

Spin observable measurements in pseudo
scalar-meson polarized photo-production
using polarized neutrons in solid HD

@NSTAR2013

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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

Polarization observables in γn (p) \rightarrow photo-production :

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

This talk \nearrow

Full set of 16

status	CLAS run period	beam	target
complete	g13	$\vec{\gamma}_L, \vec{\gamma}_c$	LD ₂
complete	g14	$\vec{\gamma}_L, \vec{\gamma}_c$	HDice (Longitudinally polarized)

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

Pseudoscalar meson reactions and observables measured in this experiment

<i>reaction</i>	<i>observable</i>
$\gamma + n(p) \rightarrow \pi^- p(p)$	$\sigma_0, \Sigma, \mathbf{E}, G$
$\gamma + n(p) \rightarrow \pi^+ \pi^- n(p)$	$\sigma_0, I^c(\Sigma), I^s, I^o, P_z,$ $P_z^o(E), P_z^s(G), P_z^c$
$\gamma + n(p) \rightarrow K^0 \Lambda(p)$	σ_0, Σ, E, G $O_{x'}, O_{z'}, C_{x'}, C_{z'}, P, T=(-O_{y'})$ $L_{x'}, L_{z'}, T_{x'}, T_{z'}$
$\gamma + n(p) \rightarrow K^0 \Sigma^0(p)$	$\sigma_0, \Sigma, P, E, G$
$\gamma + n(p) \rightarrow K^+ \Sigma^-(p)$	σ_0, Σ, E, G

From proposal E06-101

2. Experimental apparatus

Circularly and linearly polarized photon beams

CLAS detectors and electron tagging system

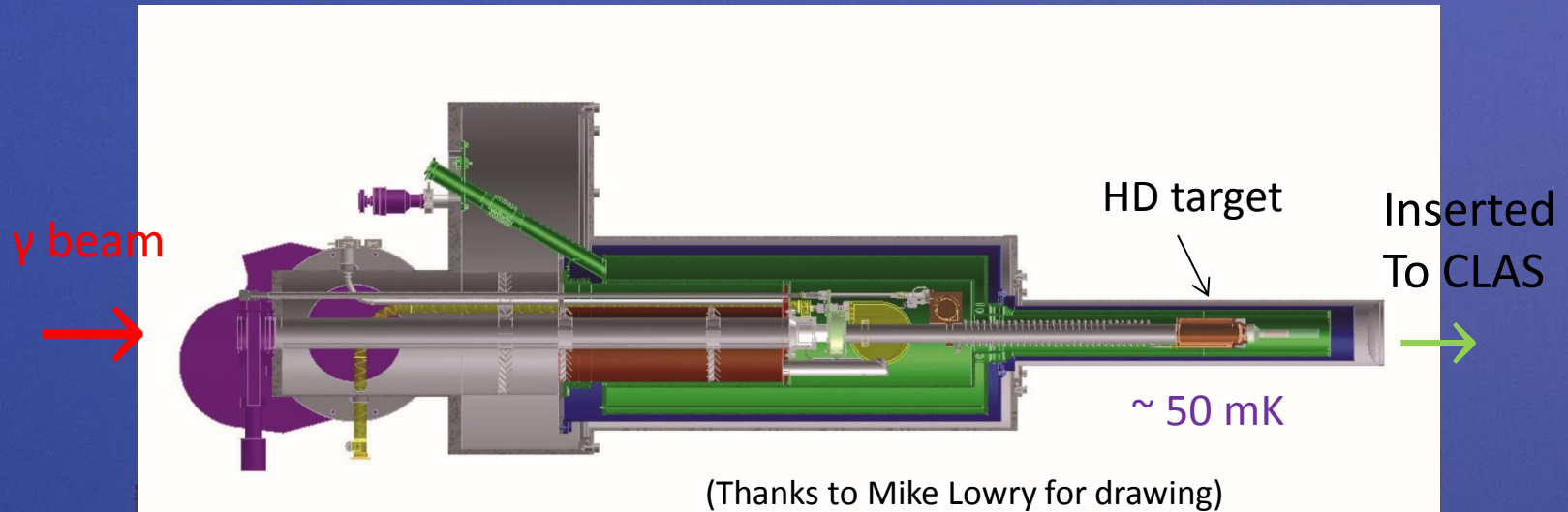
Polarized neutron target (Solid HD) : newly installed



New longitudinally polarized target for this experiment

Frozen Spin Polarized solid HD target

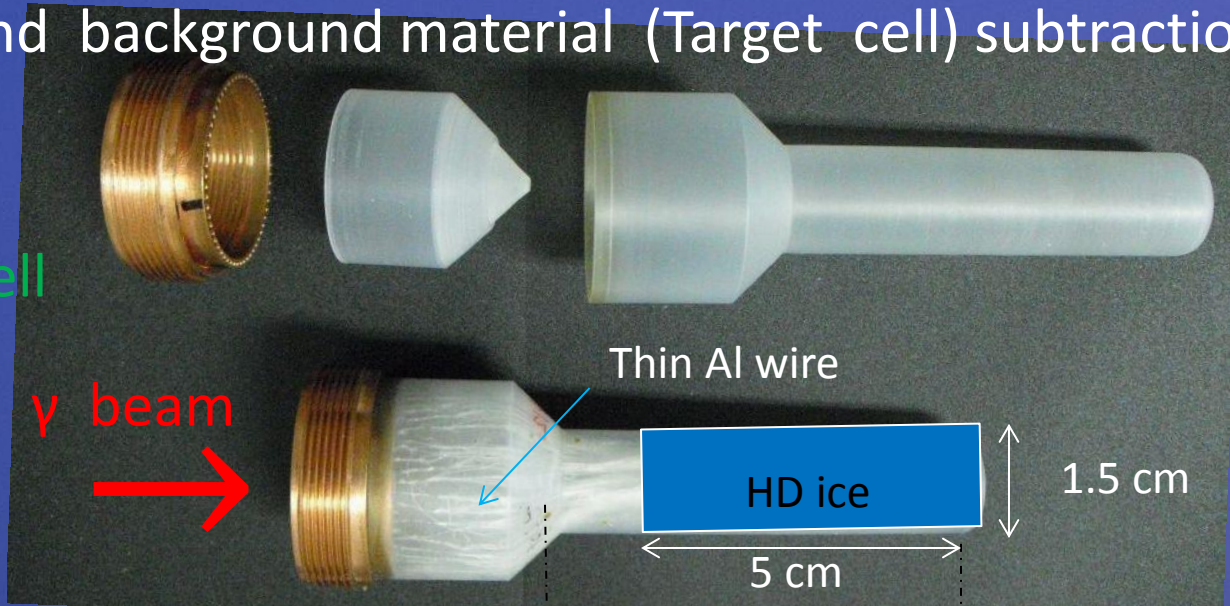
Relaxation time > 1 year @ ~ 50 mK and 0.9 Tesla



- * 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

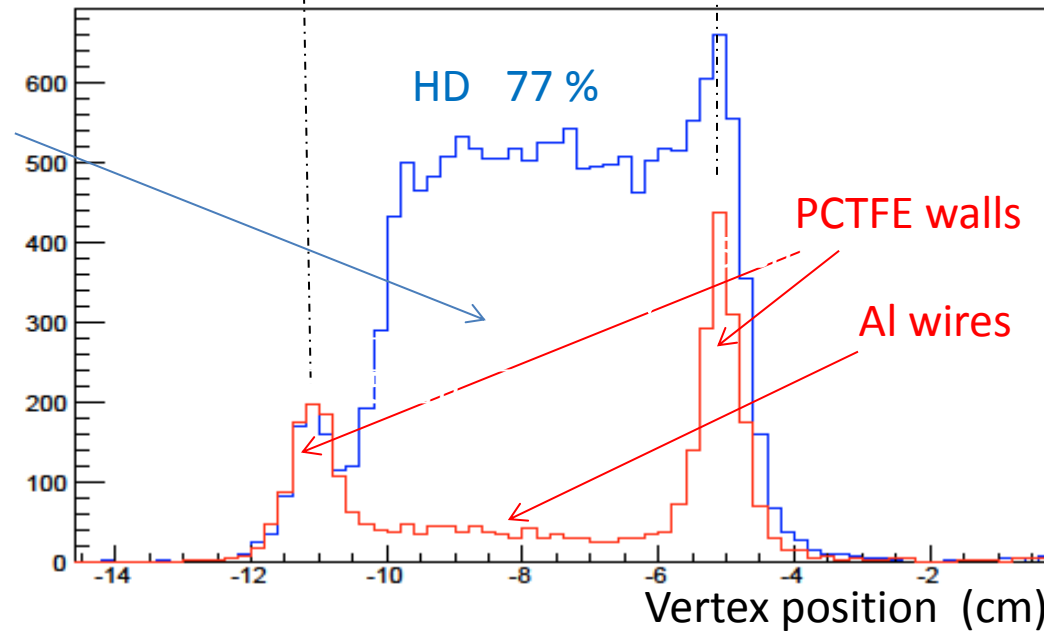
Target and background material (Target cell) subtraction

Target Cell



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

HD and target cell



3. Running conditions and Preliminary results

Triggers

* 1 charged: $\gamma + p \rightarrow \pi^+ + X$

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

* 2 charged: $\gamma + n(p) \rightarrow \pi^- + p + X(0, \pi^0, \dots)$

g14 experiments: Dec. 2011 – May. 2012

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

\vec{D} : 27 days \rightarrow 4.5 B events

\overleftarrow{D} : 37 days \rightarrow 6.1 B events

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

\vec{D} : 21 days \rightarrow 2.5 B events

\overleftarrow{D} : 9 days \rightarrow 1.2 B events

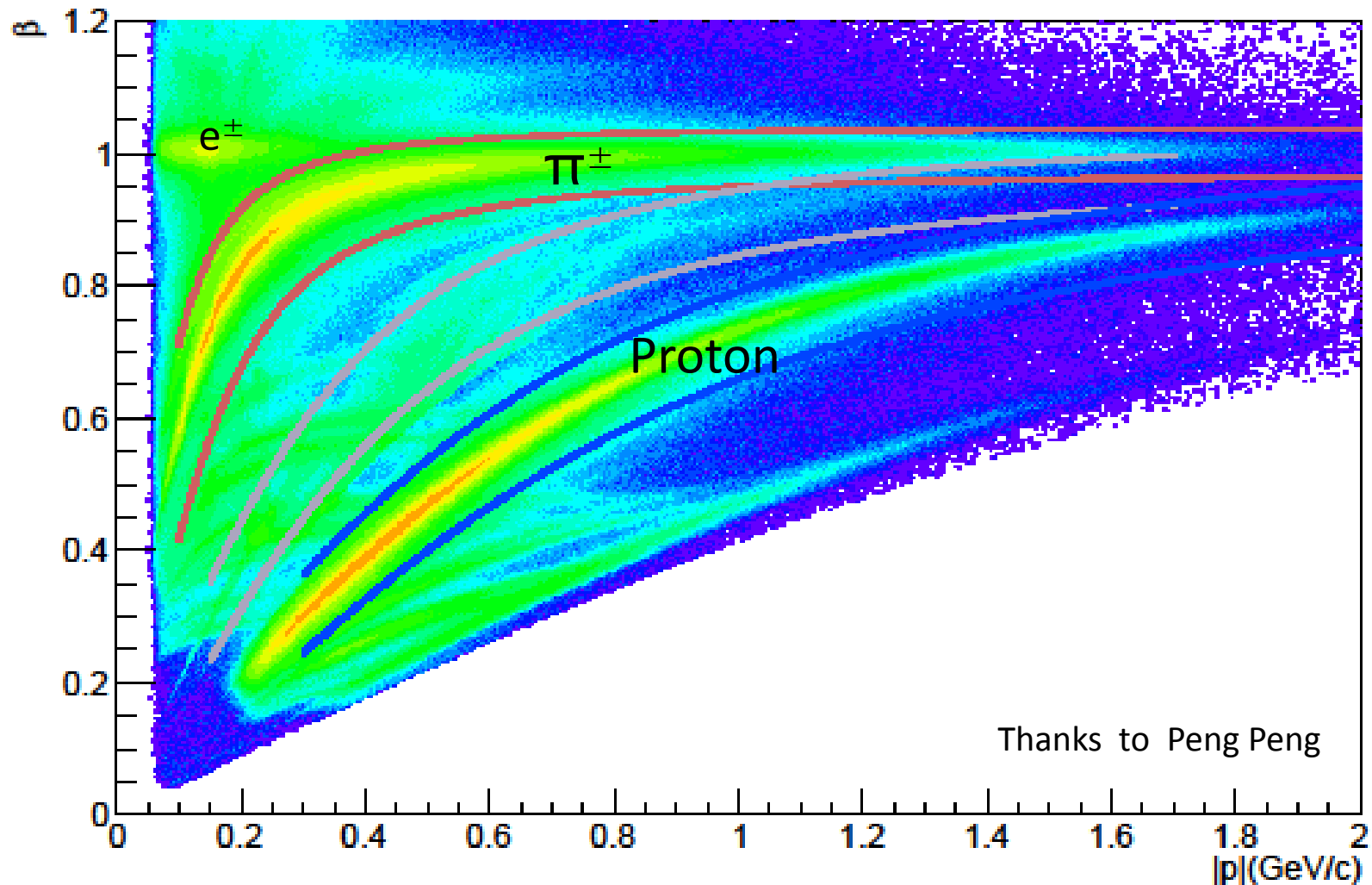
Data reductions for $\gamma + n(p) \rightarrow \pi^- + p(p)$

- (a) Only π^- and Proton detected in CLAS
- (b) Coplanarity cut
- (c) Cut for Missing mass squared
- (d) Missing momentum cut
- (e) Target Cell subtraction and vertex cut



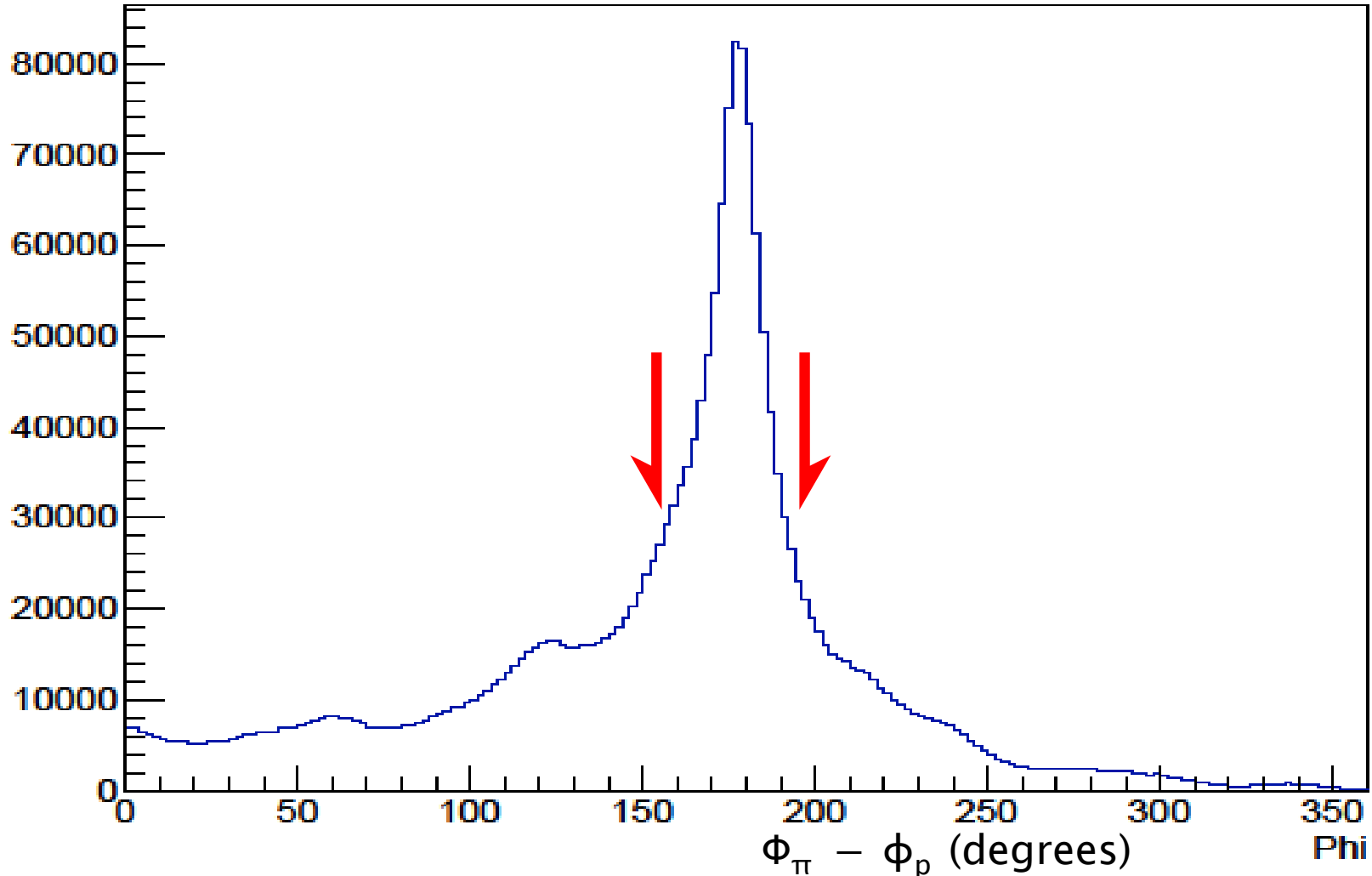
(a) Select events; only π^- and Proton detected in CLAS

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



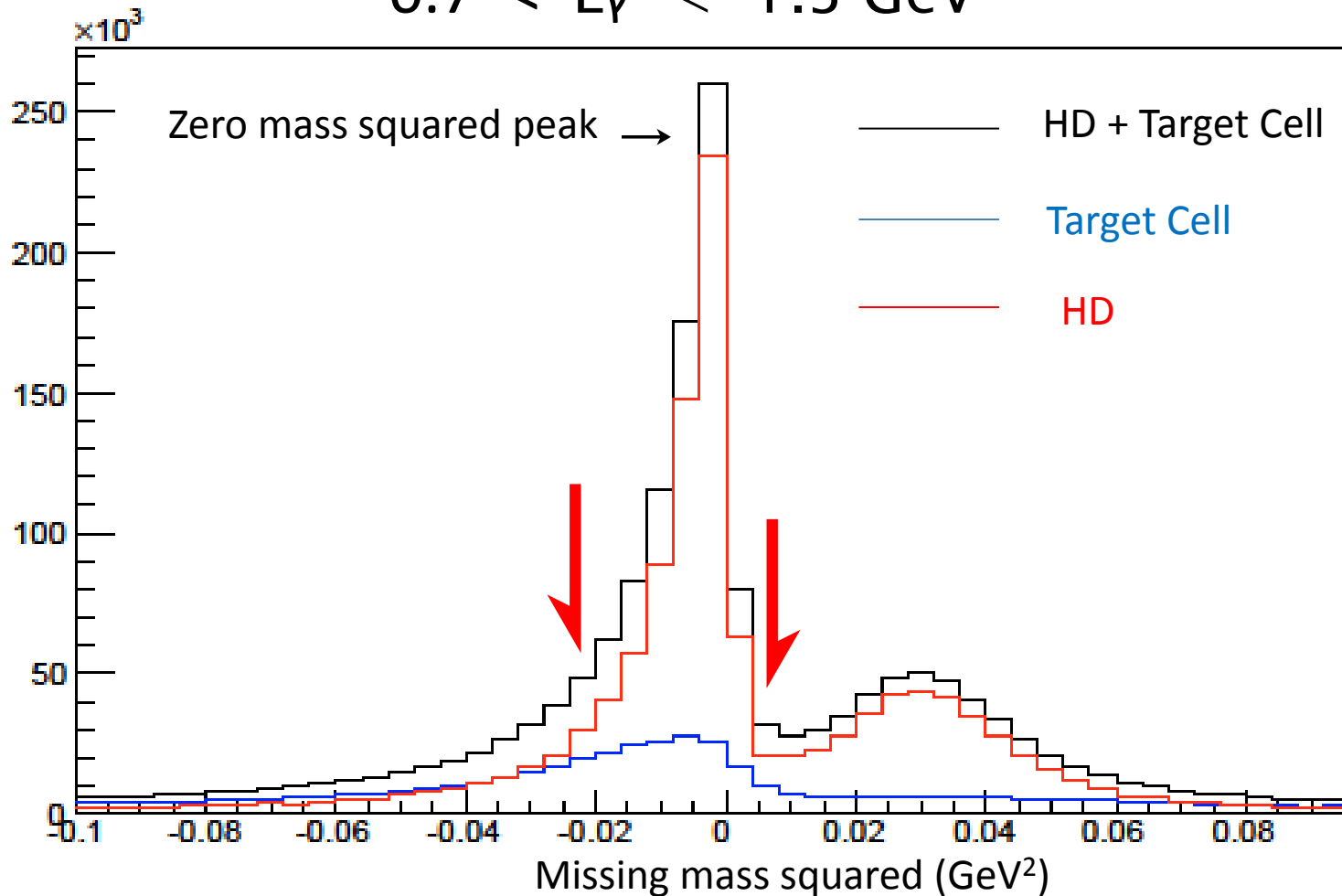
(b) $\phi_{\pi^-} - \phi_p$ distribution and coplanarity cut for π^- and proton

$0.7 < E_\gamma < 1.3 \text{ GeV}$



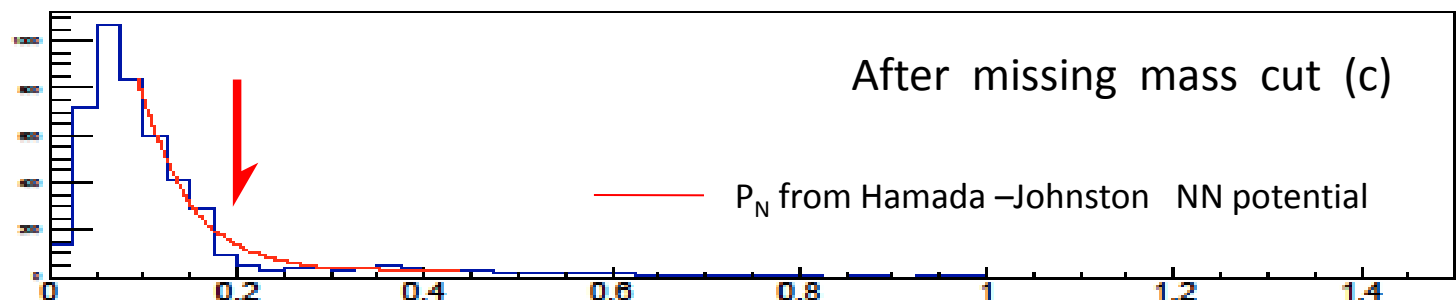
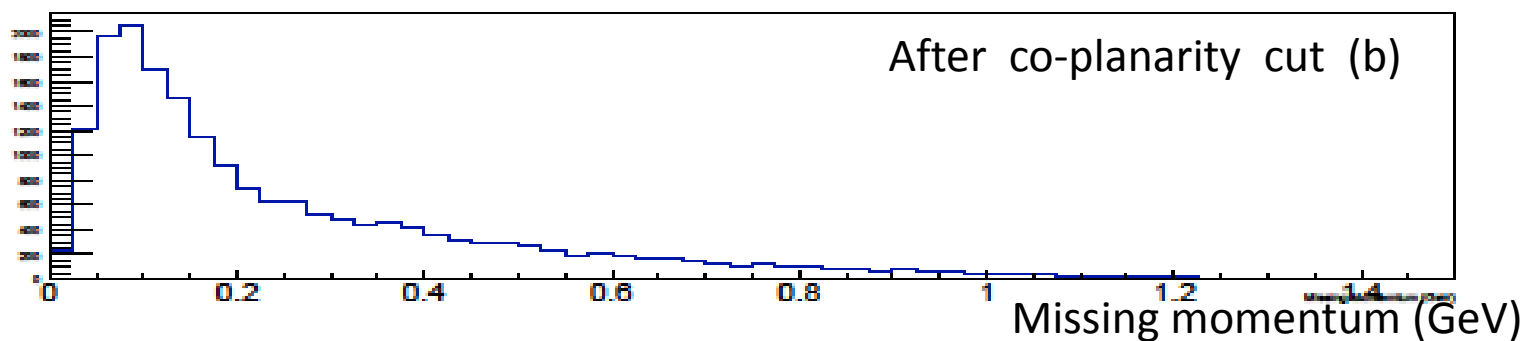
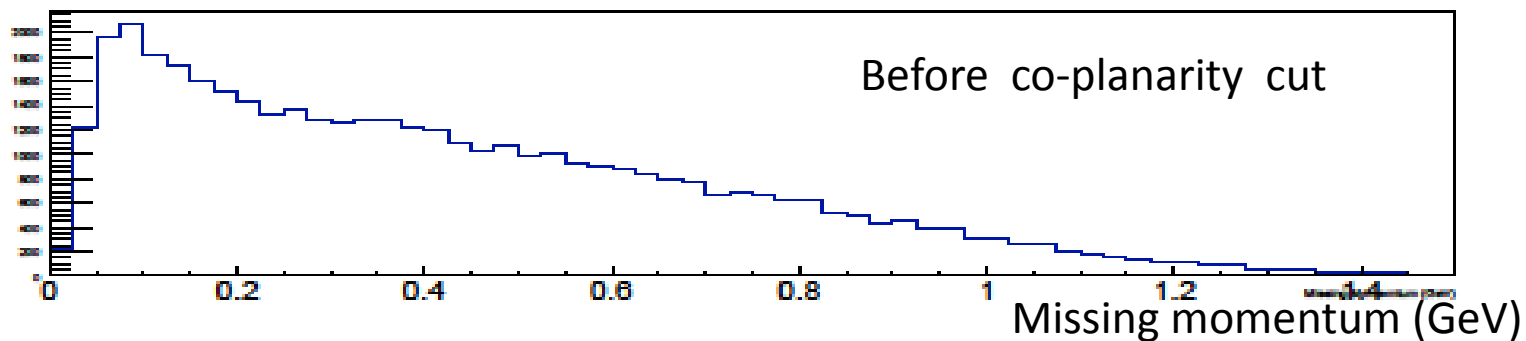
(c) Missing mass squared distribution for $\gamma + n(p) \rightarrow \pi^- + p + X$ and cut; selection of quasi-free neutrons

$0.7 < E_\gamma < 1.3 \text{ GeV}$



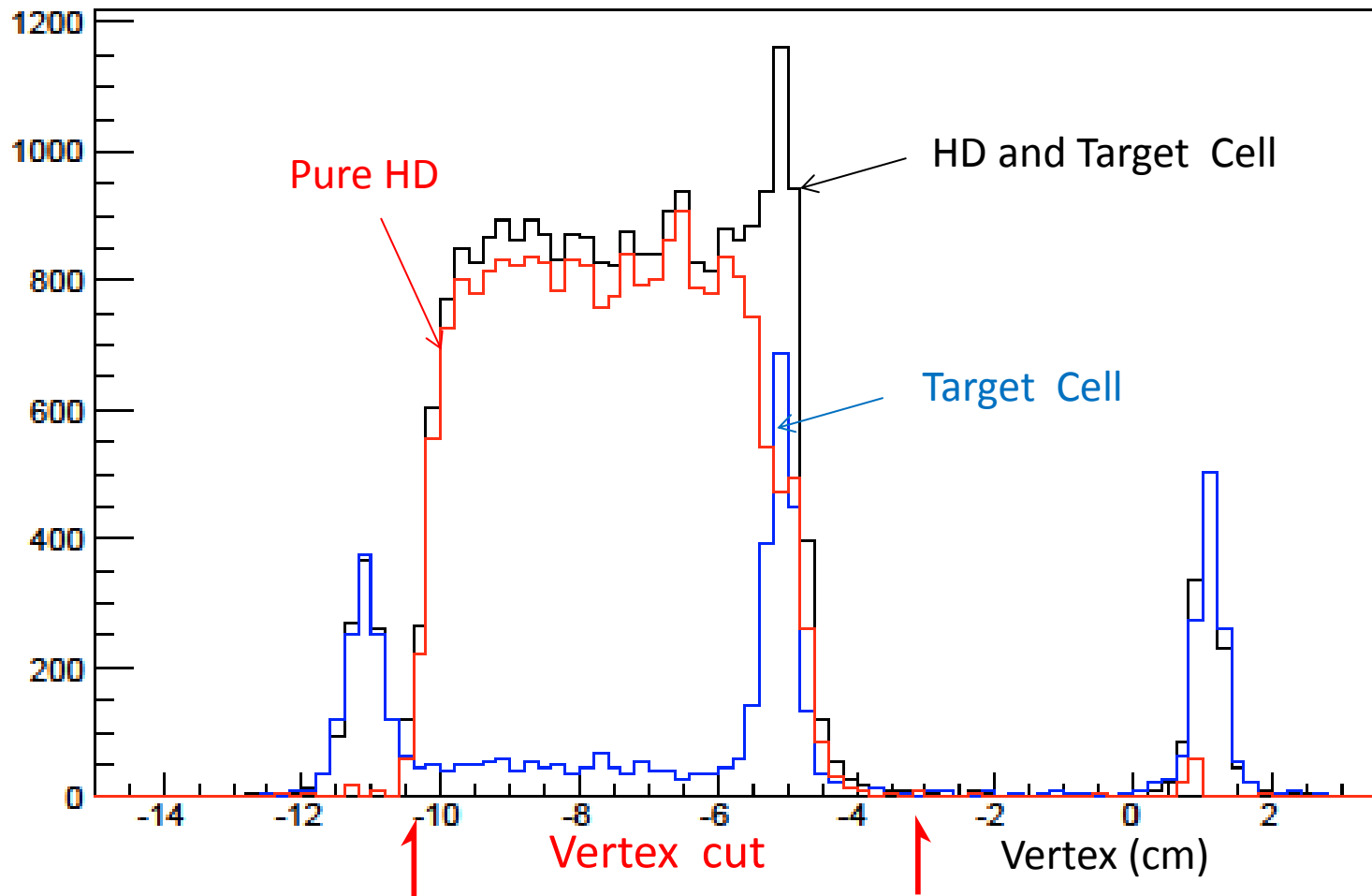
(d) Missing momentum distribution for $\gamma + n(p) \rightarrow \pi^- + p + X$; selection of quasi-free neutrons

$$0.7 < E_\gamma < 1.3 \text{ GeV}$$



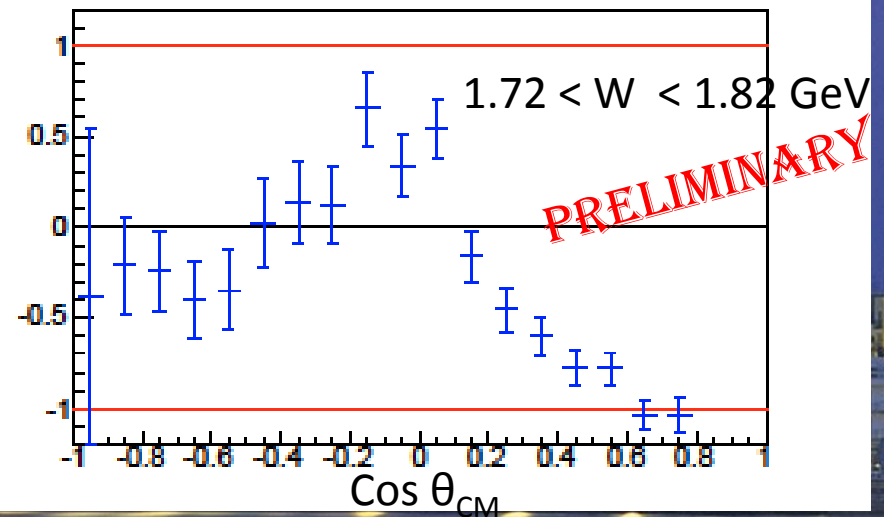
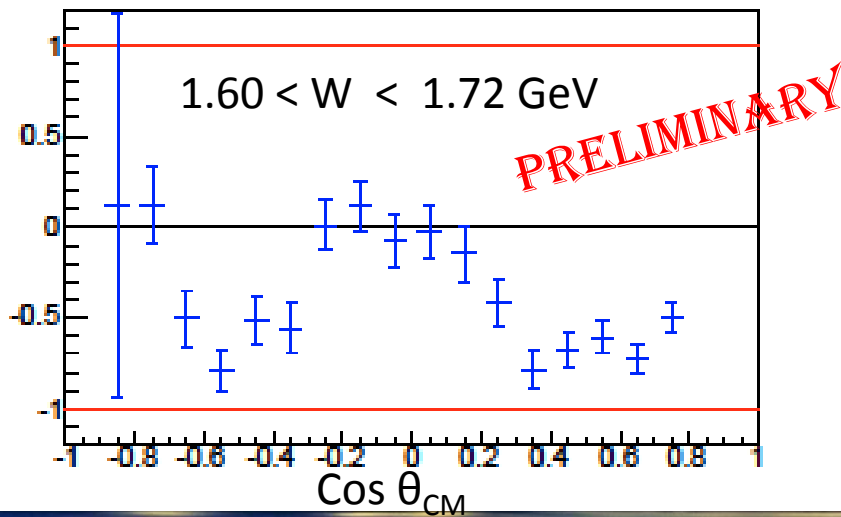
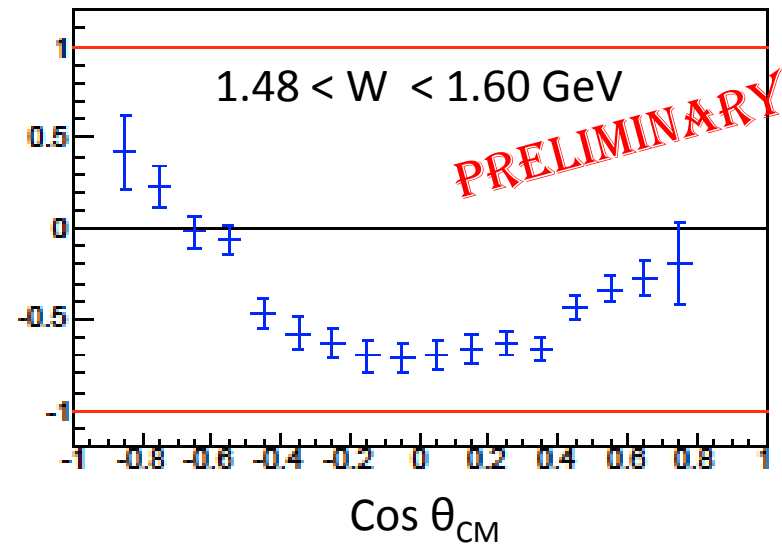
(e) Target Cell subtraction and vertex cut

Reconstructed vertex along beam axis for spin parallel



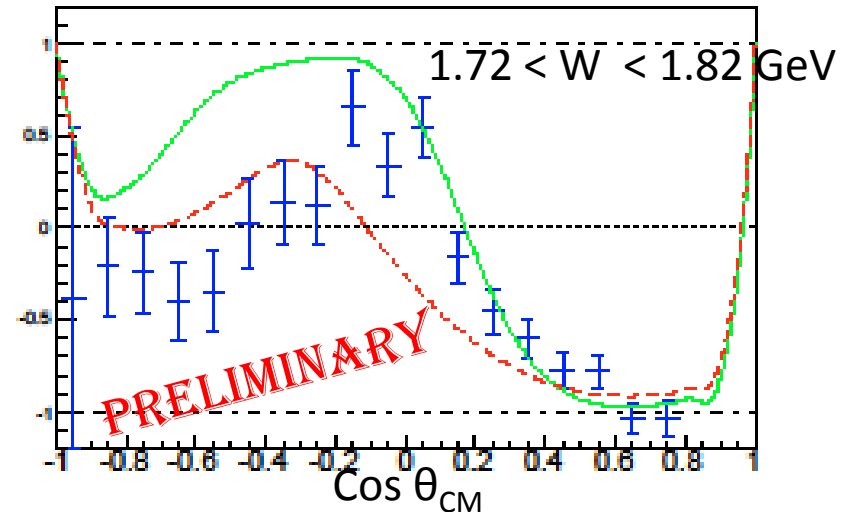
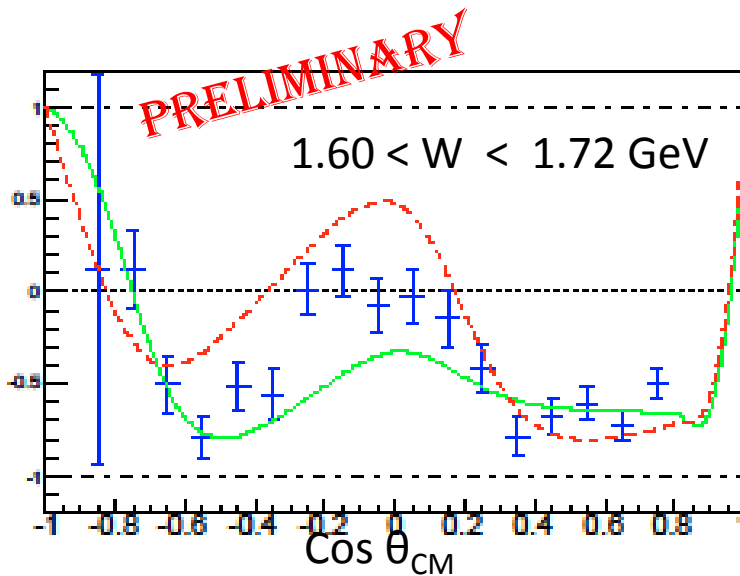
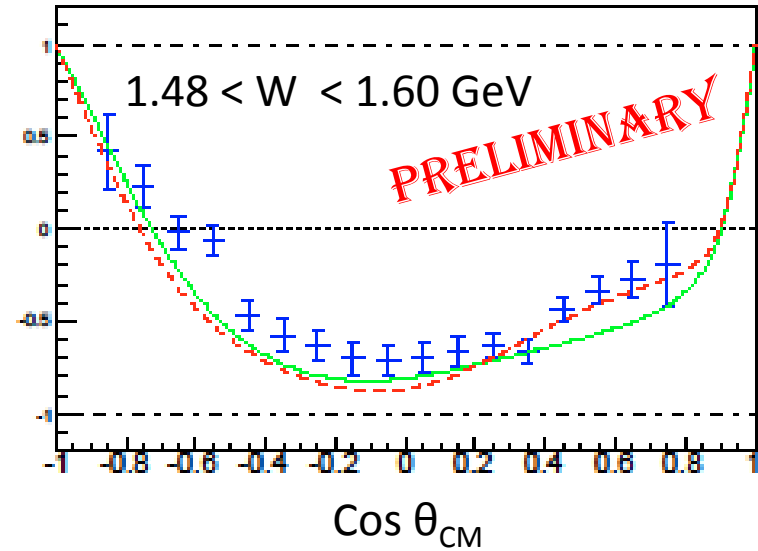
Preliminary E asymmetries for $\gamma + n (p) \rightarrow \pi^- + p$

- All cuts applied
- Use $\sim 10\%$ of Data
- $P_D \sim 26.5\%$



Preliminary E asymmetries for $\gamma + n(p) \rightarrow \pi^- + p$

— SAID (SN11)
- - - MAID



4. Summary

- a. Completed experiments for pseudoscalar-meson photo-production from longitudinally polarized HD at CLAS.
- b. The experiment was done for 64 days of circularly and 30 days of linearly polarized photon beams.
- c. Average target D polarization during the experiments have been estimated to be $\sim 20\%$.
- d. Analyses for target polarizations have been ongoing.
- e. Calibrations for experimental data have been carried out. Some preliminary asymmetries are shown.
- f. Analyses for other channels, like $\gamma + n(p) \rightarrow n \pi^+ \pi^- (p)$ are ongoing.

The Hall B tool set: CEBAF Large Acceptance Spectrometer

Torus magnet
6 superconducting coils

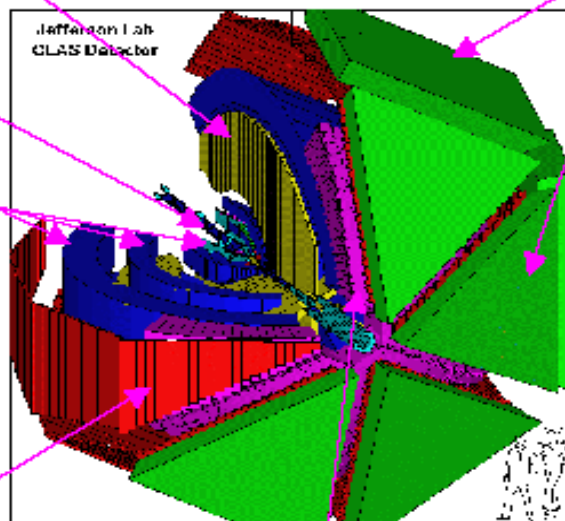
Electromagnetic calorimeters
Lead/scintillator, 1296 photomultipliers

**polarized target +
start counter**

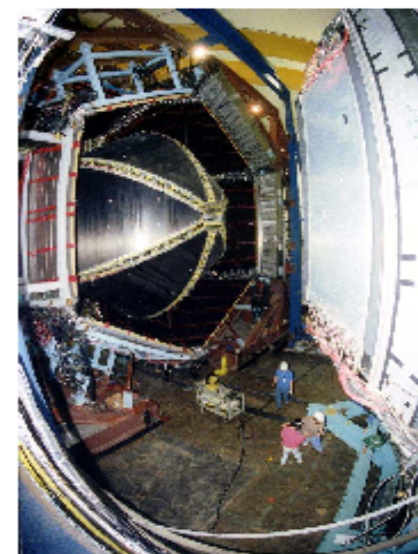
Drift chambers
argon/ CO_2 gas, 35,000 cells



Time-of-flight counters
plastic scintillators, 684 photomultipliers



Gas Cherenkov counters
 e/π separation, 256 PMTs



DAQ limit \sim 6kHz (\sim 1.5TB/day)

CLAS side view

