DVCS WITH LONGITUDINALLY POLARIZED TARGET USING CLAS AT 6 GEV

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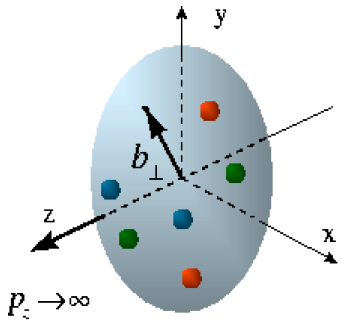
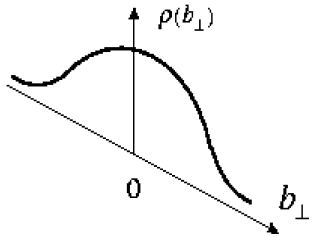
Outline

- Background
- Previous measurements
- Experimental apparatus
- Analysis procedure
- Expected results

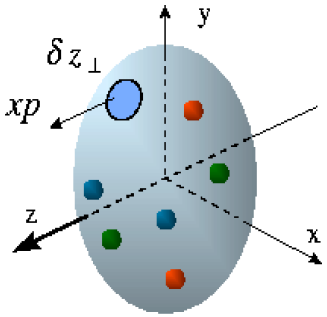
Generalized Parton Distributions (GPD)

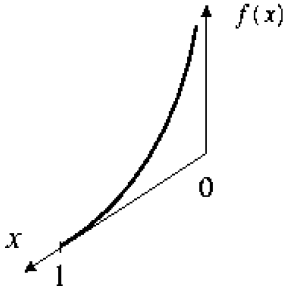
3-dimensional quark structure of nucleon



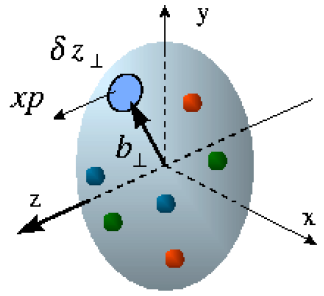


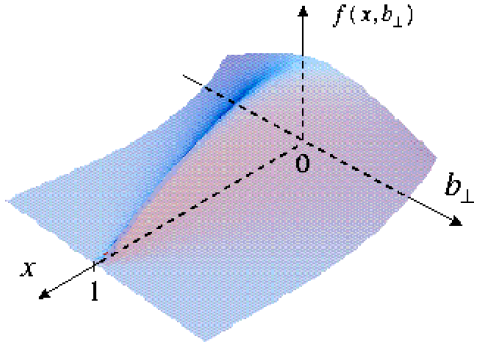
Elastic Scattering
transverse quark distribution in coordinate space





Deep inelastic scattering
Longitudinal quark Distribution in momentum space



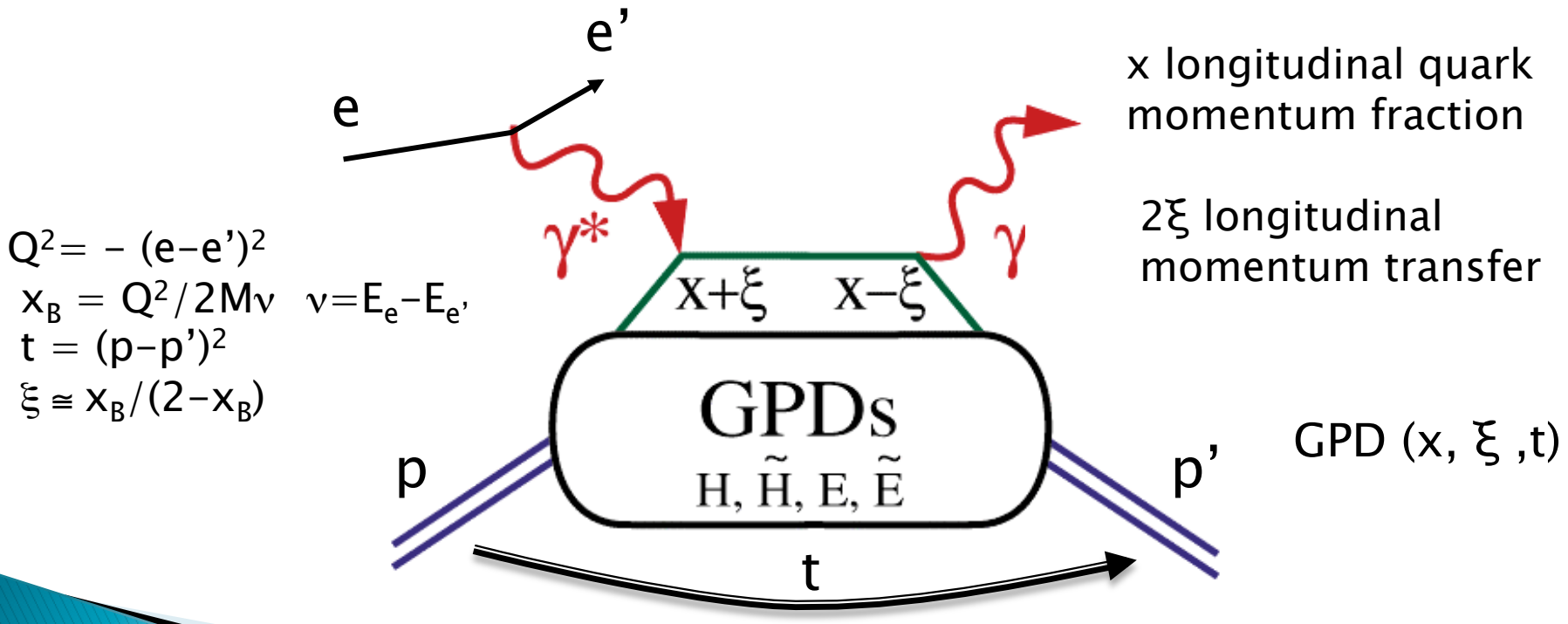


Deep exclusive scattering
Fully-correlated quark distribution in both coordinate and momentum space - GPDs

Deeply Virtual Compton Scattering and GPDs

- DVCS is the cleanest process to access GPDs

Handbag mechanism: the exclusive process can be factorized into a hard scattering part and a nucleon structure part parameterized via GPDs



$Q^2 = -(e-e')^2$

$x_B = Q^2/2M\nu \quad \nu = E_e - E_{e'}$

$t = (p-p')^2$

$\xi \cong x_B/(2-x_B)$

x longitudinal quark momentum fraction

2ξ longitudinal momentum transfer

GPD (x, ξ ,t)

Link between GPDs, DIS and form factors

- DIS at t=ξ=0: ordinary parton distributions

$H^q(x,\xi=0,t=0)=q(x)$ unpolarized quark distributions

$\tilde{H}^q(x,\xi=0,t=0)=\Delta q(x)$ polarized quark distributions

$E^q,\tilde{E}^q$ new information

- First moments: form factors

Dirac

$$\int_{-1}^{1} dx H^q(x,\xi,t)=F_1^q(t)$$

axial

$$\int_{-1}^{1} dx \tilde{H}^q(x,\xi,t)=G_A^q(t)$$

Pauli

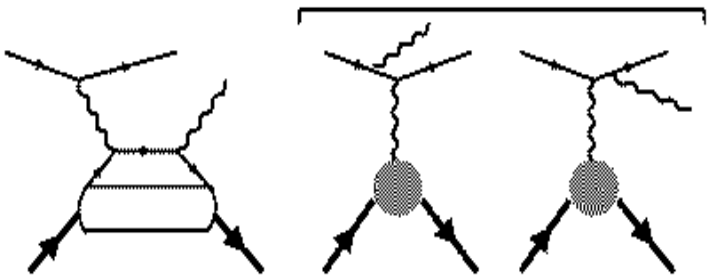
$$\int_{-1}^{1} dx E^q(x,\xi,t)=F_2^q(t)$$

pseudo-scalar

$$\int_{-1}^{1} dx \tilde{E}^q(x,\xi,t)=G_P^q(t)$$

Accessing GPDs via DVCS

DVCS BH

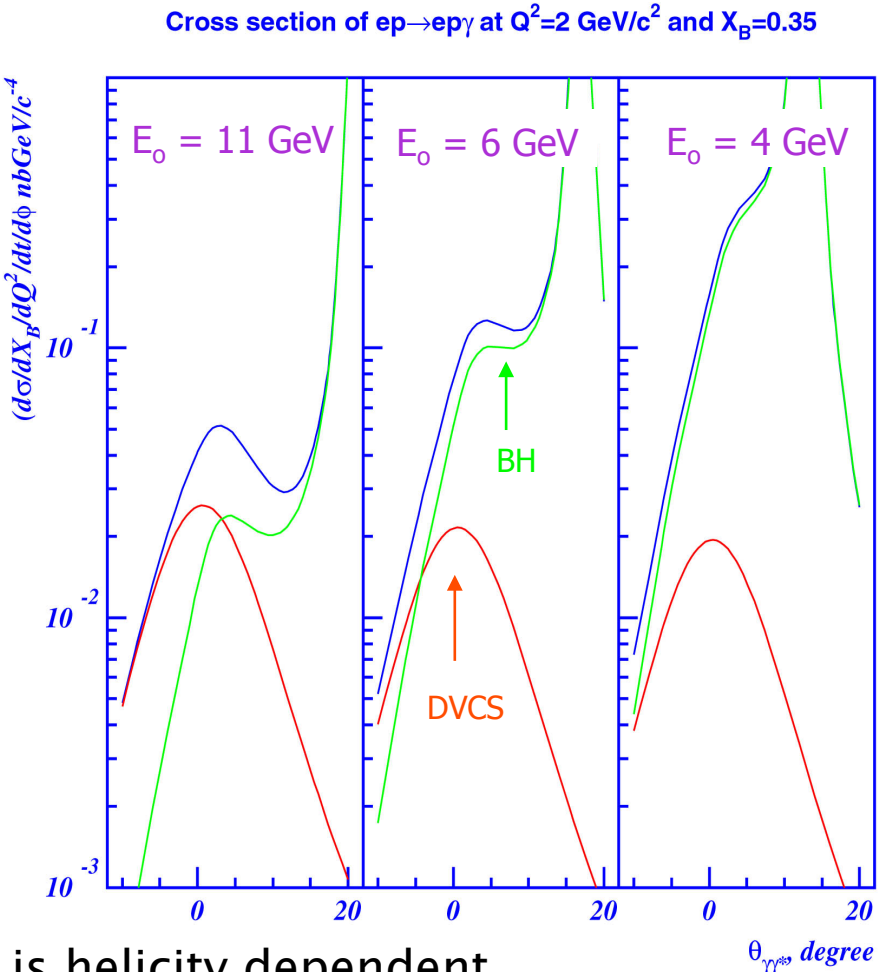


$$\frac{d^4\sigma}{dQ^2 dx_B dt d\phi} \approx |T^{DVCS} + T^{BH}|^2$$

GPDs

Elastic form factors

$$\frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} \propto \frac{I(DVCS \bullet BH)}{|DVCS|^2 + |BH|^2 + I}$$



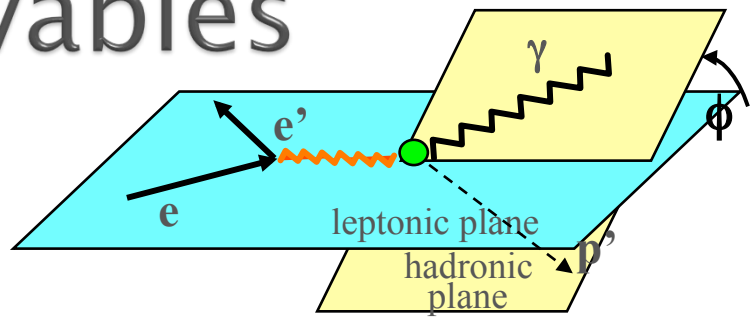
BH and DVCS interference is helicity dependent

DVCS can be measured via beam and target asymmetries

Polarization observables

$$A = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$$

$\xi = x_B/(2-x_B)$
$k = -t/4M^2$



Polarized beam, unpolarized target

$$\Delta\sigma_{LU} \sim \sin\phi\,\mathrm{Im}\left\{F_1 H + \xi(F_1 + F_2)\tilde{H} + kF_2 E\right\}d\phi \Rightarrow H, \tilde{H}, E$$

Unpolarized beam, longitudinal target

$$\Delta\sigma_{UL} \sim \sin\phi\,\mathrm{Im}\left\{F_1 \tilde{H} + \xi(F_1 + F_2)(H + ..)\right\}d\phi \Rightarrow H, \tilde{H}$$

Unpolarized beam, transverse target

$$\Delta\sigma_{UT} \sim \sin\phi\,\mathrm{Im}\left\{k(F_2 H - F_1 E) + ...\right\}d\phi \Rightarrow H, E$$

Beam charge asymmetry

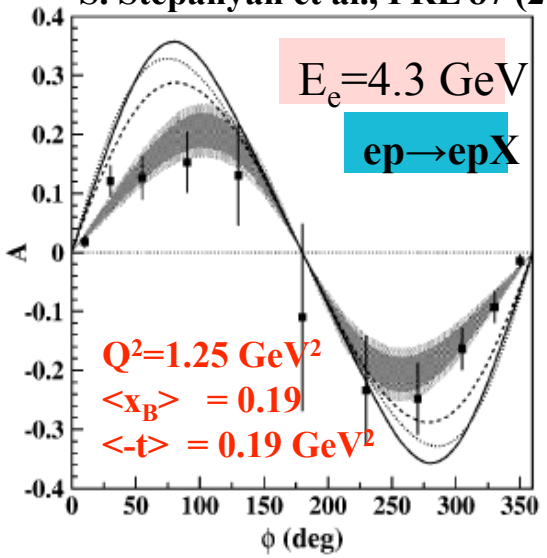
$$\Delta\sigma_{C} \sim \cos\phi\,\mathrm{Re}\left\{F_1 H + \xi(F_1 + F_2)\tilde{H} - kF_2 E\right\}d\phi \Rightarrow H, \tilde{H}, E$$

Cross section and BSA measurements

CLAS

Beam-spin asymmetry

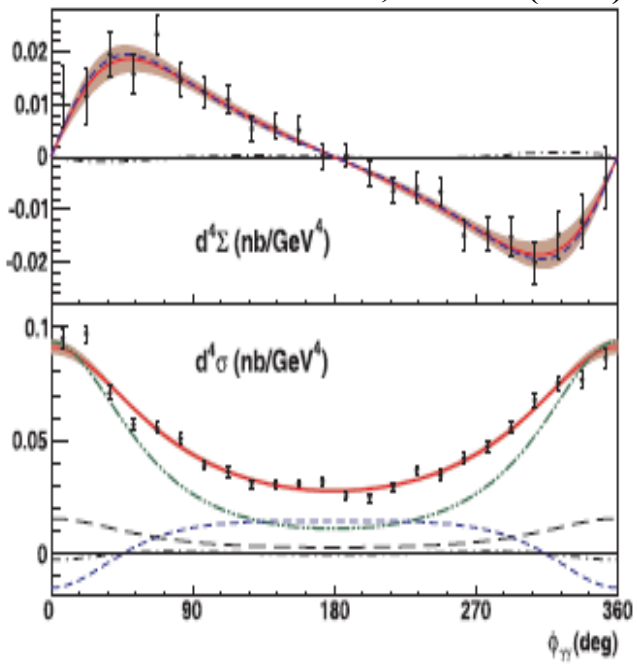
S. Stepanyan et al., PRL 87 (2001)



Hall A

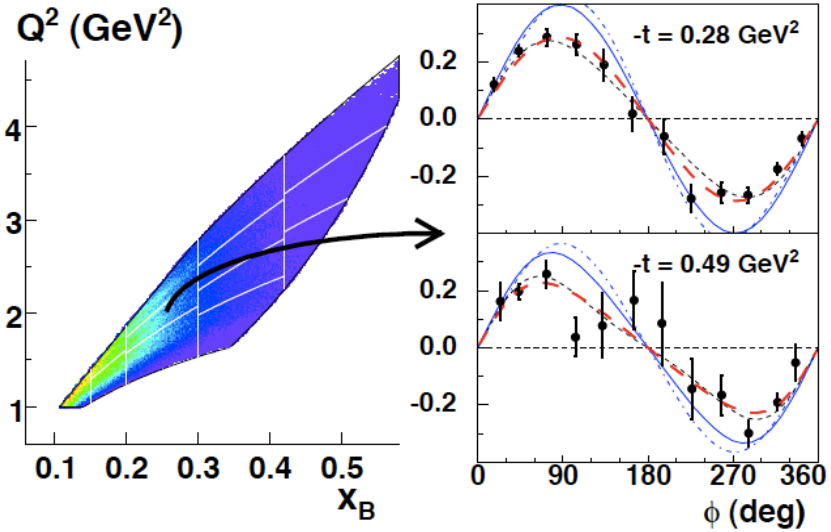
Cross section

C.M. Camacho et al., PRL 97 (2006)



HERMES

F.X. Girod et al., PRL 100 (2008)

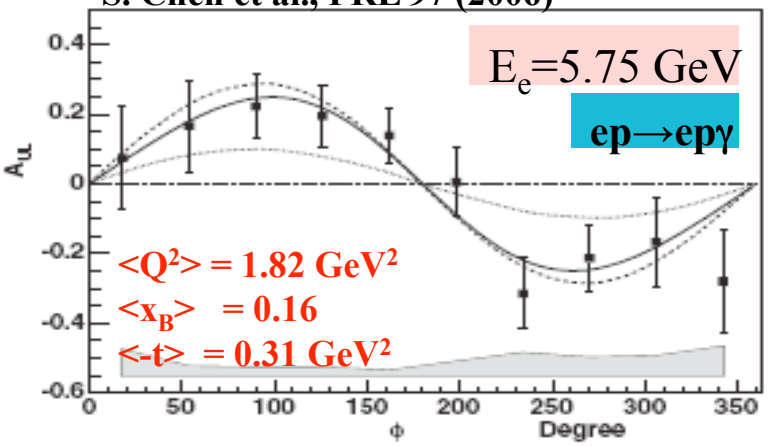


BSA A. Airapetian et al, Phys. Rev. D 75 (2007)

BCA A. Airapetian et al, Phys. Rev. Lett 96 (2001)

TSA measurements

S. Chen et al., PRL 97 (2006)



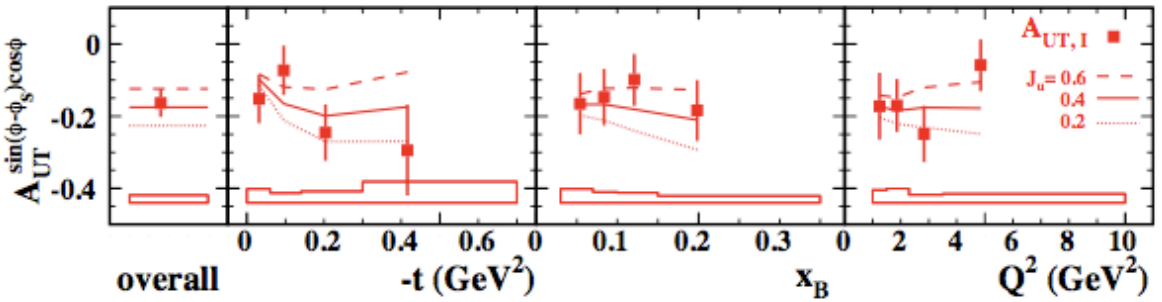
Target-spin (L) asymmetry (**H**, $\tilde{\mathbf{H}}$)

CLAS

Data were collected as a by-product during the Eg1 2000 run: 5.7 GeV
with NH_3 longitudinally polarized target, Q^2 up to 4.5 GeV^2

Non dedicated experiment

A. Airapetian et al., JHEP 0806 (2008)



Target-spin (T) asymmetry (**H**, **E**)

HERMES

TSA with transverse polarized target

Also longitudinal polarized target asymmetry

DVCS at 6 GeV with polarized target and polarized beam using the CLAS detector

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DVCS at 6 GeV with polarized target and polarized beam using the CLAS detector

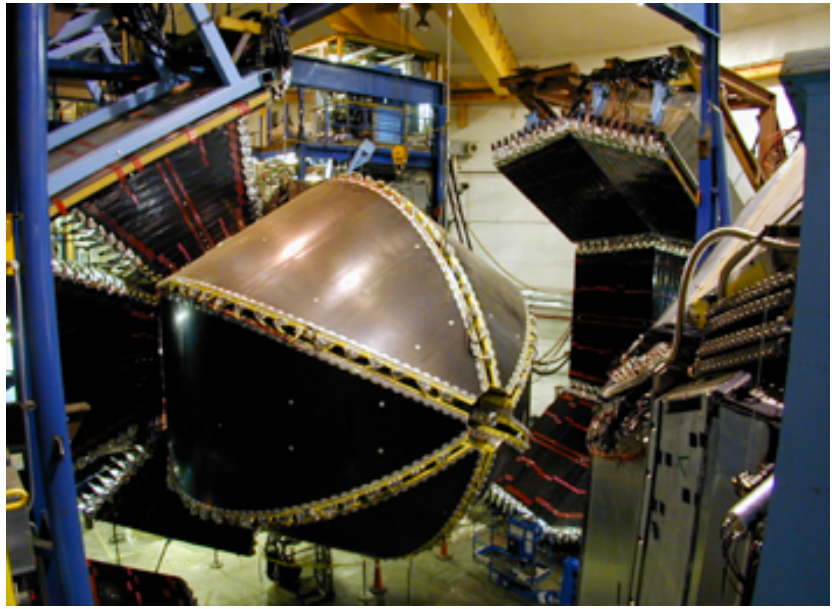
- First dedicated DVCS experiment with the polarized target
- Approved for 60 PAC days
- According to the current accelerator schedule: Feb 4th – Mar 11th @ 5.9 GeV
  Apr 9th – May 31st @ 6.1 GeV
  Aug 21st – Sept 20th @ 5.9 GeV

Jefferson Lab

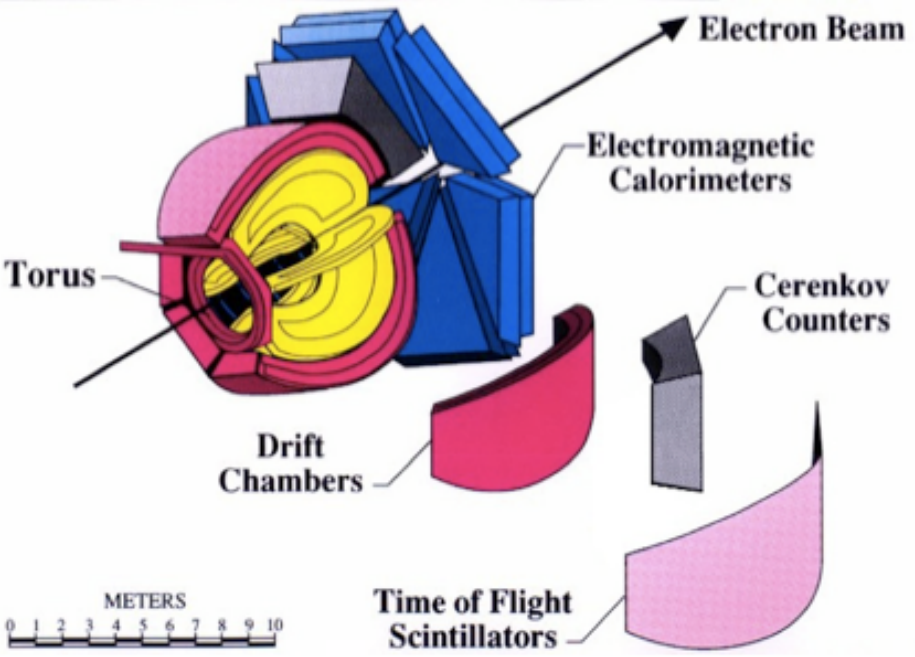
Continuous
Electron
Beam
Accelerator
Facility

$I_{max}=200\mu A$
$E_{max}=6$ GeV
$\sigma_E/E\sim2.5\ 10^{-5}$
Beam Pol~80%

The CLAS detector



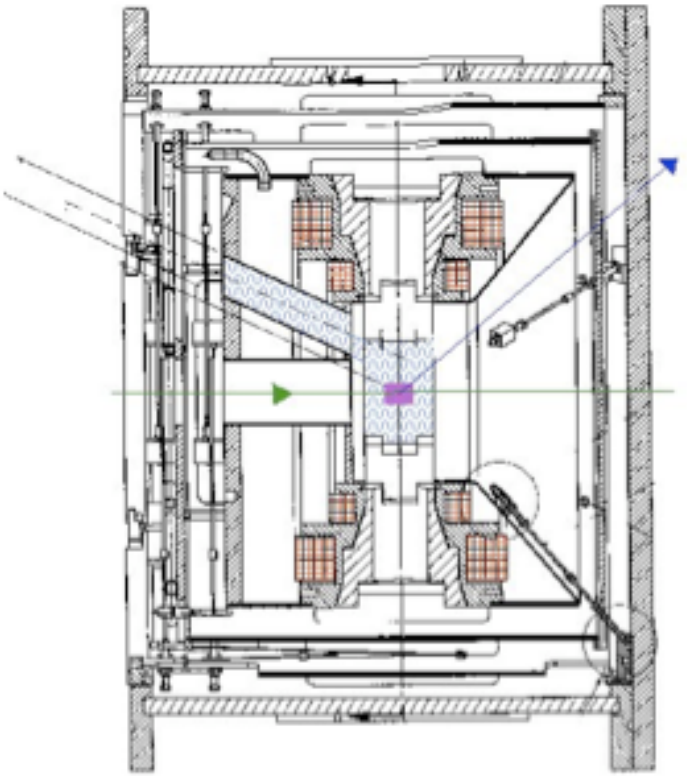
CEBAF
Large
Acceptance
Spectrometer



- Six individually instrumented sectors
- Toroidal magnetic field
- Multi-particle final state
- Large acceptance

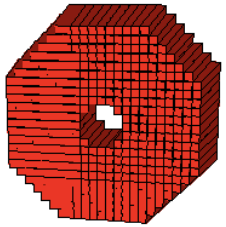
The polarized target

Targets:
- $^{14}NH_3$ P ~ 70 – 80%
- ^{12}C & He-4 background studies

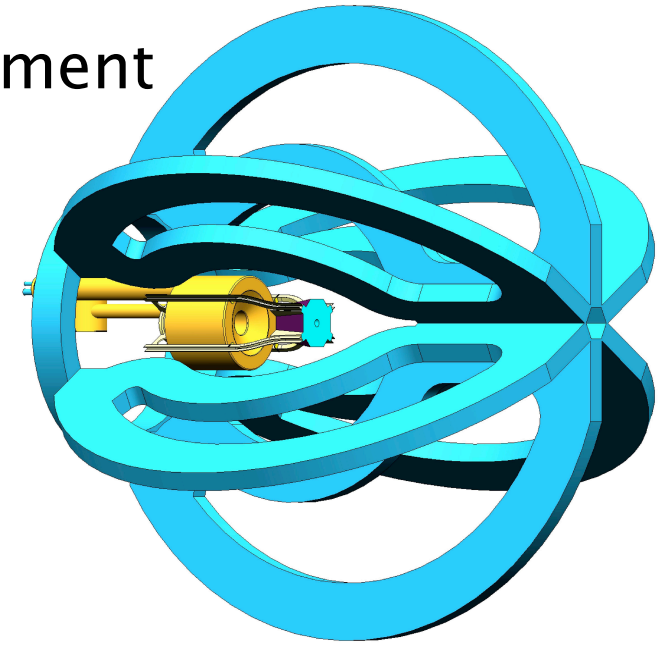


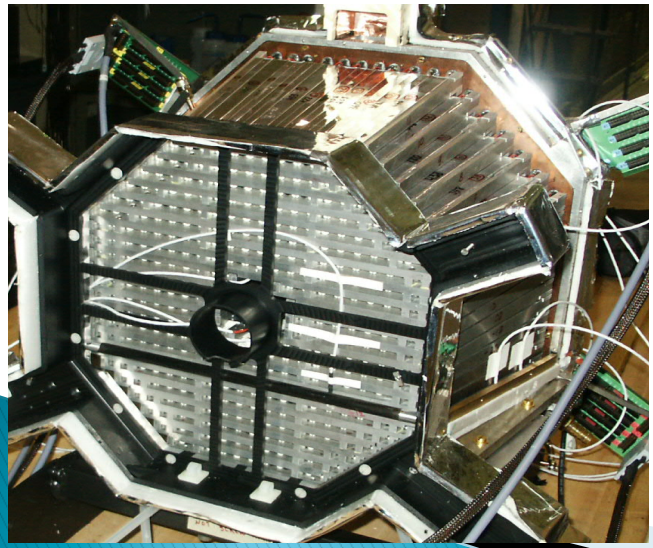
- Polarized by DNP along the beam
- 5 Tesla magnetic holding field
- He-4 cooling bath T=1 K
- Field uniformity $\Delta B/B \sim 10^{-4}$

The Inner Calorimeter (IC)



- Designed for the e1-DVCS experiment
- Increase γ acceptance
  - EC: $17^{o}<\theta<43^{o}$
  - IC: $4^{o}<\theta<15^{o}$
- Better resolution

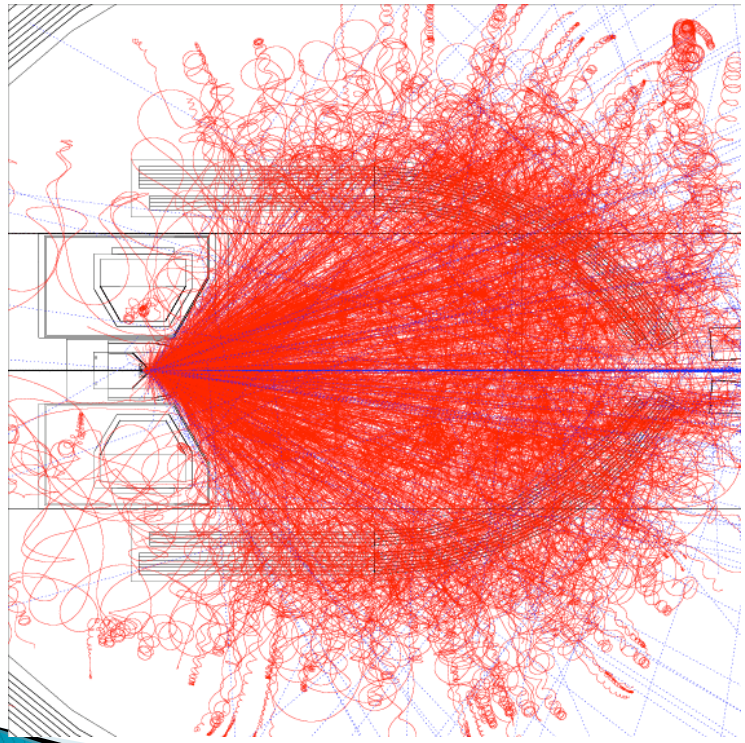


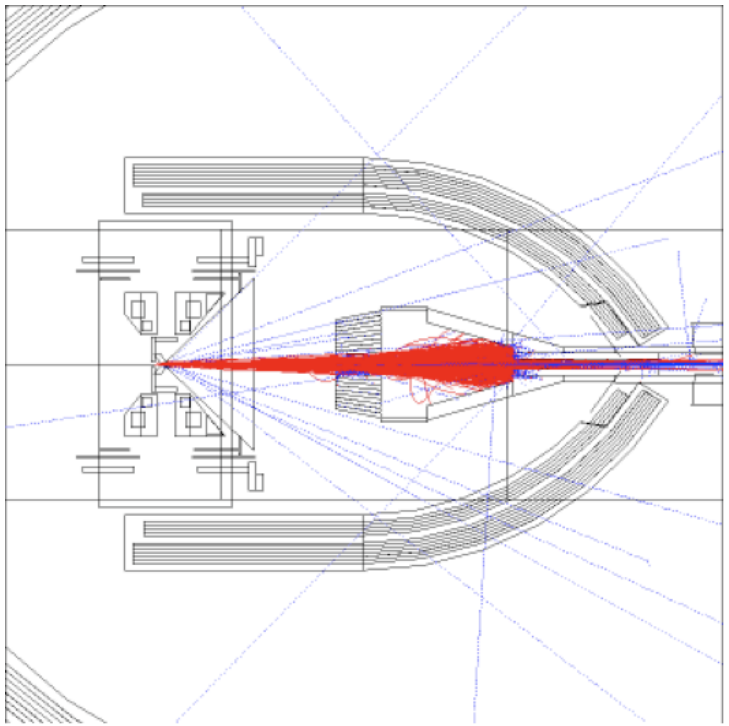


- 424 $PbWO_4$ crystals
- 16 cm x 1.3 cm x 1.3 cm
- Pointing geometry
- ~1.2 degree/crystal
- 18 radiation lengths
- APD readout

Moller background

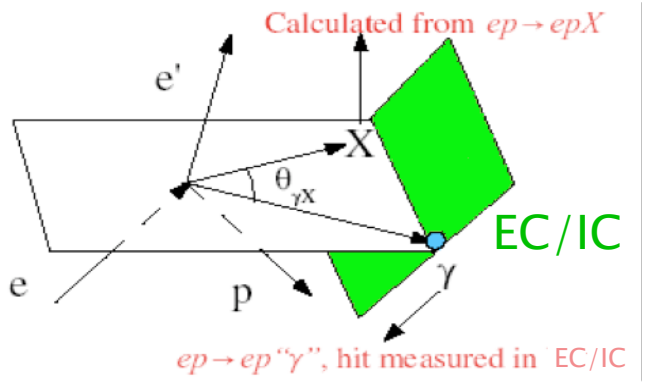
- Moller background “naturally” shielded by the target field

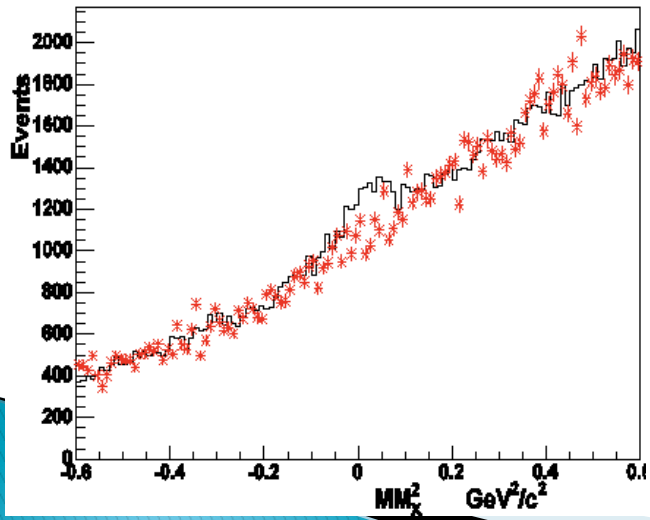


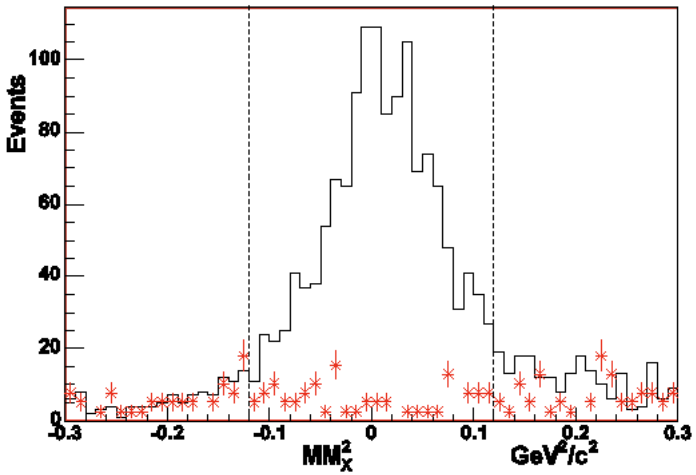


Analysis

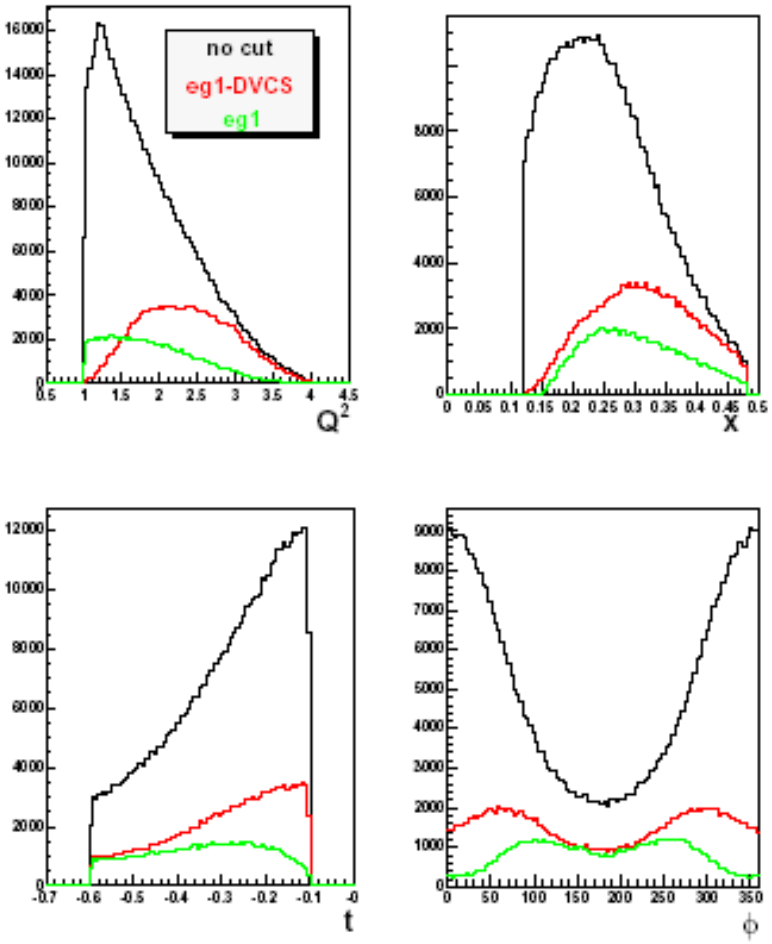
- Detection of all final state particles e p γ
- DVCS: $Q^2>1$ GeV^2, $W>2$ GeV, $-t < 0.6$ GeV^2
- Background from unpolarized target nucleons and π^0 highly reduced by geometry cut

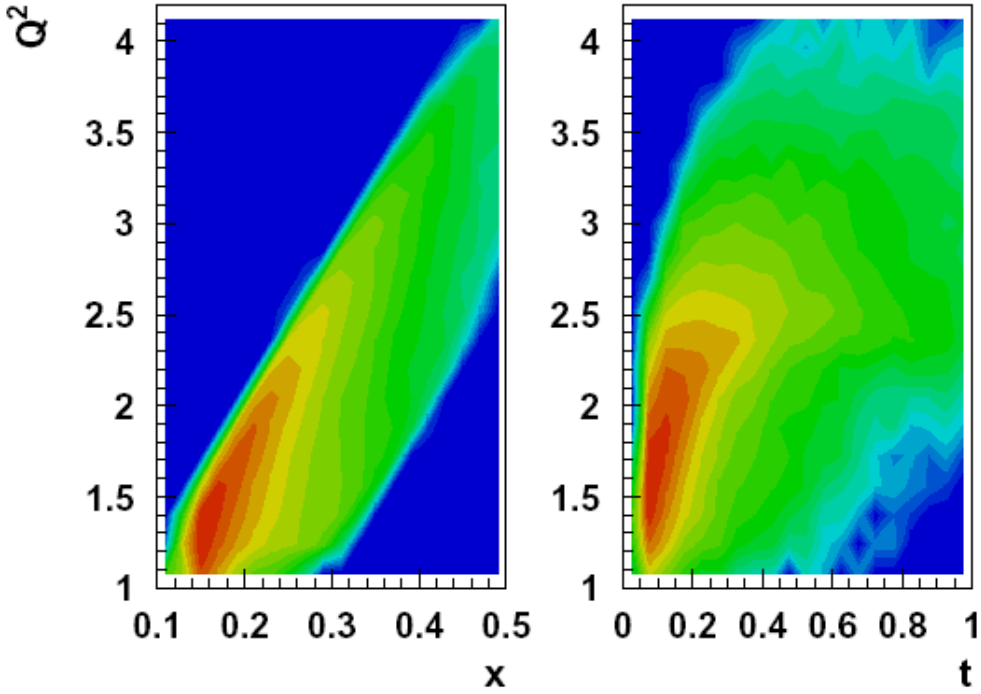






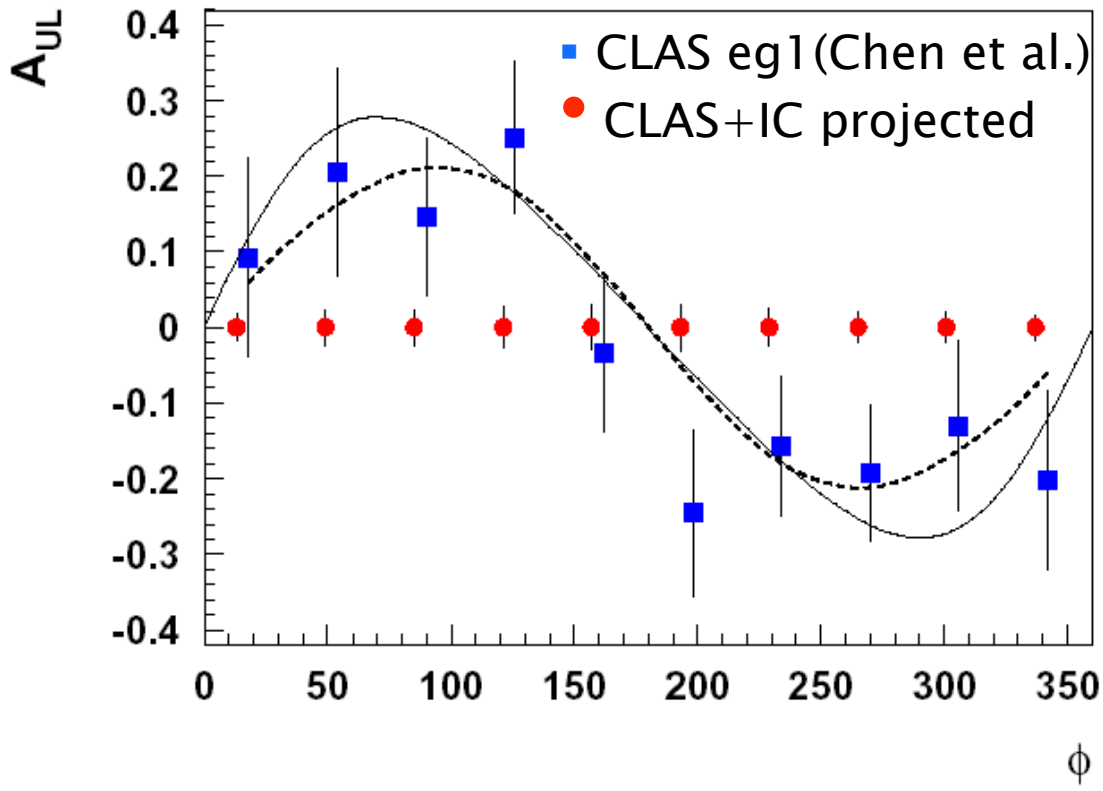
Kinematics and acceptance





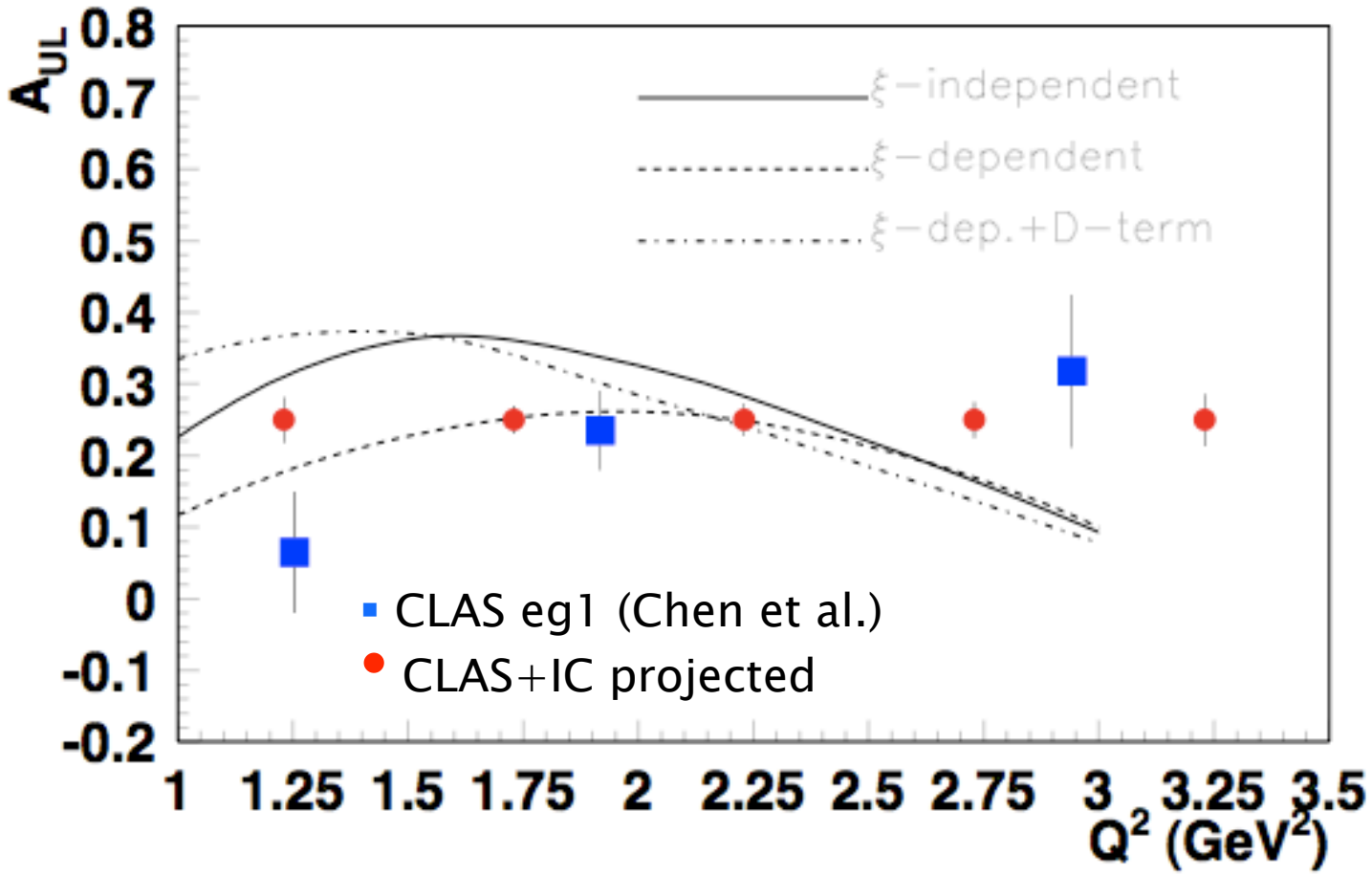
- Improved acceptance as compared to eg1
- Much higher statistics -> bins in t and x_B

Target spin asymmetry: ϕ dependence



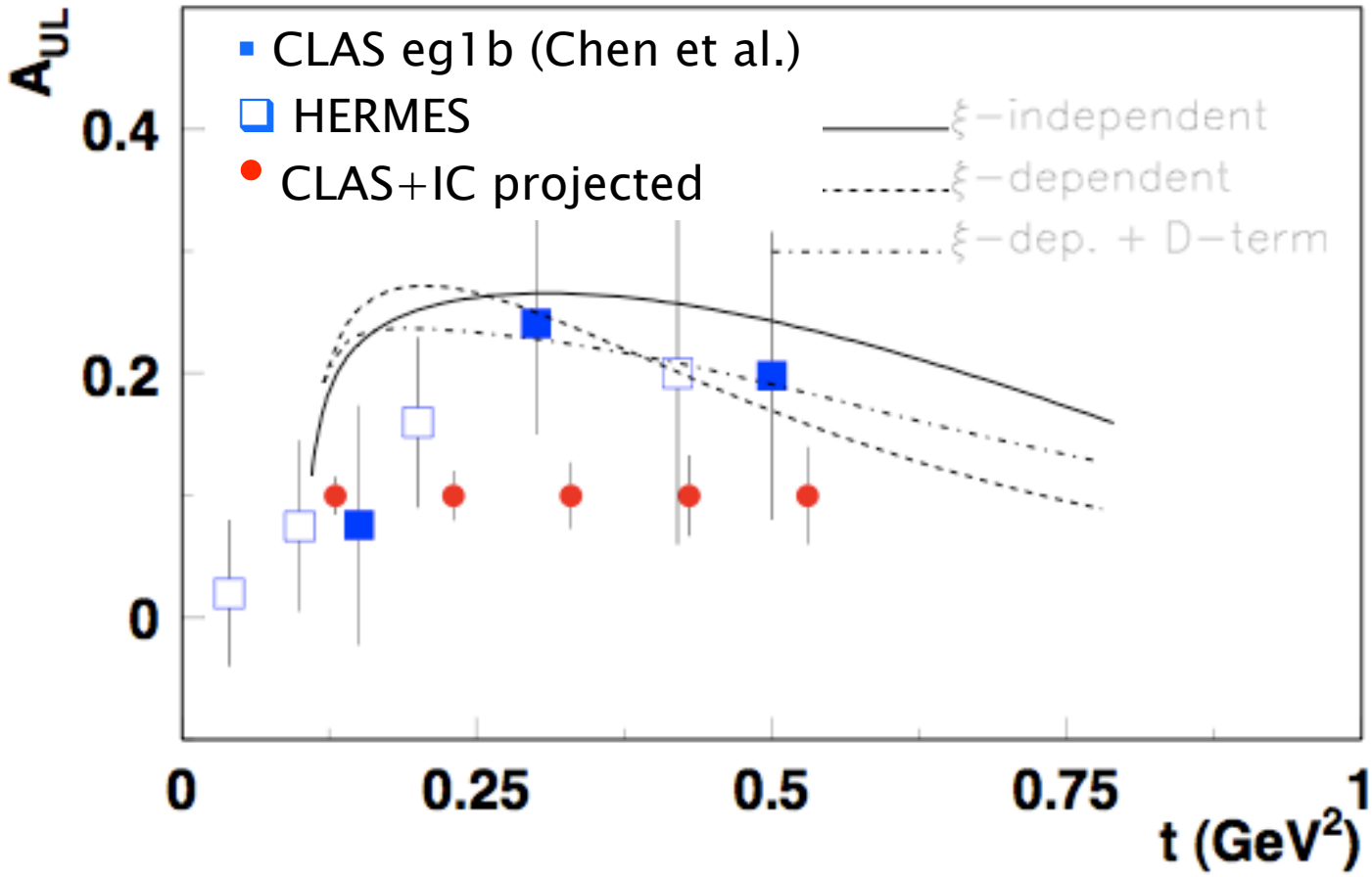
Target spin asymmetry: Q^2 dependence

$x_B=0.3,\ t = 0.325\ GeV^2,\ \phi = 90^o$



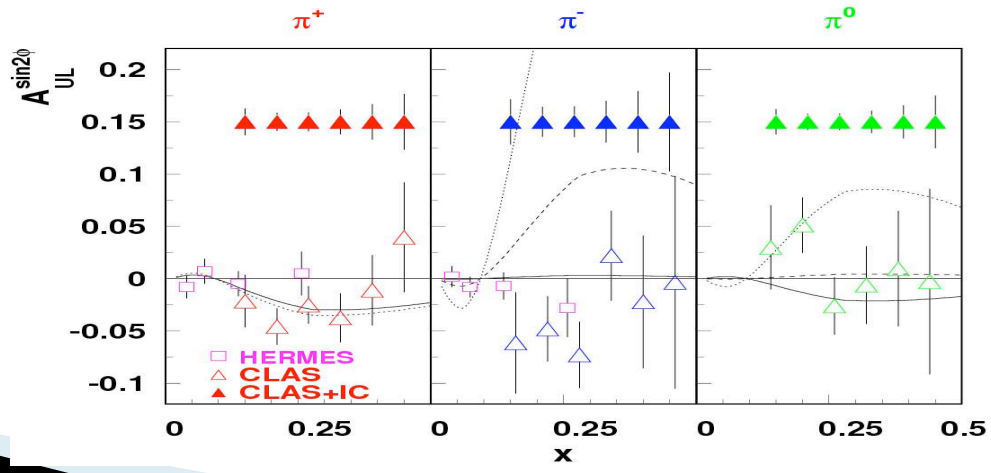
Target spin asymmetry: t dependence

$x_B = 3,\ Q^2 = 2.3\ GeV^2,\ \phi = 90^o$



Semi-Inclusive Pion Production with a Longitudinally Polarized Target at 6 GeV

- Concurrent to DVCS experiment
- Single- and double spin azimuthal asymmetries in semi-inclusive electroproduction of pions using the 6 GeV
- Study of transverse momentum dependent parton distributions at $Q^2 > 1\ GeV^2$



Conclusions

- First dedicated DVCS experiment with polarized target
- Improvement on statistical and systematic errors by a factor 4 and 2.
- The large acceptance will allow to study x_B, Q^2 and t dependence of the DVCS amplitude
- The target asymmetry will increase the sensitivity to $\tilde{H}$, adding new information to existing polarized beam data.
- This experiment together with polarized beam experiment with the CLAS detector and the Hall-A DVCS program, will greatly contribute to our knowledge of GPDs and will provide a crucial step for the 12 GeV program.

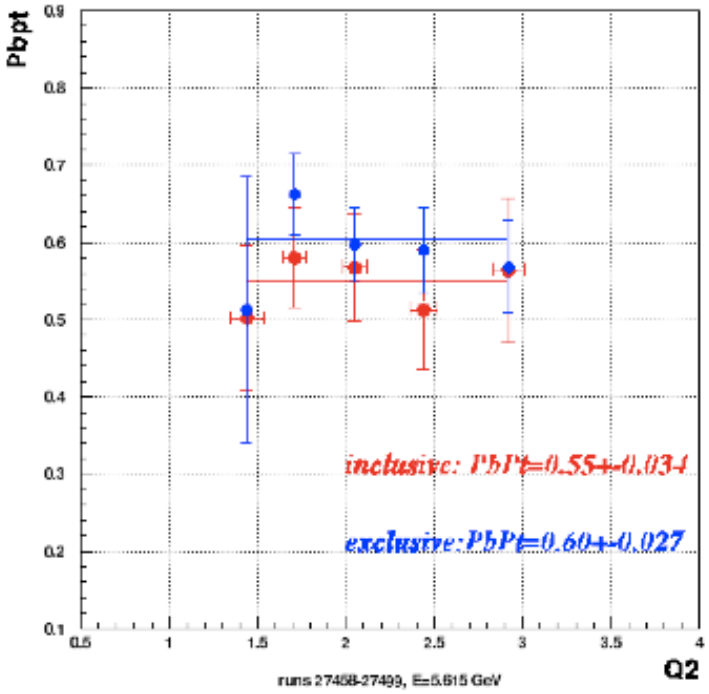
Target polarization

- Target polarization extracted by measuring elastic asymmetry

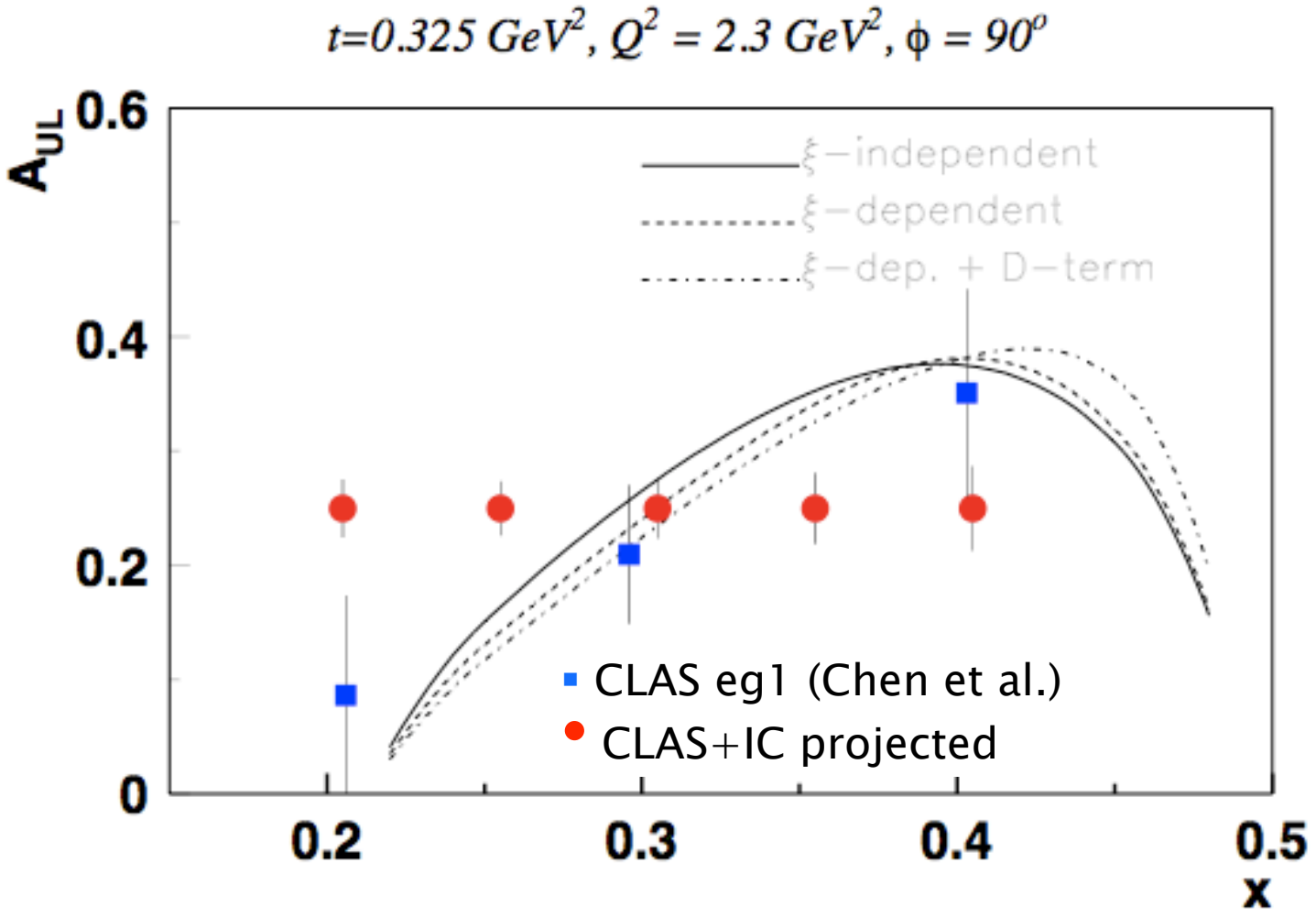
$$A_{meas} = \frac{N^+ - N^-}{N^+ - N^-} = P_e P_t A_{theo}$$

- IC-target distance is important for electron detection

eg1 $P_e P_t$ @ 5.6 GeV



Target spin asymmetry: x_B dependence



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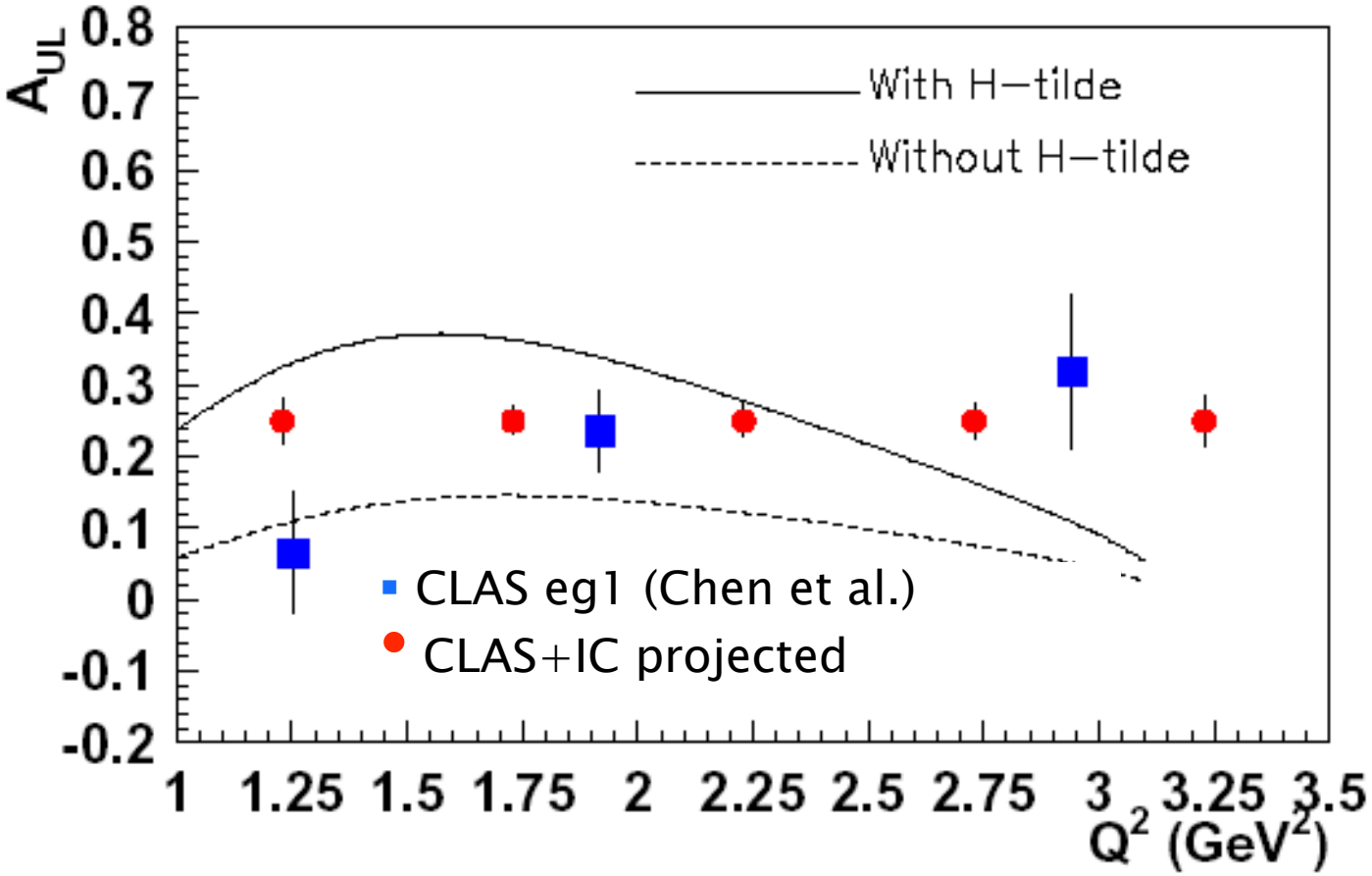

Target spin asymmetry: t dependence

x_B=.3, $Q^2 = 2.3\ GeV^2$, $\phi = 90^o$