conditions and data reduction

g14 experiments: Dec. 2011 – May. 2012

* Circularly polarized photon beams: $0.85 < E_\gamma < 2.4$ GeV

$\vec{D}$: 27 days → 4.5 B events (Dpol. ~ + 25 %)

Dpol : Preliminary

* Linearly polarized photon beams: $1.6 < E_\gamma < 2.2$ GeV

$\vec{D}$: 21 days → 2.5 B events (Dpol. ~ + 25 %)

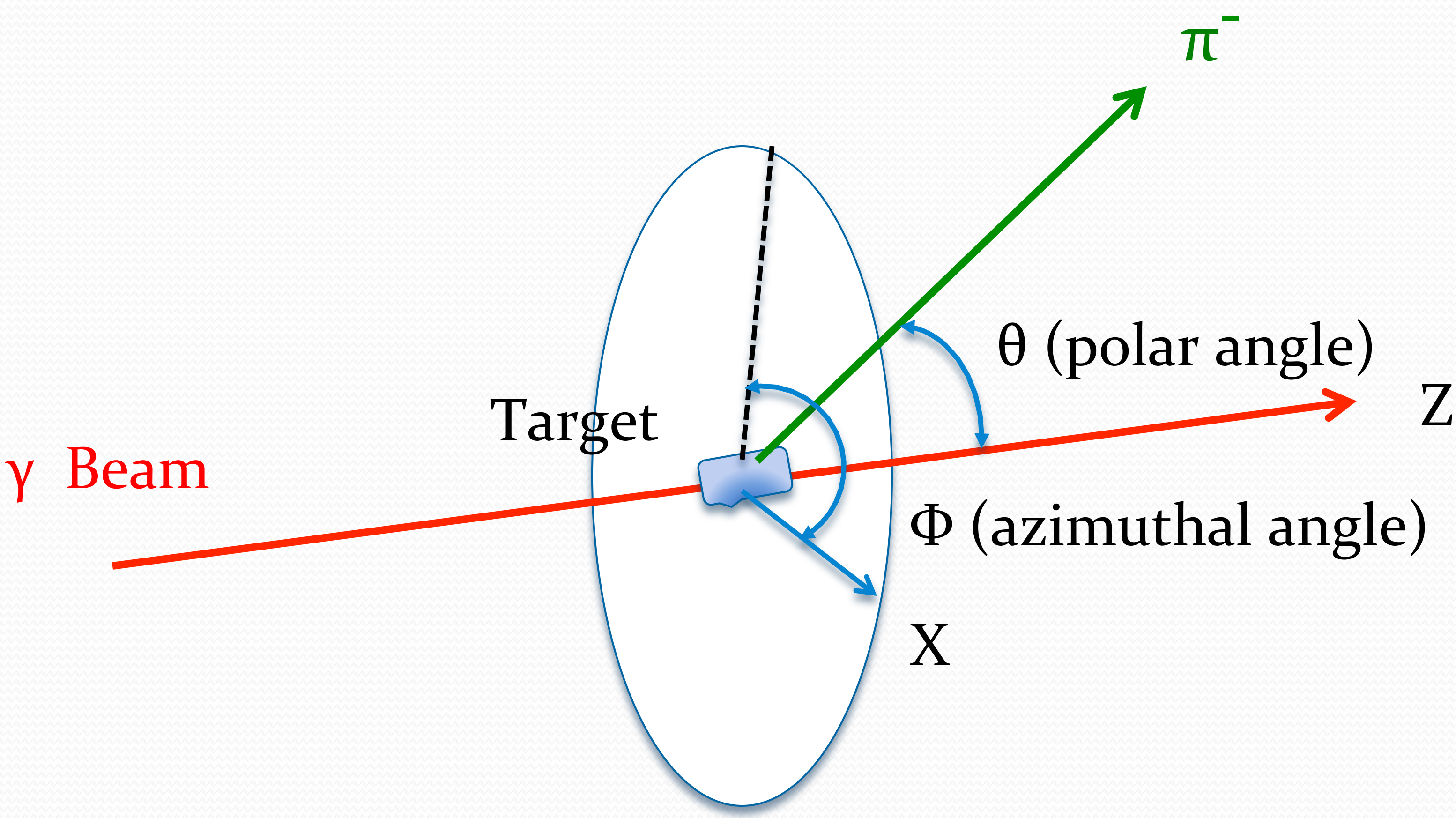
$\overleftarrow{D}$: 9 days → 1.2 B events (Dpol. ~ - 17 %)

Data reductions for E asymmetry on

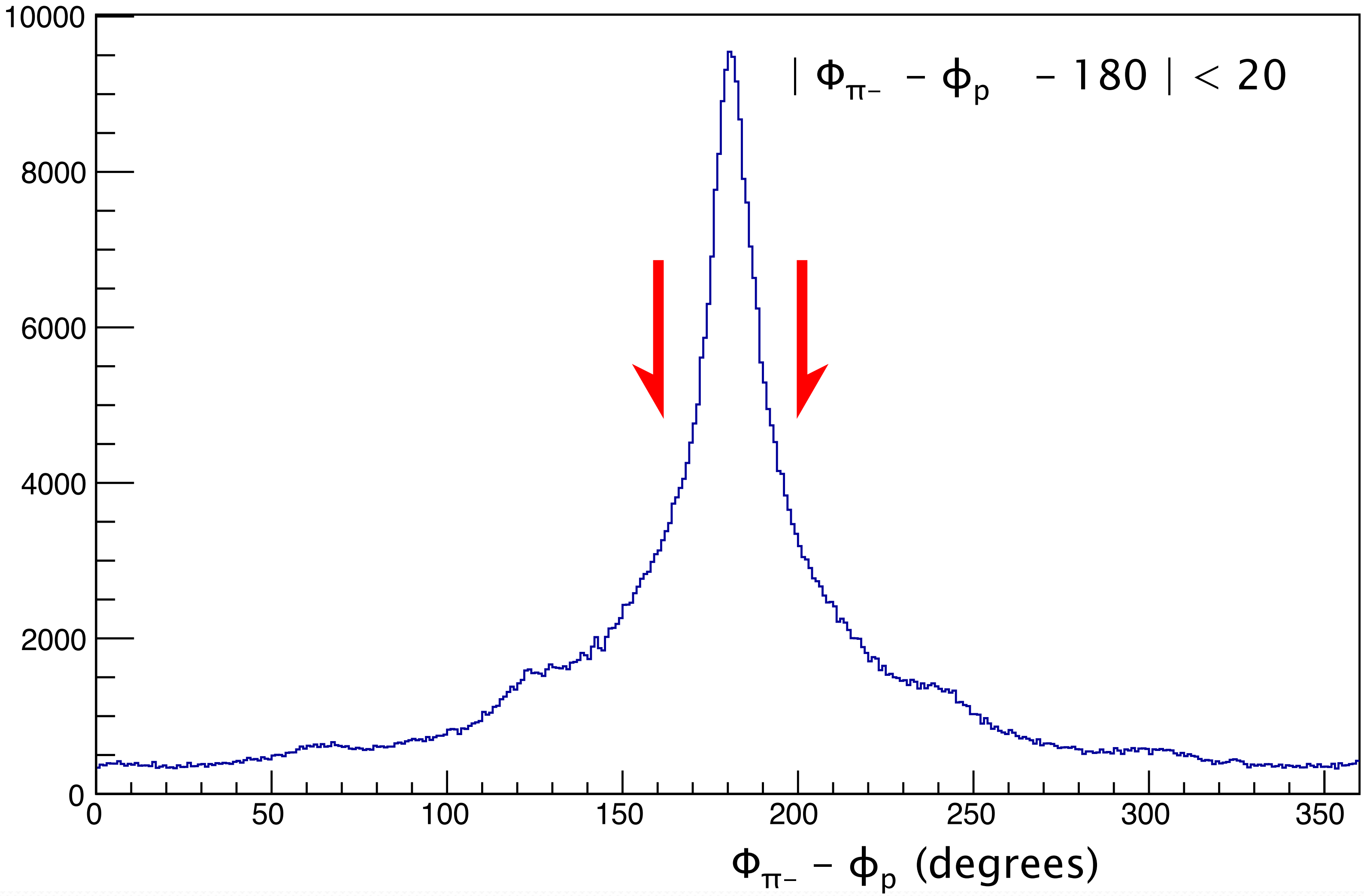
$$\gamma + n(p) \rightarrow \pi^{-} + p\ (p)$$

(a) Select events: only π^- and Proton detected and identified in CLAS
(b) Energy loss corrections
(c) Momentum correction
(d) Tagger correction
(e) Coplanarity cut
(f) Cut for Missing mass squared
(g) Missing momentum cut
(h) Target Cell subtraction and vertex cut

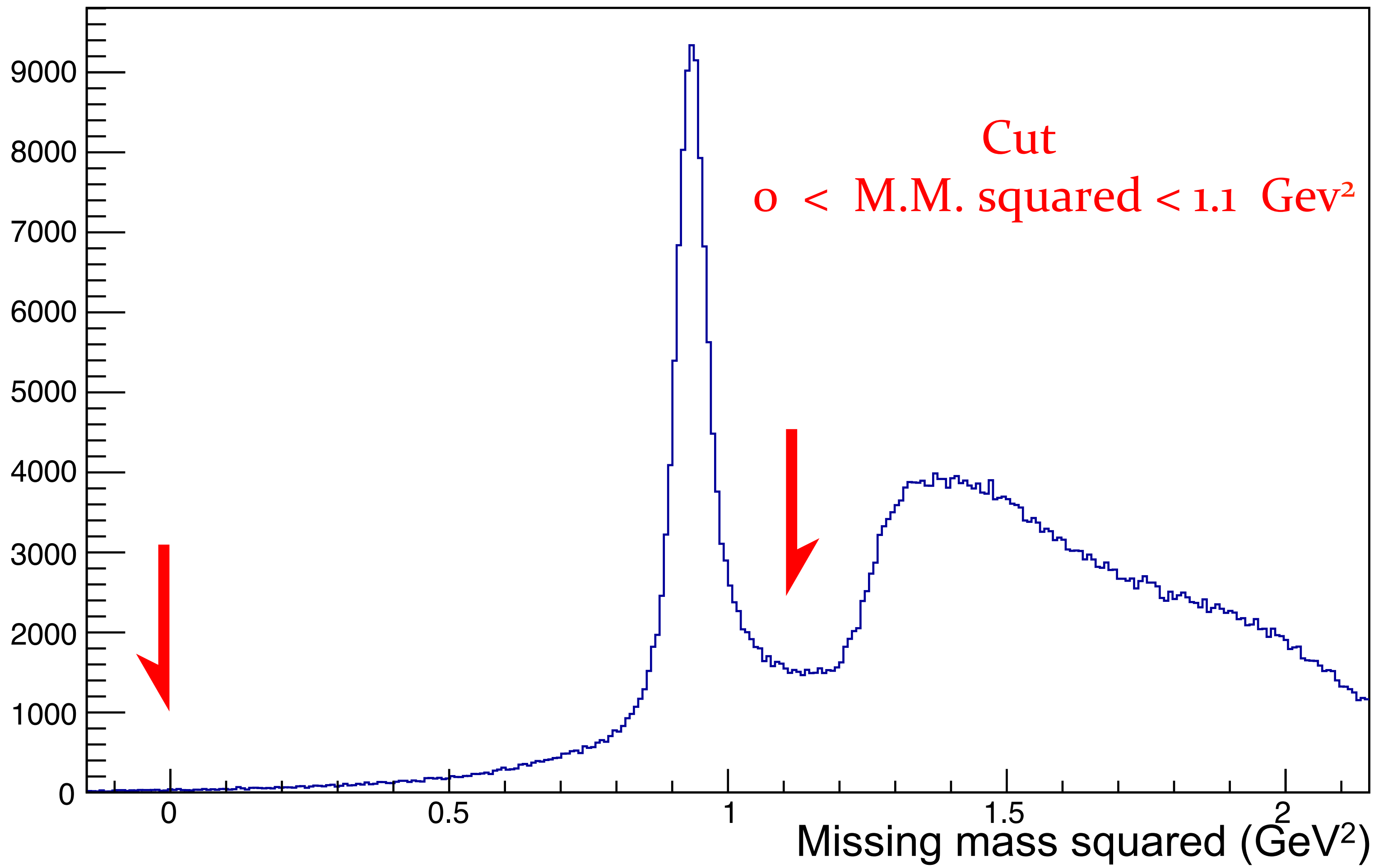
Definitions of axes and angles



(e) $\Phi_{\pi^-} - \phi_p$ distribution and coplanarity cut for π^- and proton

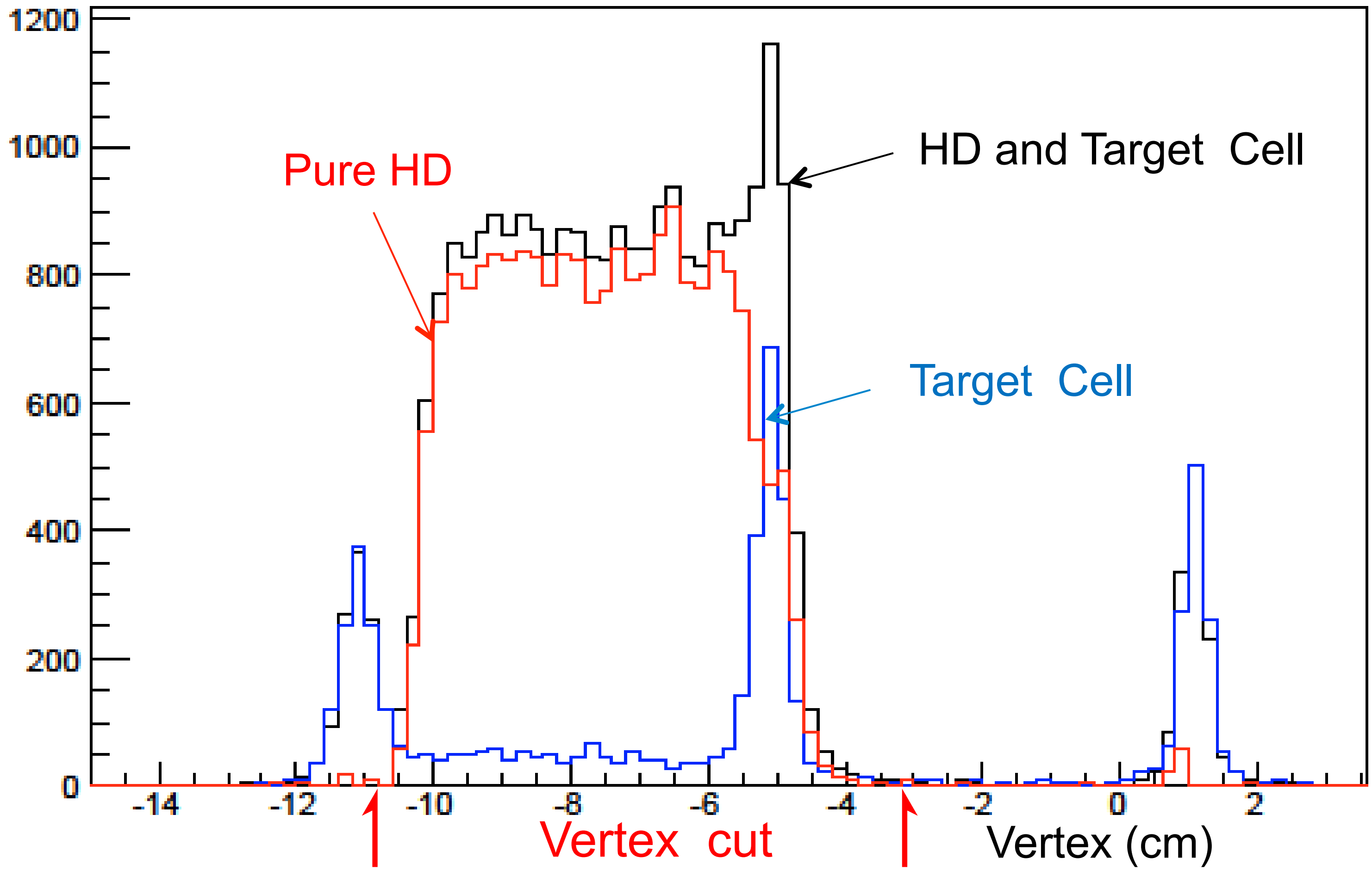


(f) Missing mass squared distribution for $\gamma + D \rightarrow \pi^- + P + X$ and cut



(h) Target Cell subtraction and vertex cut

Reconstructed vertex along beam axis for spin parallel



Other analysis methods for E asymmetries

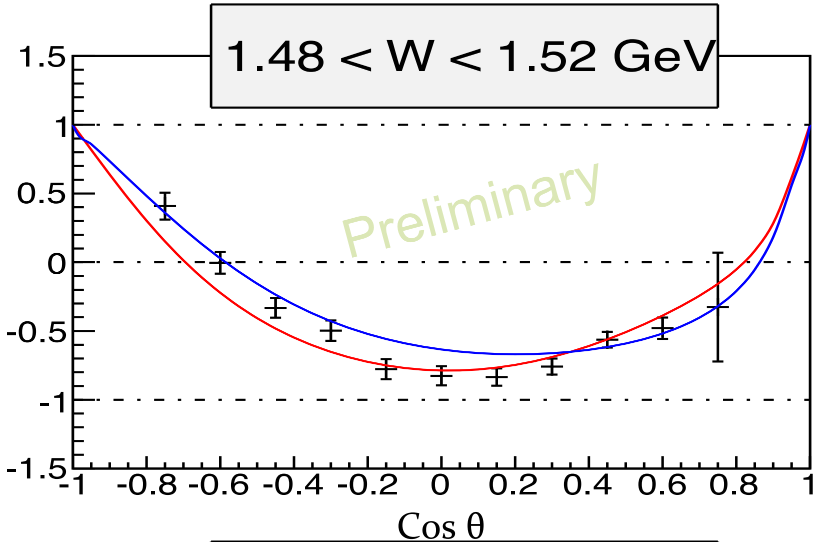
Comparing these results with ones from other two methods to check consistencies for this channel;

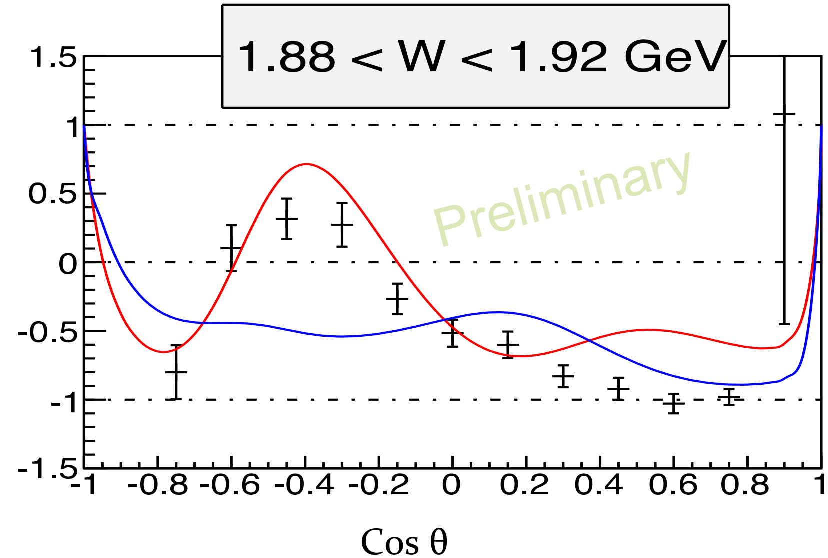
* BDT (Boosted Decision Trees)
* Kinematical fitting

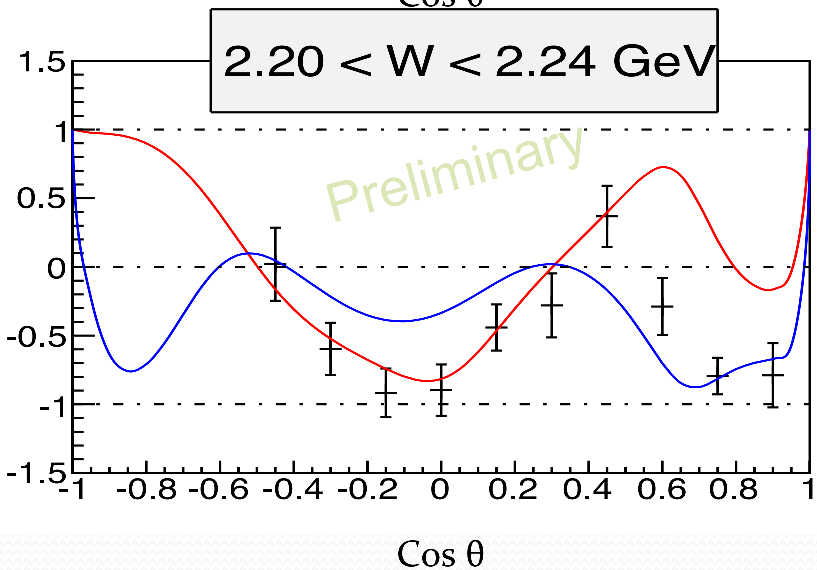
These two methods could be good for low statistics channels.

4. Preliminary results

E asymmetries for $\gamma + n\,(p) \rightarrow \pi^- + p(p)$ (cos θ_{CM} of π-)





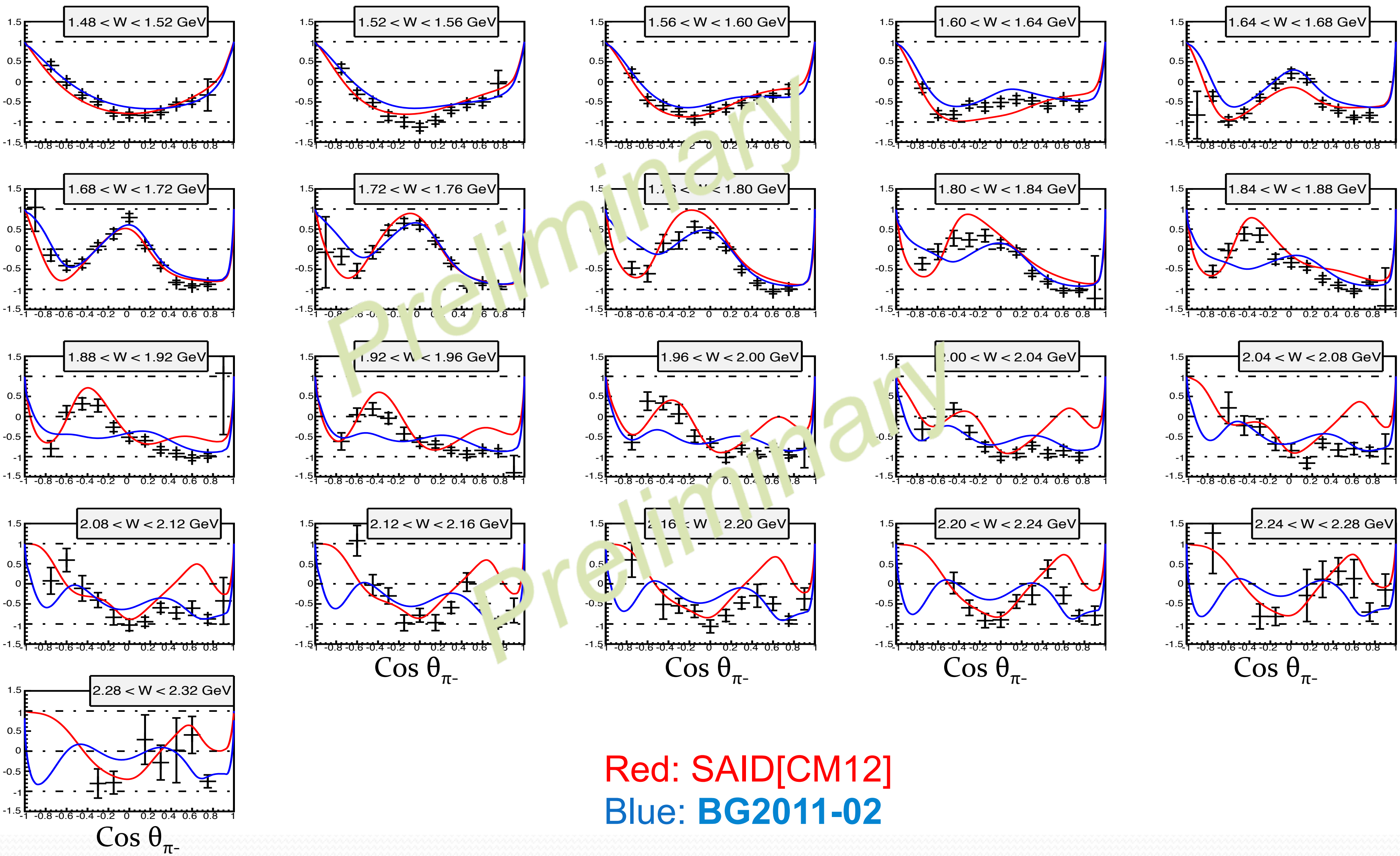


Red: SAID[CM12]

Blue: **BG2011-02**

E asymmetries for γ+n (p) → π⁻ + p + (p)

All energy bins from this experiment (as a function of Cos θ_{CM})



Red: SAID[CM12]

Blue: **BG2011-02**

Formula

- General formula of cross section for single psudoscaler meson production:
  $d\sigma(\theta,\phi) =$
  $\frac{1}{2}d\sigma_0\left(1 - \Sigma(\theta)P_g(L)cos(2\phi) + G(\theta)P_g(L)P_t(z)sin(2\phi)\right)$
  $P_g(L)$: polarization of photon
  $P_t(z)$: polarization of target
- Four cases of beam polarization (linear) and target polarization (longitudinal):
  (1) parallel, positive; (2) parallel, negative;
  (3) perpendicular, positive; (4) perpendicular, negative
- p'_t: degree of negative target polarization
  (1) $d\sigma_1 = \frac{1}{2}d\sigma_0\left(1 - \Sigma(\theta)p_g cos(2\phi) + G(\theta)p_g p_t sin(2\phi)\right)$
  (2) $d\sigma_2 = \frac{1}{2}d\sigma_0\left(1 - \Sigma(\theta)p_g cos(2\phi) - G(\theta)p_g p'_t sin(2\phi)\right)$
  (3) $d\sigma_3 = \frac{1}{2}d\sigma_0\left(1 + \Sigma(\theta)p_g cos(2\phi) - G(\theta)p_g p_t sin(2\phi)\right)$
  (4) $d\sigma_4 = \frac{1}{2}d\sigma_0\left(1 + \Sigma(\theta)p_g cos(2\phi) + G(\theta)p_g p'_t sin(2\phi)\right)$

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Formula (cont.)

- (5) Normalization with acceptance:
  $p'_t d\sigma_1 + p_t d\sigma_2 + p'_t d\sigma_3 + p_t d\sigma_4 = d\sigma_0(p_t + p'_t) = d\sigma'_0$
  $d\sigma_0$ is a function of θ and ϕ
- (6) Cross section of only Σ term:
  $-p'_t d\sigma_1 - p_t d\sigma_2 + p'_t d\sigma_3 + p_t d\sigma_4 = d\sigma'_0 \Sigma p_g cos2\phi$
- (7) Cross section of only G term:
  $d\sigma_1 - d\sigma_2 - d\sigma_3 + d\sigma_4 =$ $d\sigma'_0 G P_g sin2\Phi$
- (8):Extracting Σ:
  (6)/(5)= $\Sigma P_g cos2\Phi$
- (9):Extracting G:
  (7)/(5)= $G P_g sin2\Phi$
- $p_t = 0.245$ and $p'_t = 0.17$

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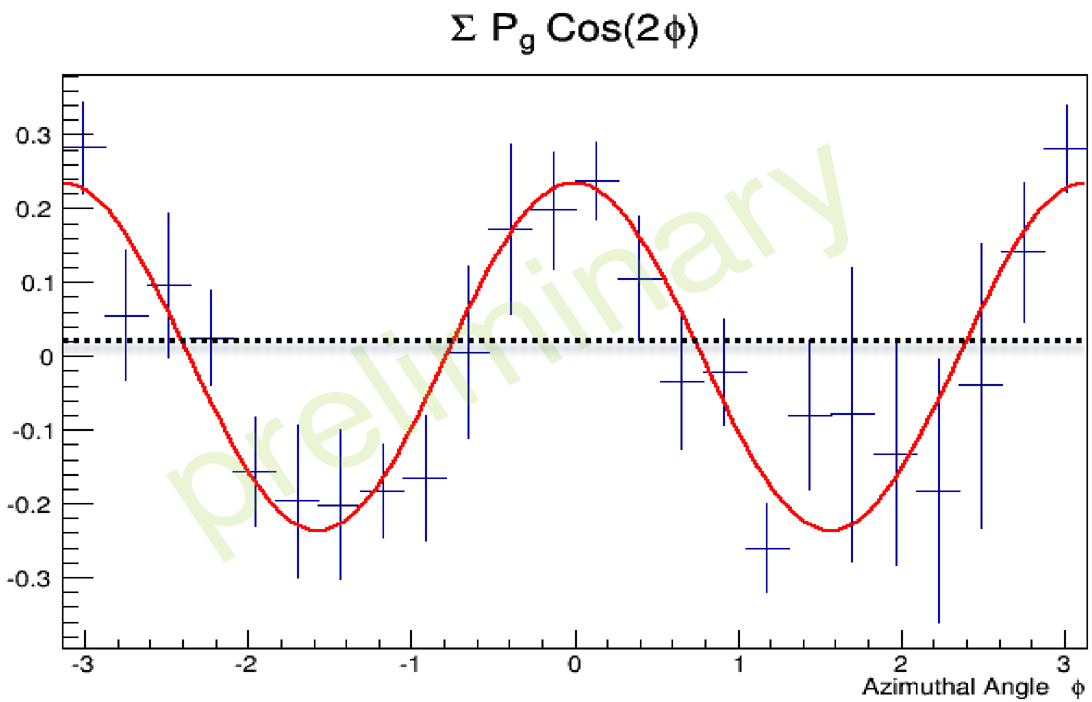
Example of extracting Σ asymmetry



An example histogram from Eq. 8 with a fitting to $cos(2\phi)$

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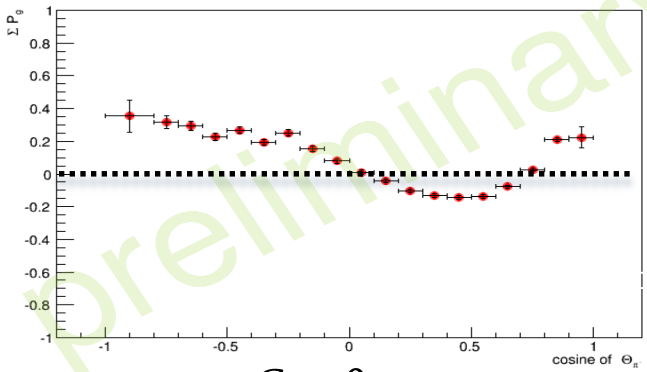
Result of Σ asymmetry

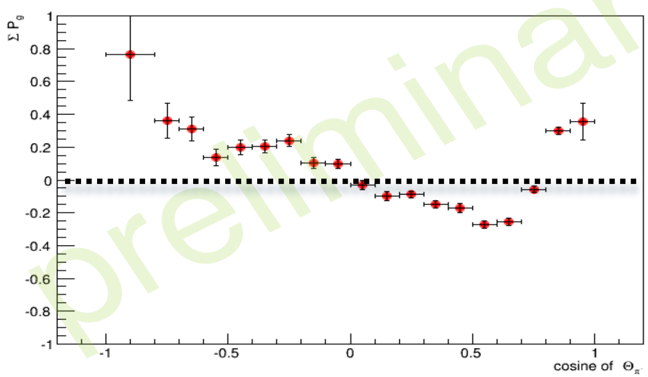
E γ = 1800 MeV



Cos $\theta_{\pi-}$

(A)

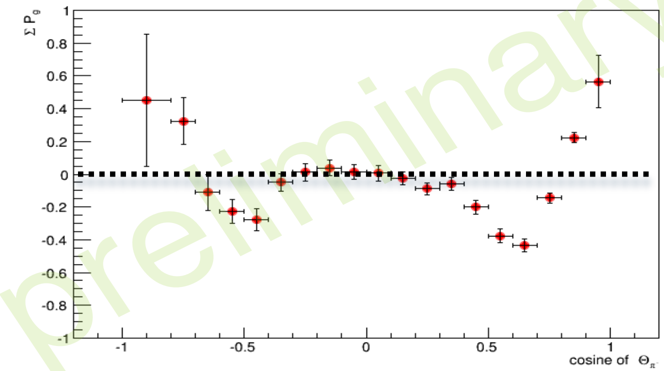
E γ = 2000 MeV



(B)

Cos $\theta_{\pi-}$

E γ = 2200 MeV



Cos $\theta_{\pi-}$

(C)

(A) Σ dependent on $cos(\theta)$ with beam energy at 1800 MeV
(B) Σ dependent on $cos(\theta)$ with beam energy at 2000 MeV
(C) Σ dependent on $cos(\theta)$ with beam energy at 2200 MeV

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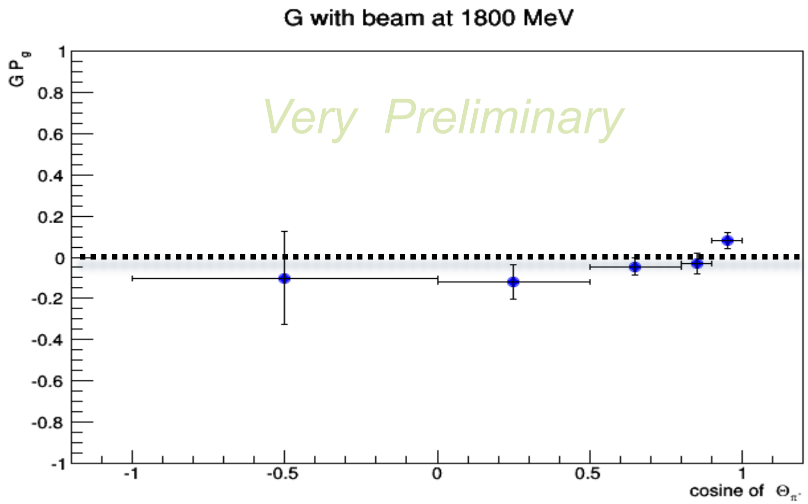
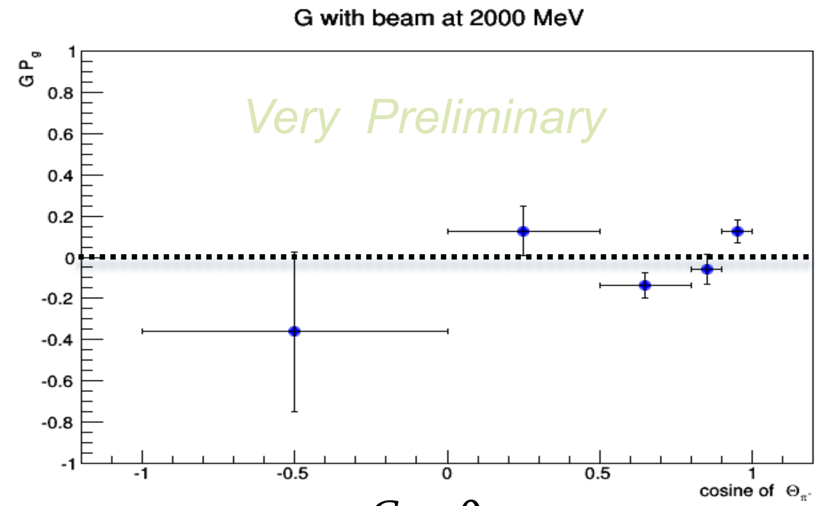
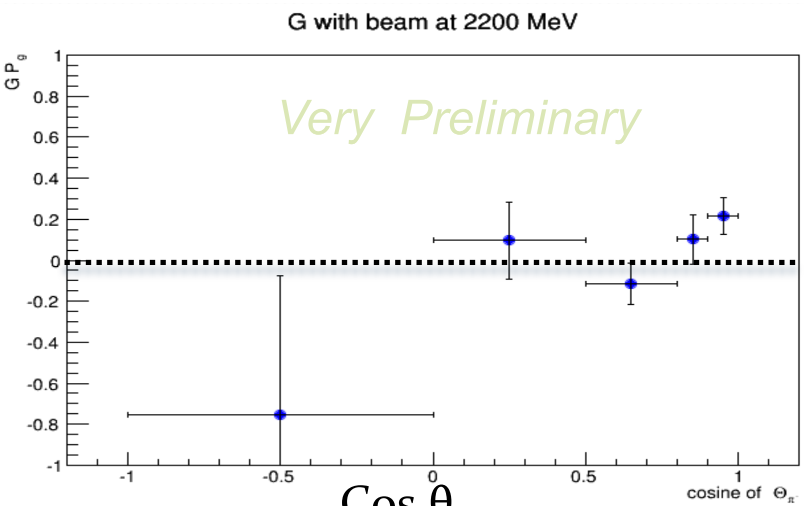
G asymmetries (Very Preliminary)





Cos $\theta_{\pi-}$



Cos $\theta_{\pi-}$

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5. Summary

a. Completed experiments for pseudoscalar-meson photo-production from longitudinally polarized HD at CLAS for 64 days of circularly and 30 days of linearly polarized photon beams.

b. Analyses for target polarizations have been ongoing.

c. Preliminary results for $\gamma + n(p) \rightarrow \pi^- p\ (p)$ were shown.

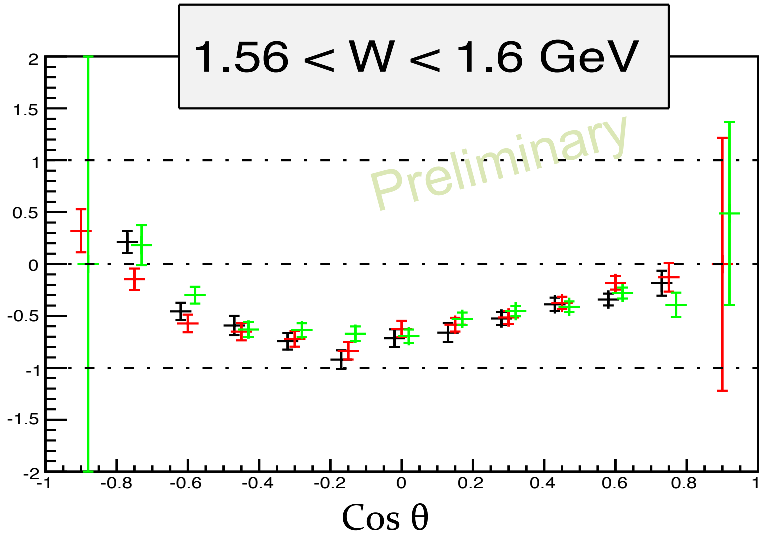
d. Analyses for other channels, like $\gamma + p(n) \rightarrow p\ \pi^+ \pi^-\ (n)$, $\gamma + n(p) \rightarrow n\ \pi^+ \pi^-\ (p)$, $K^0\Lambda$ and $K^+\Sigma^-$ are in progress.

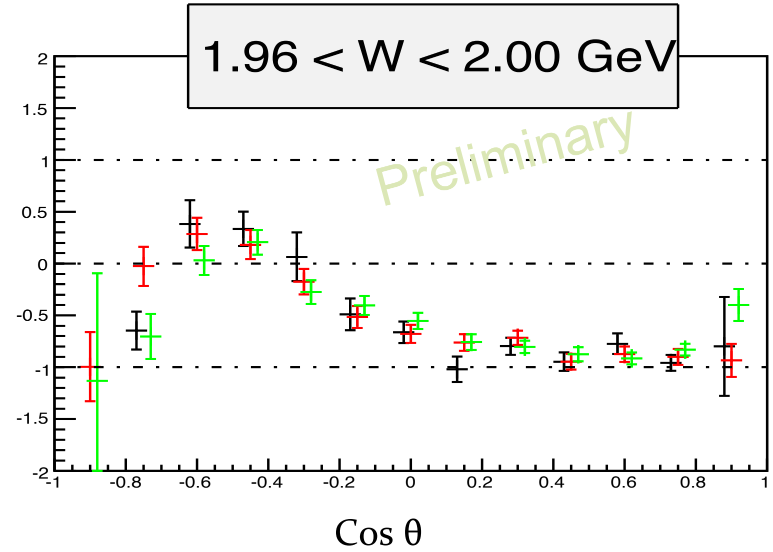
e. For vector meson production, $\gamma + p(n) \rightarrow p\ \rho\ \ (n)$, analyses are ongoing.

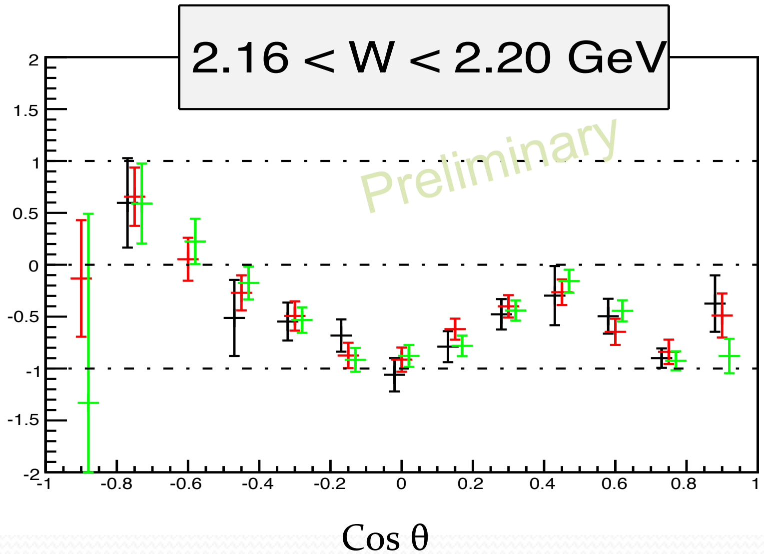
f. Irene Zonta (next speaker) will talk about these three reactions.

Backup slides

Comparisons of three analysis methods on E asymmetries for $\gamma + n\,(p) \rightarrow \pi^- + p(p)$





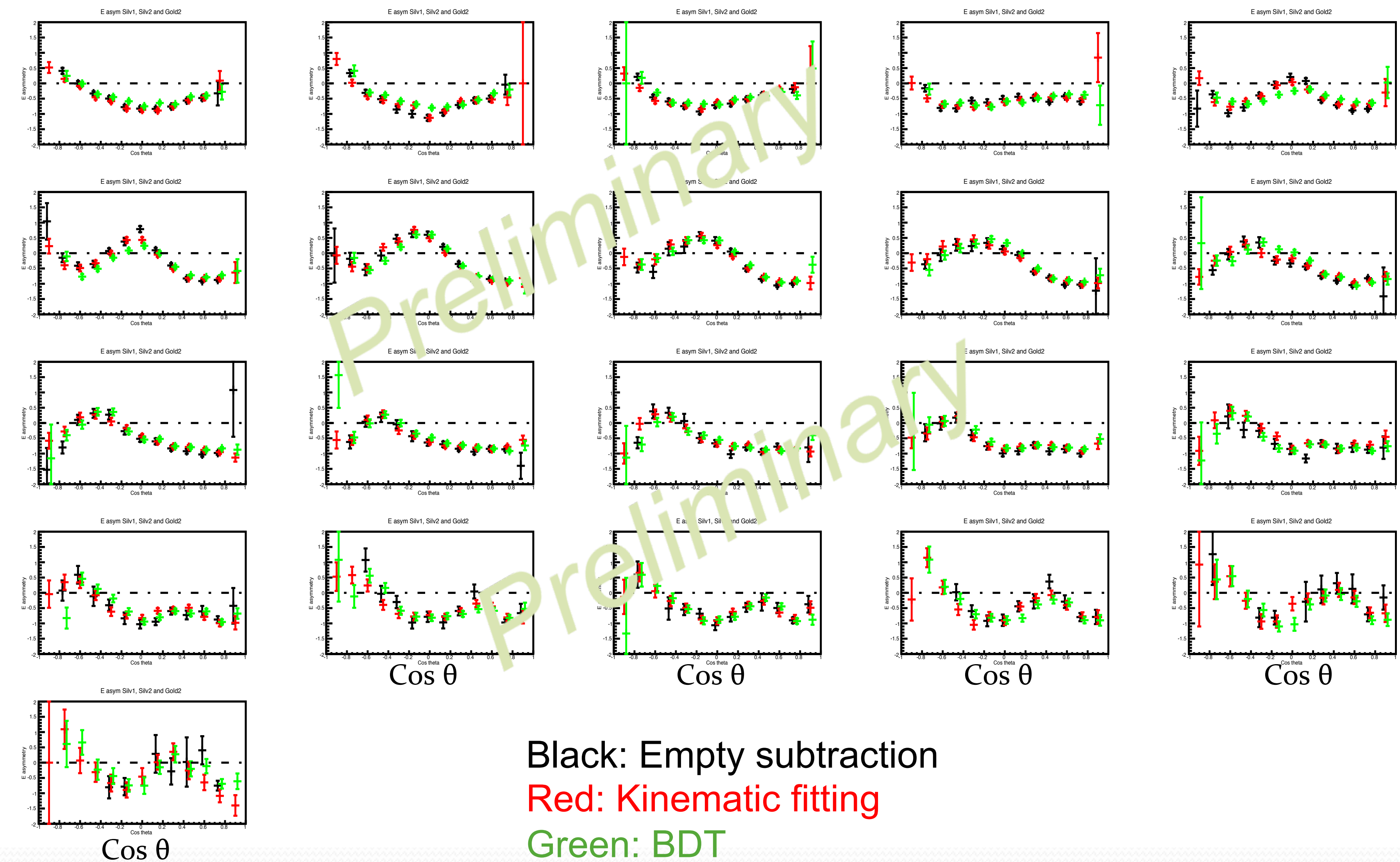


Black: Empty subtraction

Red: Kinematic fitting

Green: BDT

Comparisons of three analysis methods on E asymmetries for $\gamma + n$ (p) $\rightarrow \pi^- + p$(p) (All energy bins from this experiment)



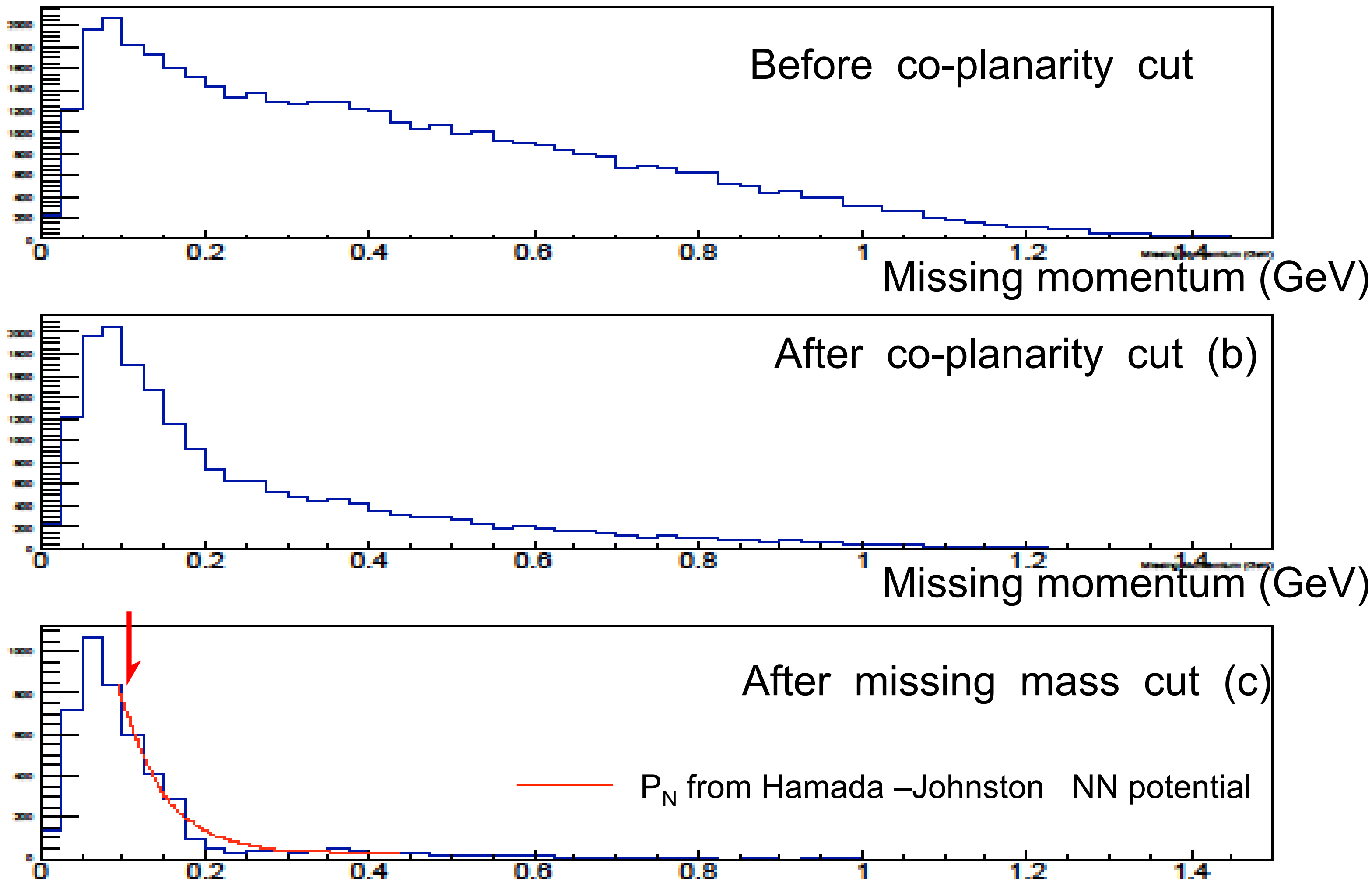
Black: Empty subtraction

Red: Kinematic fitting

Green: BDT

(e) Missing momentum distribution for $\gamma + n(p) \rightarrow \pi^- + p + X$; selection of quasi-free neutron

0.7 < Eγ < 1.3 GeV



Cuts for E and G asymmetry Extractions (No.1)

Overview

- The missing momentum is calculated from $\gamma d \rightarrow p\pi^-$.
- Assign the inverse of the missing momentum to the neutron target as the momentum.
- Calculate the momentum (p_1)of produced proton in the center of mass frame of γn.
- The detected proton was boosted into the center of mass frame of γn with momentum (p_2).
- The difference between p_1 and p_2 is used as the criteria.
- The cut on the missing momentum has not been applied yet.

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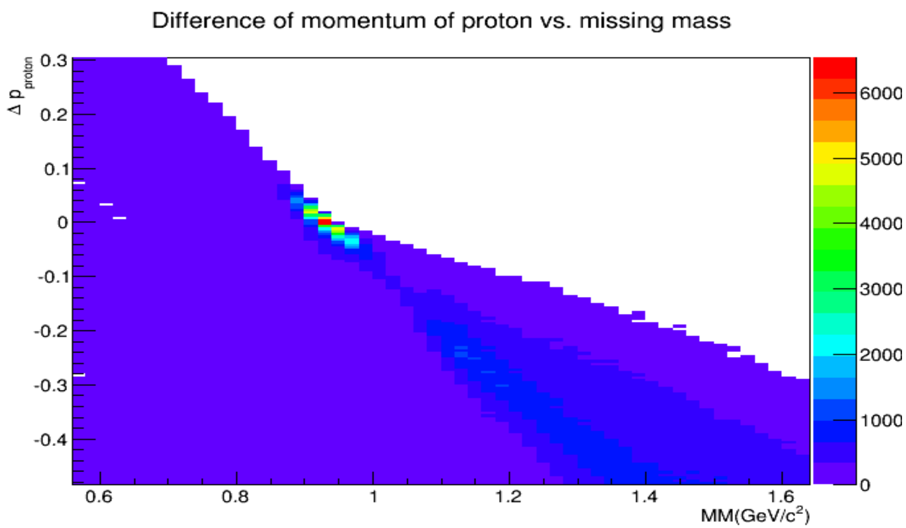
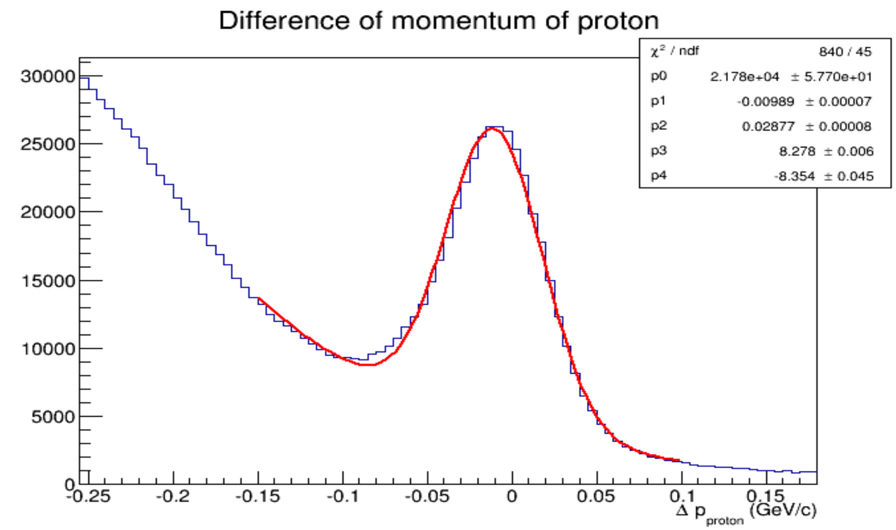
Proton Momentum Difference



Proton momentum difference vs. missing mass.



The proton momentum difference was fitted and a 3-σ cut was applied afterwards.

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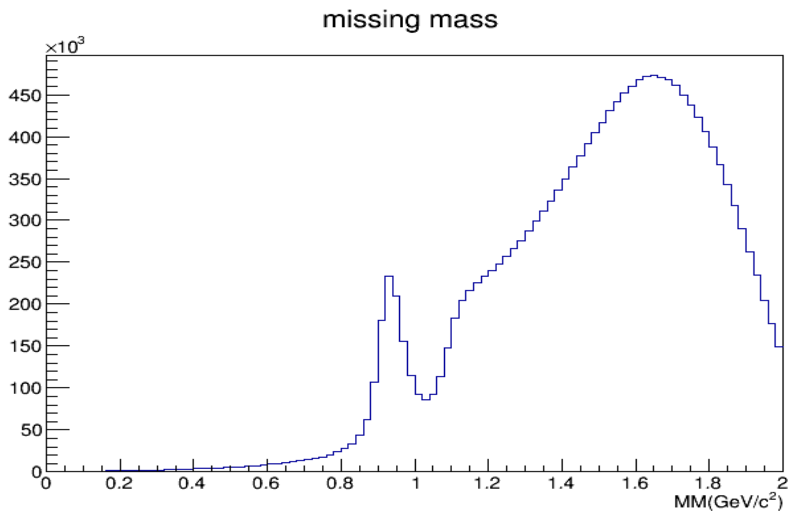
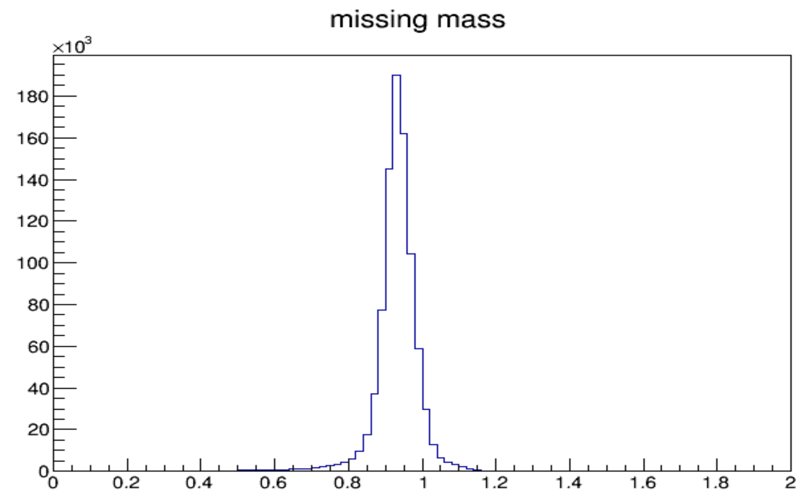
The Resulting Missing Mass



Missing mass before cutting the proton momentum difference.



Missing mass after cutting the proton momentum difference.

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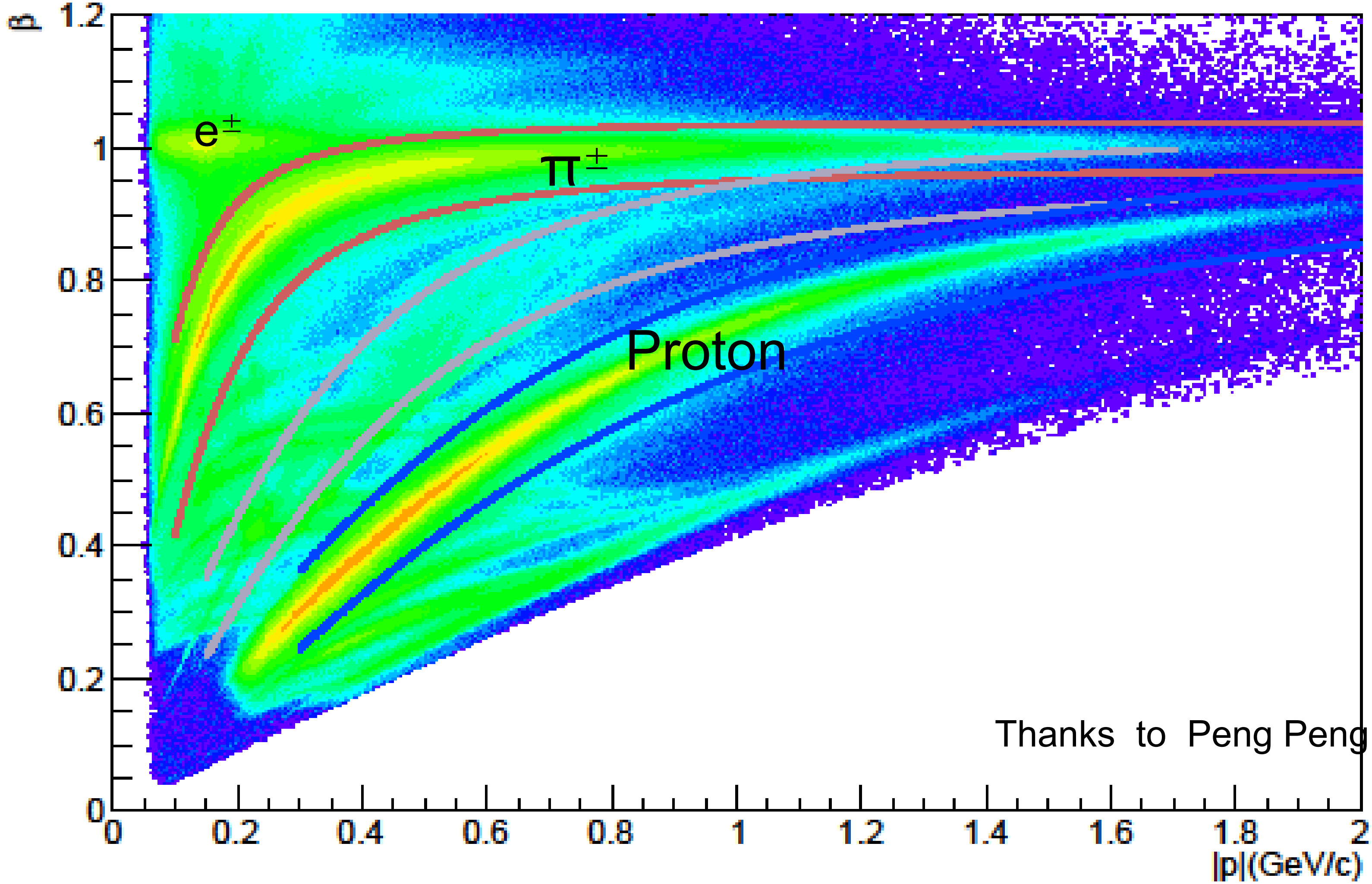
Pseudoscalar meson reactions and observables measured in this experiment (try Neutron reactions using Deuteron)

reaction	*observable*
$\gamma + n\,(p) \rightarrow \pi^- p\,(p)$	σ_0, Σ, E, G This Talk
$\gamma + n\,(p) \rightarrow \pi^+ \pi^- n\,(p)$	σ_0, $I^c\,(\Sigma)$, I^s, I^o, P_z, $P^o_z\,(E)$, $P^s_z\,(G)$, P^c_z
$\gamma + n\,(p) \rightarrow K^0 \Lambda\,(p)$	σ_0, Σ, E, G $O_{x'}$, $O_{z'}$, $C_{x'}$, $C_{z'}$, P, $T=(-O_{y'})$ $L_{x'}$, $L_{z'}$, $T_{x'}$, $T_{z'}$
$\gamma + n\,(p) \rightarrow K^0 \Sigma^0\,(p)$	σ_0, Σ, P, E, G
$\gamma + n\,(p) \rightarrow K^+ \Sigma^-\,(p)$	σ_0, Σ, E, G

From proposal E06-101

(a) Select events; only π^- and Proton detected in CLAS

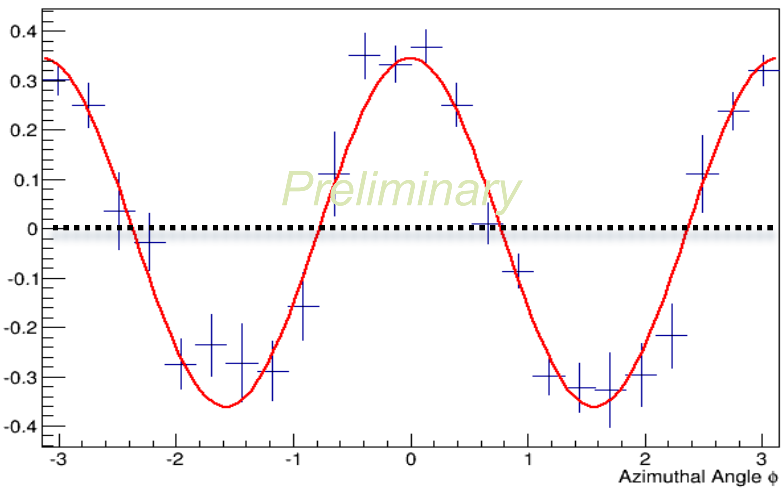
Particle Identification using $\beta = v/c$ vs P (v: from TOF)



Σ and G asymmetries (Preliminary)

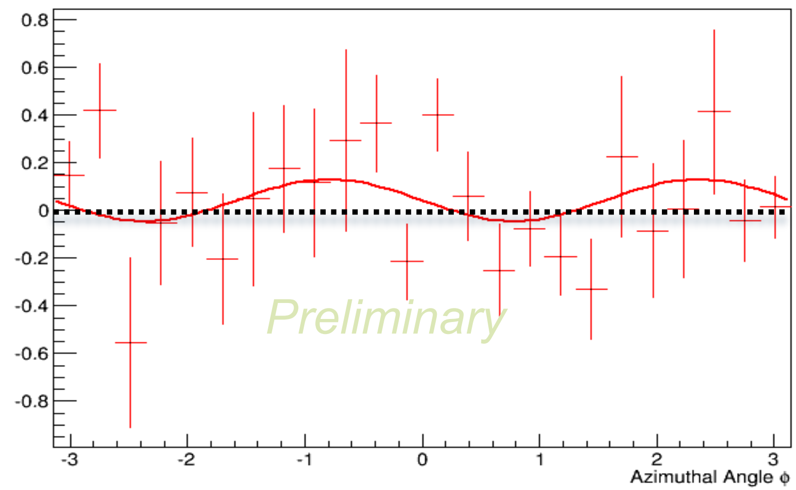
Example of Fitting Σ and G

$\Sigma\ P_g \cos(2\Phi)$



Fitting Σ of $cos\Theta$ from 0.0 to 0.5 at 1800 MeV of beam energy

$G\ P_g \sin(2\Phi)$



Fitting G of $cos\Theta$ from 0.0 to 0.5 at 1800 MeV of beam energy

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