

RESULTS ON DEEPLY VIRTUAL COMPTON SCATTERING AT HERMES

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FOR THE HERMES–Collaboration

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- INTRODUCTION
- DVCS MEASUREMENT AT HERMES
- HERMES RESULTS ON AZIMUTHAL ASYMMETRIES
- SUMMARY AND OUTLOOK

MOTIVATION

NUCLEON SPIN COMPOSITION:

$$\text{NUCLEON'S SPIN} = \underbrace{1/2 (\Delta u + \Delta d + \Delta s)}_{30\%} + \underbrace{L_q}_{J_q} + J_g$$

J1'S RELATION: TOTAL ANGULAR MOMENTUM

$$J^q = \lim_{t \rightarrow 0} \frac{1}{2} \int_{-1}^1 dx x \left[\underbrace{H^q(x, \xi, t)}_{GPDs} + \underbrace{E^q(x, \xi, t)}_{GPDs} \right]$$

WE STUDY DVCS TO CONSTRAIN GPDs

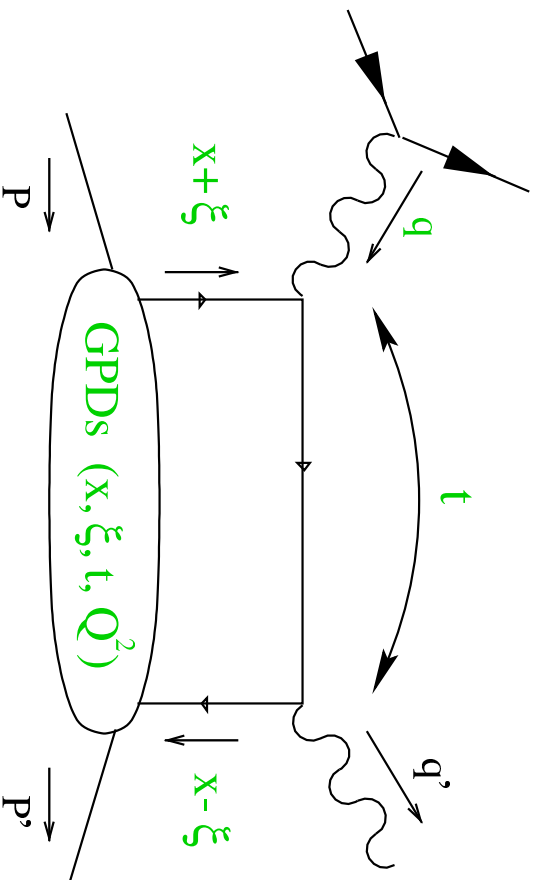
DEEPLY VIRTUAL COMPTON SCATTERING (DVCS)

GPDs ACCESSIBLE IN HARD **EXCLUSIVE** REACTIONS:

DVCS: HARD PHOTOPRODUCTION OF A REAL PHOTON:

$(\gamma^* N \rightarrow N' \gamma)$ HIGHLY VIRTUAL PHOTON GENERATED BY

LEPTON SCATTERING $\Rightarrow e N \rightarrow e' N' \gamma$



NUCLEON STRUCTURE:

GPDs : $H, \tilde{H}, E, \tilde{E}$

GPDs \rightarrow **PDFs**

$$\tilde{H}(x, 0, 0) = q(x)$$

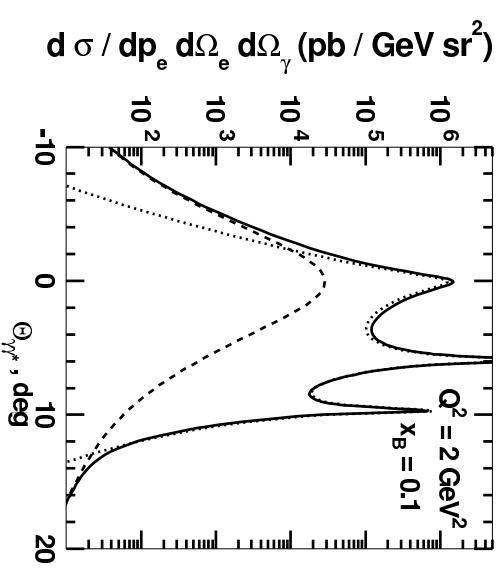
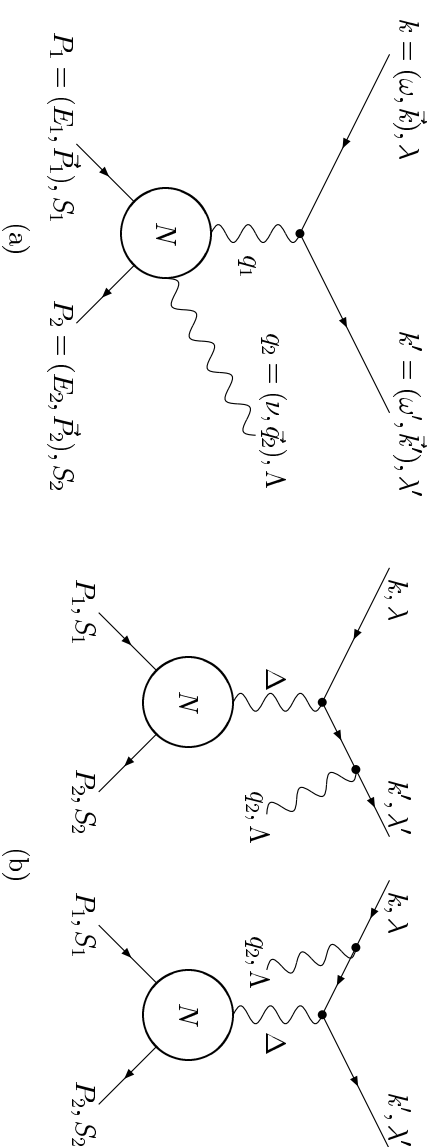
$$\tilde{H}(x, 0, 0) = \Delta q(x)$$

GPDs \rightarrow **FFs**

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

DVCS-BH INTERFERENCE

DVCS AND BETHE-HEITLER (BH) PROCESSES HAVE THE SAME INITIAL AND FINAL STATES \Rightarrow TWO SUBPROCESSES INTERFERE



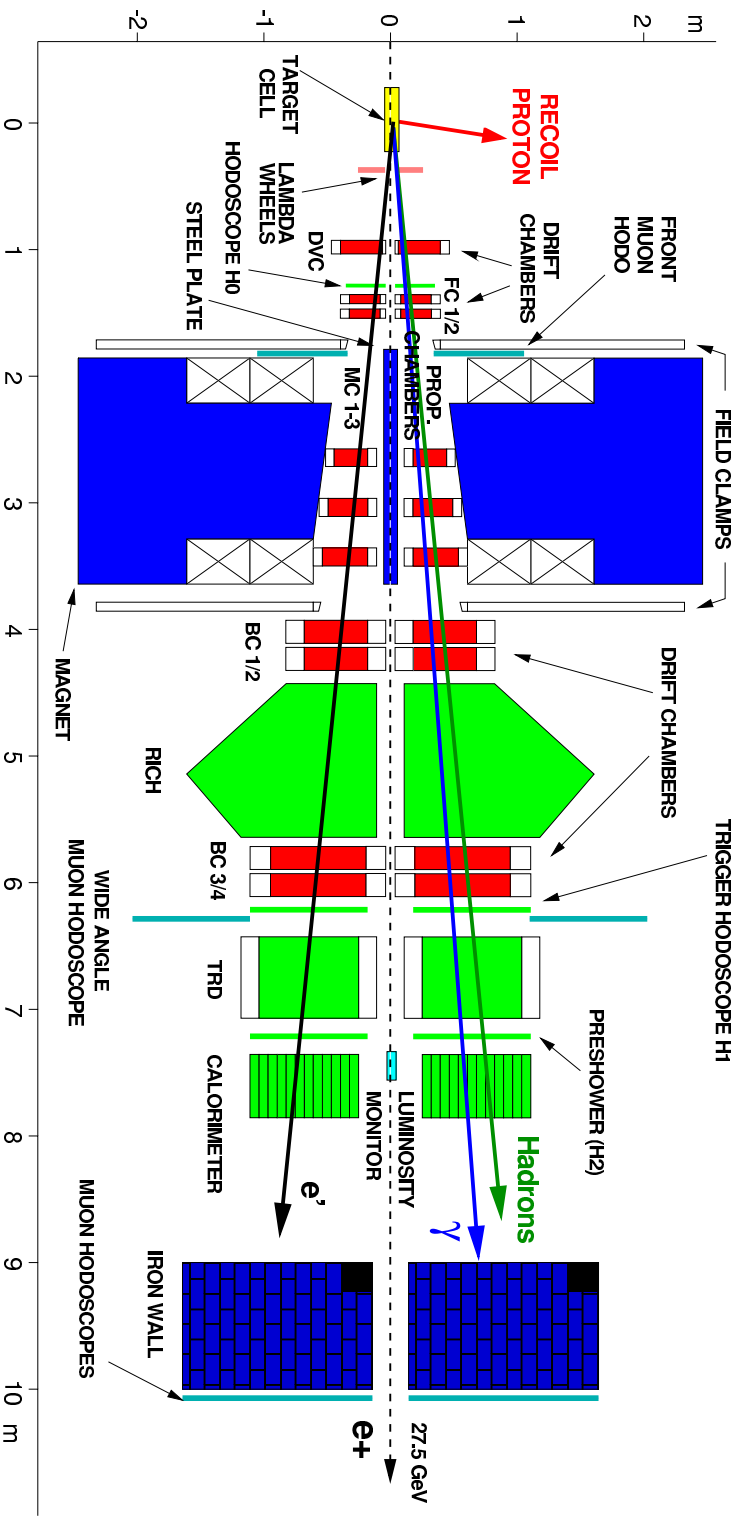
PHOTON LEPTOPRODUCTION CROSS SECTION:

$$d\sigma \propto |\tau_{\text{DVCS}} + \tau_{\text{BH}}|^2 = |\tau_{\text{DVCS}}|^2 + |\tau_{\text{BH}}|^2 + \underbrace{(\tau_{\text{DVCS}}^* \tau_{\text{BH}} + \tau_{\text{BH}}^* \tau_{\text{DVCS}})}_I$$

$$|\tau_{\text{DVCS}}|^2 \ll \ll |\tau_{\text{BH}}|^2$$

DVCS AMPLITUDES: ACCESSIBLE THROUGH AZIMUTHAL ASYMMETRIES VIA **I**
 (GPDs ENTER IN LINEAR COMBINATIONS IN AMPLITUDES)

HERMES EVENT SELECTION



GAS TARGET:

- LONG. POLARIZED H, D
 - UNPOLARIZED H, D, Ne, Kr, Xe
 - TRANSVERSELY POLARIZED H
- $\langle |P_T| \rangle \approx 85\%$

BEAM:

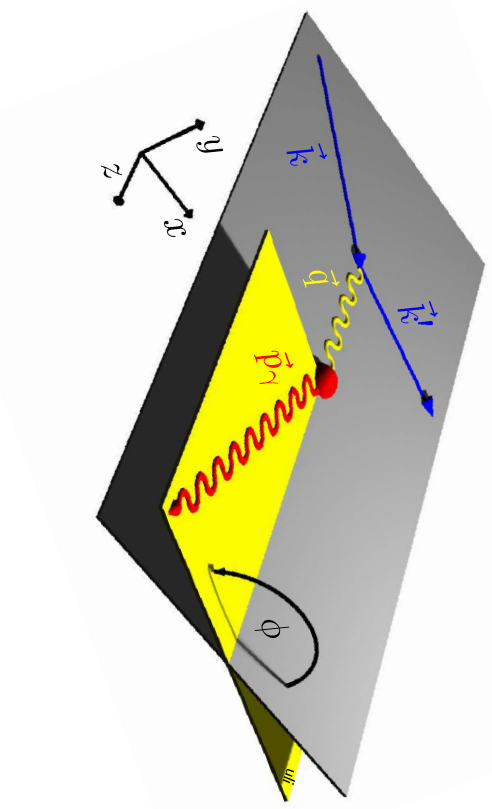
- LONG. POLARIZED e^+ AND e^-
 - ENERGY 27.6 GeV
 - BOTH HELICITIES
- $\langle |P_B| \rangle \approx 55\%$

NO RECOIL DETECTION \Rightarrow EXCLUSIVITY VIA MISSING MASS: $M_x^2 = (q + P - q')^2$



AZIMUTHAL ASYMMETRIES AT HERMES

- BEAM-CHARGE ASYMMETRY (BCA)
- BEAM-SPIN ASYMMETRY (BSA)
- LONGITUDINAL TARGET-SPIN ASYMMETRY (LTSA)
- TRANSVERSE TARGET-SPIN ASYMMETRY (TTSA)



$$\text{BCA : } d\sigma(e^+p) - d\sigma(e^-p) \sim c_1^I \cos(\phi) \simeq \cos(\phi) \times \text{Re } \mathcal{H}$$

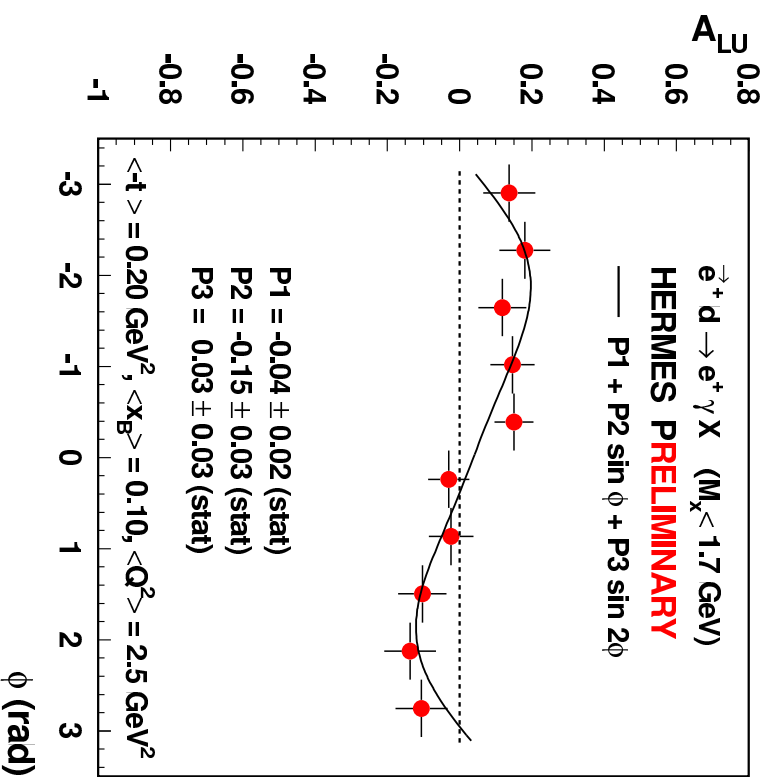
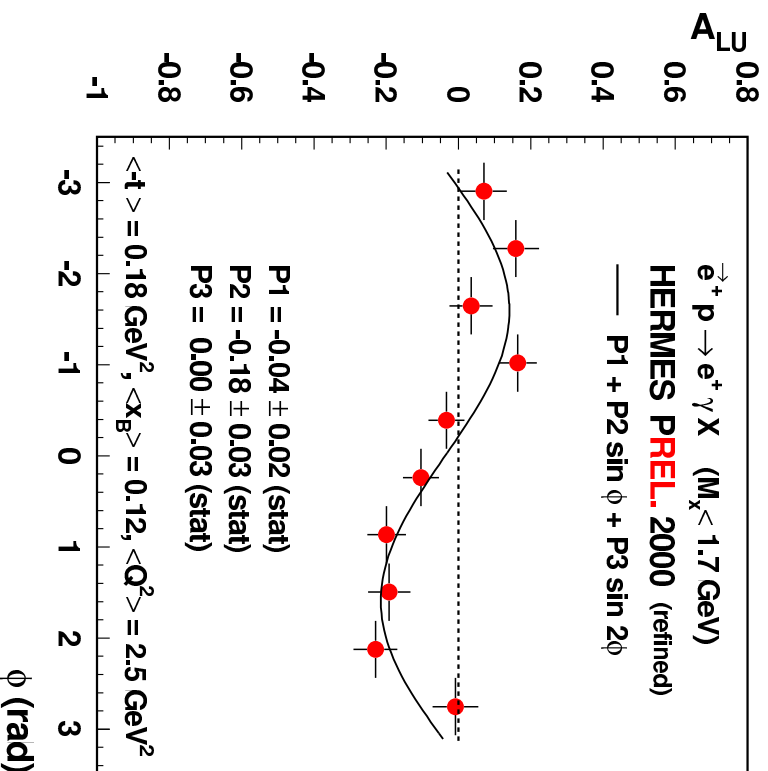
$$\text{BSA : } d\sigma(e^+p) - d\sigma(e^+p) \sim s_1^I \sin(\phi) \simeq \sin(\phi) \times \text{Im } \mathcal{H}$$

$$\text{LTSA : } d\sigma(e^+\overleftarrow{p}) - d\sigma(e^+\overrightarrow{p}) \sim s_{1,LP}^I \sin(\phi) \simeq \sin(\phi) \times \text{Im } \tilde{\mathcal{H}}$$

$$\text{TTSA : } d\sigma(e^+p^\uparrow) - d\sigma(e^+p^\downarrow) \Rightarrow \text{ACCESS TO GPD E}$$

BEAM-SPIN ASYMMETRY ON PROTON AND DEUTERON

$$A_{LU}(\phi) = \frac{1}{\langle |P_b| \rangle} \frac{\vec{N}(\phi) - \overleftarrow{\vec{N}}(\phi)}{\vec{N}(\phi) + \overleftarrow{\vec{N}}(\phi)}$$



A_{LU} IN EXCLUSIVE BIN: EXPECTED
 $\sin(\phi)$ DEPENDENCE $\Rightarrow \text{Im } \mathcal{H}$

$$A_{LU}^{\sin \phi, \text{Deuteron}} = -0.15 \pm 0.03$$

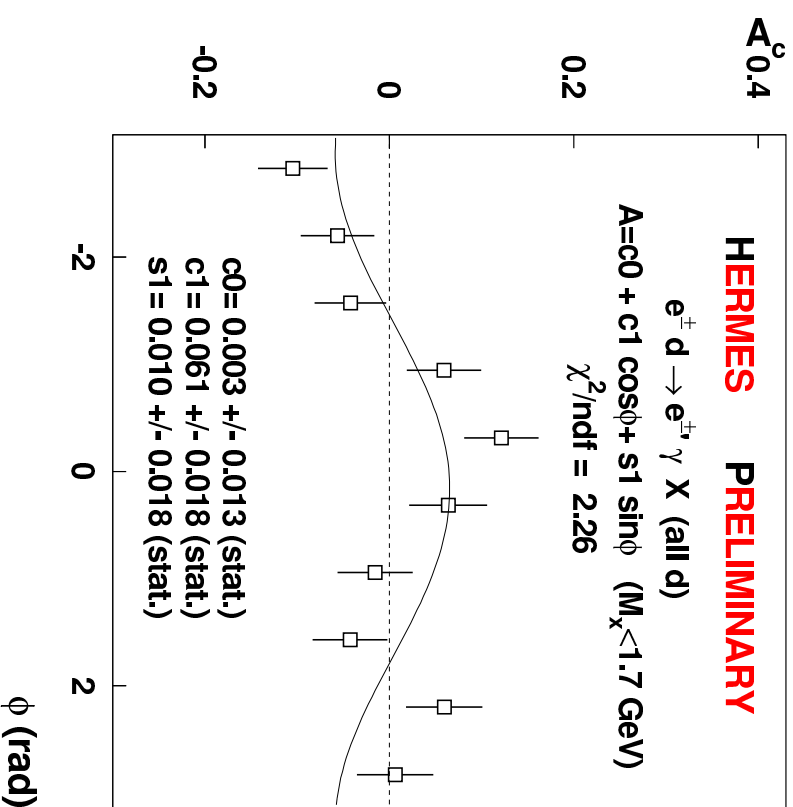
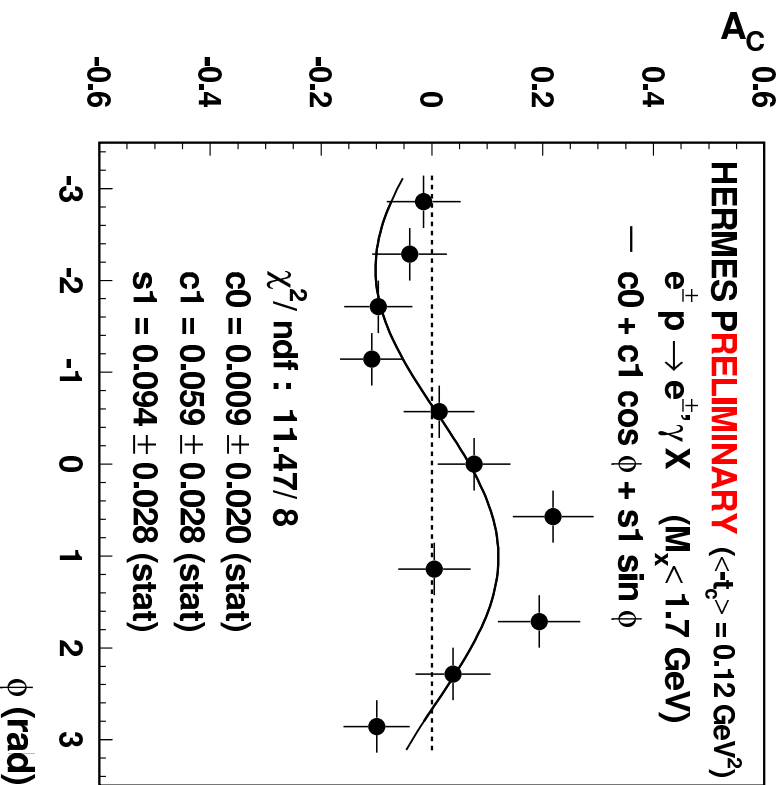
$$A_{LU}^{\sin \phi, \text{Proton}} = -0.18 \pm 0.03$$

BSA RESULTS: HERMES-PRL **87**, 182001 (2001)



BEAM-CHARGE ASYMMETRY ON PROTON AND DEUTERON

$$A_C(\phi) = \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

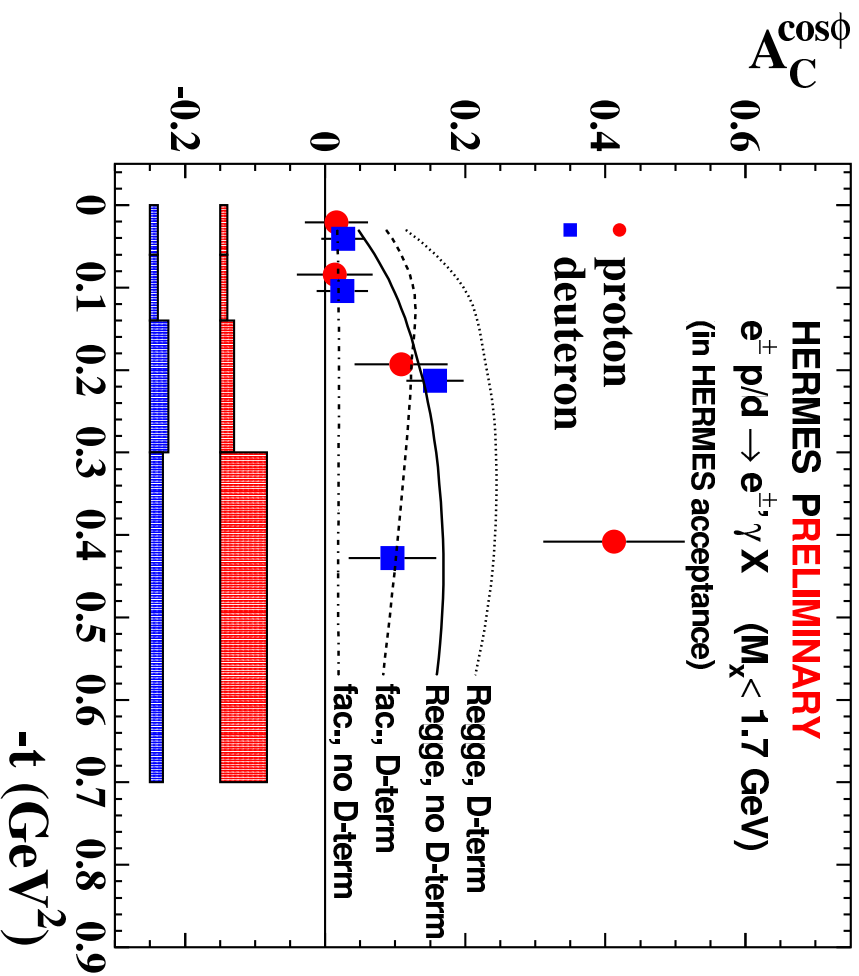


$$A_C^{\cos \phi} = 0.061 \pm 0.018$$

$$A_C^{\cos \phi} \approx A_C^{\cos(\phi)}$$

A_C IN EXCLUSIVE BIN: **EXPECTED**
 $\cos(\phi)$ DEPENDENCE $\implies \text{Re } \mathcal{H}$
 $\sin(\phi)$ -NON ZERO $\langle P_b \rangle(e^-)$

COMPARISON TO MODEL CALCULATIONS



$$e d \rightarrow e \gamma X$$

CONTRIBUTED PROCESSES:

$e d \rightarrow e d \gamma$, COHERENT PROCESS

$e d \rightarrow e p n \gamma$, INCOHERENT PROCESS

$e N \rightarrow e N^* \gamma$, RESONANT STATES

$-t < 0.7 \text{ GeV}^2 \Rightarrow$ COHERENT $\approx 20\%$

$\Rightarrow M_x$ CALCULATED VIA PROTON MASS

SMALLER $-t \Rightarrow$ COHERENT ENHANCED

CORRECTION ON BACKGROUND \Rightarrow

DECAY PHOTONS FROM

SEMI-INCLUSIVE π^0 ($\approx 6\%$)

GPD MODEL: M. VANDERHAEGHEN *et al.*

● ed COHERENT (FIRST t -BIN $\approx 40\%$) \Rightarrow NO DIFFERENCE ep AND ed

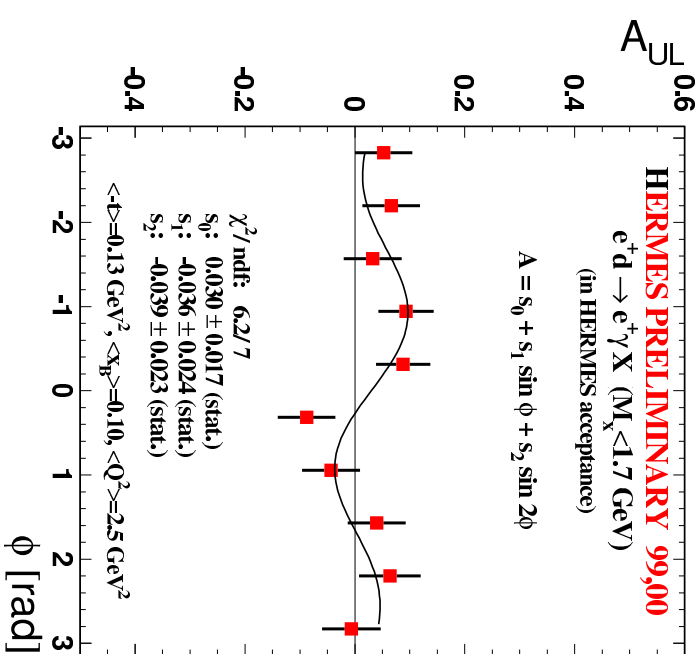
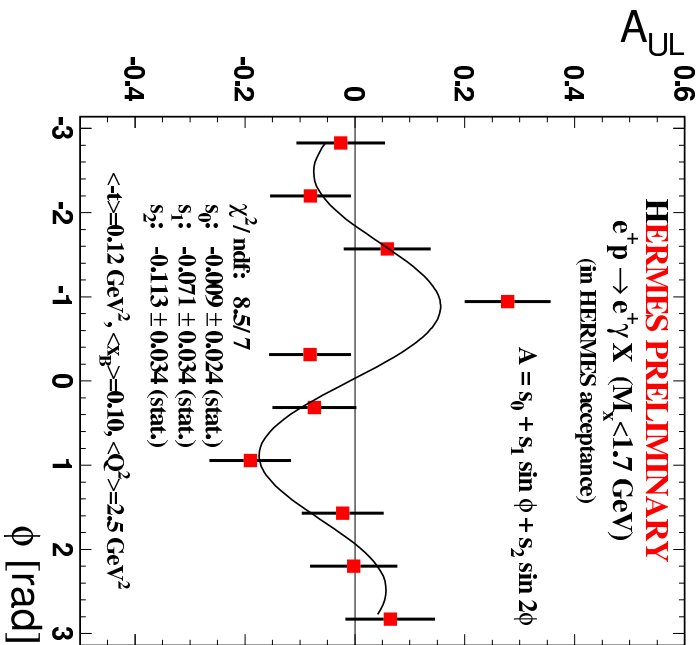
● DIFFERENCE IN LAST BIN \Rightarrow NEUTRON RESONANCES, NEUTRON

SMALL e^-p SAMPLE ($L \approx 10 \text{ PB}^{-1}$)

$\Rightarrow t$ -DEPENDENCE OF BCA \rightarrow POSSIBLE TOOL TO CONSTRAIN GPDs

NEW! LONGITUDINAL TARGET-SPIN ASYMMETRY

$$A_{UL}(\phi) = \frac{1}{\langle |P_T| \rangle} \frac{N_{\leftarrow}^{\leftarrow}(\phi) + N_{\leftarrow}^{\leftarrow}(\phi) - N_{\rightarrow}^{\rightarrow}(\phi) - N_{\rightarrow}^{\rightarrow}(\phi)}{N_{\leftarrow}^{\leftarrow}(\phi) + N_{\leftarrow}^{\leftarrow}(\phi) + N_{\rightarrow}^{\rightarrow}(\phi) + N_{\rightarrow}^{\rightarrow}(\phi)}$$



A_{UL} IN EXCLUSIVE BIN: EXPECTED $\sin(\phi)$ DEPENDENCE $\implies \text{Im } \tilde{\mathcal{H}}$

$$A_{UL,Proton}^{\sin \phi} = -0.071 \pm 0.034$$

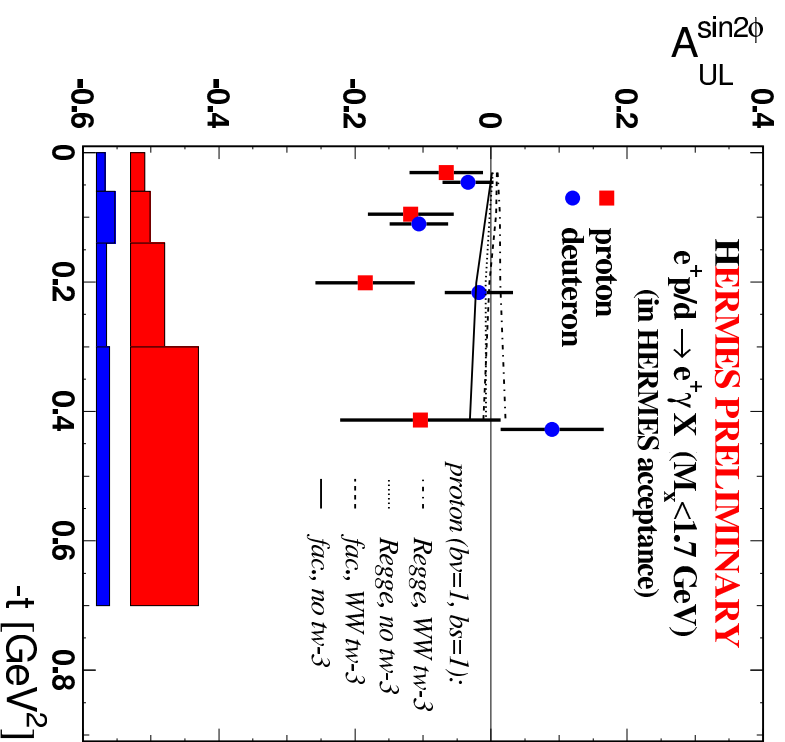
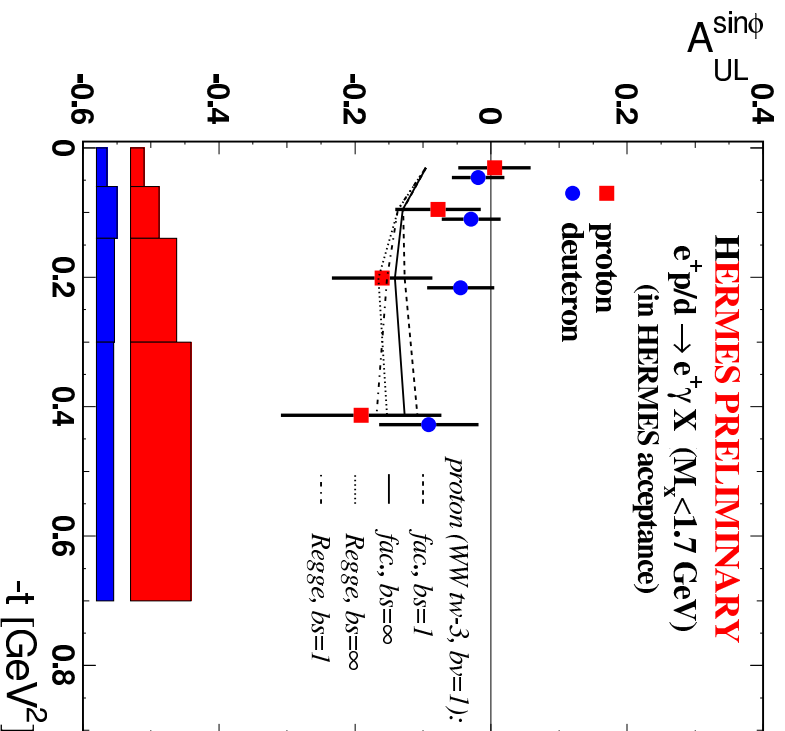
$$A_{UL,Proton}^{\sin 2\phi} = -0.113 \pm 0.034$$

$\sin 2\phi \implies$ TWIST-3 ?

$$A_{UL,Deuteron}^{\sin \phi} = -0.036 \pm 0.024$$

$$A_{UL,Deuteron}^{\sin 2\phi} = -0.039 \pm 0.023$$

NEW! LONGITUDINAL TARGET-SPIN ASYMMETRY VS t



- ed COHERENT ($\approx 40\%$ 1ST BIN) \implies NO DIFFERENCE ep AND ed
- GPD MODEL: TWIST-3 IS A SIMPLE W.W. TWIST-3
- $A_{UL}^{\sin 2\phi} \implies (qGq)$ TWIST-3 IS MISSING ?

SUMMARY AND OUTLOOK

AZIMUTHAL ASYMMETRIES \Rightarrow DVCS-AMPLITUDES \Rightarrow GPDs

\Rightarrow STRUCTURE OF NUCLEONS (L_q)

EXISTING DATA ON H, D :

- BEAM-SPIN ASYMMETRY $\Rightarrow \text{Im}H$
- BEAM-CHARGE ASYMMETRY $\Rightarrow \text{Re}H$
- LONGITUDINAL TARGET-SPIN ASYMMETRY $\Rightarrow \text{Im}\tilde{H}$

PRESENT DATA TAKING:

- TRANSVERSE POLARIZED H TARGET \Rightarrow TTSA $\Rightarrow E \Rightarrow J_u$

END OF 2005:

NEW DETECTOR

- ALLOWS TO DETECT THE RECOILING PROTON
- BACKGROUND-FREE DVCS: SEMI-INCLUSIVE BGD: $5\% \Rightarrow \ll 1\%$
ASSOCIATED BGD: $10\% \Rightarrow 1\%$
- IMPROVES t -RESOLUTION

