Studies of Deeply Exclusive Processes with a Longitudinally Polarized NH_3 Target

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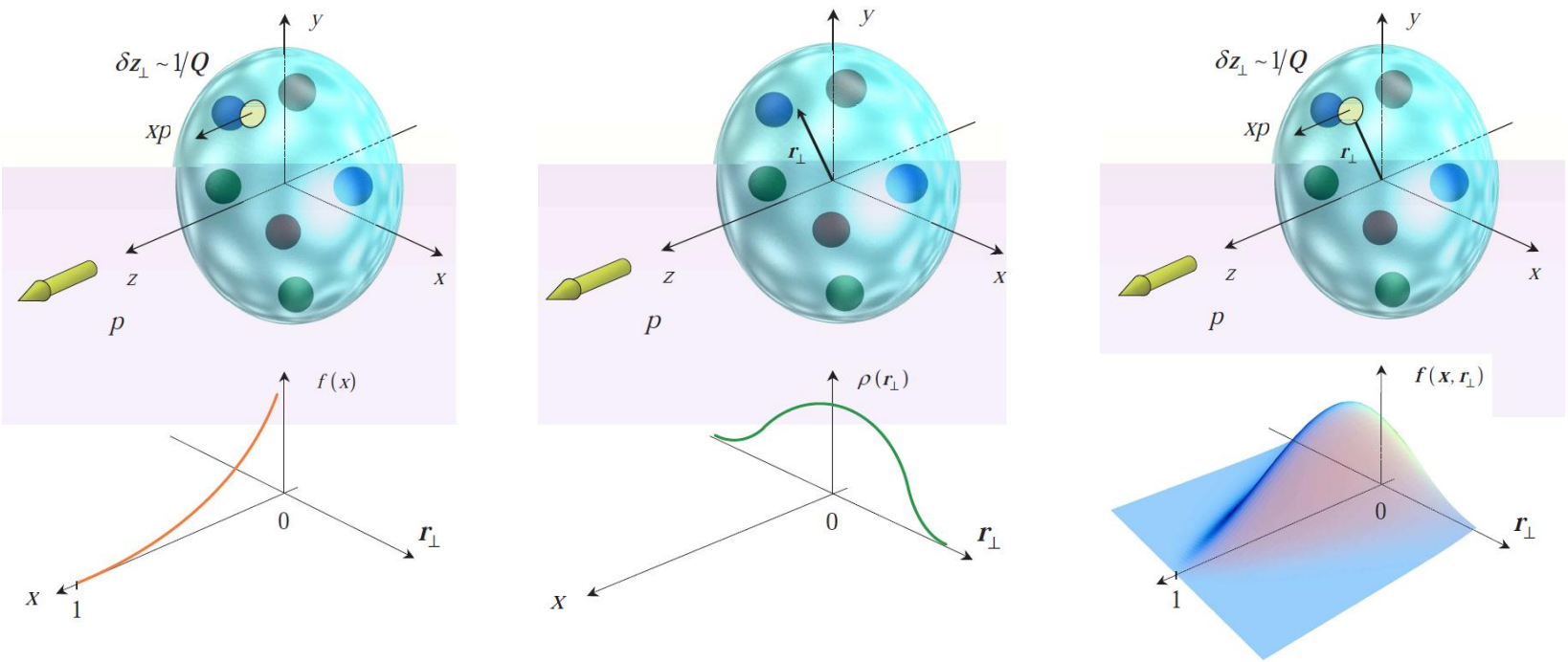
Outline

- GPDs and Deeply Exclusive Processes
- eg1-DVCS Experiment
- Particle Identification and Exclusivity Cuts
- Kinematic Coverage
- Target Single Spin Asymmetry
- Future plans

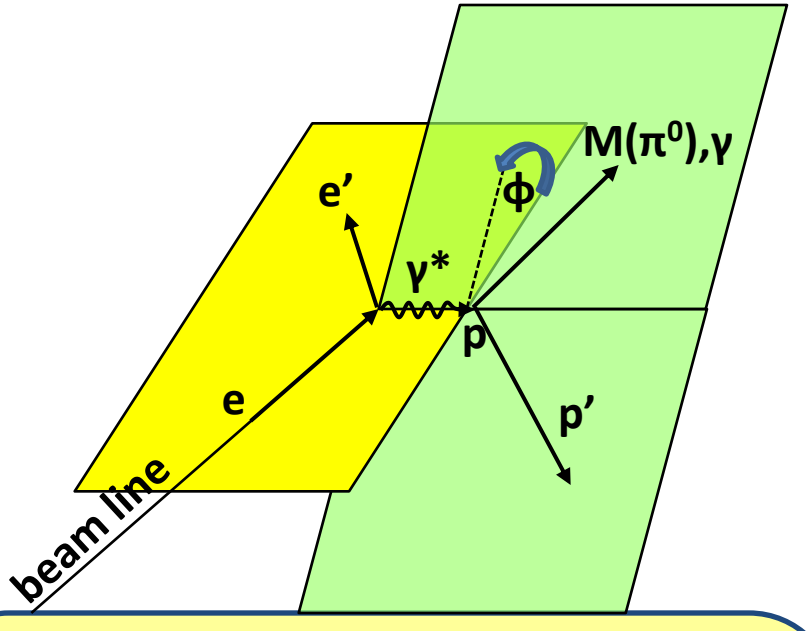
Generalized Parton Distributions

Image from: A.V. Belitsky, A.V. Radyushkin, Phys.Rept.418:1-387,2005



Probabilistic interpretation of form factors, parton densities and generalized parton distributions at η=0 in the infinite momentum frame $p_z \to \infty$

GPDs and Deeply Exclusive Processes



➢ **large Q^2**

GPDs depend on 3 variables:

X represents average momentum fraction carried by the struck quark in the quark loop

ξ – longitudinal fraction of the 4-momentum transfer Δ

t – transverse momentum transfer

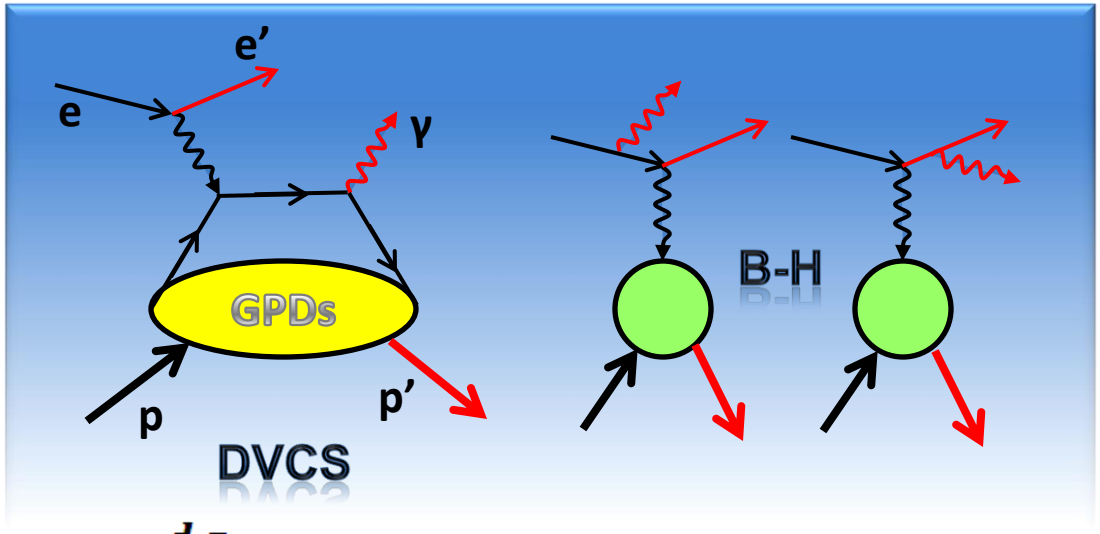
$$q = e - e' = (\nu, \vec{q}) \qquad W = \sqrt{(p+q)^2}$$

$$Q^2 = -q^2 \qquad \Delta = p' - p$$

$$x_B = \frac{Q^2}{2m\nu} \qquad t = \Delta^2$$

$$\xi = \frac{Q^2 - M_{ll'}^2 + \frac{\Delta^2}{2}}{\frac{2Q^2}{x_B} - Q^2 - M_{ll'}^2 + \Delta^2} \xrightarrow{Q^2 >> 1} \xi \approx \frac{x_B}{2 - x_B}$$

Deeply Virtual Compton Scattering



$$\frac{d\sigma}{dx_B dQ^2 dt d\phi} \sim |T|^2 = |T_{BH} + T_{DVCS}|^2$$

$$= |T_{BH}|^2 + |T_{DVCS}|^2 + T_{DVCS}T^*_{BH} + T^*_{DVCS}T_{BH}$$

$$A_{LU} \sim \Im m\left\{F_1\mathcal{H} + \xi(F_1+F_2)\tilde{\mathcal{H}} - \frac{\Delta^2}{4M^2}F_2\mathcal{E}\right\}\sin\phi$$

Suppressed at the CLAS kinematics

$$A_{UL} = \Im m\left\{F_1\tilde{\mathcal{H}} + \xi(F_1+F_2)\left(\mathcal{H} - \frac{x_B}{2}\mathcal{E}\right) - \xi\left(\frac{x_B}{2}F_1 + \frac{\Delta^2}{4M^2}F_2\right)\tilde{\mathcal{E}}\right\}\sin\phi$$

BH-DVCS Interference

↓

Beam and Target Spin Asymmetries

↓

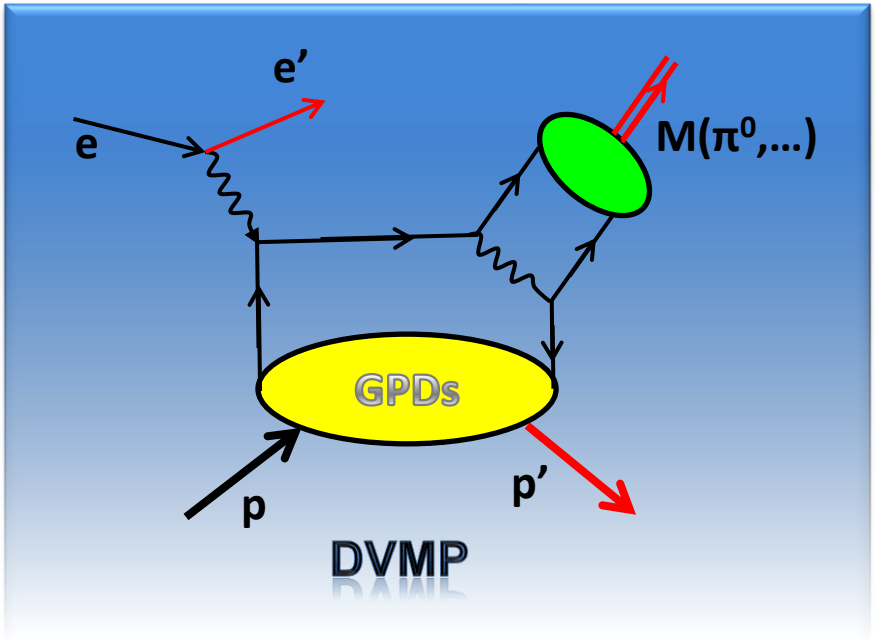
Access to GPDs functions

e.g. for longitudinally polarized target:

$$d\sigma = d\sigma_{UNP} + d\sigma_{LP}(\Lambda)$$

where Λ =±1 - target helicity

Deeply Virtual Meson Production



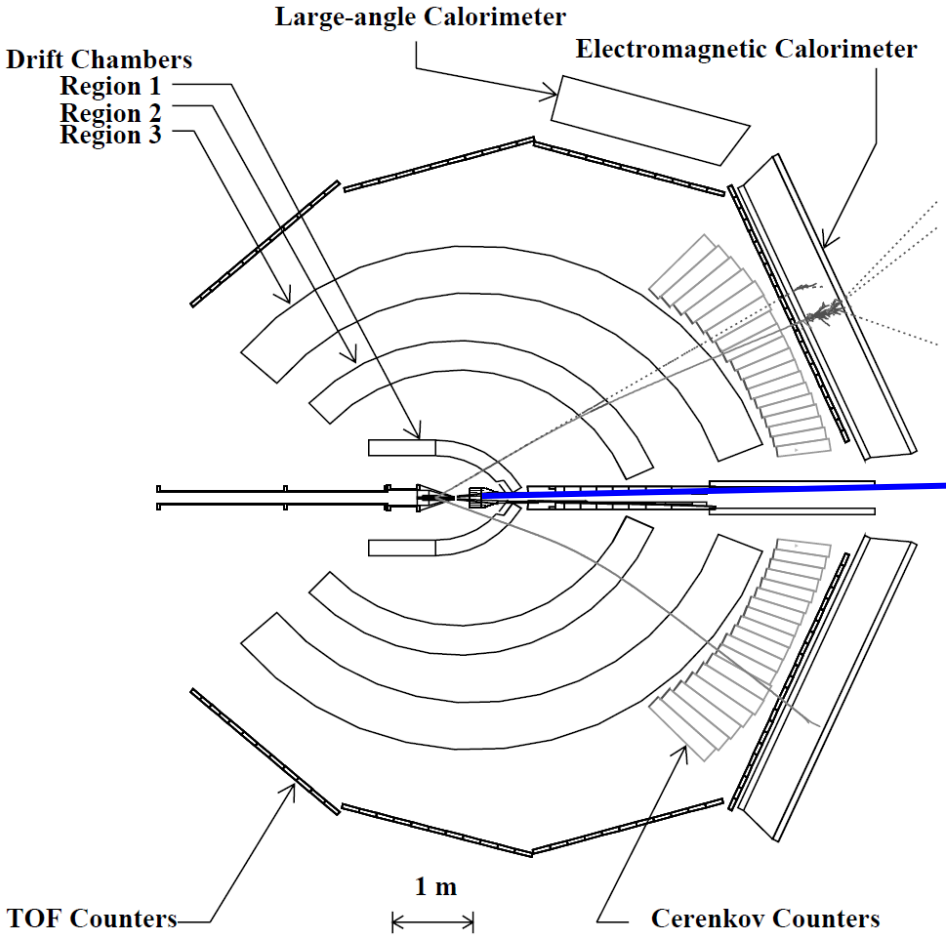
Production of pseudoscalar mesons (π^0,…)

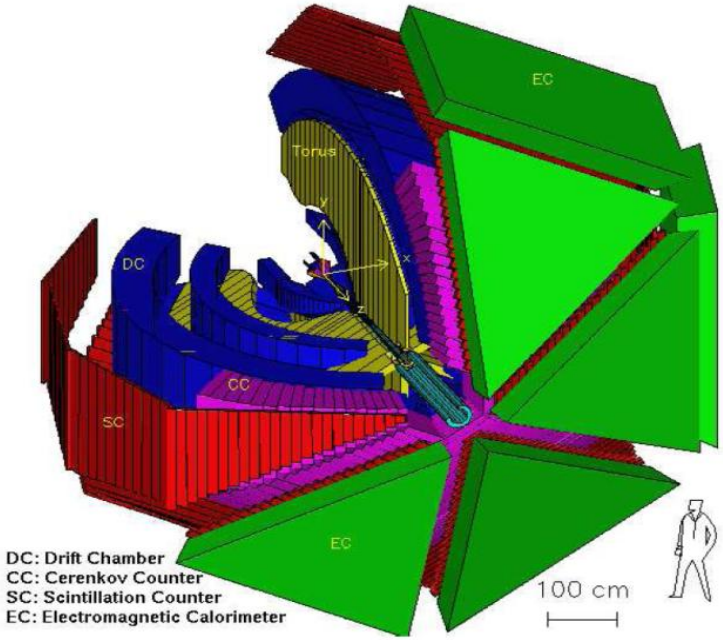
Access to spin dependent GPD functions $\tilde{H}$, $\tilde{E}$ in the Bjorken regime

Quark flavor filter of GPD

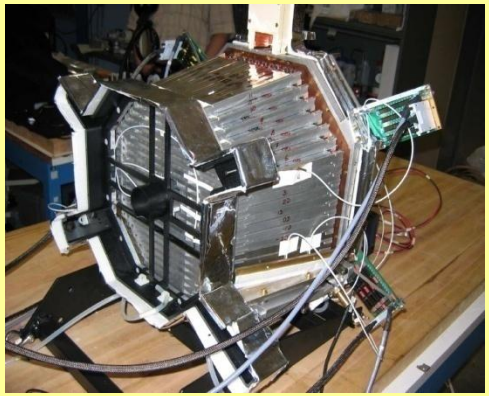
Deeply Exclusive Processes in CLAS

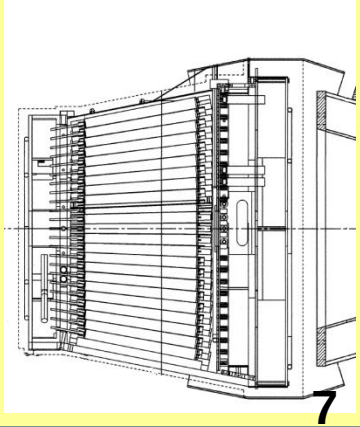
- ✓electron detection - EC, DC, CC
- ✓proton detection – SC, DC
- ✓photons detection – EC, IC





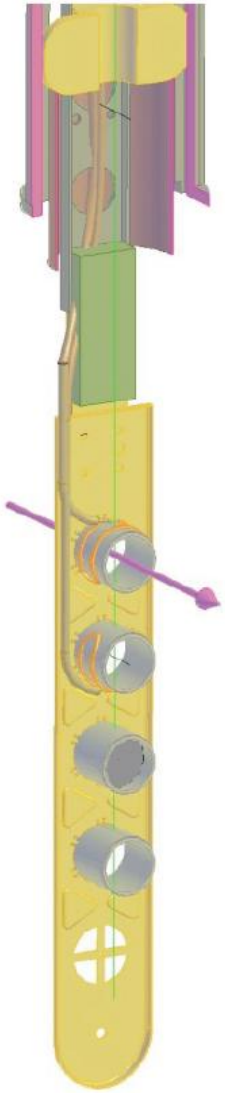
Inner Calorimeter

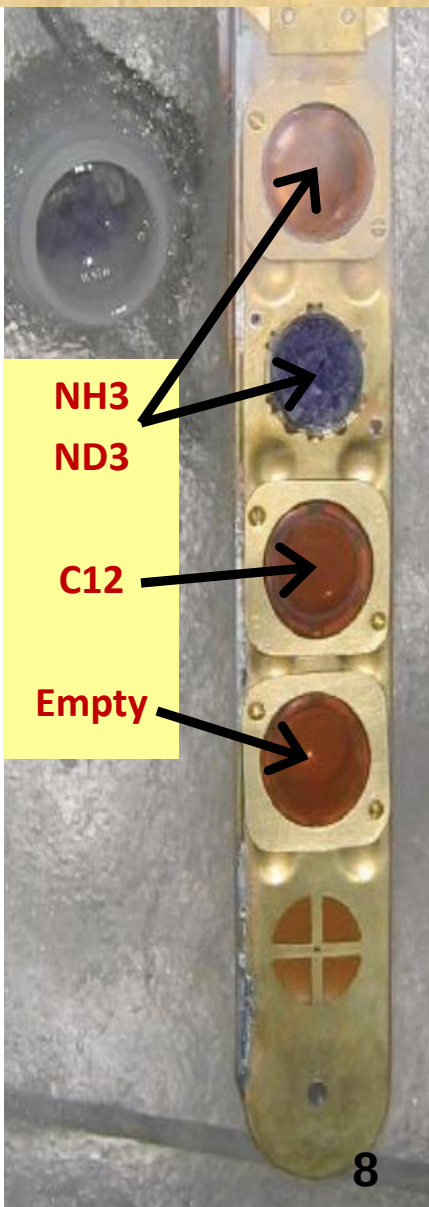




eg1-DVCS Experiment

- Data collected between February to September 2009
- High polarized electron beam (>80%)
- Longitudinally polarized targets NH_3 and ND_3 with average polarization ~80% for NH_3 and ~25% for ND_3
- Target polarization is monitored by Nuclear Magnetic Resonance (NMR) System
- Runs with ^{12}C target for background evaluation





eg1-DVCS Experiment

Part A, B and C

- Hydrogen target
- Beam energy:
  - 5.892 GeV
  - 4.735 GeV
- Luminosity:
  - 22.7 fb^{-1}

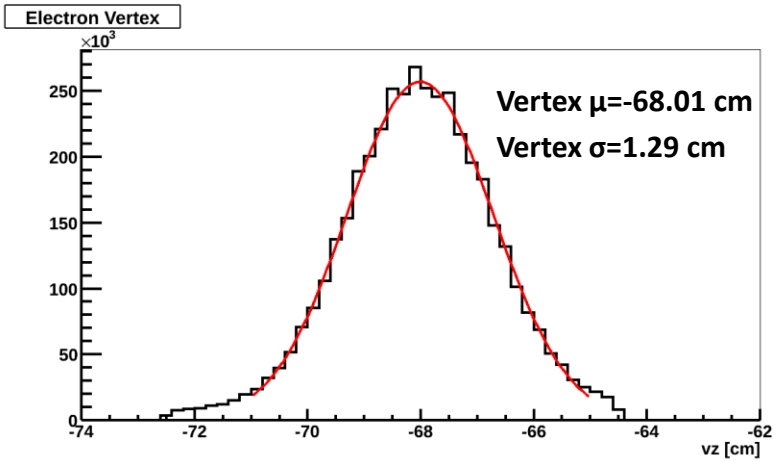
- Hydrogen target
- Beam energy:
  - 5.967 GeV
- Luminosity:
  - 50.7 fb^{-1}
- Used for results shown in this presentations

- Deuterium target
- Beam energy:
  - 5.764 GeV
- Luminosity
  - 25.3 fb^{-1}

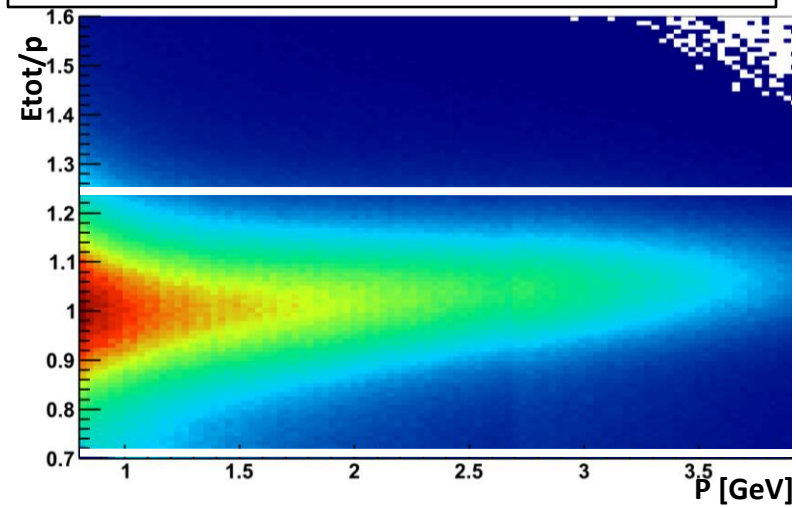
Particle Identification (electron, proton)

Electron ID cuts:

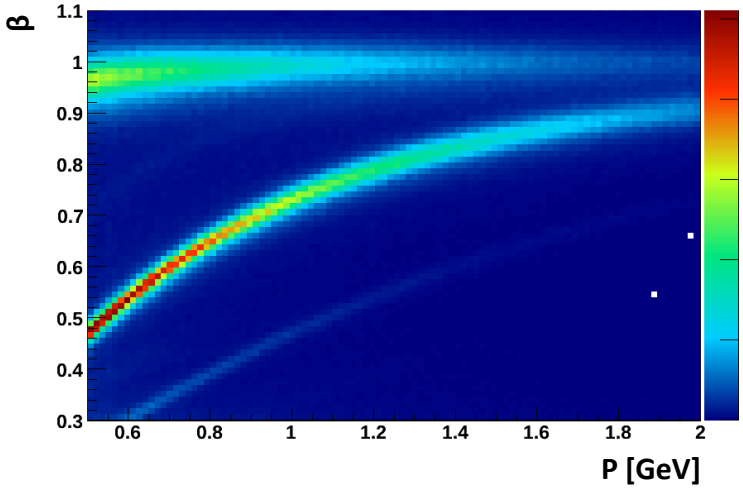
- $0.7 < \frac{Energy\ deposited\ in\ scintillator\ material}{p} < 1.25$
- p>0.8 GeV
- Cherenkov triggered
- Vertex position within 3σ ≈ 4 cm



Energy deposited/p corrected by sampling fraction



β vs momentum for positively charged particles



Proton ID cuts: $\Delta\beta = |\beta_{meas} - \beta_{calc}| < 0.035$

Using Time-Of-Flight Counter:

$$\beta_{meas} = \frac{\ell_{SC}}{c \cdot (t_{SC} - t_{start})} \qquad \beta_{calc} = \frac{p}{\sqrt{p^2 + M_{proton}^2}}$$

Particle Identification (π^0->γ+γ)

Photon cuts for π^0 :

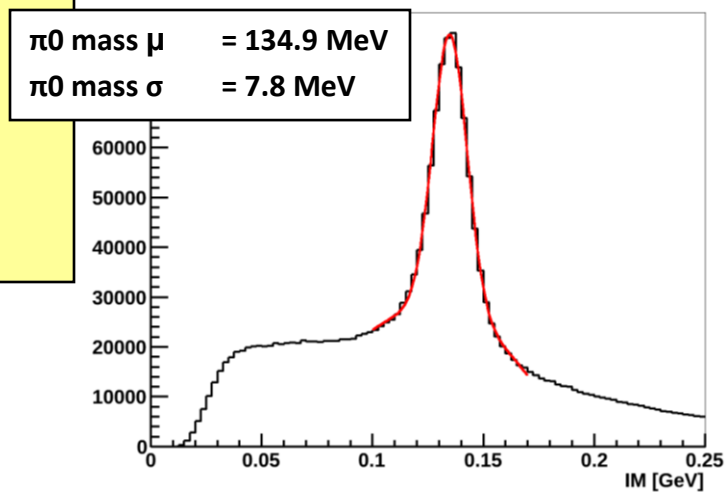
Inner Calorimeter γ at low angles:

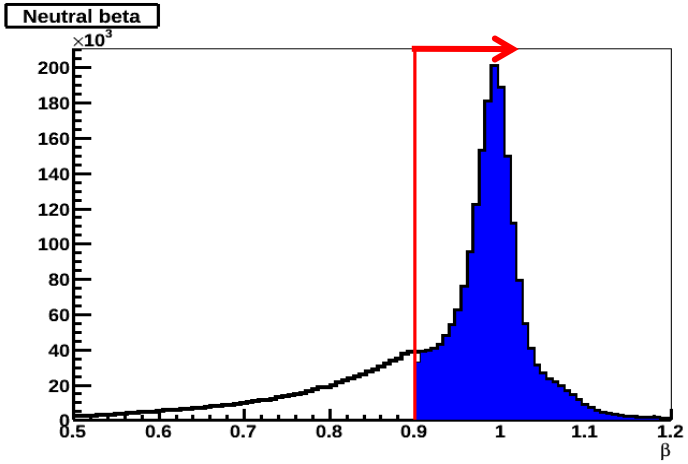
- **E_γ > 0.5GeV**

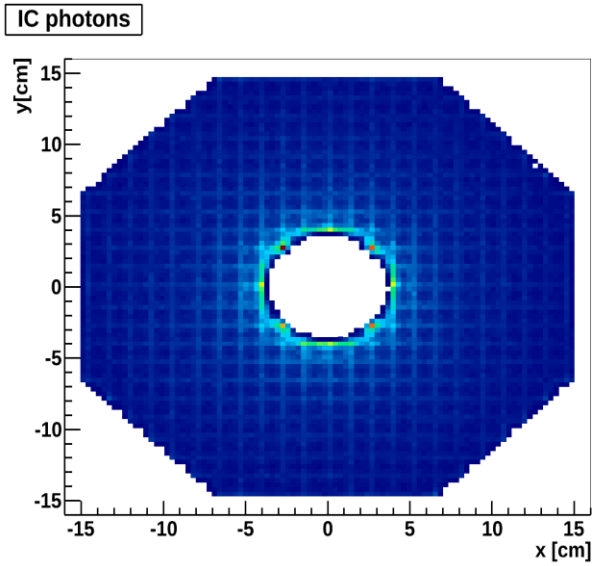
Electromagnetic Calorimeter γ at higher angles:

- **β > 0.9**

Invariant Mass for 2 gamma system







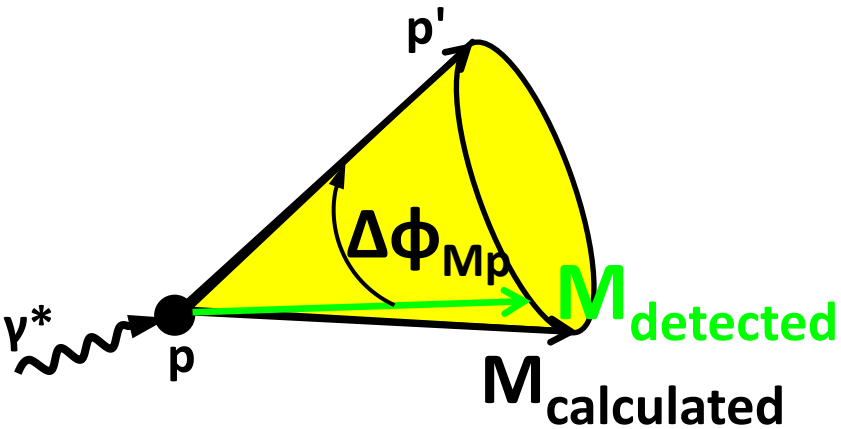
NOTE: exclusivity cuts take care of remaining background events passed due to loose photon cuts.

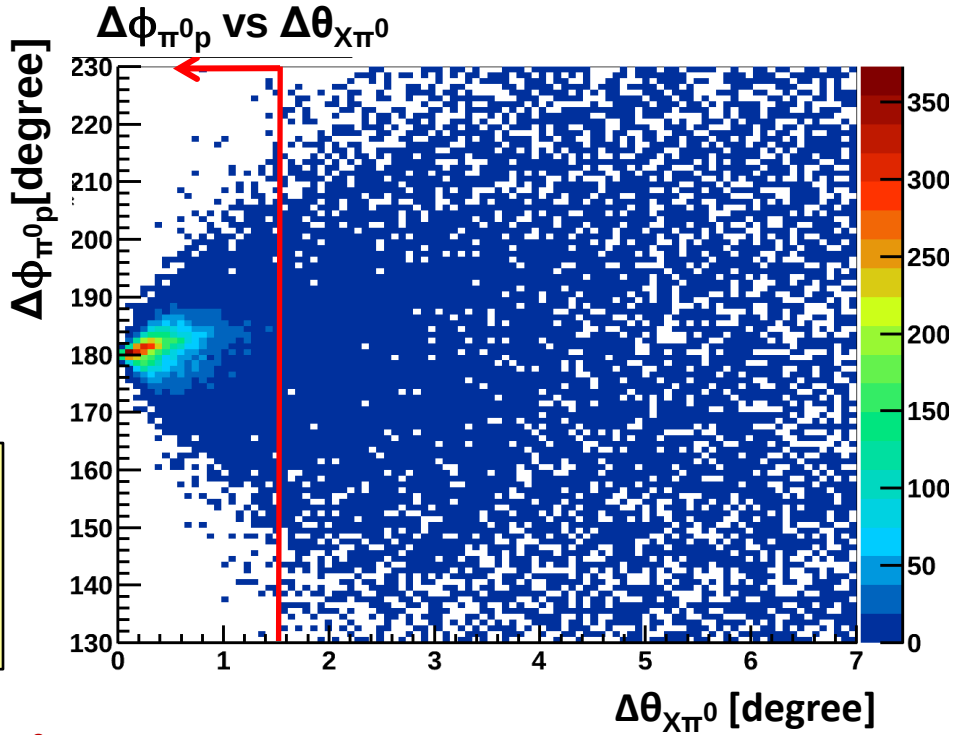
Photon cuts for DVCS :

Inner Calorimeter

- **single photon with E_γ > 2 GeV**

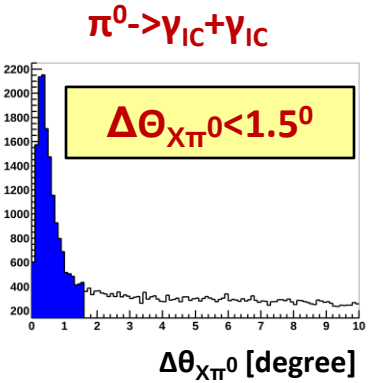
Exclusivity Cuts

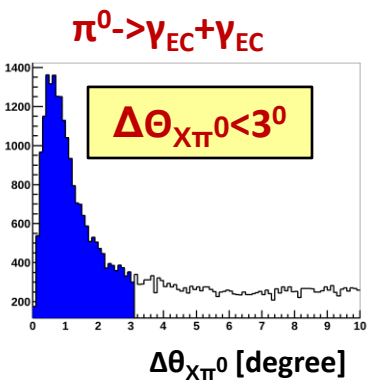


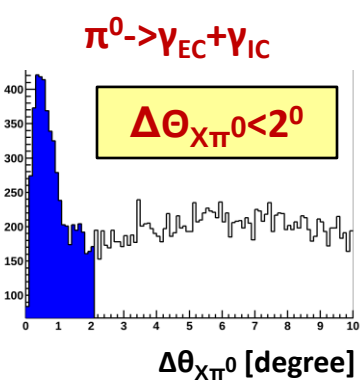


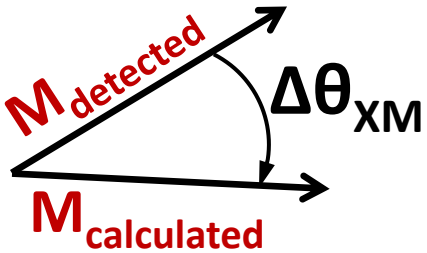
Due to different configuration the resolutions for 3 data sets are different.

$-0.1<MM^2_{(epX)}<0.14$ GeV^2



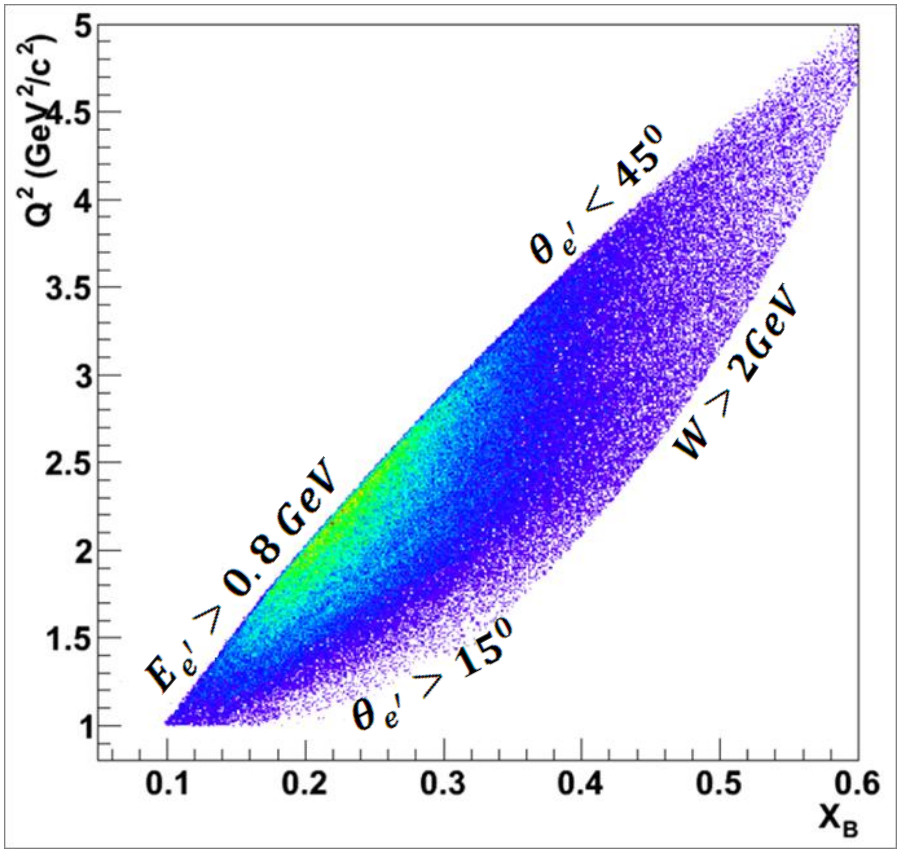


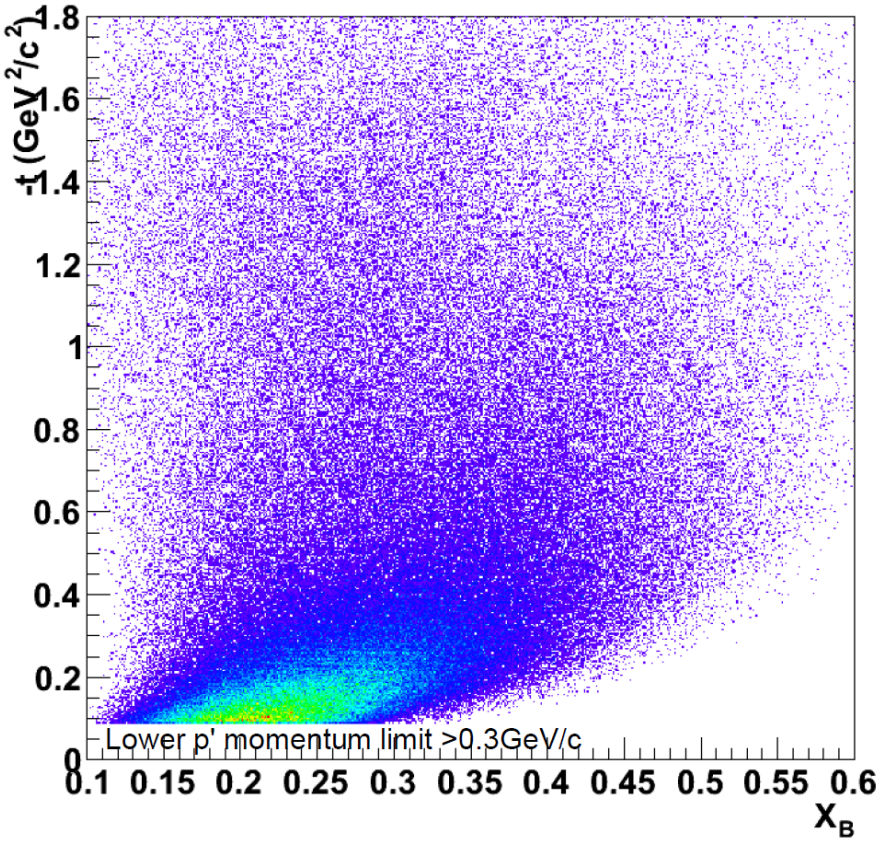




Kinematic Coverage (DVCS)

CLAS provides wide kinematical coverage.





For Deep Processes:

- **$Q^2 > 1$ GeV^2**
- **W > 2 GeV**
- **small X_b**

*** Plots from Erin Seder**

DVCS Target Spin Asymmetry

$$A_{UL} = \frac{n^+ - n^-}{fP(n^+ + n^-)} = \alpha sin\phi + \beta sin2\phi$$

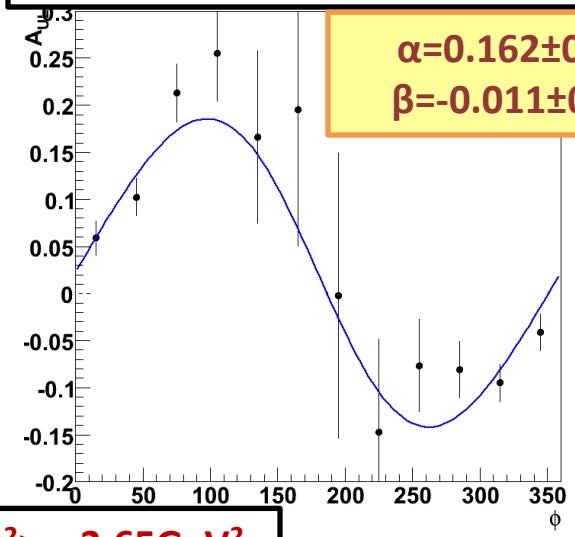
$n^{+(-)}$ – rate of events with positive (negative) target polarizations

P – average target polarizations

f – dilution factor

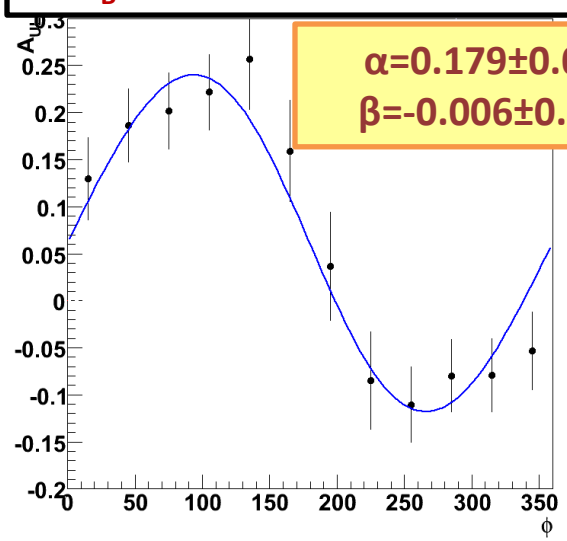
✓$\langle x_B \rangle \approx 0.46$, $\langle Q^2 \rangle \approx 3.0 GeV^2$

α=0.162±0.019
β=-0.011±0.017



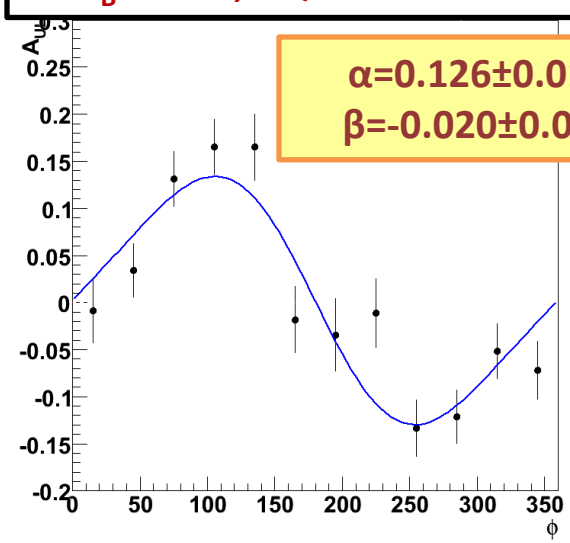
✓$\langle x_B \rangle \approx 0.21$, $\langle Q^2 \rangle \approx 2.15 GeV^2$

α=0.179±0.017
β=-0.006±0.018



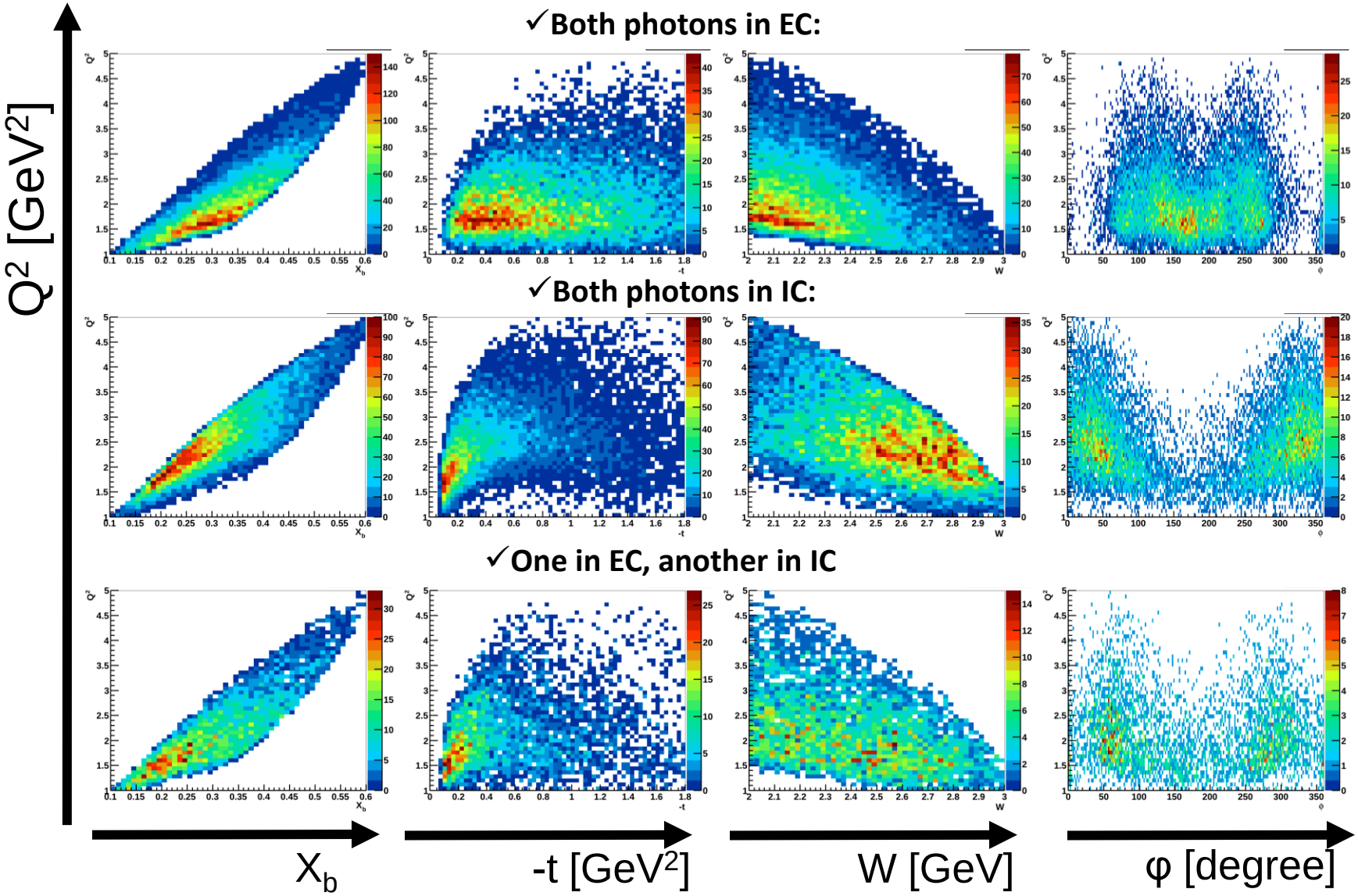
✓$\langle x_B \rangle \approx 0.21$, $\langle Q^2 \rangle \approx 3.65 GeV^2$

α=0.126±0.012
β=-0.020±0.013



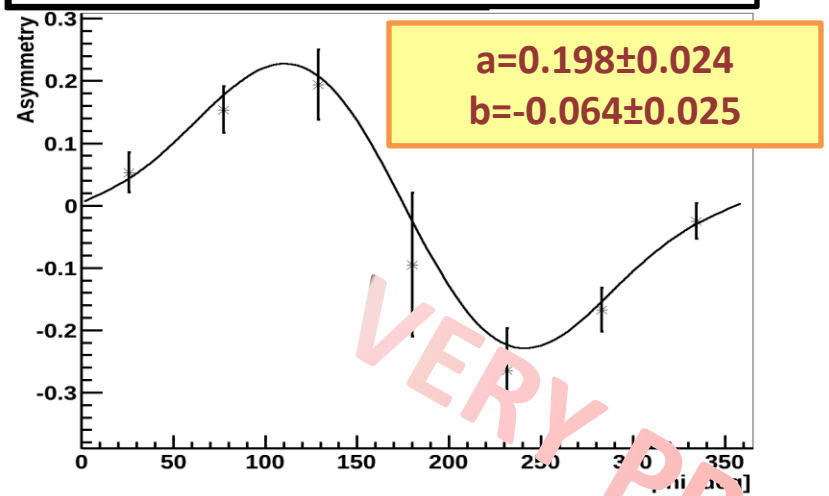
* Plots from Erin Seder

Kinematic Coverage (DVMP)



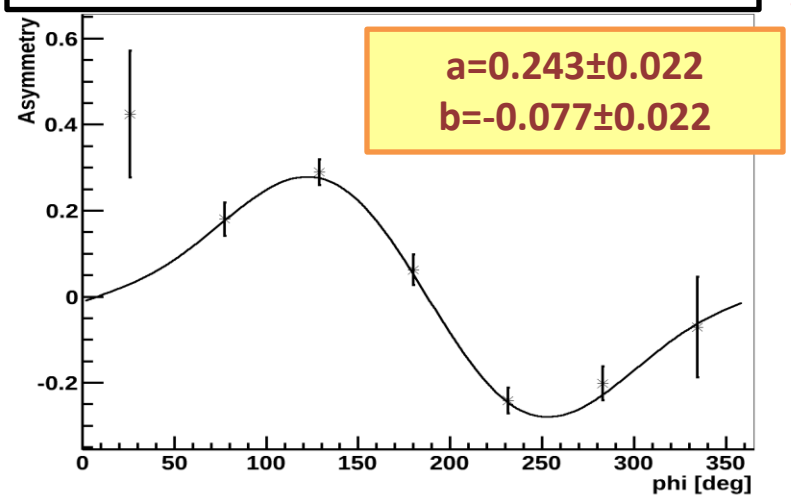
DVMP Target Spin Asymmetry

✓**Both photons in IC:**

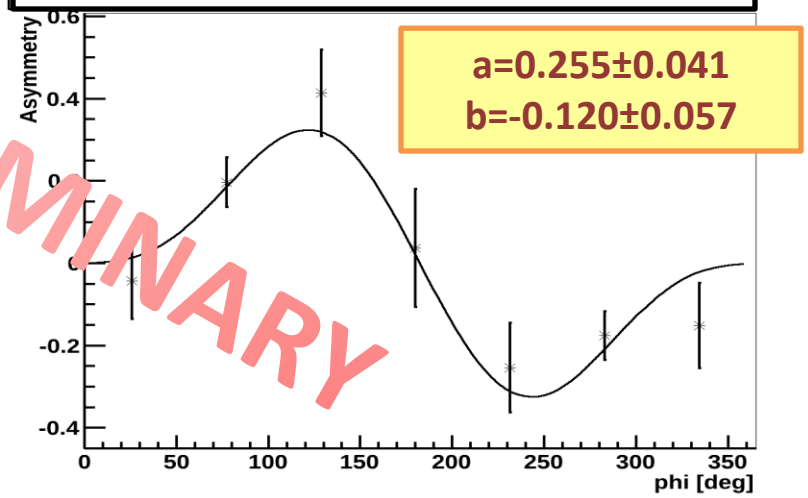


$$A = a \cdot \sin\phi + b \cdot \sin 2\phi$$

✓**Both photons in EC:**



✓**One photon in EC, second in IC:**

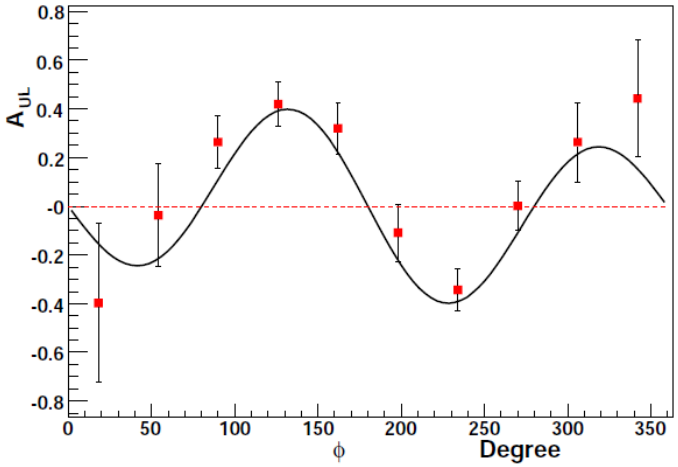


VERY PRELIMINARY

Future Plans

- Improve:
  - Nitrogen background evaluation
  - Carbon data fitting
  - Subtract π^0 counts in single γ sample
  - Charge normalization
  - Systematic error study
  - Radiative corrections
- Improved calibrations promise better π^0 mass reconstruction from EC region
- Kinematic bins definition
- Bin A_{UL} in different kinematic bins (Q^2, X_b, t)

Support Slide

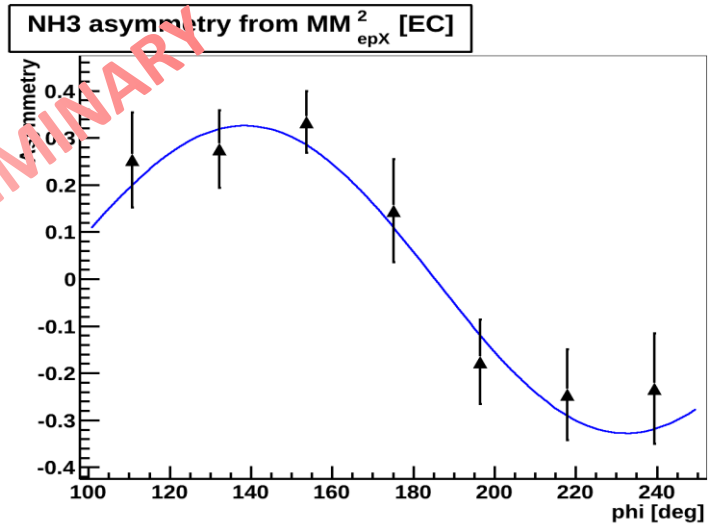


A=a·sinϕ + b·sin2ϕ

ShiFeng Chen thesis 2006 y.
Target Spin Asymmetry for ep->epπ^0 channel using eg1b experiment data

a=0.109±0.056
b=-0.319±0.061

Figure 6.12. Target Spin Asymmetry in the reaction $e\vec{p} \rightarrow ep\pi^0$ from all of the data. Points are fitted with function $F = p_0 sin\phi + p_1 sin2\phi$, and $p_0 = 0.109 \pm 0.056$, and $p_1 = -0.319 \pm 0.061$. $< Q^2 >= 1.64$, $< -t >= 0.36$, and $< x_B >= 0.28$.

PRELIMINARY data from eg1dvcs experiment

a=0.02±0.18
b=-0.31±0.14