Double-spin observables in charged pion photo-production from polarized neutrons in solid HD using the CLAS at Jefferson Lab

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(On behalf of CLAS collaboration)

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

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

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

Full set of 16

(Longitudinally polarized)

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

2. Experimental apparatus

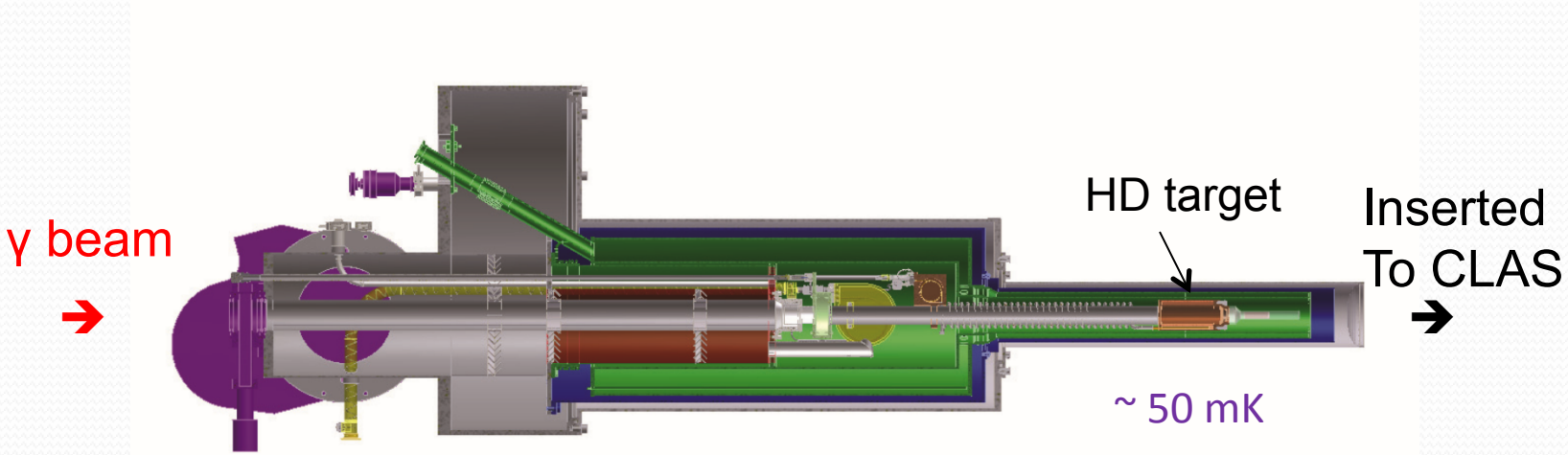
Circularly and linearly polarized photon beams

CLAS detectors and electron tagging system

Polarized neutron target (Solid HD) : newly installed

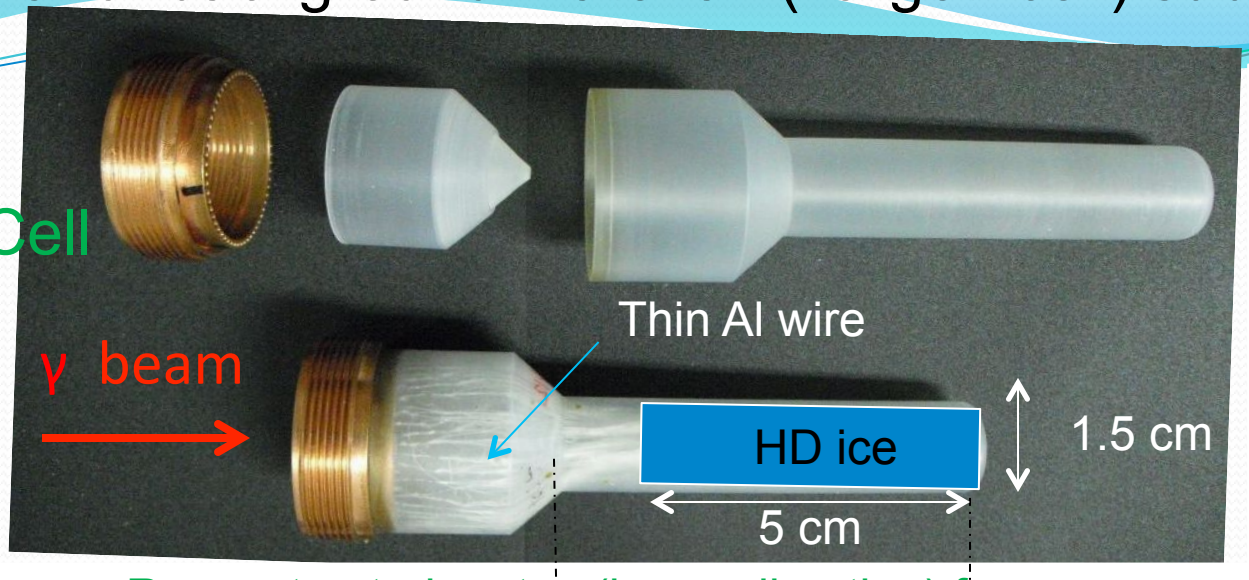
New longitudinally polarized target for this experiment

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



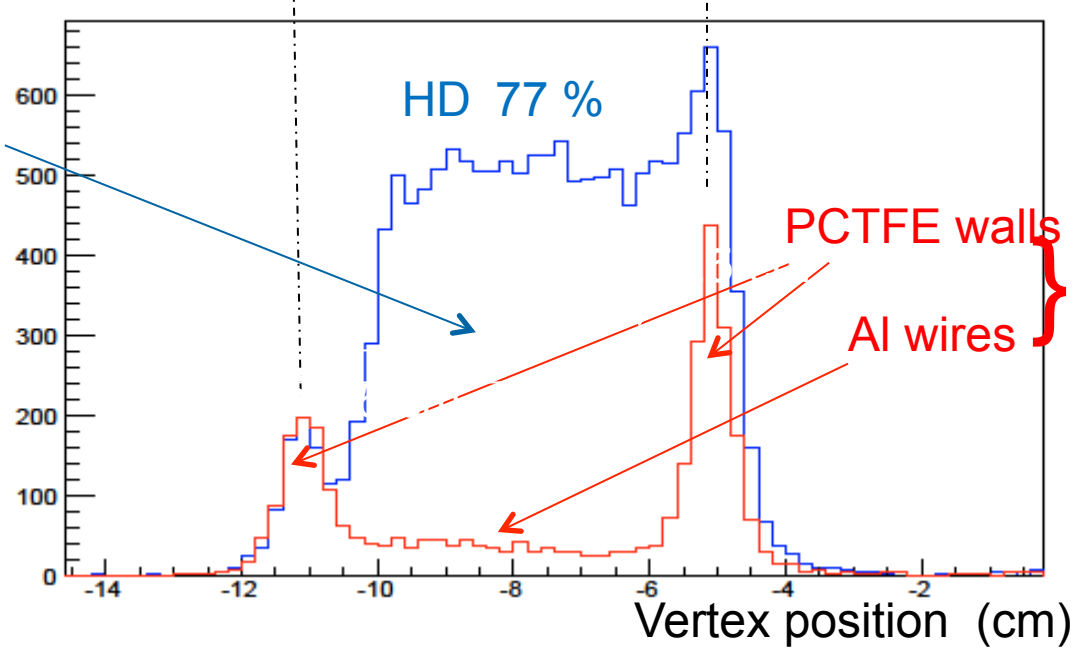
* Horizontal Dilution Fridge (designed and constructed by HDice group at Jlab)
* 1 Tesla main Solenoid for longitudinal holding field
* Transverse field of 750 Gauss for field rotation (spin flip)
* NMR coil: polarization monitor during the run and spin transfer and H-spin flip, Birdcage coil

Target and background material (Target cell) subtraction



Reconstructed vertex (beam direction) for π^- and proton

HD and target cell



3. Experimental conditions and data reduction

g14 experiments: Dec. 2011 – May. 2012

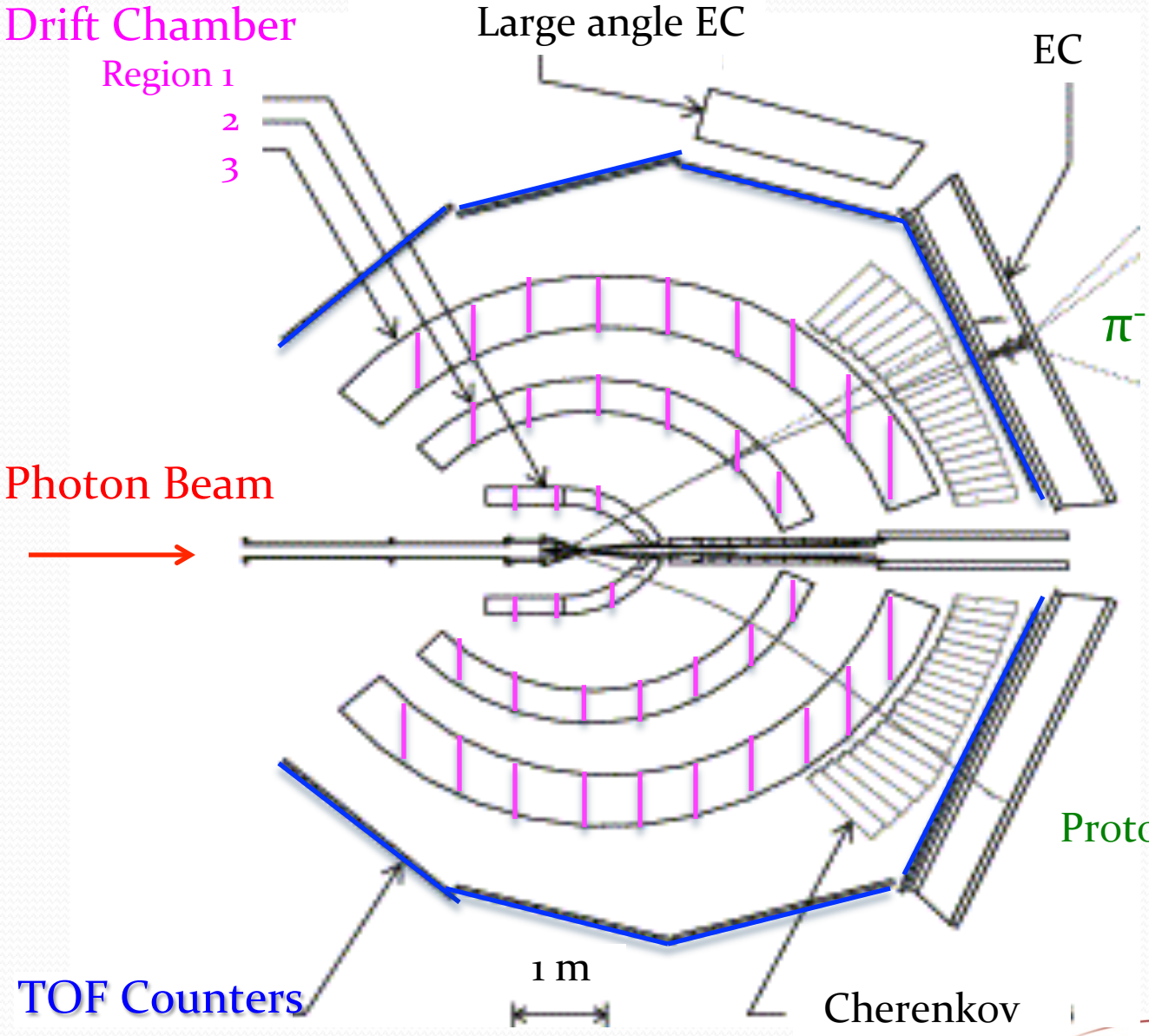
* Circularly polarized photon beams: $0.85 < E_\gamma < 2.4$ GeV

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

Used for this analysis

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

CLAS detector side view (reconstruct and identify π^- & proton)



Data reductions for E asymmetry on

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

(a) Select events: only $\pi-$ and Proton detected and identified in CLAS (from the same photon)

(b) Energy loss correction

(c) Momentum correction

(d) Tagger photon beam energy correction

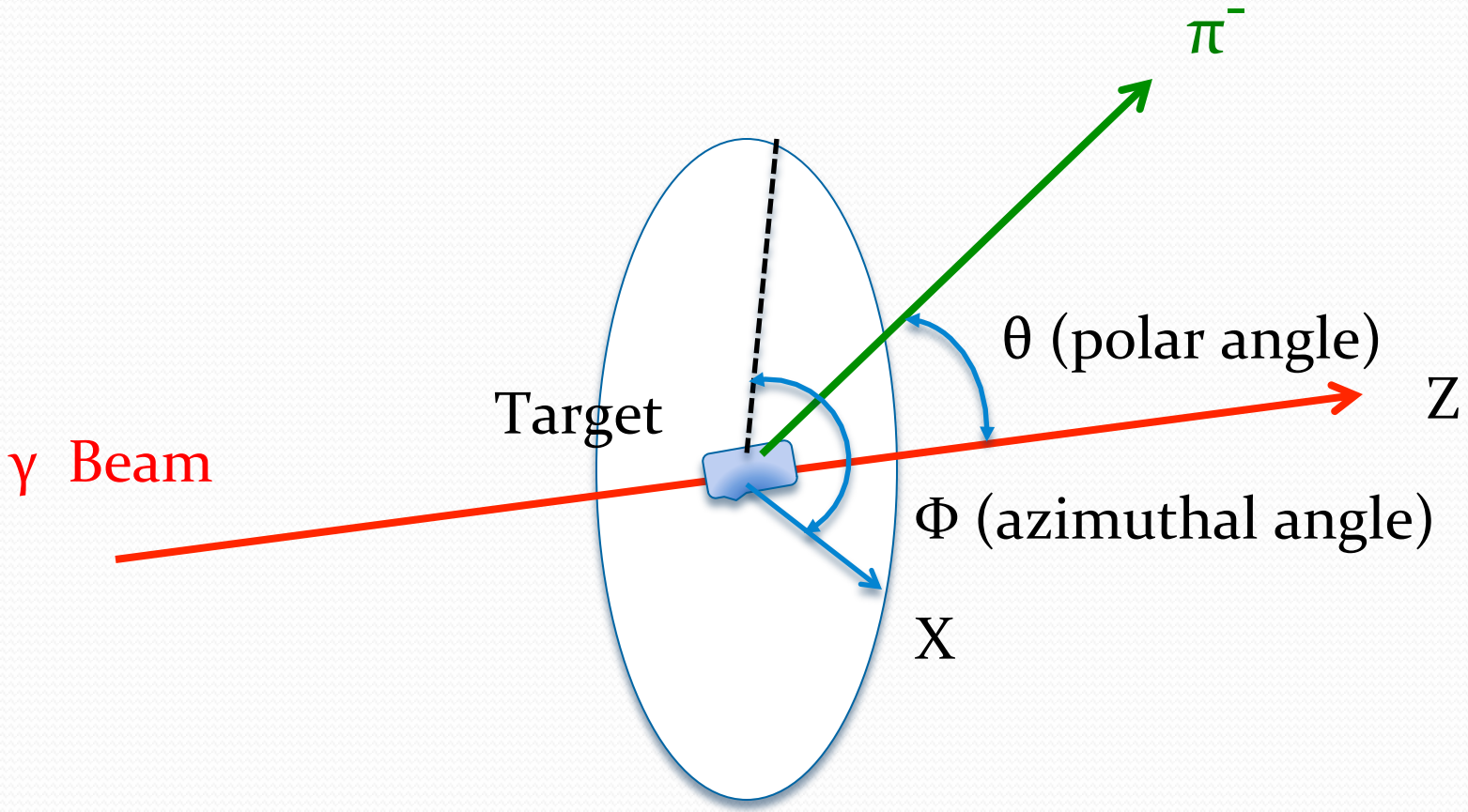
(e) Coplanarity cut

(f) Cut for Missing mass squared

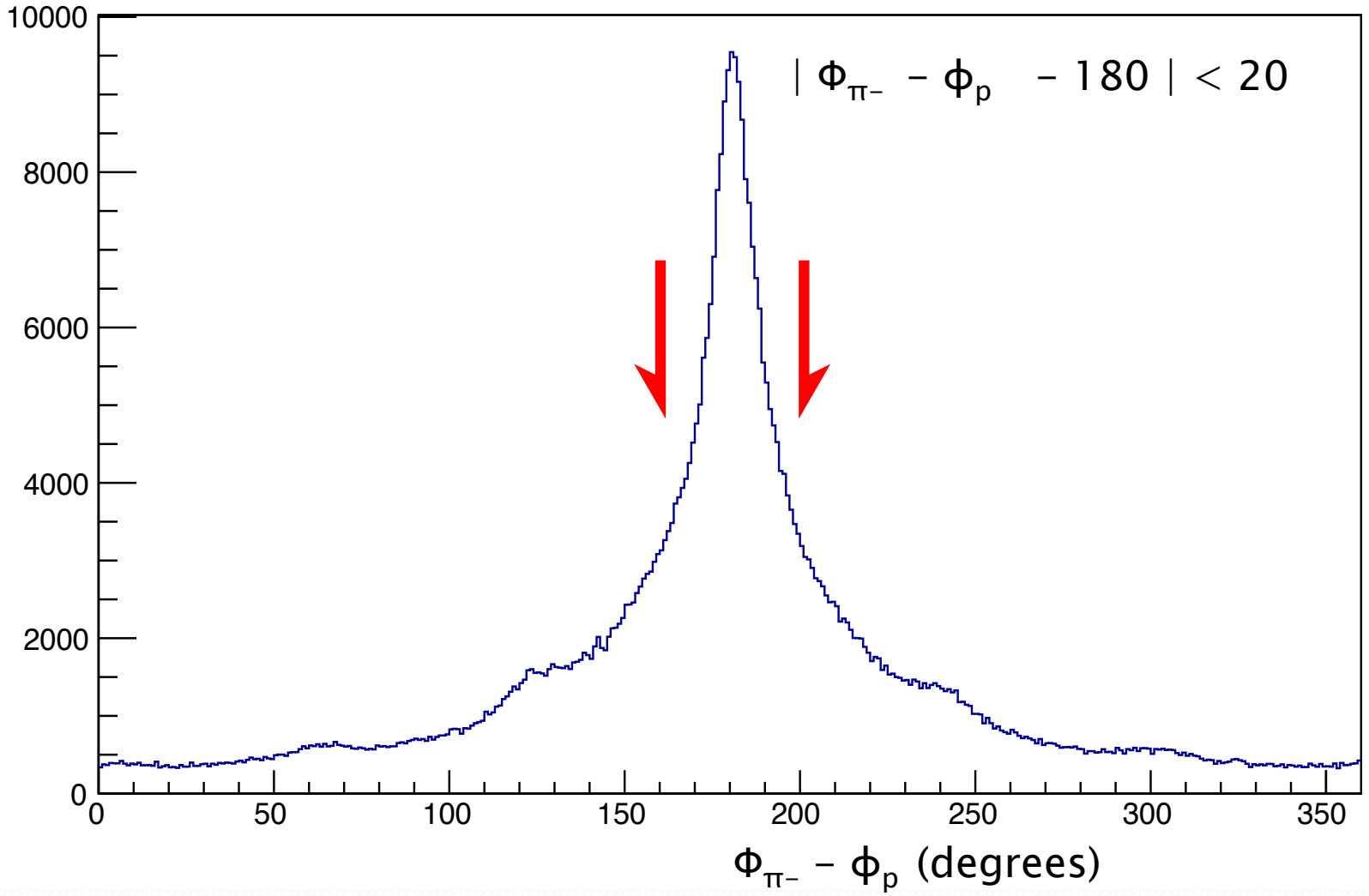
(g) Missing momentum cut

(h) Target Cell subtraction and vertex cut

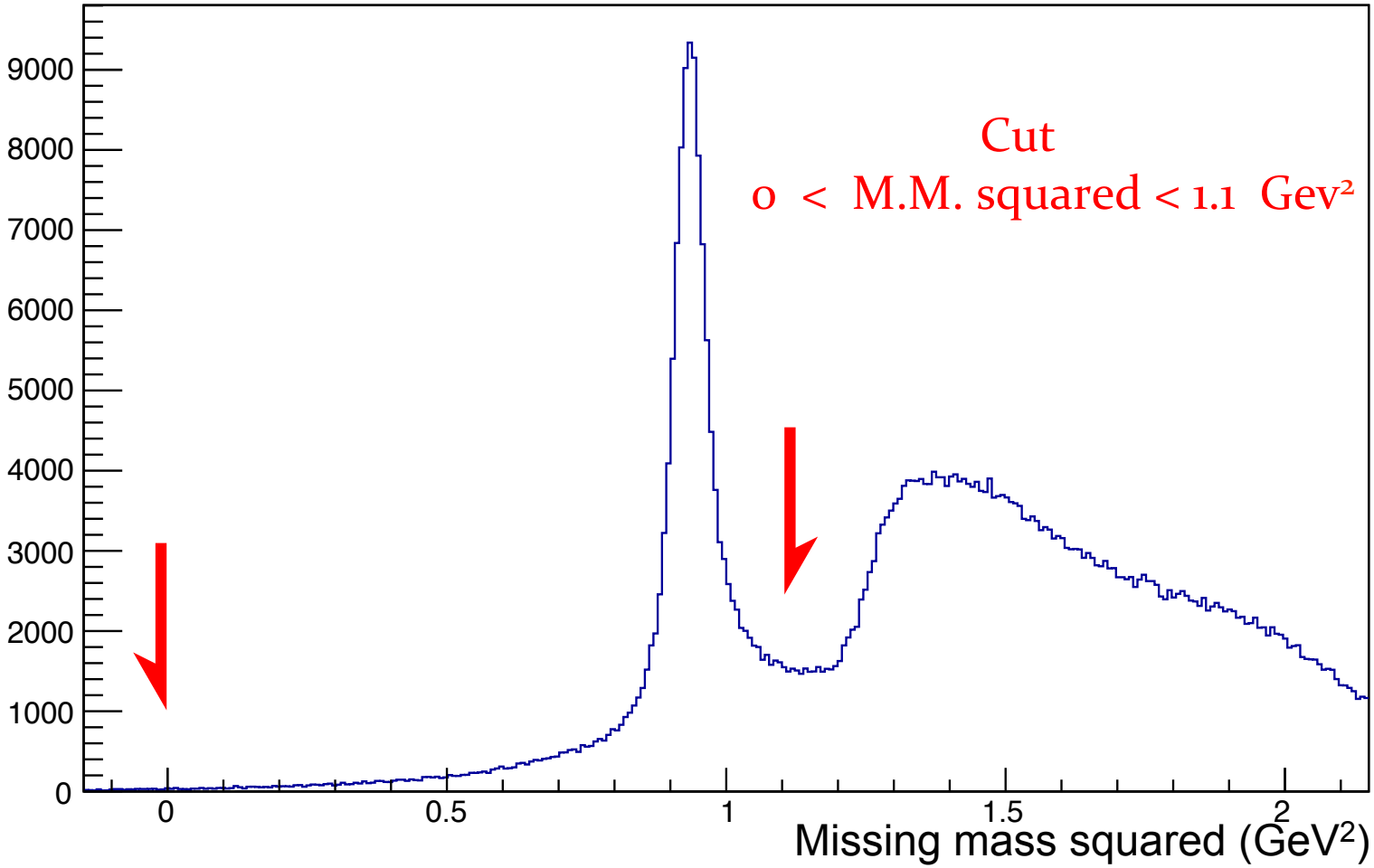
Definitions of axes and angles



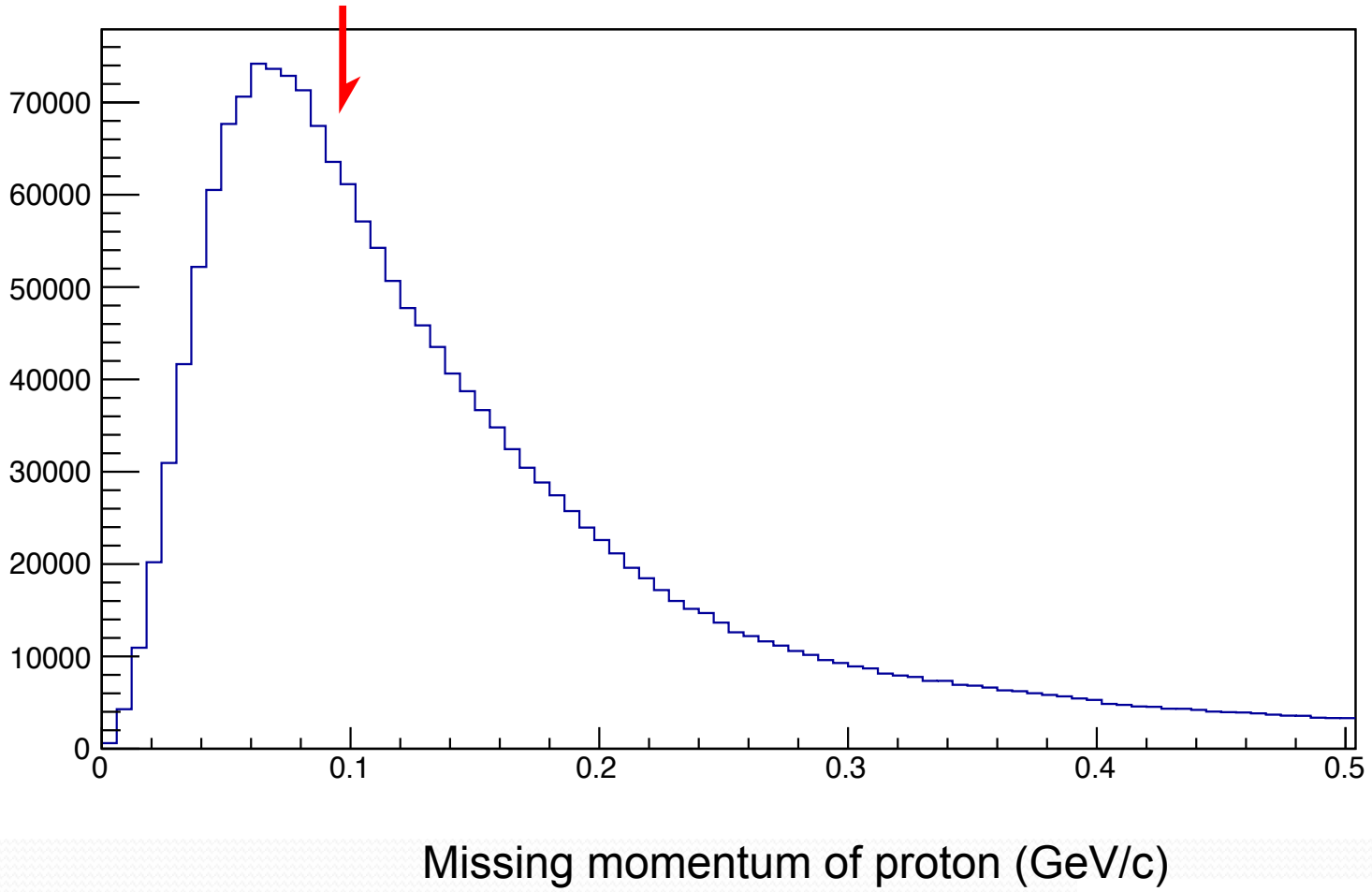
(e) $\Phi_{\pi^-} - \phi_p$ distribution and coplanarity cut for π^- and proton



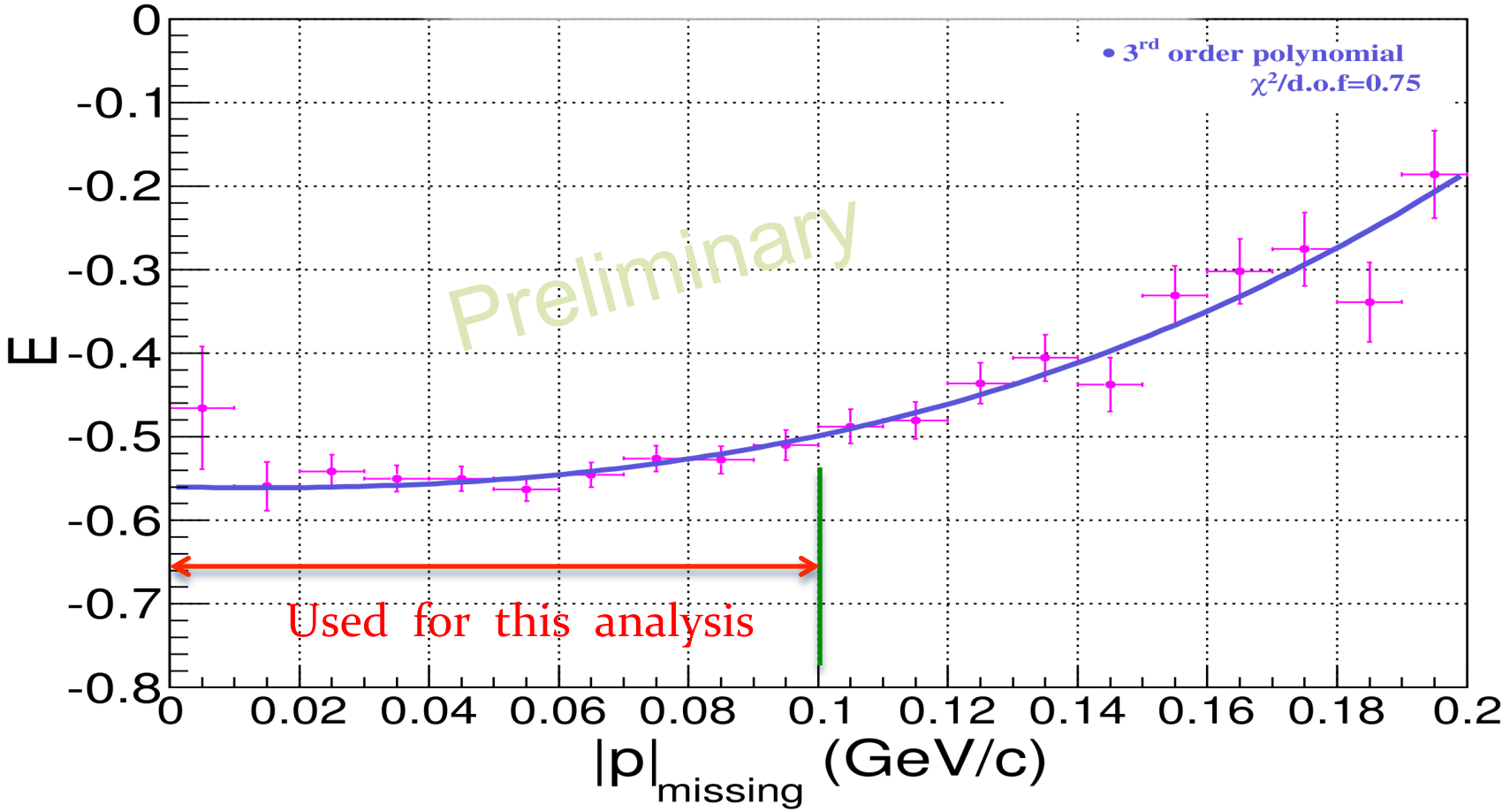
(f) Missing mass squared distribution for $\gamma + D \rightarrow \pi^- + P + X$ and cut



(g) Missing momentum distribution (after (a) – (f)) for $\gamma + D \rightarrow \pi^- + P + X$ and cut

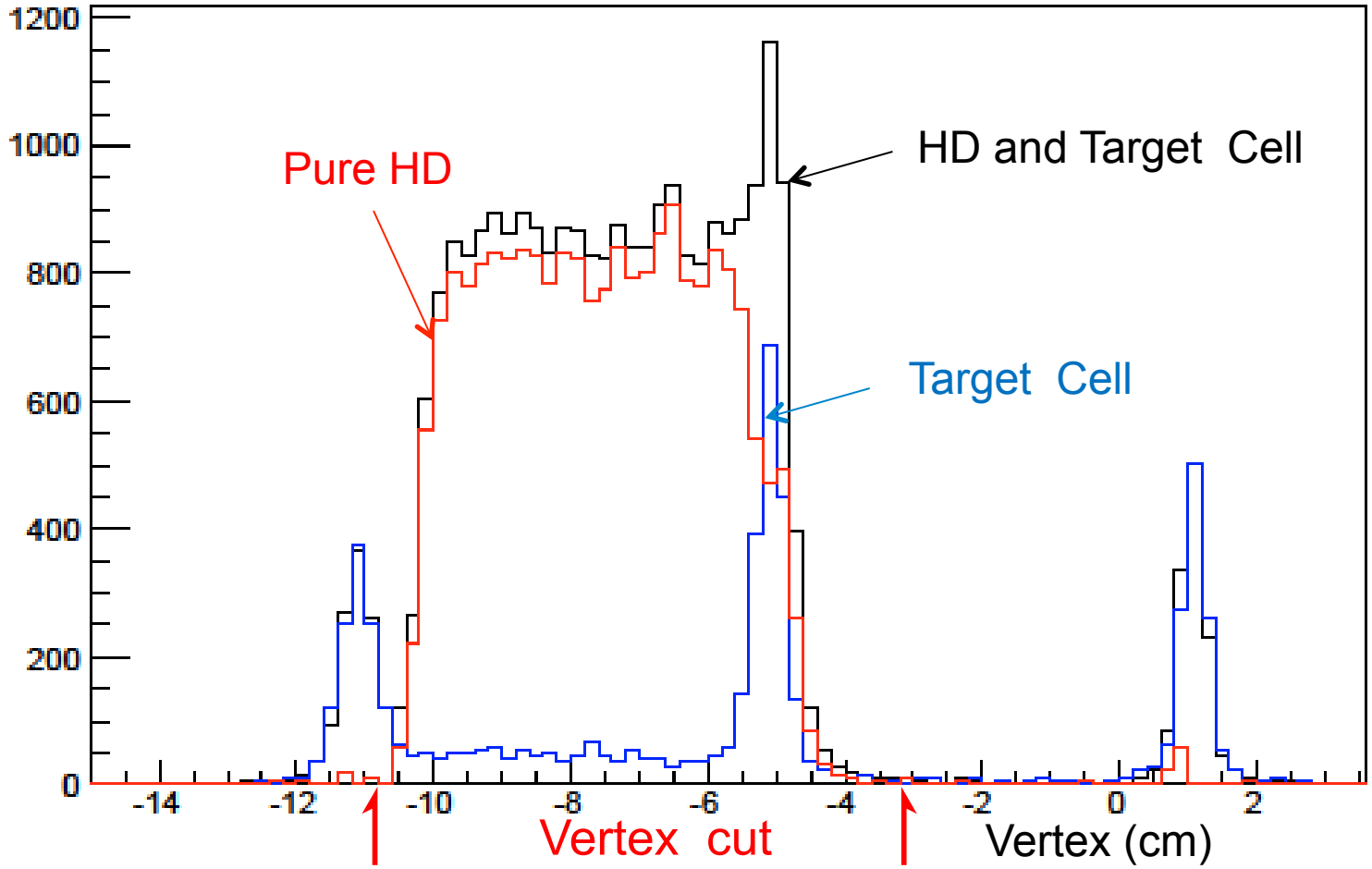


E asymmetry dependence on the missing momentum ranges (BDT method) (integrated to cos θ_{CM} of π-)



(h) Target Cell subtraction and vertex cut

Reconstructed vertex along beam axis for spin parallel



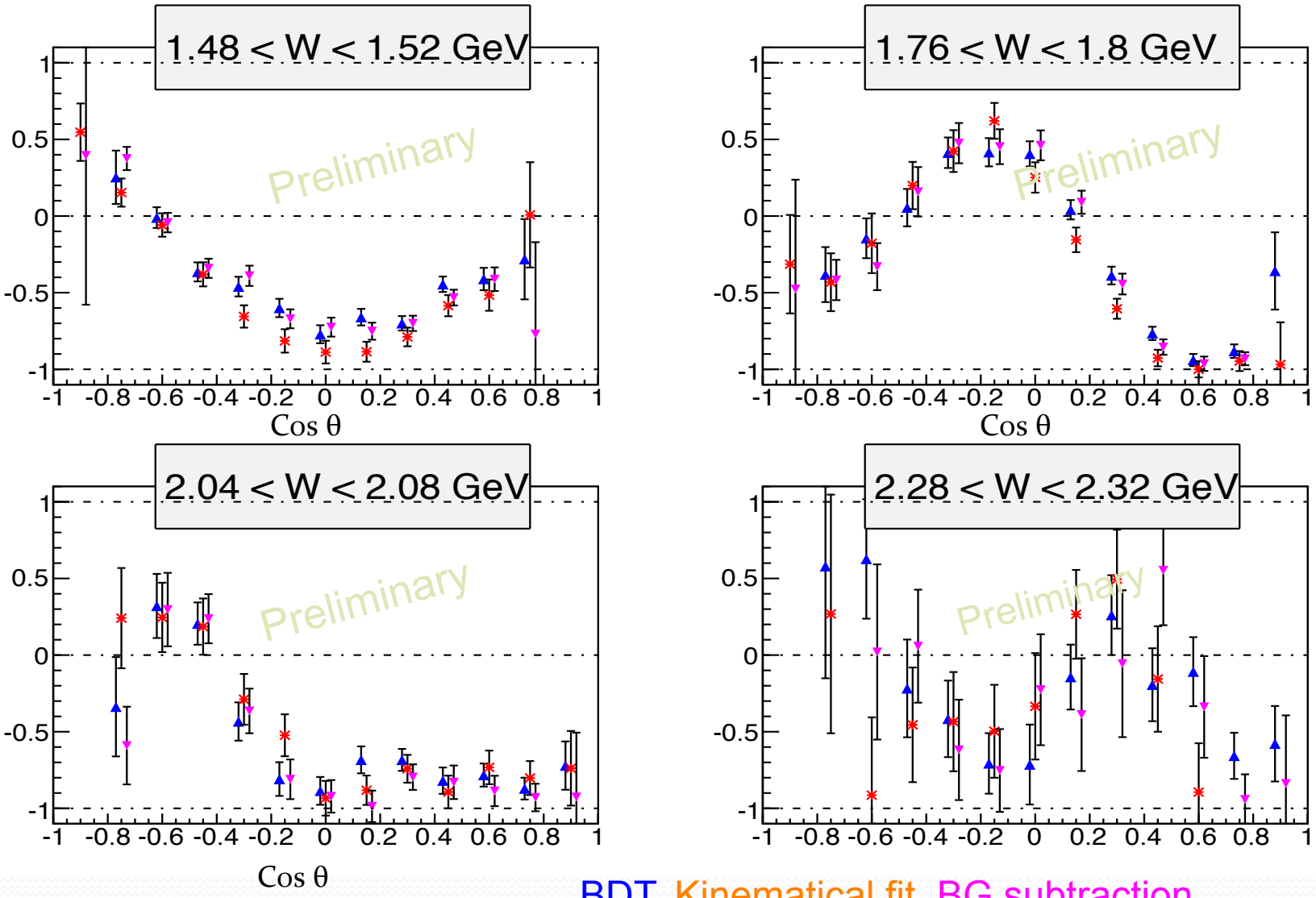
Independent analyses of this E asymmetry with three methods

* Background subtraction (1D-Bsub)
* BDT (Boosted Decision Trees)
* Kinematical fitting

These two methods could be good for low statistics channels.

Compare and combine the results from three analysis methods

4. Preliminary results; E asymmetries from 3 methods for $\gamma + n(p) \rightarrow \pi^- + p(p)$ ($\cos\theta_{CM}$ of π-)

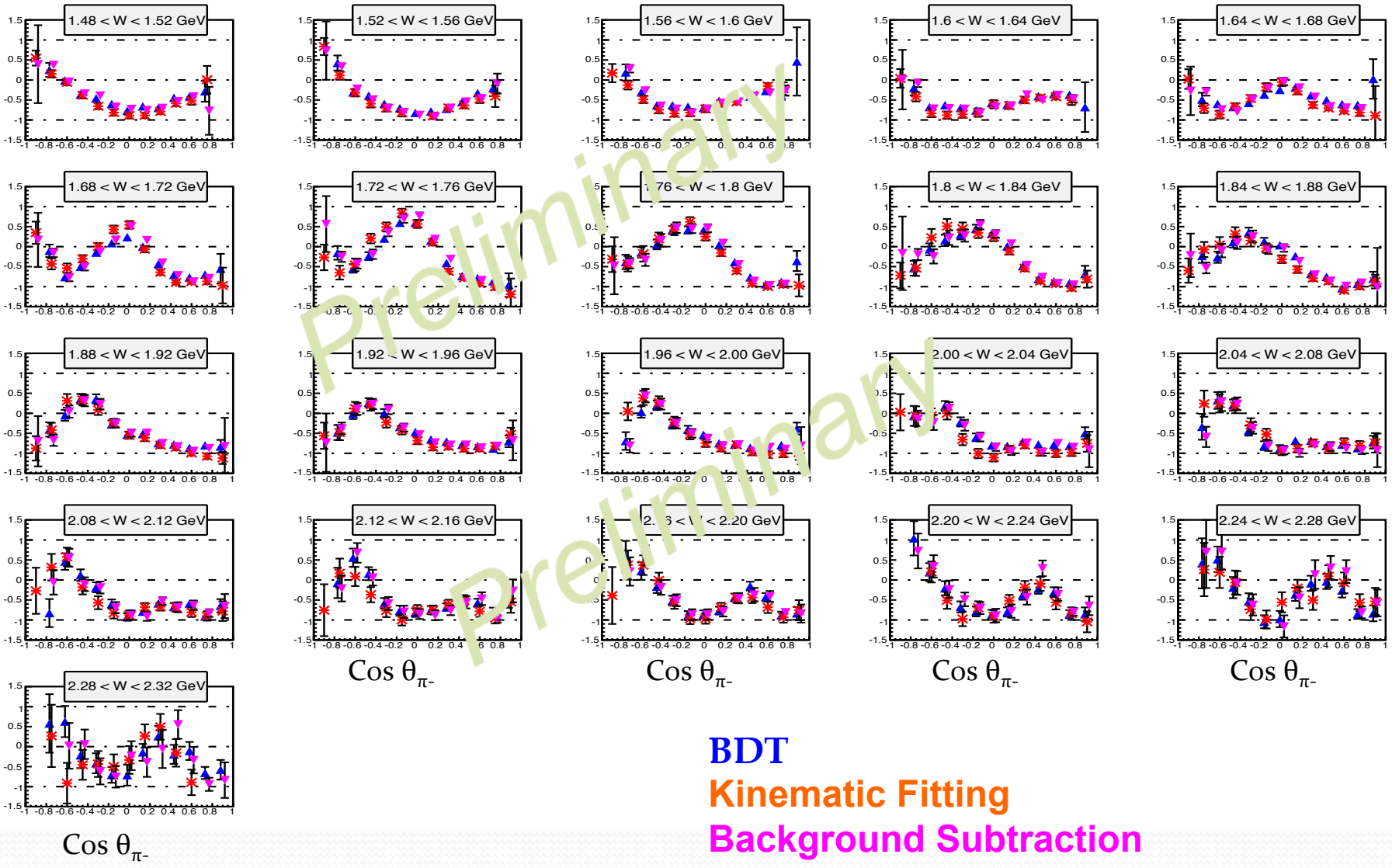


BDT, Kinematical fit, BG subtraction

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

Comparisons of three methods

(as a function of Cos θ_{CM})



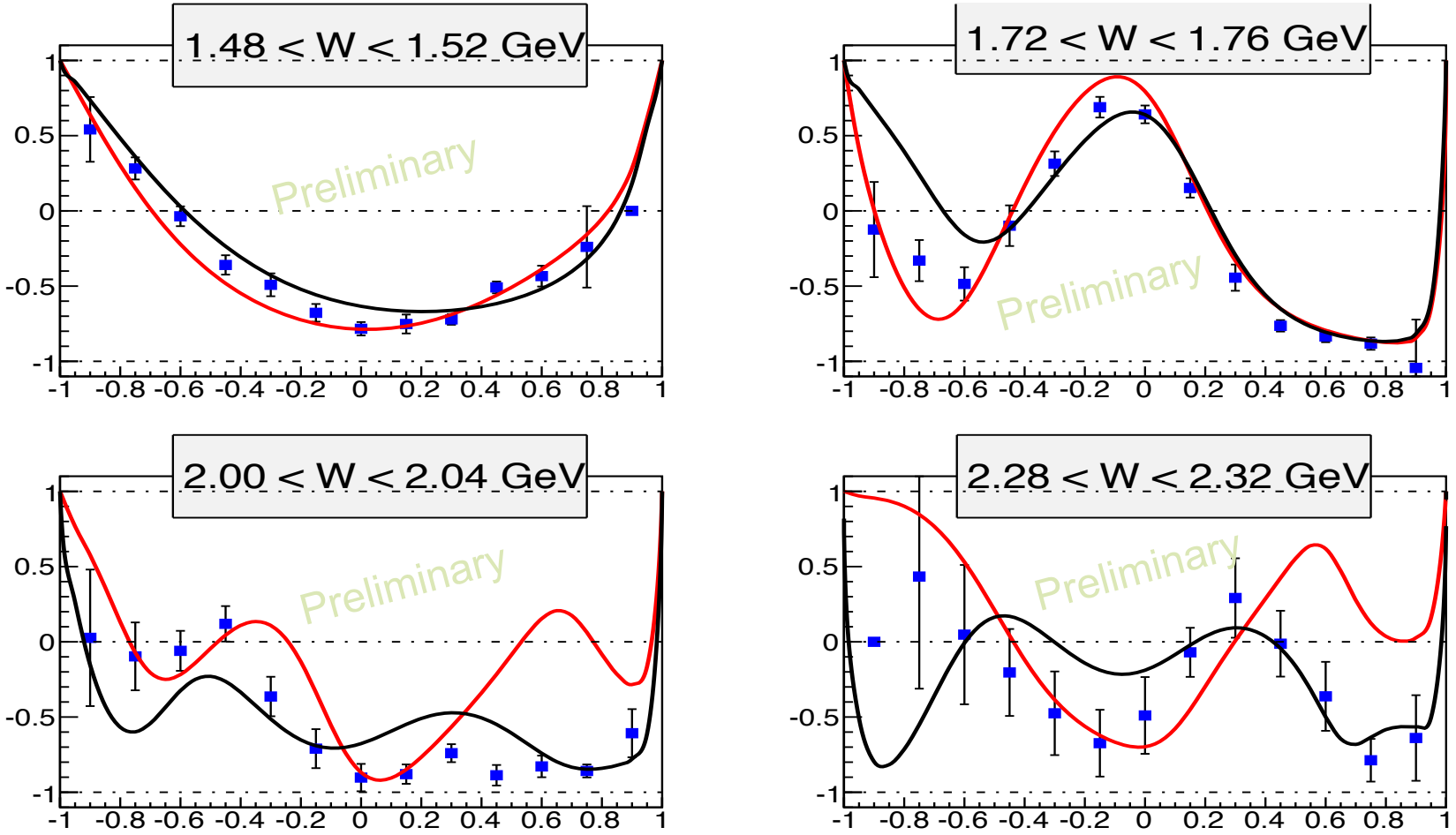
BDT

Kinematic Fitting

Background Subtraction

E asymmetries for combining 3 methods with PWA analysis

for $\gamma + n(p) \rightarrow \pi^- + p(p)$ ($\cos\theta_{CM}$ of π-)



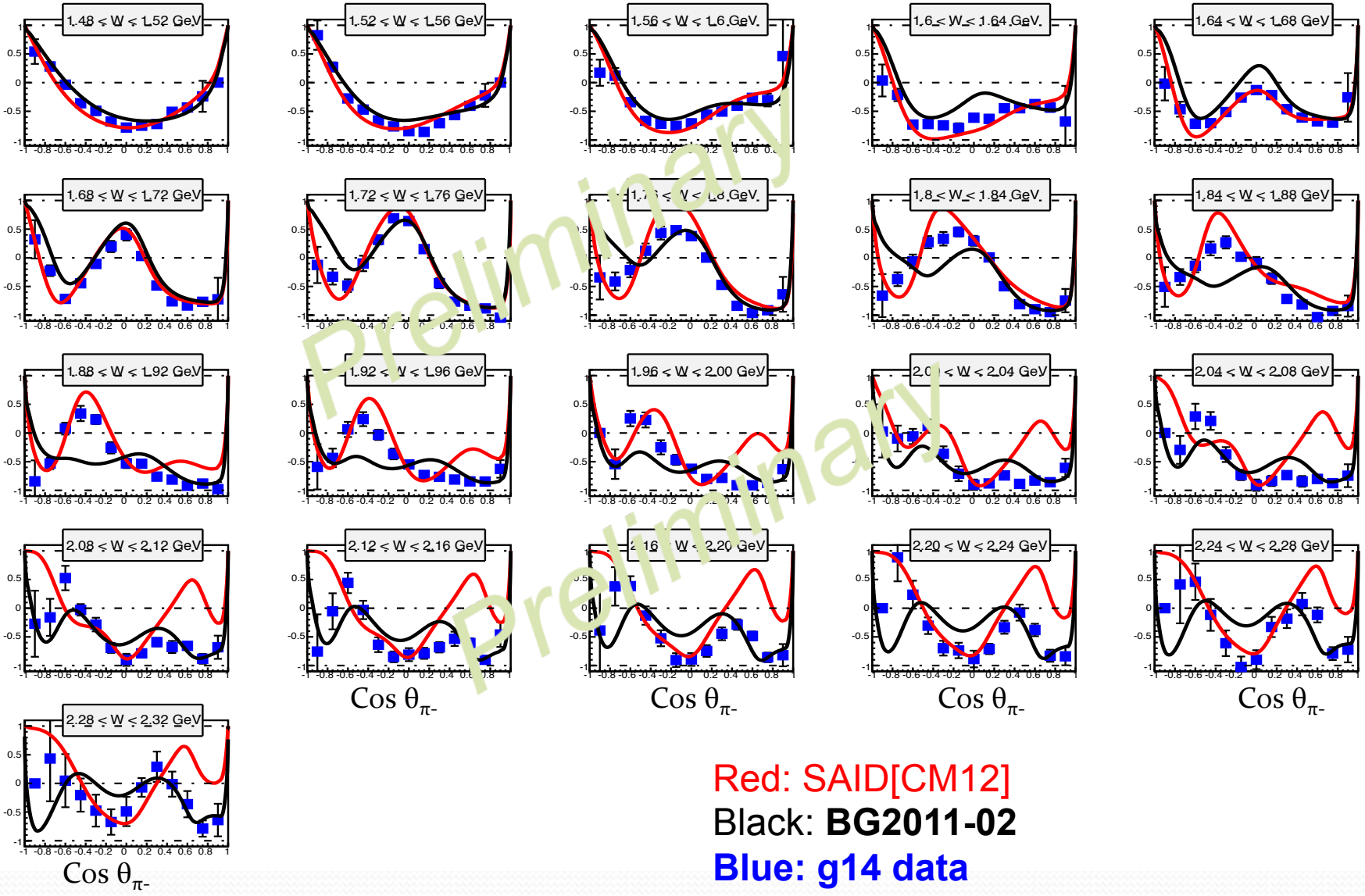
Red: SAID[CM12]

Black: **BG2011-02**

Blue: g14 data

E asymmetries for γ+n (p) → π⁻+ p + (p) (3 methods combined)

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



Red: SAID[CM12]

Black: **BG2011-02**

Blue: g14 data

Combined systematic errors (relative) for the three analysis methods

Contributions to σ_{sys}	σ_{sys}		
	1D-Bsub	kinematic fit	BDT
z-vertex cut / Kel-F suppression:	2.6 %	1.4 %	1.7 %
Confidence level cut / BDT cut:		1.3 %	0.7 %
Missing momentum cut:	1.7 %	2.9 %	1.4 %
PID cut:	1.3 %		
Missing mass cut:	1.4 %		2.6 %
Coplanarity cut:	0.4 %		
Monte Carlo (DC resolution):			0.4 %
Extrapolation to $\lvert p_{missing} \rvert = 0$	2.2 %	2.2 %	2.2 %
σ (cuts)	4.3 %	4.1 %	4.1 %
Photon beam polarization:	3.4 %	3.4 %	3.4 %
Target polarization:	6.0 %	6.0 %	6.0 %
σ (polarization):	6.9 %	6.9 %	6.9 %
σ (total)	8.1 %	8.0 %	8.0 %

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. Preliminary results for E asymmetry for $\gamma + n(p) \rightarrow \pi^- p\,(p)$ were shown. Systematic errors are estimated.

c. Study of Σ and G asymmetries for $\gamma + n(p) \rightarrow \pi^- p\,(p)$ is ongoing

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.

Backup slides

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

3. Experimental conditions and data reduction

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* 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 %)

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

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