Future DVCS in Hall B at Jefferson Lab

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Measuring GPDs through polarization

$$A = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{\Delta\sigma}{2\sigma}$$

Polarized beam, unpolarized target:

$$\Delta\sigma_{LU} \sim \sin\phi\{F_1 H + \xi(F_1+F_2)\tilde{H} + kF_2 E\}d\phi \quad \Rightarrow \quad H(\xi,t)$$

Kinematically suppressed

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

$k = t/4M^2$

Unpolarized beam, longitudinal target:

$$\Delta\sigma_{UL} \sim \sin\phi\{F_1\tilde{H} + \xi(F_1+F_2)(H + \xi/(1+\xi)E) - ..\}d\phi \quad \Rightarrow \quad \tilde{H}(\xi,t),\ H(\xi,t)$$

Kinematically suppressed

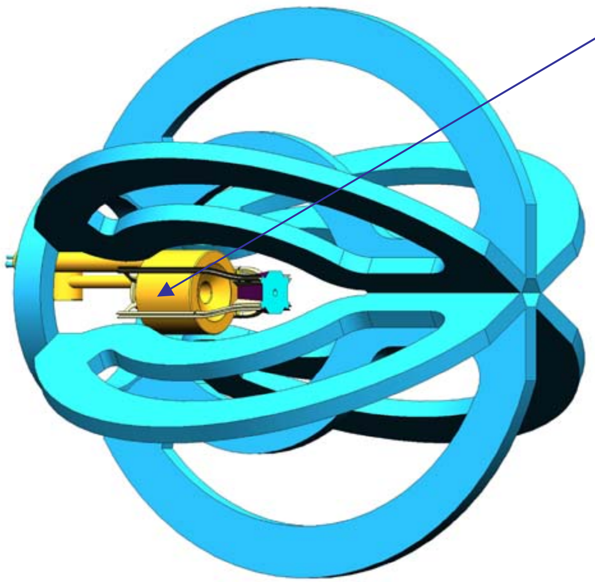
Unpolarized beam, transverse target:

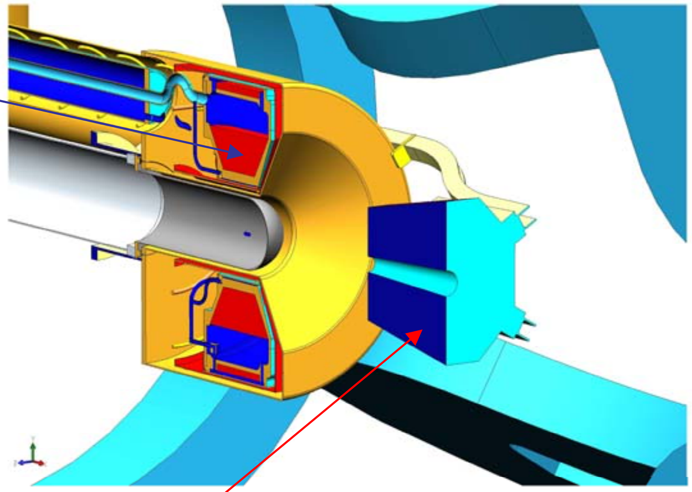
$$\Delta\sigma_{UT} \sim \sin\phi\{k(F_2 H - F_1 E) + ...\}d\phi \quad \Rightarrow \quad H(\xi,t),\ E(\xi,t)$$

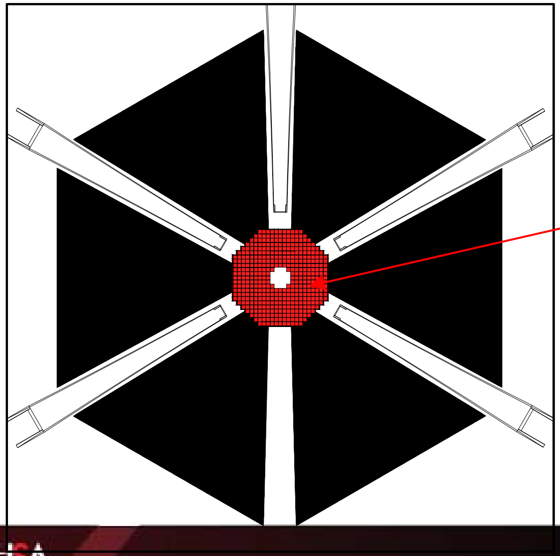
Kinematically suppressed

DVCS@CLAS – a dedicated experiment

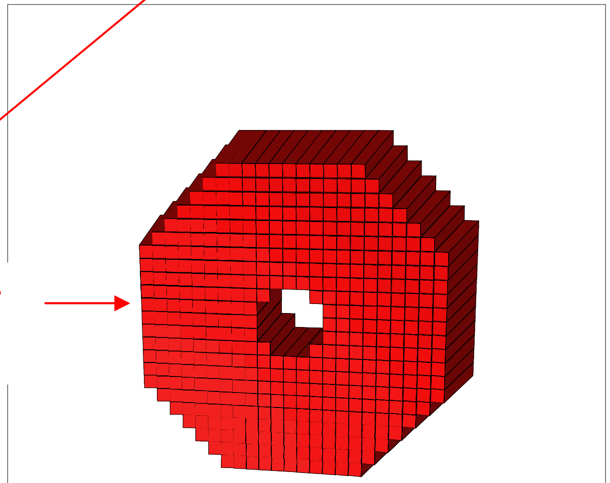
Superconducting solenoid





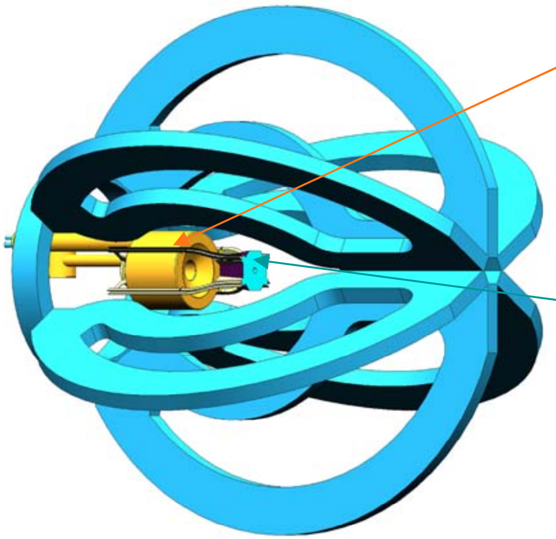


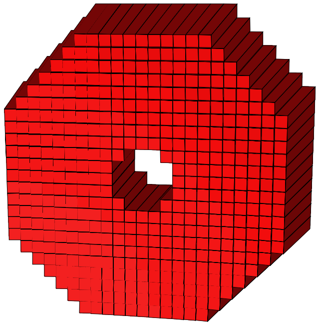
Inner calorimeter ($PbWO_4$)



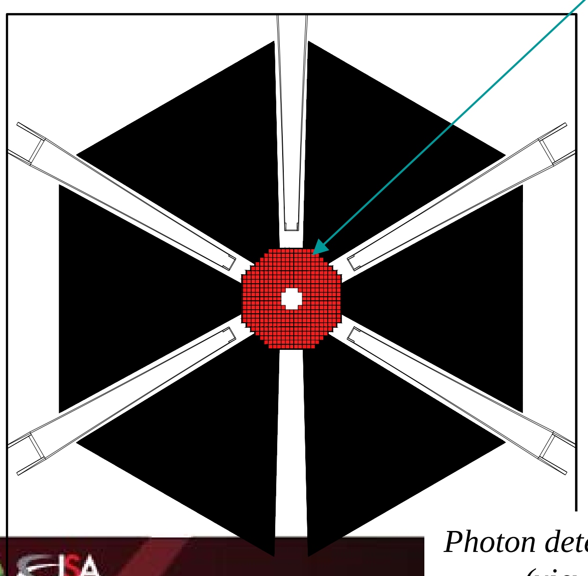
424 crystals, 16 mm long,
pointing geometry, ~ 1 degree/crystal,
APD readout

CLAS Setup for DVCS Experiments



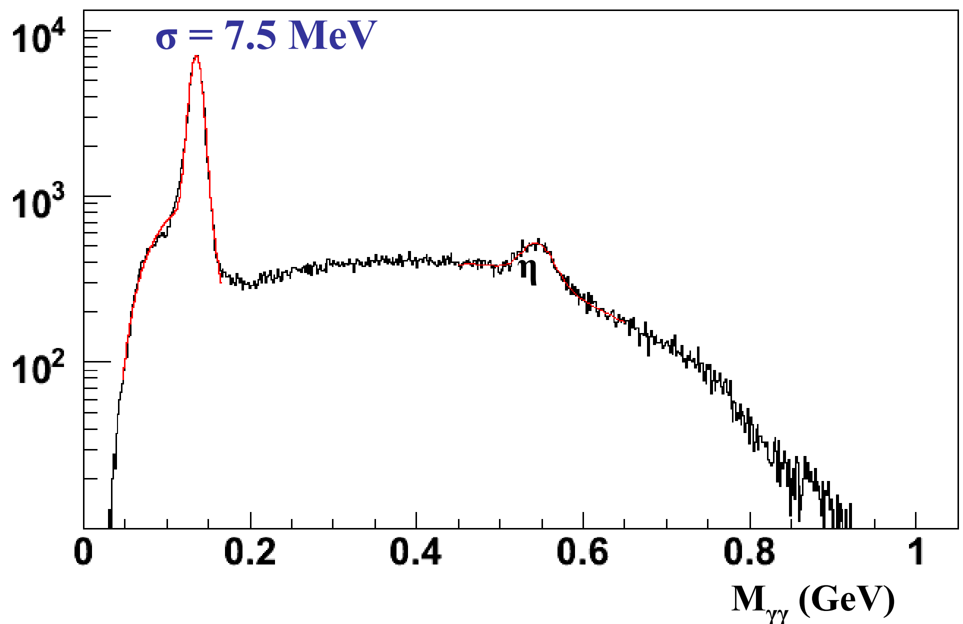


424 crystals, 16 mm long,
pointing geometry, ~ 1.2 degree/crystal,
APD readout



Photon detection in IC and EC (view from target)

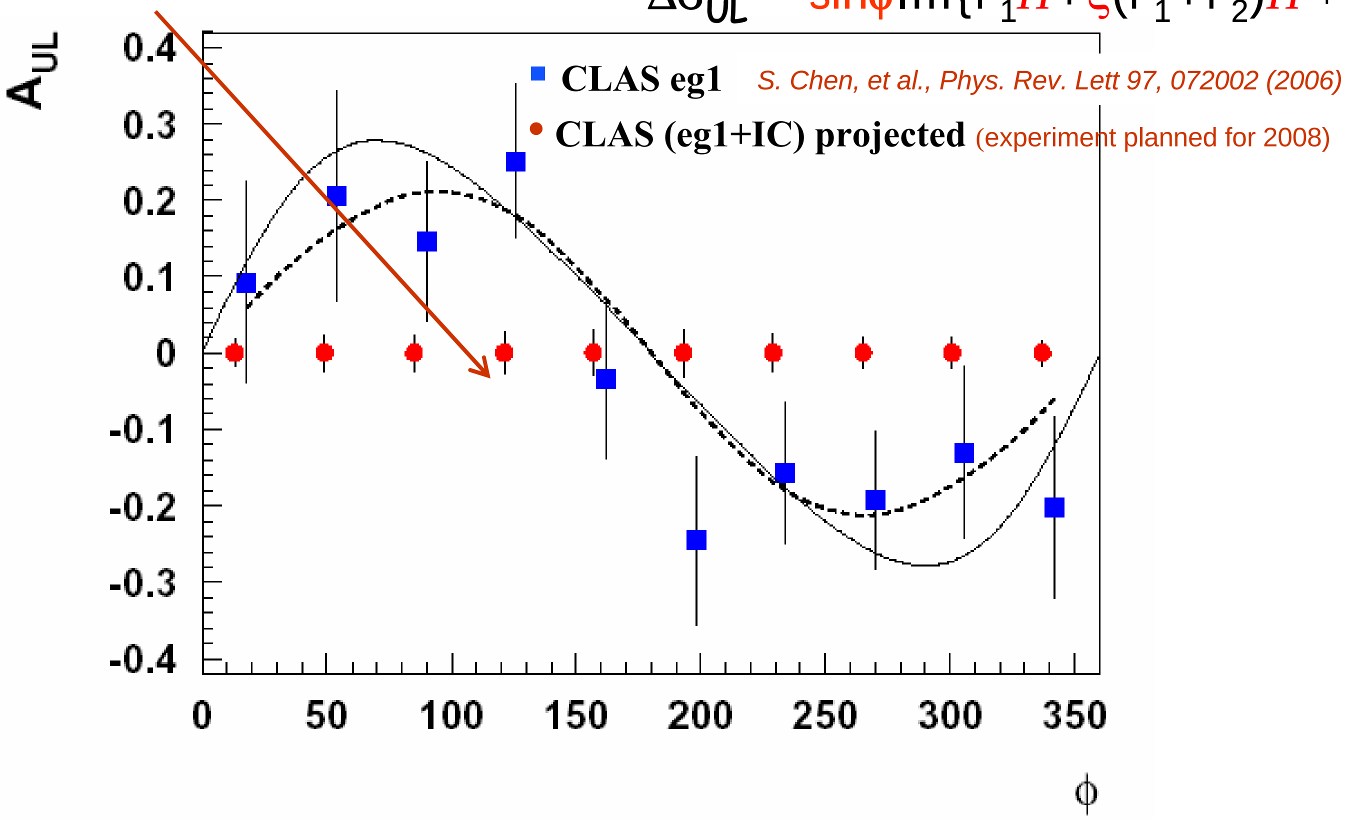
Calibration via $\pi^0 \rightarrow \gamma\gamma$



Target Spin Asymmetry: ϕ Dependence

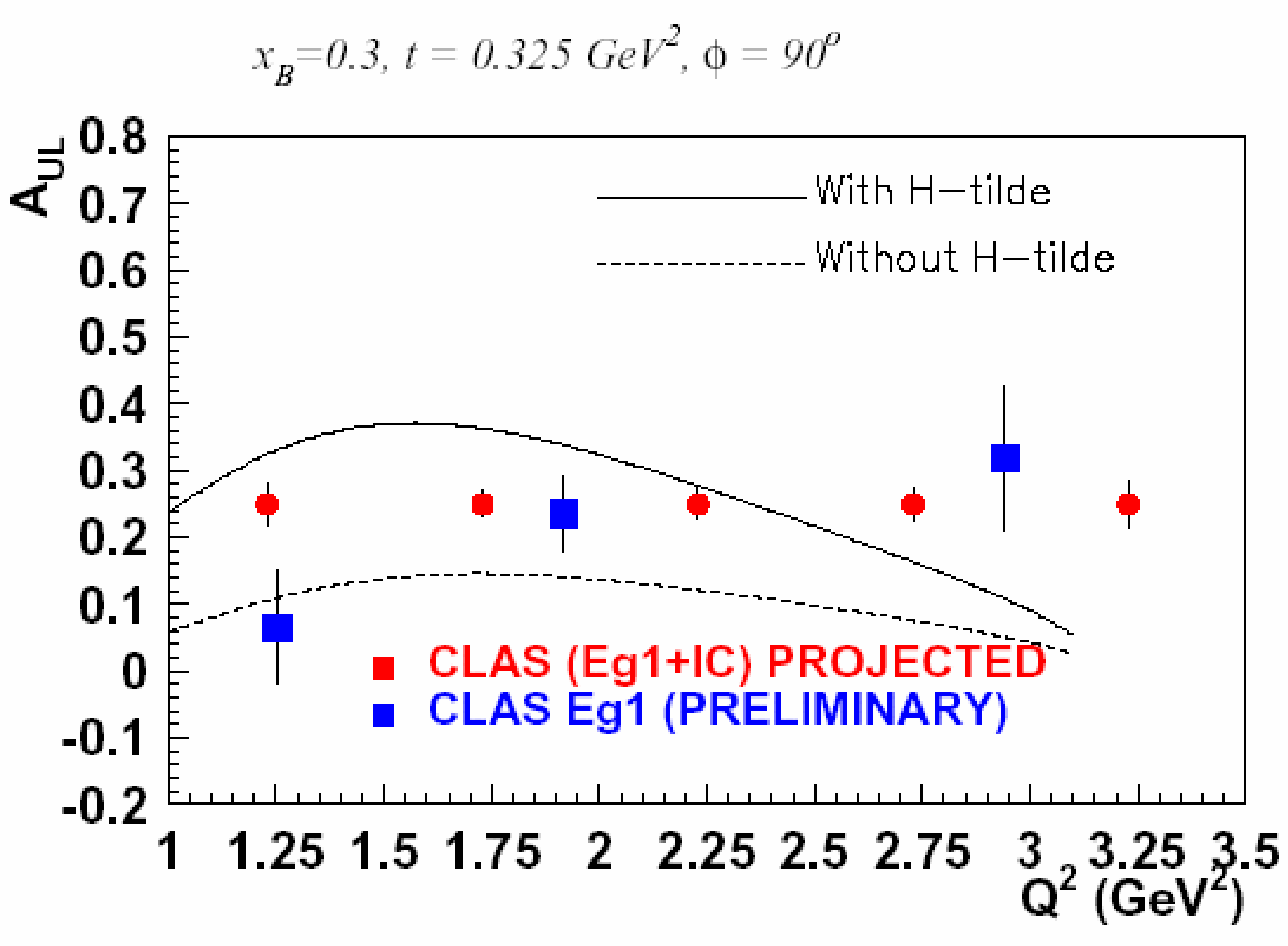
6 GeV run with NH_3 longitudinally polarized target (CLAS + IC) 60 days of beam time

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

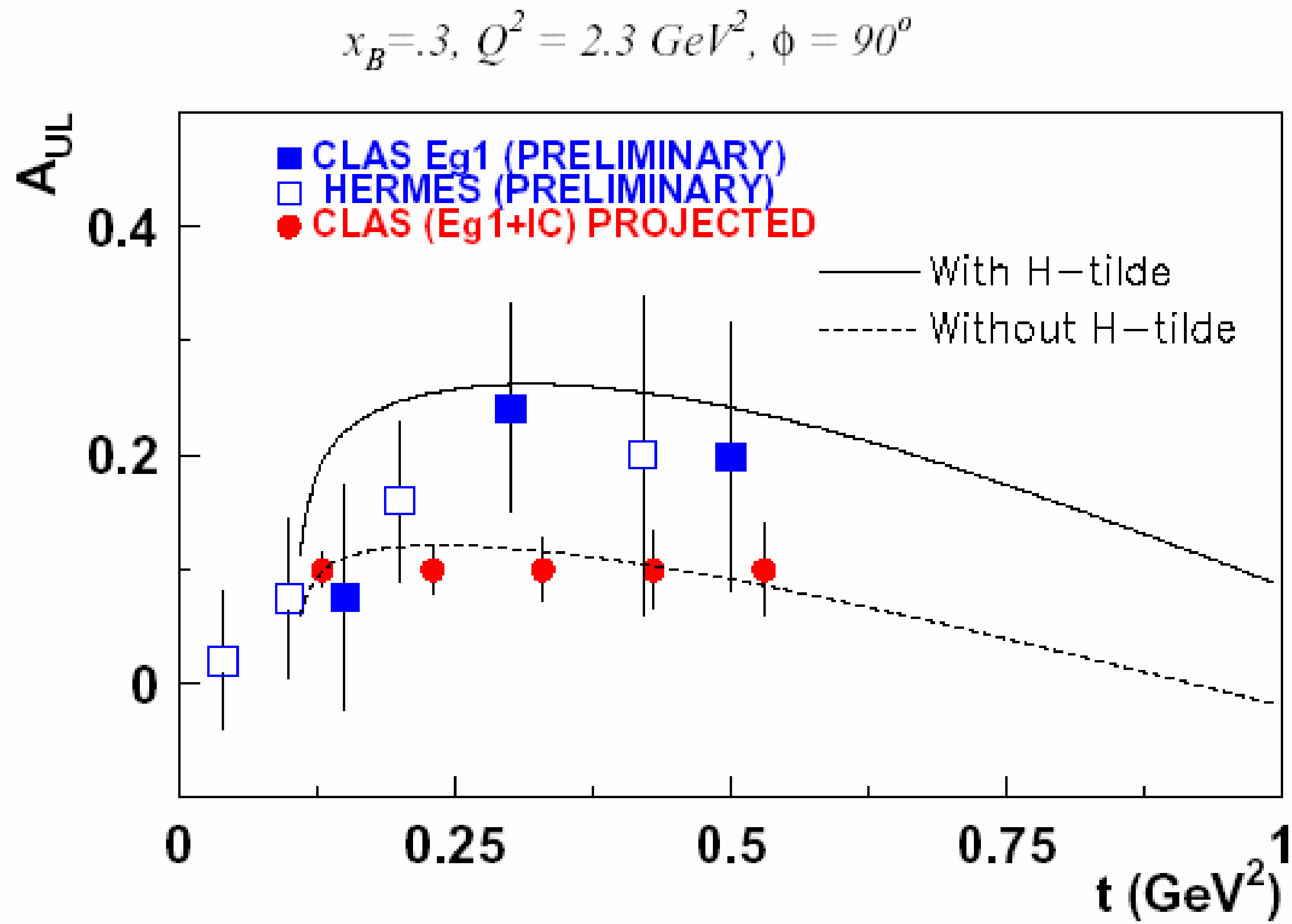


A dedicated CLAS experiment with longitudinally polarized target will provide a statistically significant measurement of the kinematical dependences of the DVCS target SSA

Target Spin Asymmetry: Q^2 Dependence



Target Spin Asymmetry: t- Dependence

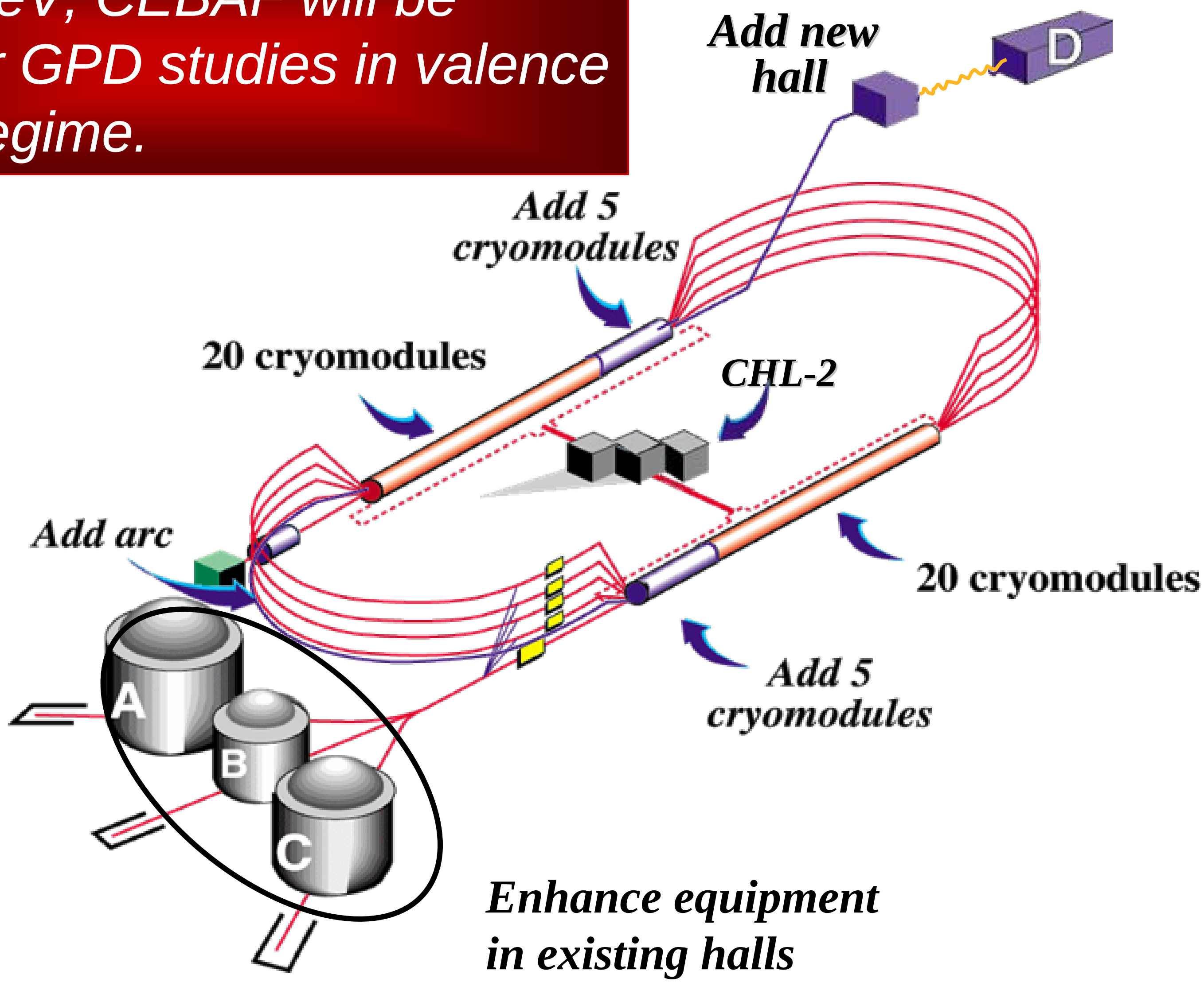


Higher t values will also be measured. The interpretation within the handbag formalism needs to be clarified.

In the past few years, we were able to glimpse some of the new physics that is accessible through GPDs. However, much more experimental and theoretical work is needed to efficiently unravel the complex structure of the proton.

JLab Upgrade to 12 GeV

At 12 GeV, CEBAF will be ideal for GPD studies in valence quark regime.



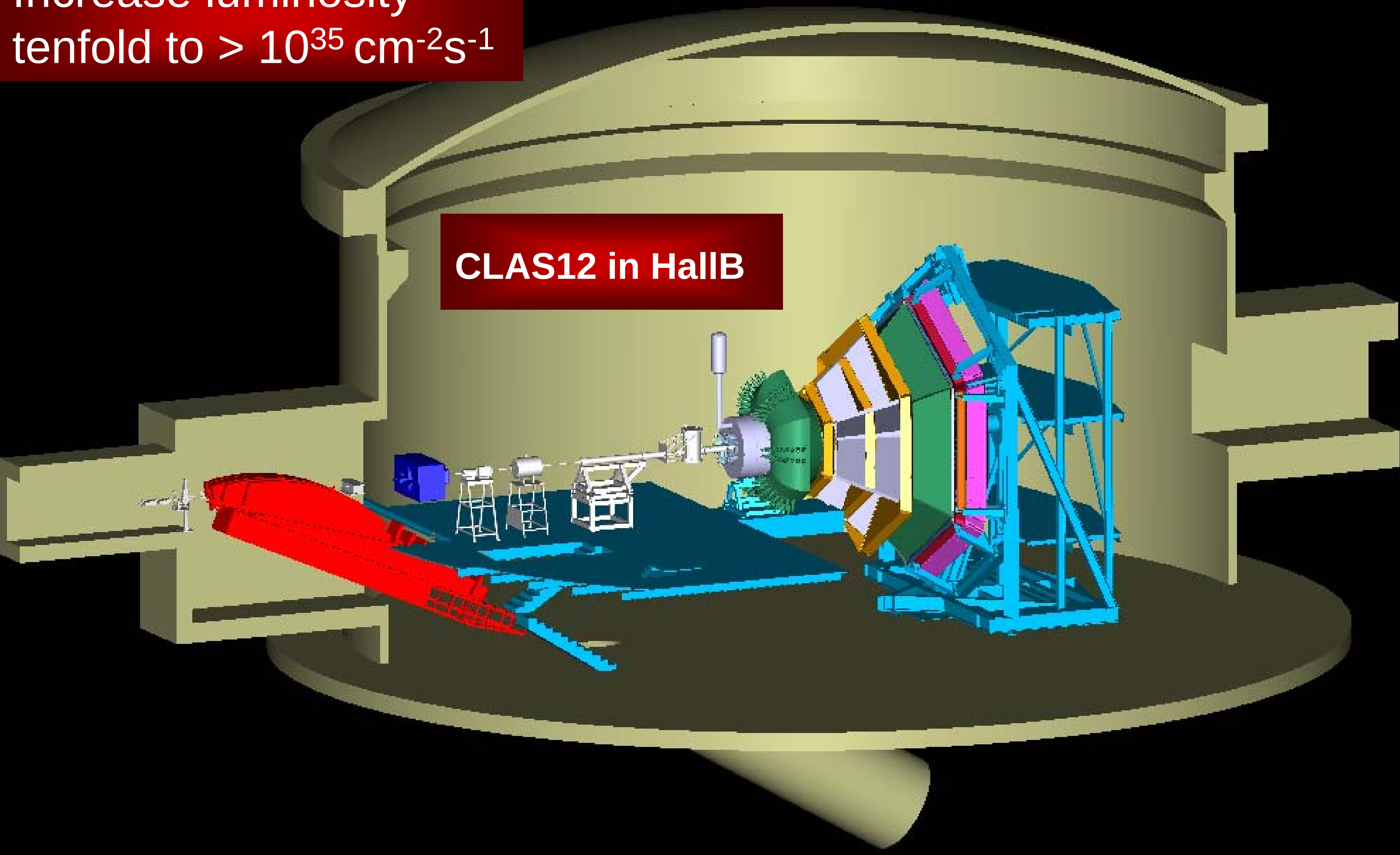
CLAS12 in HallB

- **CLAS** will be modified and upgraded to ***CLAS12*,** which will be worldwide the only large acceptance, multi-purpose detector for fixed target electron scattering experiments.

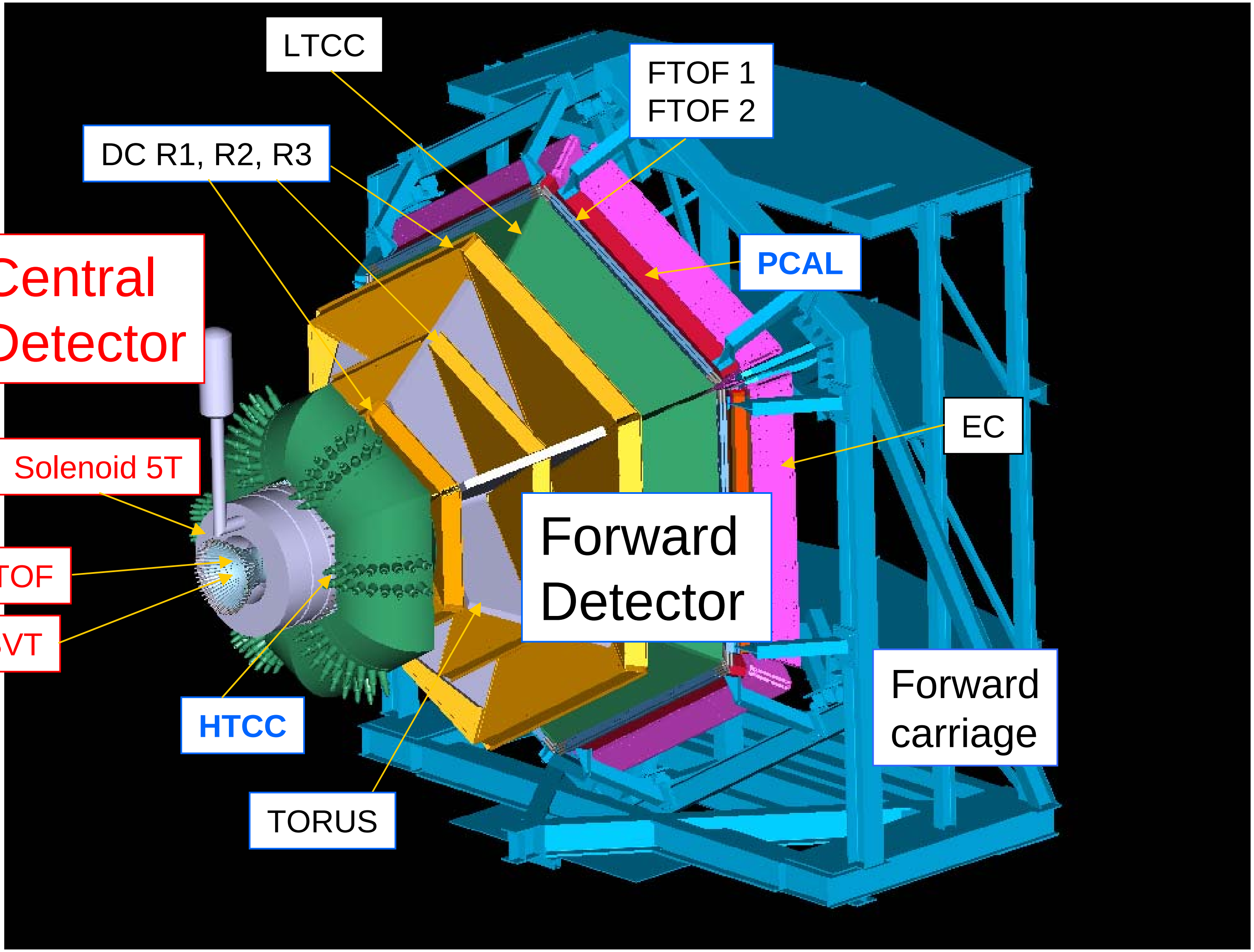
- ***CLAS12*** will operate with an upgraded luminosity of $>10^{35}cm^{-2}s^{-1}$, more than an order of magnitude increase, and improved particle identification.

- With these capabilities ***CLAS12*** will support a broad experimental program in fundamental nuclear physics

Increase luminosity tenfold to $> 10^{35}\ \mathrm{cm^{-2}s^{-1}}$

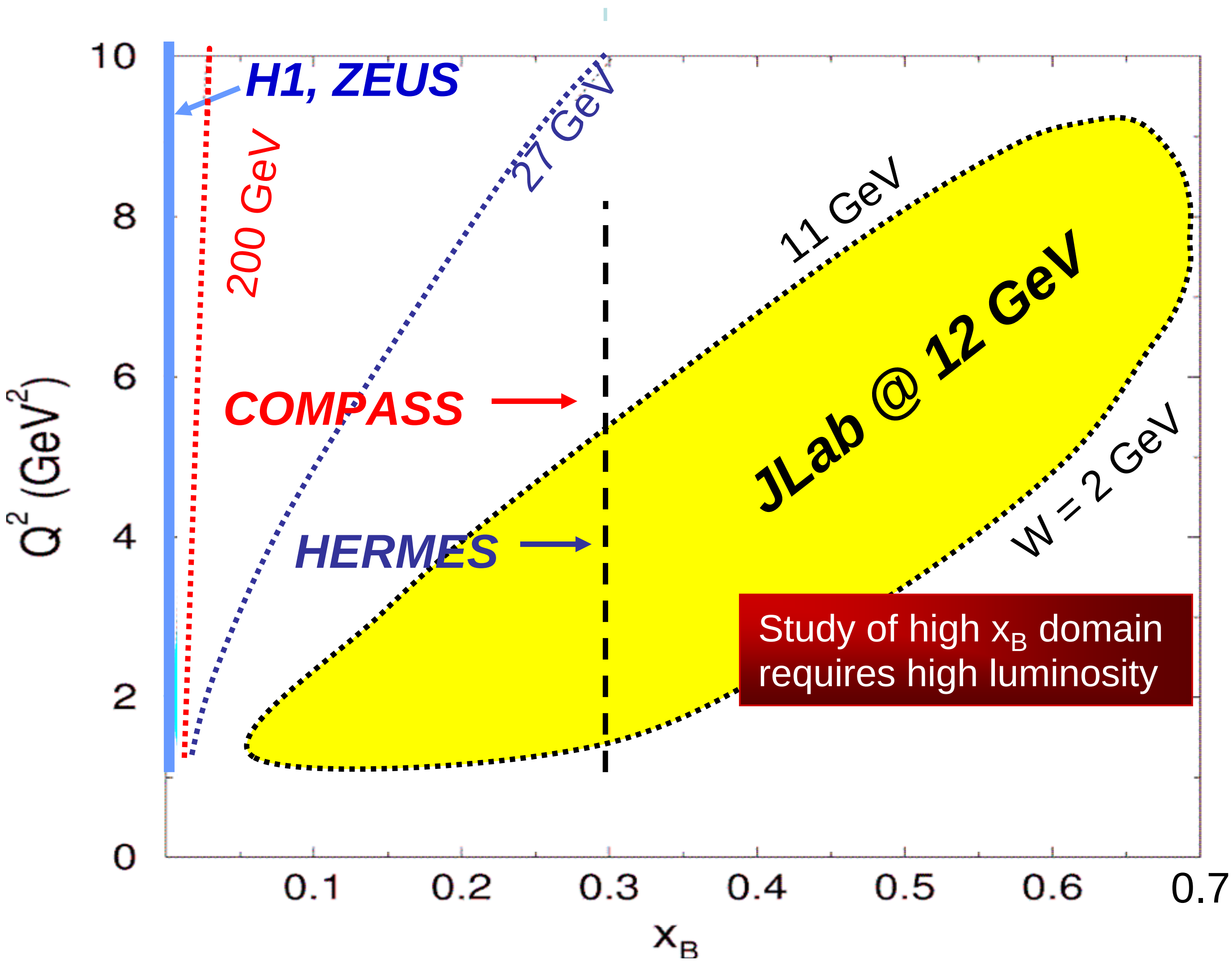


CLAS12

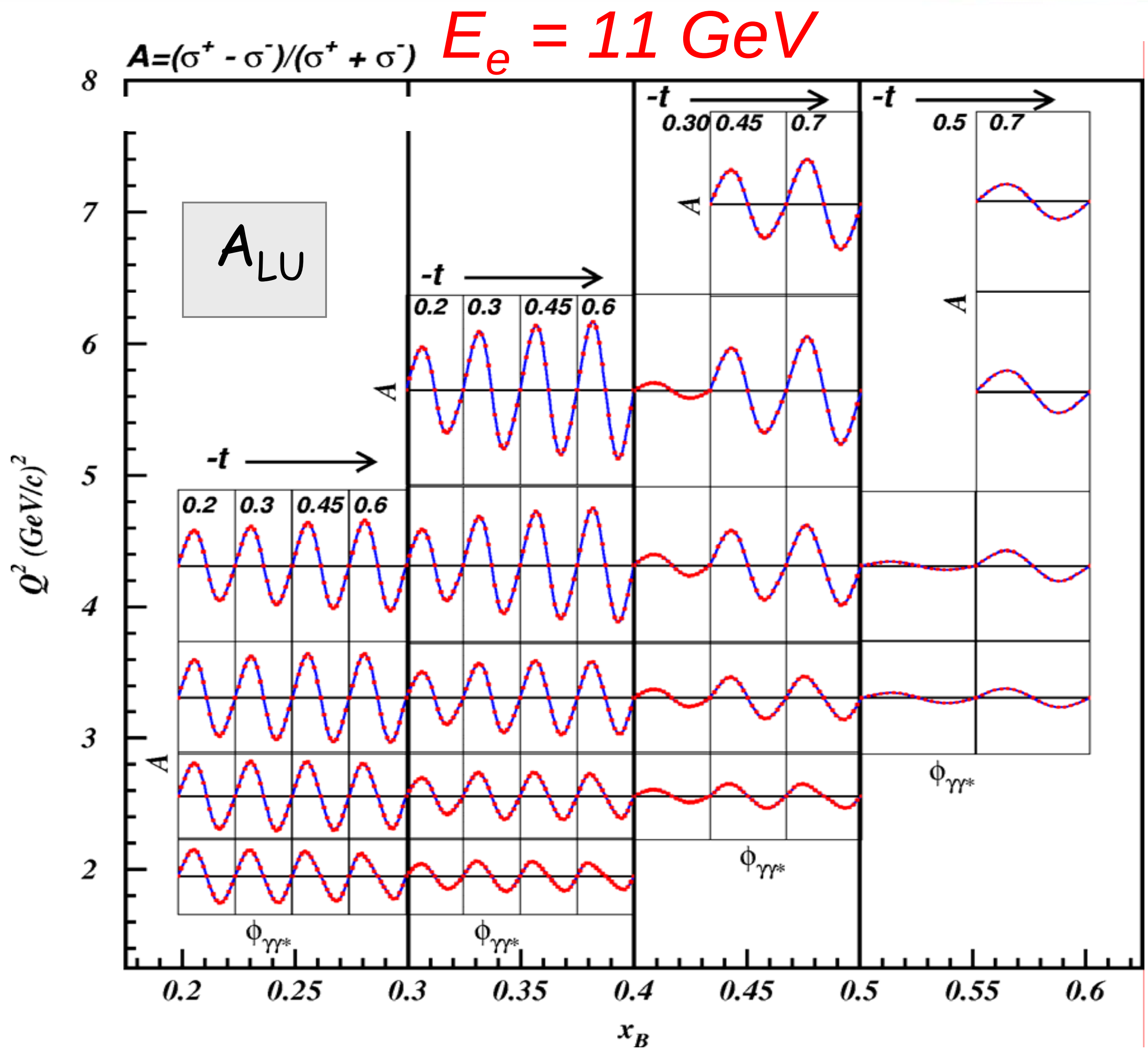


LTCC
FTOF 1
FTOF 2
DC R1, R2, R3
Central Detector
PCAL
EC
Solenoid 5T
CTOF
SVT
Forward Detector
HTCC
TORUS
Forward carriage

Deeply Virtual Exclusive Processes
Kinematics Coverage of the 12 GeV Upgrade



DVCS/BH- Beam Asymmetry



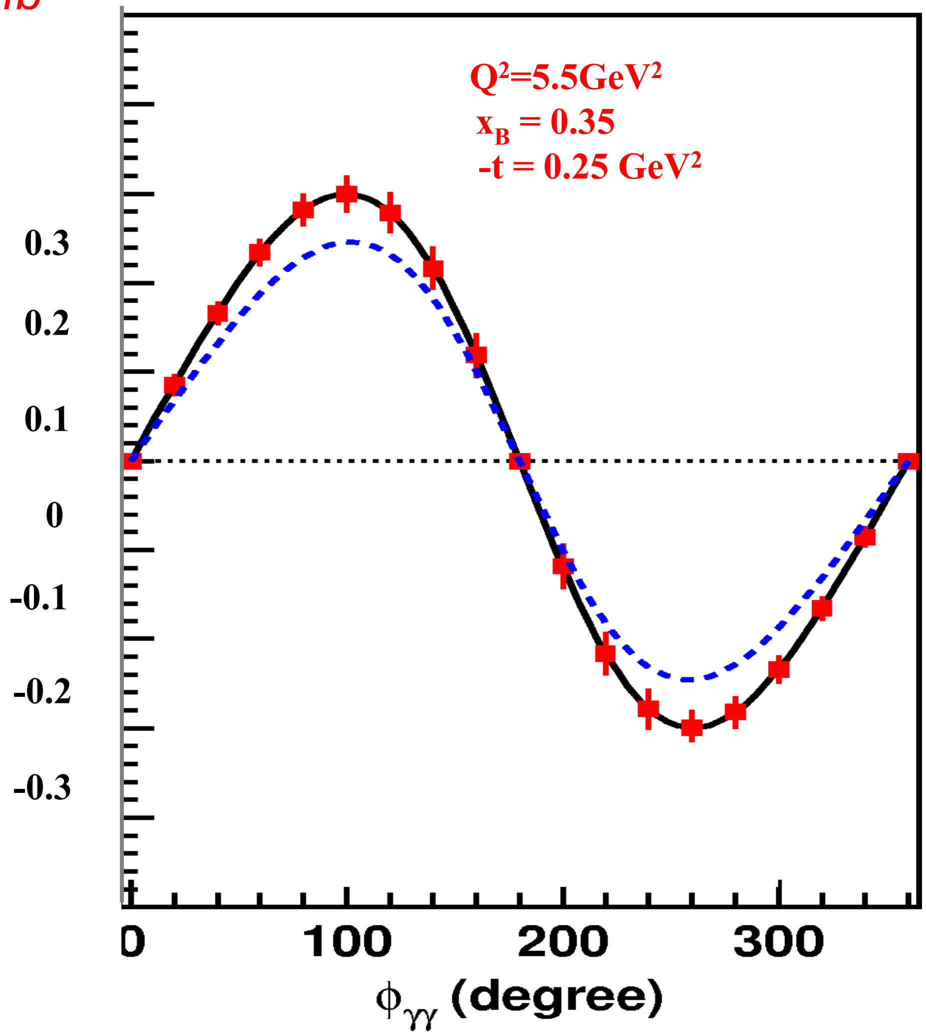
With large acceptance, measure large Q^2, x_B, t ranges simultaneously.

$A(Q^2,x_B,t)$
$\Delta\sigma(Q^2,x_B,t)$
$\sigma\ (Q^2,x_B,t)$

CLAS12 - DVCS/BH- Beam Asymmetry

$E_e = 11$ GeV

Luminosity = 720fb^{-1}



CLAS12 – DVCS/BH Beam Asymmetry

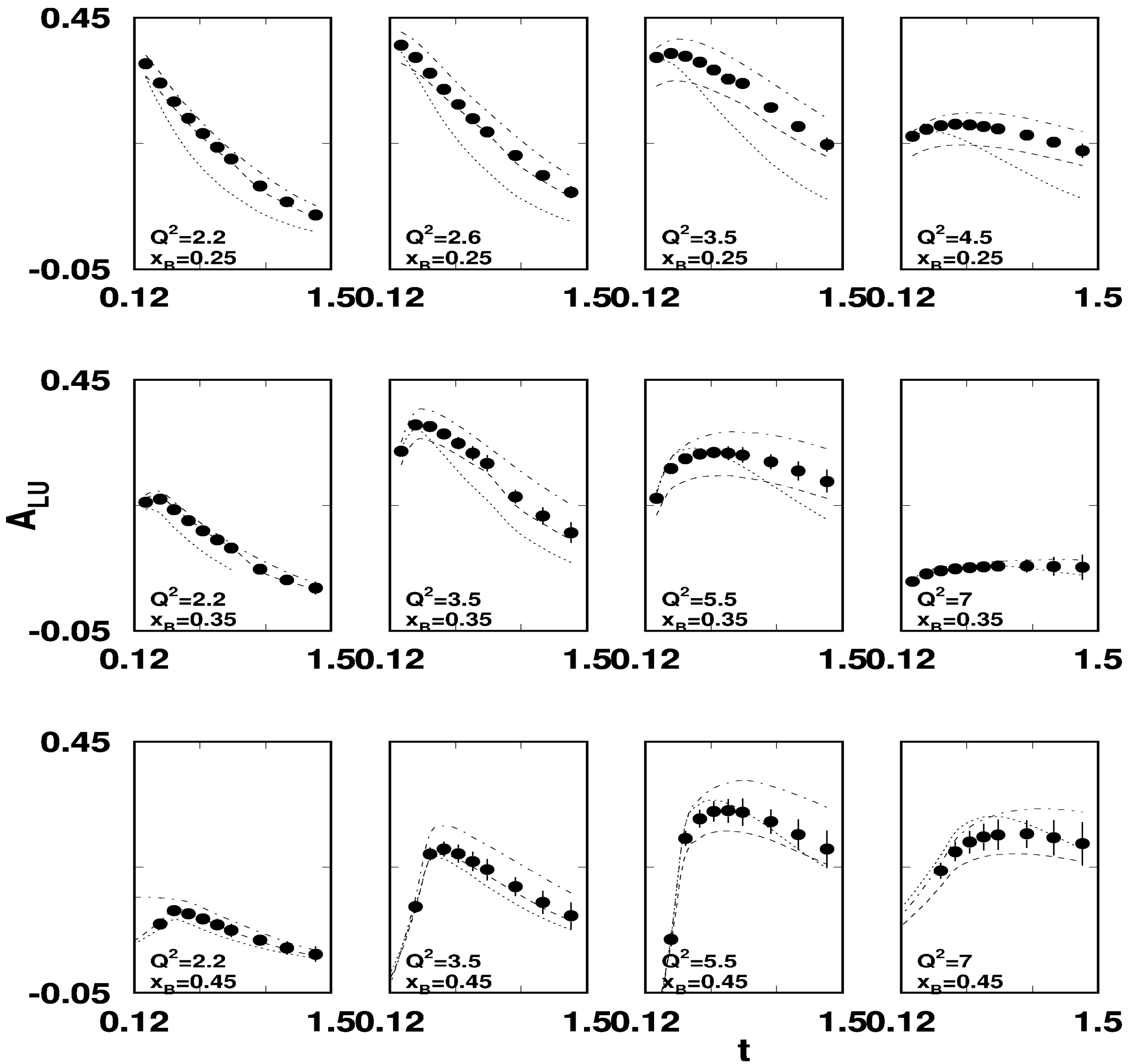
$\vec{e}\,p \longrightarrow ep\gamma$

E = 11 GeV

$\Delta\sigma_{LU} \sim \sin\phi \, \mathrm{Im}\{F_1 \mathcal{H} + ..\} d\phi$

Selected Kinematics

$L = 1 \times 10^{35}$
T = 2000 hrs
$\Delta Q^2 = 1\ GeV^2$
$\Delta x = 0.05$



CLAS12 – DVCS/BH Target Asymmetry

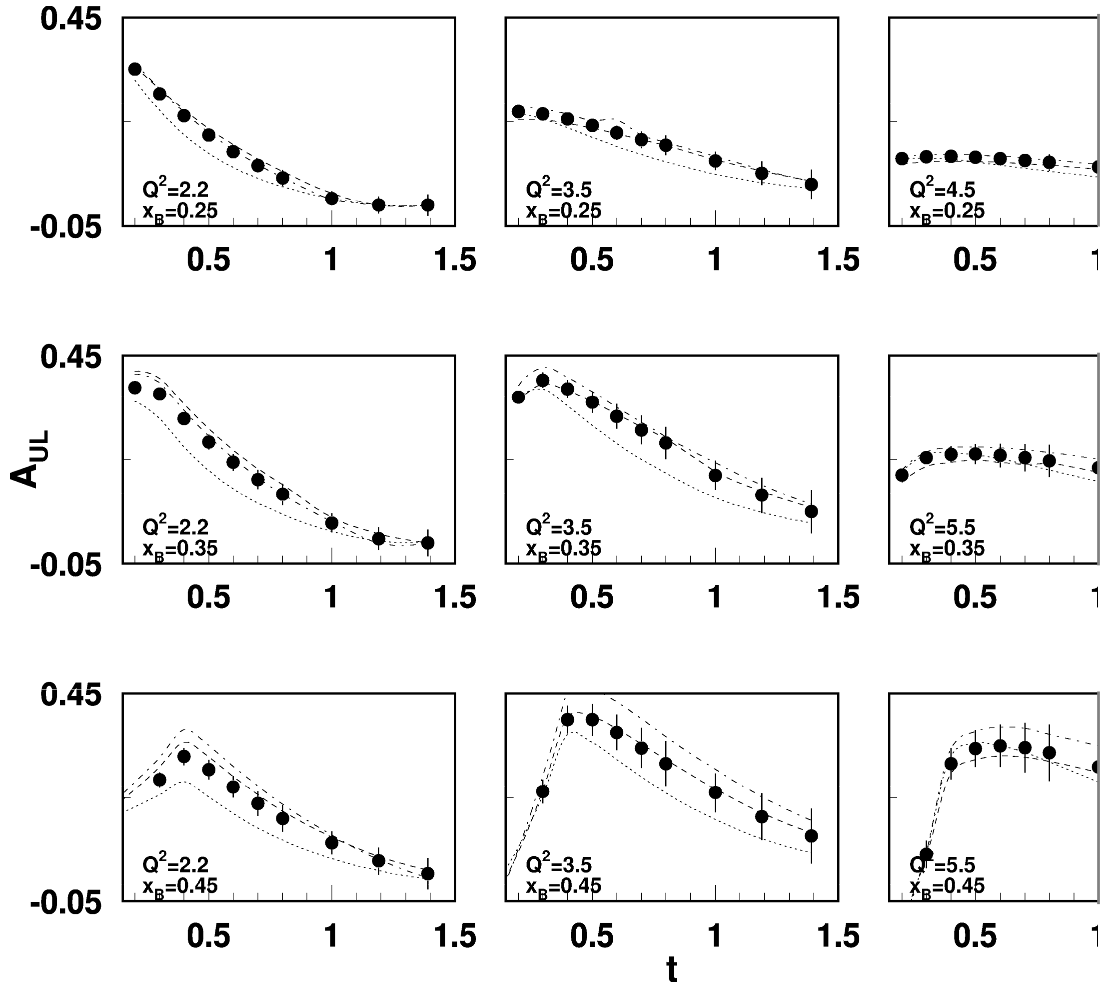
$e\,\vec{p} \longrightarrow e p \gamma$

Longitudinally polarized target

$\Delta\sigma \sim \sin\phi\, \mathrm{Im}\{F_1\tilde{H} + \xi(F_1+F_2)H \ldots\}d\phi$

L = 2×10^{35} $cm^{-2}s^{-1}$
T = 1000 hrs
$\Delta Q^2 = 1 GeV^2$
$\Delta x = 0.05$

E = 11 GeV



CLAS12 - DVCS/BH Target Asymmetry

$e\ p^{\uparrow} \longrightarrow e p \gamma$

E = 11 GeV

Sample kinematics

Q^2=2.2 GeV^2, x_B = 0.25, -t = 0.5GeV^2

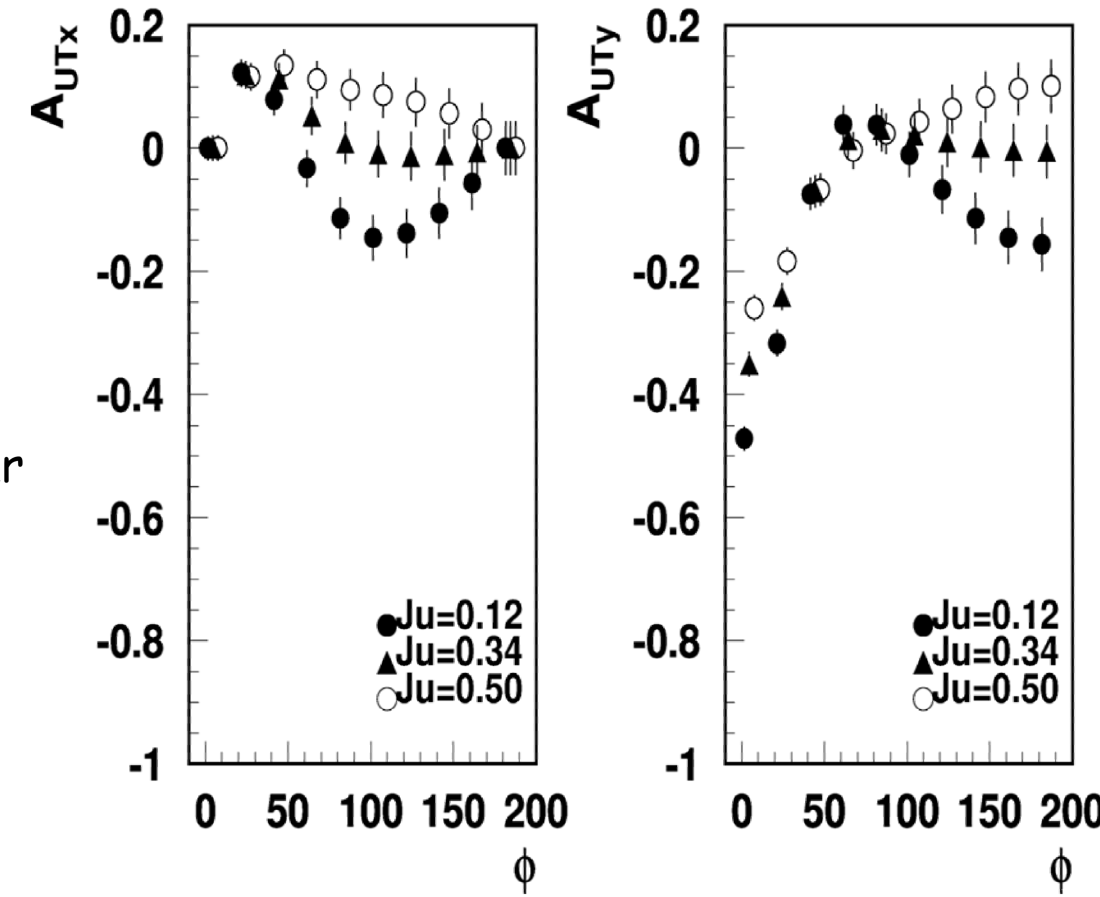
Transverse polarized target

$\Delta\sigma \sim \sin\phi \mathrm{Im}\{k_1(F_2 \mathbf{H} - F_1 \mathbf{E}) + \ldots\} d\phi$

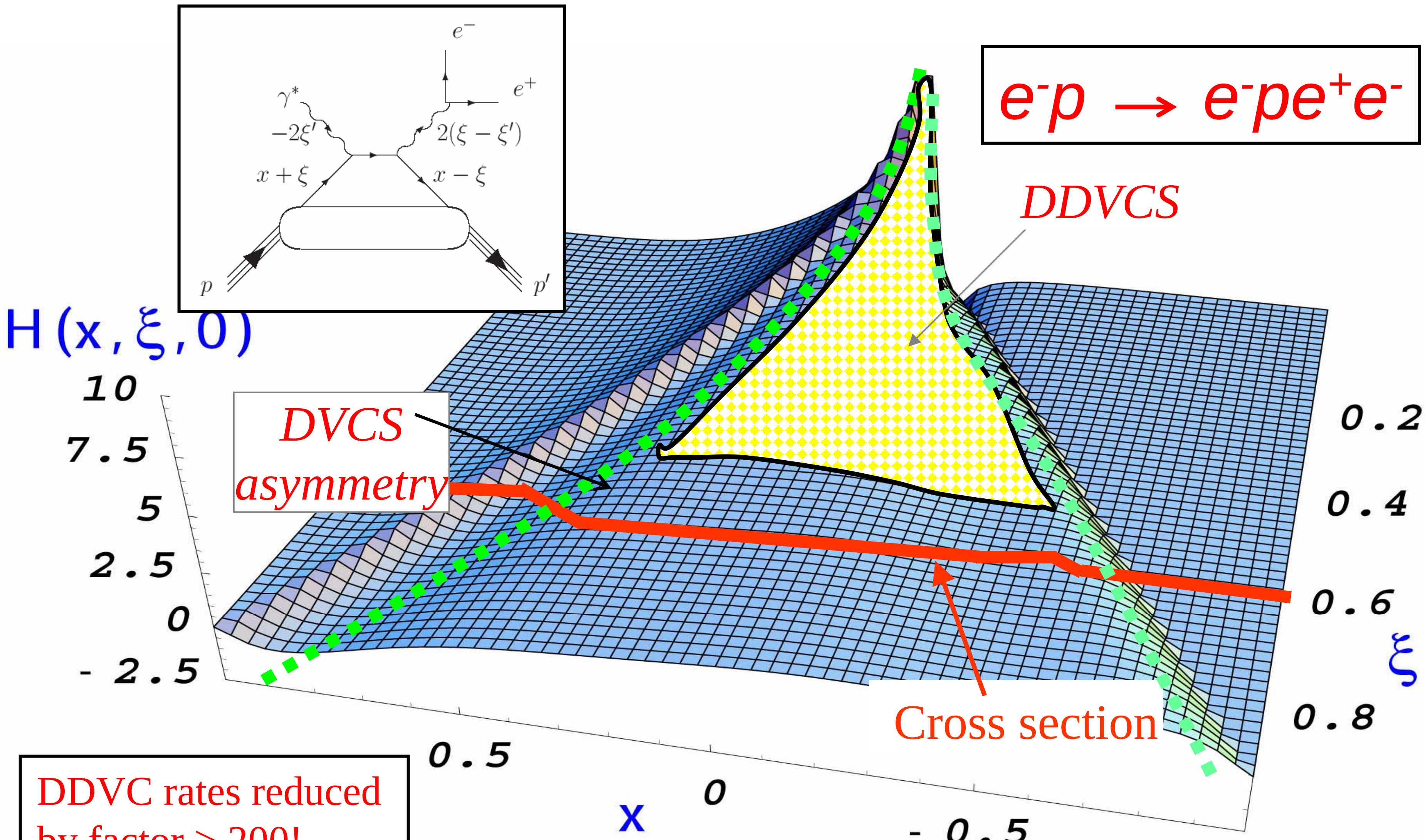
A_{UTx} Target polarization in the scattering plane

A_{UTy} Target polarized perpendicular to the scattering plane

- Asymmetries are highly sensitive to the u-quark contributions to the proton spin.



Double DVCS (DDVCS)



DDVC rates reduced by factor > 200!

Conclusions

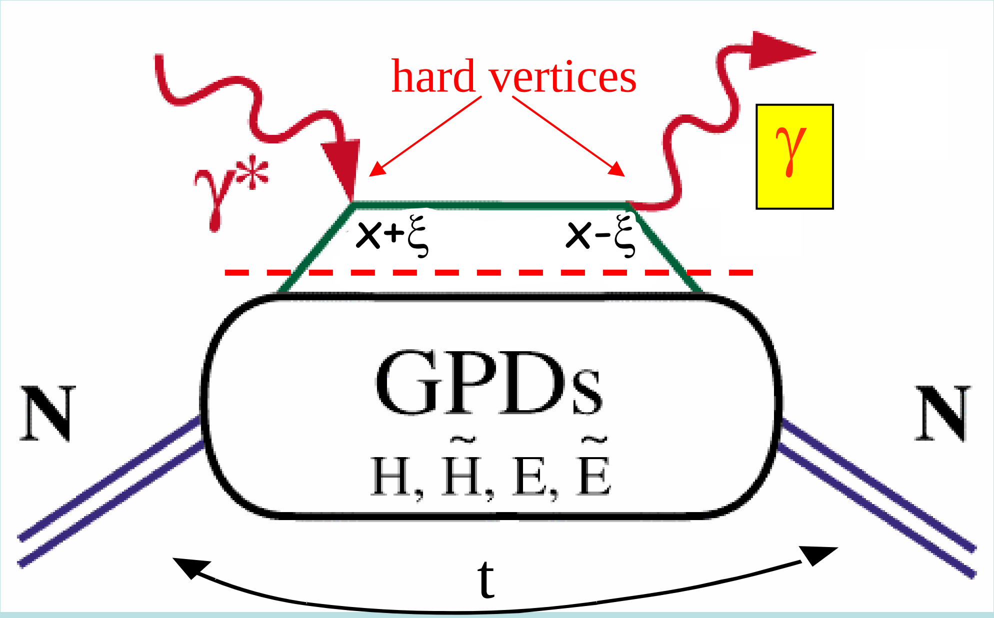
- With QCD as the theoretical framework, and the handbag mechanism and GPDs as tools the proton (and neutron) structure can be accessed systematically.

- First experiments demonstrate the applicability of the basic “handbag” mechanism at moderate (Jlab) energies.

- The JLab energy upgrade and new equipment provide the means to explore the complex proton structure in the full valence quark regime.

Basic Process – Handbag Mechanism

Deeply Virtual Compton Scattering (DVCS)



x – longitudinal quark momentum fraction

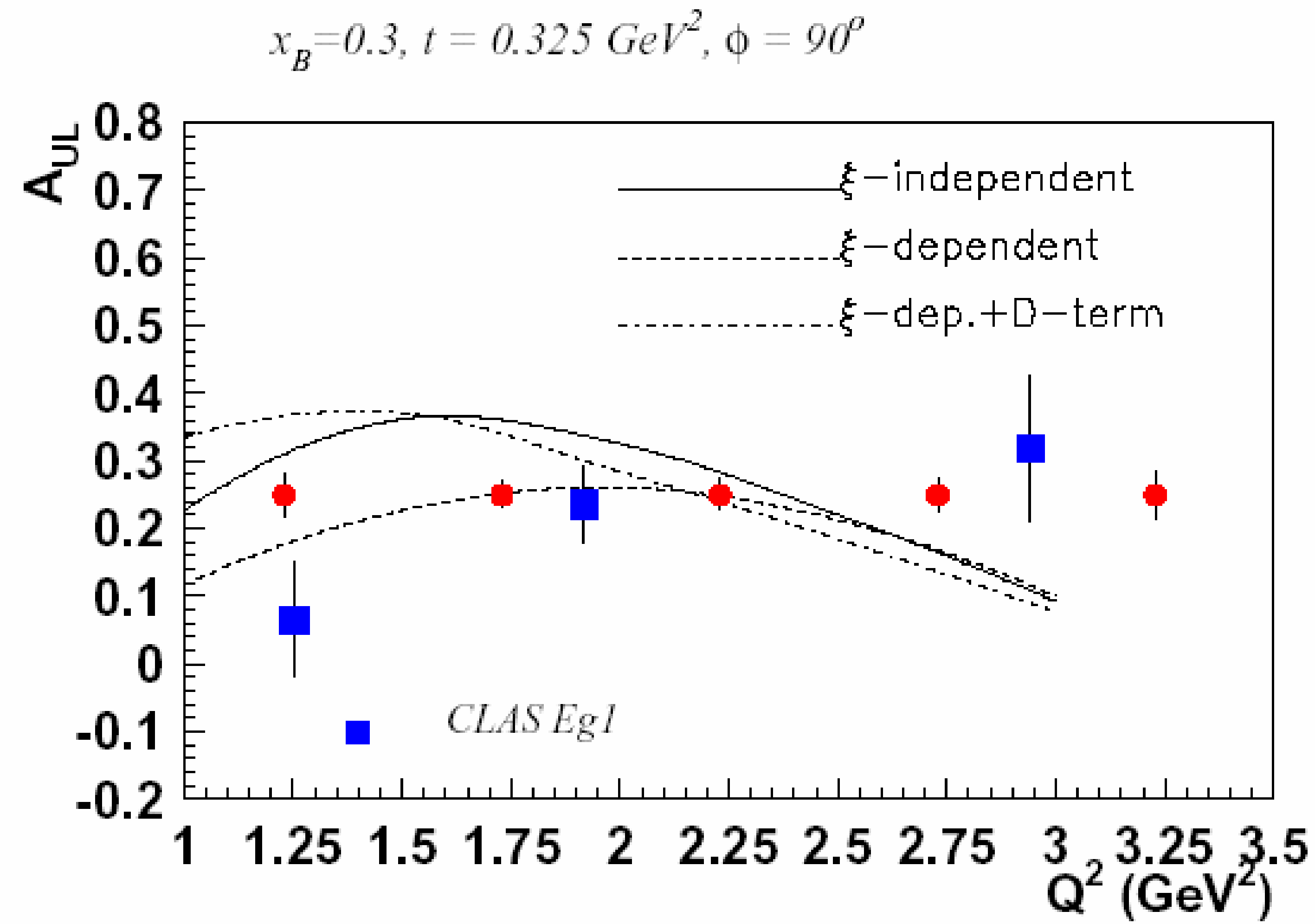
2ξ – longitudinal momentum transfer

$\sqrt{-t}$ – Fourier conjugate to transverse impact parameter

GPDs depend on 3 variables, e.g. *H(x, x, t)*. They probe the quark structure at the amplitude level.

$$\xi = \frac{x_B}{2-x_B}$$

Target Spin Asymmetry: Q^2- Dependence



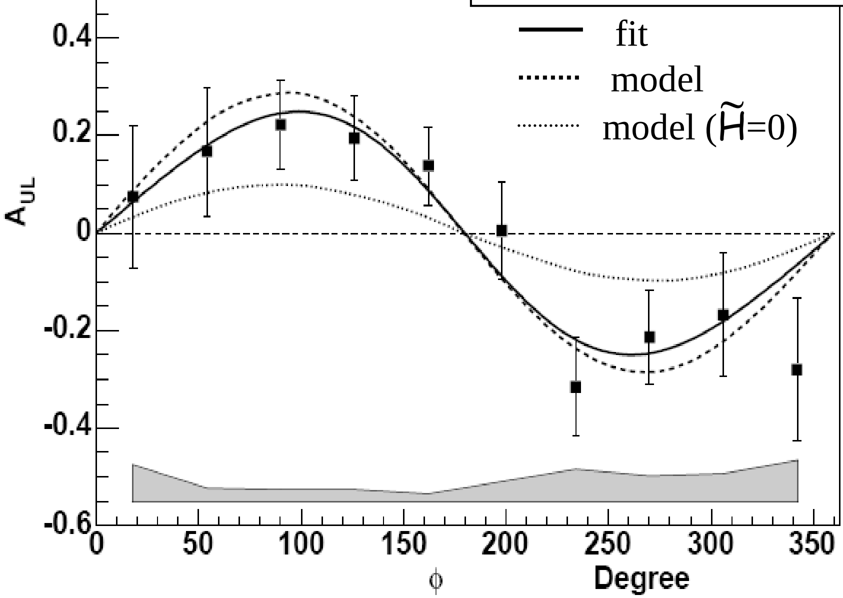
First DVCS measurement with spin-aligned target

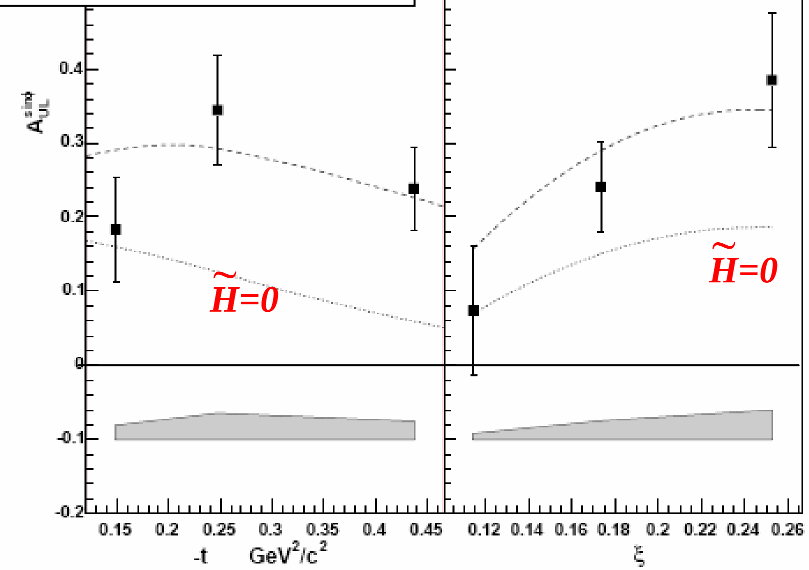
Unpolarized beam, longitudinally spin-aligned target:

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

A_{UL} is dominated by H and $\tilde{H}$

S. Chen, et al., Phys. Rev. Lett 97, 072002 (2006)



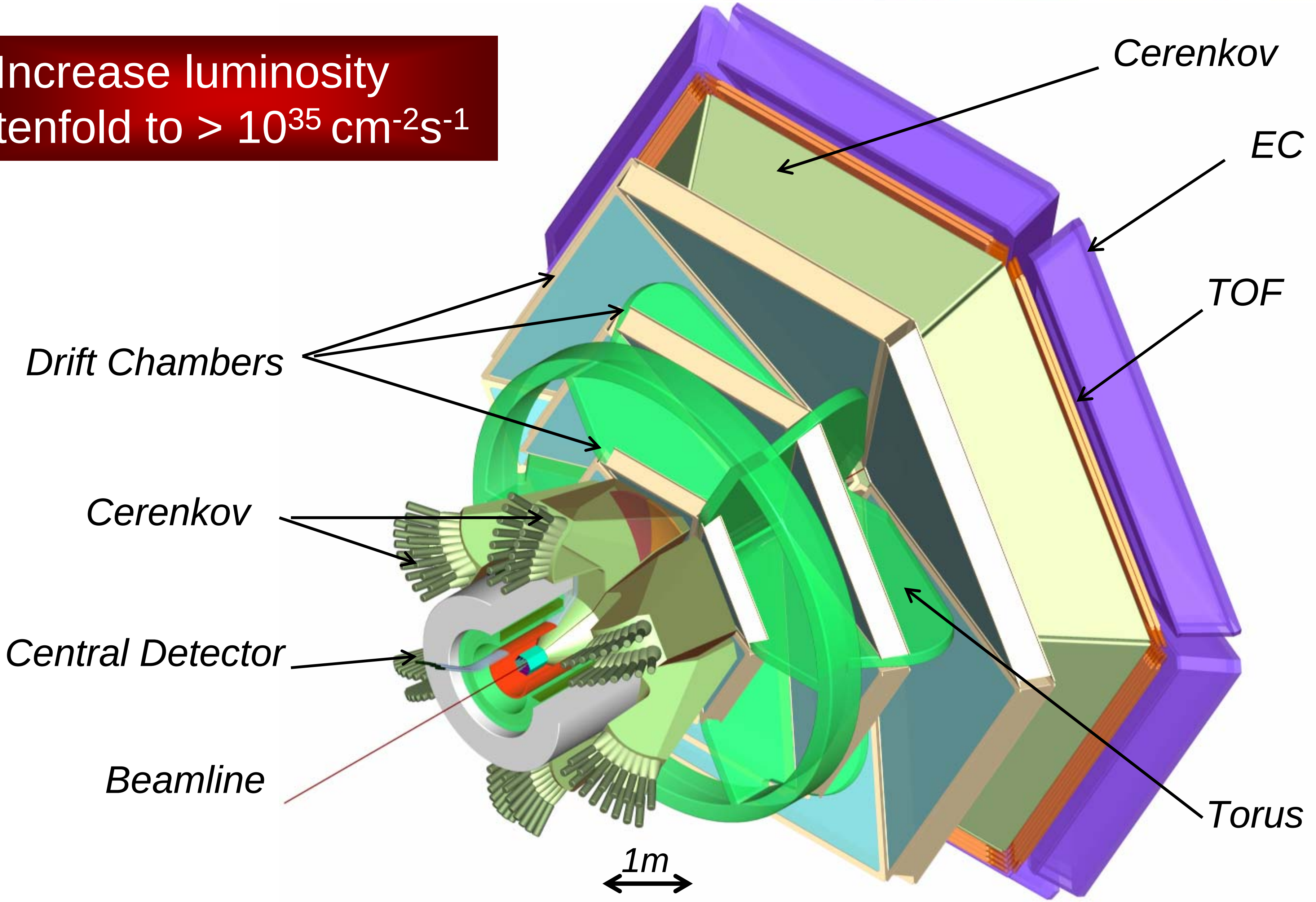


α = 0.252 ± 0.042
β = -0.022 ± 0.045

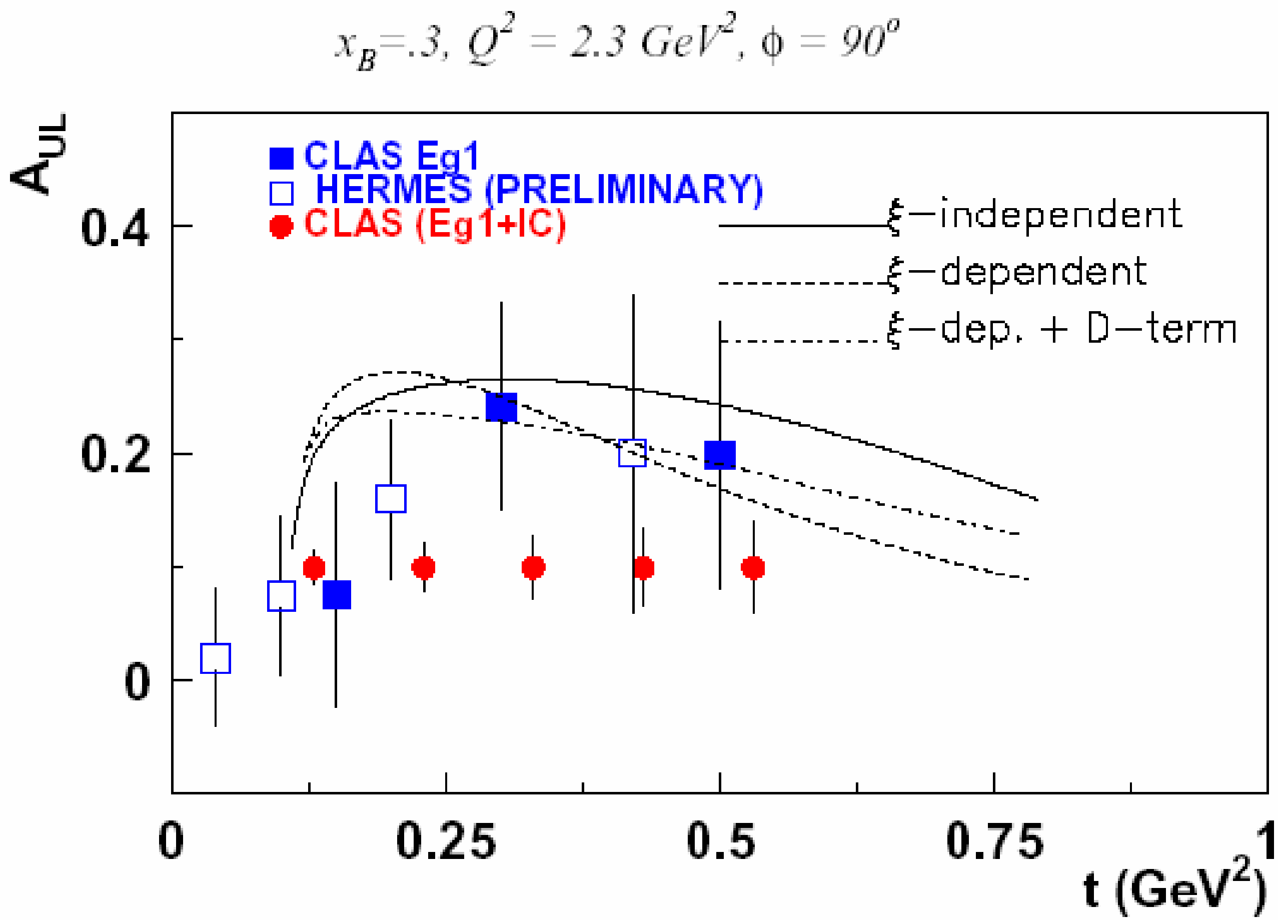
Planned experiment in 2008 will improve accuracy dramatically.

CLAS12

Increase luminosity tenfold to > 10^{35} cm^{-2}s^{-1}



Target Spin Asymmetry: t- Dependence



Target Spin Asymmetry: x- Dependence