Selected HERMES Results: DVCS from Nuclear Targets

Hrachya Marukyan

Yerevan Physics Institute, Armenia

for the HERMES Collaboration

European Nuclear Physics Conference (EuNPC09), Bochum, Germany, March 16-20, 2009

- Introduction and Motivation
- DVCS Measurement at HERMES
- Specific Issues of the Analysis
- HERMES Results for Beam-Helicity and Charge Asymmetries
- Summary

Structure of the Nucleon, GPDs. Why Nuclear DVCS?

GPDs contain a detailed information on the structure of nucleon:

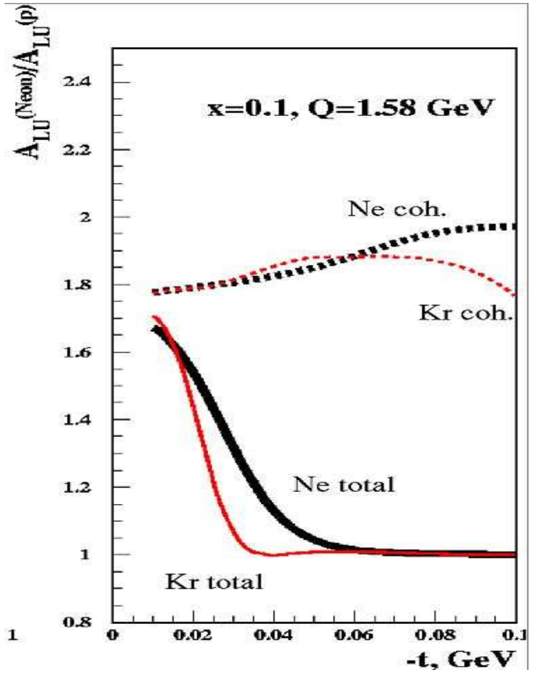
3D picture of hadrons:

longitudinal momentum fraction x at transverse location $b_\perp$

DVCS: one of the cleanest hard exclusive process to access GPDs,

Why nuclear DVCS?

- Holography of nuclei: 3-D distribution of quarks and gluons.
- A new window to study the nuclear degrees of freedom.
- GPDs modification in nuclear matter.



$\Rightarrow$ R_{coh}=1.8-2.0 for A=12-90
Guzey, Strikmann [PRC68(2003)]

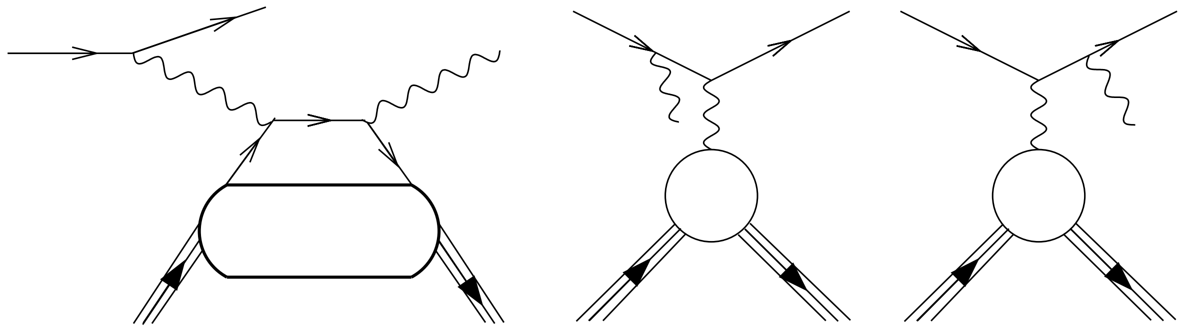
R_{coh}=1.0-1.1 for A=^4He
Liuti, Taneja [PRC68(2005)]

R_{coh}=5/3 for spin-0, 1/2
Kirchner, Müller [EPJ(2003)]

$A^{\sin\phi}_{LU,nucleus}/A^{\sin\phi}_{LU,proton} \propto A/Z$
Guzey, Siddikov [JPG32(2006)]

DVCS and BH Interference

DVCS (a) AND BETHE-HEITLER (BH) (b) PROCESSES EXPERIMENTALLY INDISTINGUISHABLE



(a) (b)

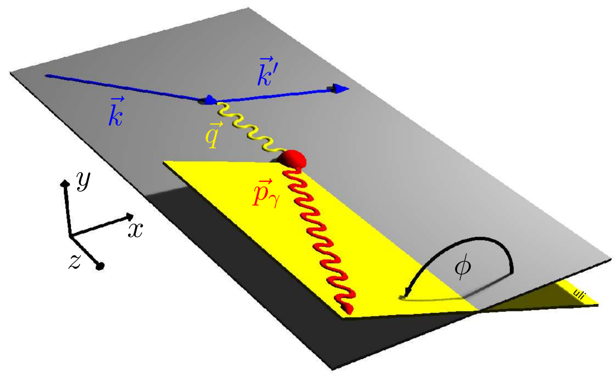
$$d\sigma \propto |\mathcal{T}_{\mathrm{DVCS}}|^2 + |\mathcal{T}_{\mathrm{BH}}|^2 + \underbrace{(\mathcal{T}^*_{\mathrm{DVCS}}\mathcal{T}_{\mathrm{BH}} + \mathcal{T}^*_{\mathrm{BH}}\mathcal{T}_{\mathrm{DVCS}})}_{I}$$

$\mathcal{T}_{\mathrm{BH}}$: CALCULABLE IN QED $\Rightarrow$ PAULI & DIRAC FORM FACTORS F_1, F_2

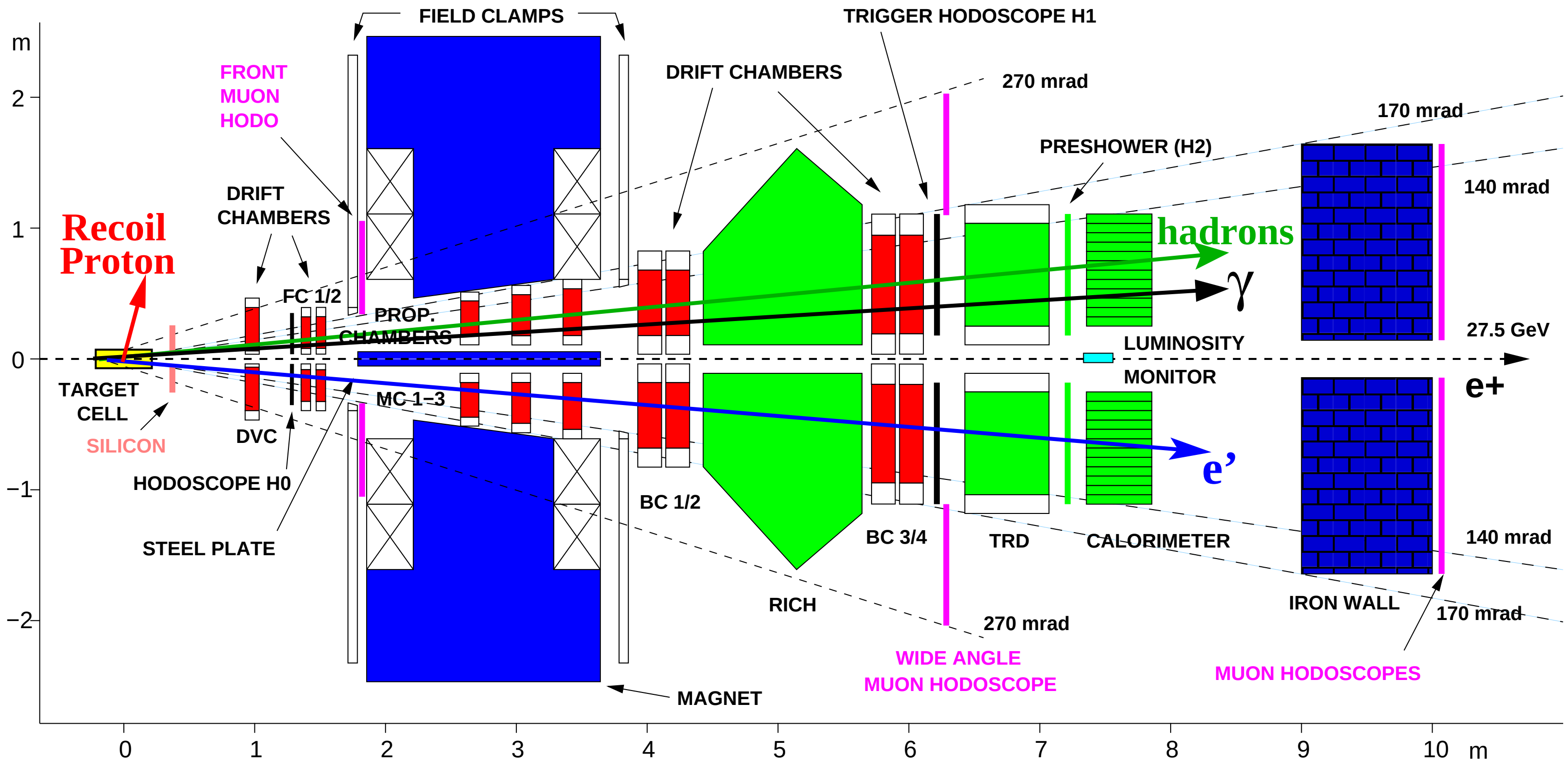
$\mathcal{T}_{\mathrm{DVCS}}$: COMPTON FORM FACTORS $\mathcal{H}, \widetilde{\mathcal{H}}, \mathcal{E}, \widetilde{\mathcal{E}} \Rightarrow$ CONVOLUTIONS OF GPDS

GPDS INDIRECTLY ACCESSIBLE THROUGH AZIMUTHAL ASYMMETRIES VIA I

- BEAM–HELICITY ASYMMETRY:
  $$d\sigma(\overrightarrow{e}, \phi) - d\sigma(\overleftarrow{e}, \phi) \propto \mathrm{Im}\,[F_1\mathcal{H}] \times \sin(\phi)$$
- BEAM–CHARGE ASYMMETRY:
  $$d\sigma(e^+, \phi) - d\sigma(e^-, \phi) \propto \mathrm{Re}\,[F_1\mathcal{H}] \times \cos(\phi)$$



The HERMES Experiment



Gas Target:

- Long. polarized H,D
- Unpolarized $H,D,{}^4He,N,Ne,Kr,Xe$
- Transversely polarized H

Beam:

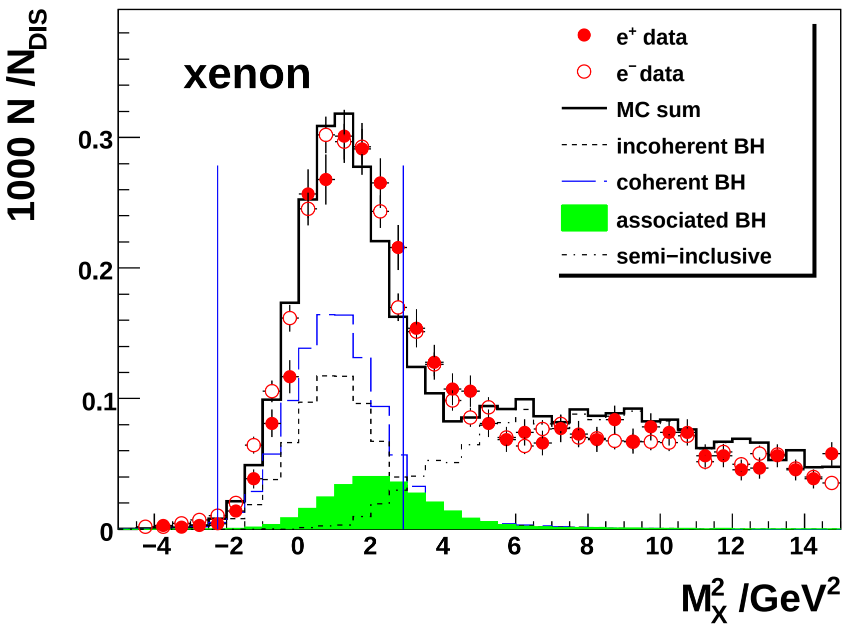
- Long. polarized e^+ and e^-
- Energy 27.6 GeV
- Both helicities

PID: $\epsilon_e > 99\%$, $\delta P/P < 2\%, \delta\theta < 1mrad$, $\delta E_\gamma/E_\gamma \approx 5\%$.

DVCS Event Selection

- Events with exactly one DIS - lepton and exactly one trackless cluster in the calorimeter.
- No recoil detection ⇒ Exclusivity via missing mass: $M_X^2 = (q + P - q')^2$

$$2 < \theta_{\gamma^*\gamma} < 45\,mrad$$
$$-t < 0.7\,GeV$$
$$0.03 < x_B < 0.35, \quad 1 < Q^2 < 10\,GeV^2$$
$$W > 3\,GeV, \quad \nu > 22\,GeV$$



MC for background and cuts,

$$e\,A \to e'\,\gamma\,X$$

$e\,A \to e'\,A\,\gamma$; Coherent BH

$e\,p(n) \to e'\,p(n)\,\gamma$; Incoherent BH

$e\,N \to e'\,N^*\,\gamma$; Associated BH

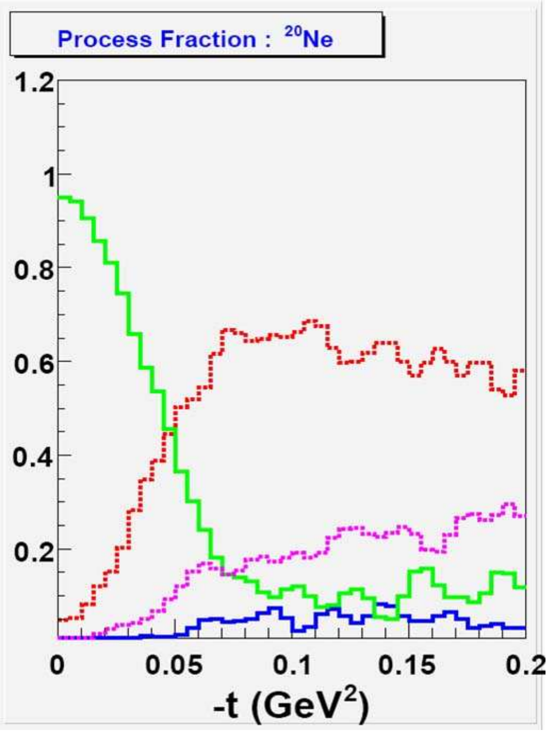
$e\,p \to e'\,\pi^0\,X$; Semi-inclusive

Correction; π^0 Background ($\approx 5\%$)

Associated ($\approx 12\%$); part of signal

⇒ Exclusive bin $(-(1.5)^2 < M_X^2 < (1.7)^2\ GeV^2)$

Coherent/Incoherent Contributions



FIND UPPER (LOWER) $-t$ CUT FOR EACH TARGET; ASYMMETRIES FOR COHERENT(INCOHERENT) PRODUCTION AT SIMILAR AVERAGE KINEMATICS

$\Rightarrow$ COHERENT: $< -t >= 0.018 GeV^2$

$\Rightarrow$ INCOHERENT: $< -t >= 0.20 GeV^2$

$Target$	$t\ cuttoff$	$estimated\ \%$ $coh., incoh.$	$\langle -t \rangle$ (RMS)	$\langle x_B \rangle$ (RMS)	$\langle Q^2 \rangle$ (RMS)
H	$-t < -t_{coh.}$	–	-0.018(0.008)	0.070(0.023)	1.81(0.75)
	$-t > -t_{incoh.}$	–	-0.200(0.120)	0.109(0.059)	2.89(1.62)
Kr	$-t < -t_{coh.}$	70	-0.018(0.015)	0.064(0.023)	1.63(0.68)
	$-t > -t_{incoh.}$	58	-0.200(0.125)	0.108(0.058)	2.84(1.61)
Xe	$-t < -t_{coh.}$	66	-0.018(0.017)	0.062(0.023)	1.60(0.66)
	$-t > -t_{incoh.}$	56	-0.200(0.126)	0.107(0.058)	2.86(1.63)

HERMES Combined Beam-Helicity and Charge Analysis

$$\sigma_{\rm LU}(\phi; P_l, e_l) = \sigma_{UU}(\phi)[1 + e_l A_C(\phi) + e_l P_l A^I_{LU}(\phi) + P_l A^{DVCS}_{LU}(\phi)]$$

Beam–Helicity Asymmetries:

$$A^I_{LU}(\phi) = -\frac{1}{\mathcal{D}(\phi)} \cdot \frac{x_B}{Q^2} \sum_{n=1}^{3} s^I_n \sin(n\phi)$$

$$A^{DVCS}_{LU}(\phi) = \frac{1}{\mathcal{D}(\phi)} \cdot \frac{x_B^2 t \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}{Q^2} \sum_{n=1}^{2} s^{DVCS}_n \sin(n\phi)$$

Beam–Charge Asymmetry:

$$A_C(\phi) = -\frac{1}{\mathcal{D}(\phi)} \cdot \frac{x_B}{y} \sum_{n=0}^{3} c^I_n \cos(n\phi)$$

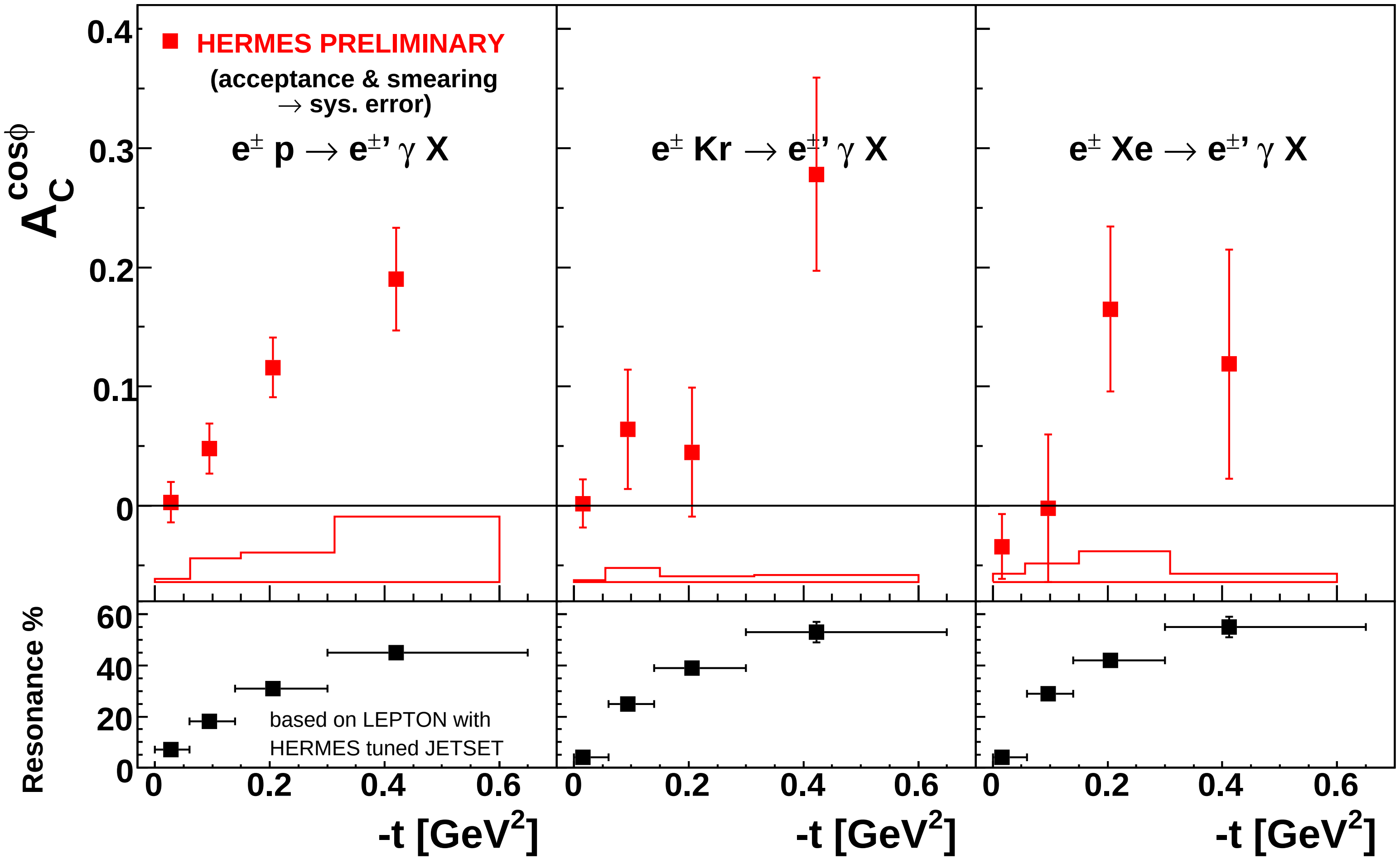
$$\mathcal{D}(\phi) = \frac{1}{(1+\varepsilon^2)^2} \sum_{n=0}^{2} c^{BH}_n \cos(n\phi) + \frac{x_B^2 t \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}{Q^2} \sum_{n=0}^{2} c^{DVCS}_n \cos(n\phi)$$

$$\sigma_{UU} = \frac{1}{32(2\pi)^2} \frac{1}{Q^2 x_B t \sqrt{(1+\varepsilon^2} \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \mathcal{D}(\phi)$$

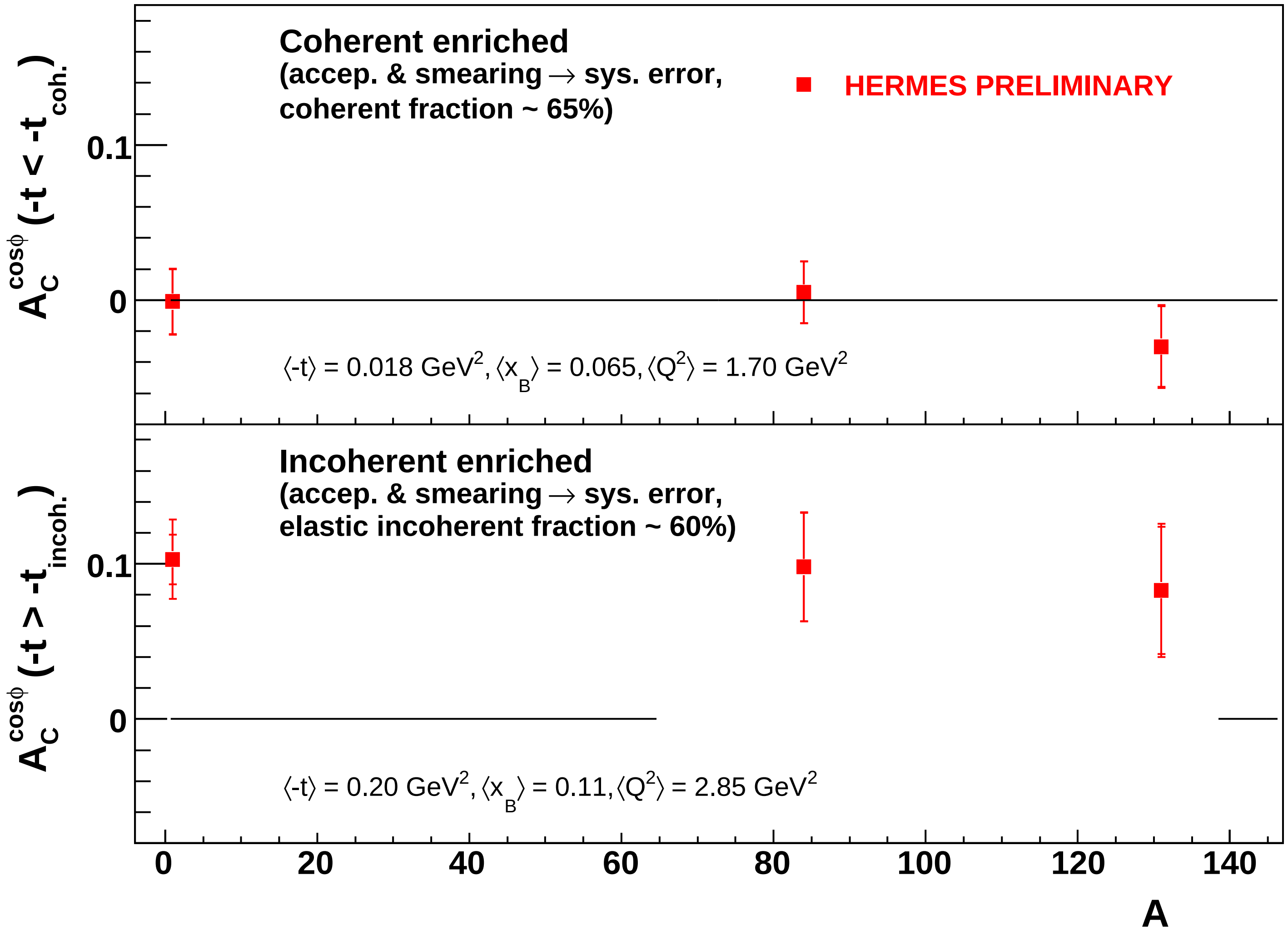
Fit to data: $A_C(\phi) = \sum_{n=0}^{3} A_C^{cos n\phi} \cos(n\phi)$; $A^I_{LU}(\phi) = \sum_{m=1}^{2} A^{sin m\phi}_{LU,I} \sin(m\phi)$; $A^{DVCS}_{LU}(\phi) = A^{sin\phi}_{LU,DVCS} \sin(\phi)$.

Beam–Charge Asymmetry Amplitude $A_C^{\cos\phi}$: t dependence

$$A_C(\phi) = \frac{\sigma^{+\rightarrow} + \sigma^{+\leftarrow} - \sigma^{-\rightarrow} - \sigma^{-\leftarrow}}{\sigma^{+\rightarrow} + \sigma^{+\leftarrow} + \sigma^{-\rightarrow} + \sigma^{-\leftarrow}}$$



Beam–Charge Asymmetry Amplitude $A_C^{\cos\phi}$: A–dependence



⇐ A_C for Coherent: consistent with zero

⇐ A_C for Incoherent: no A-dependence

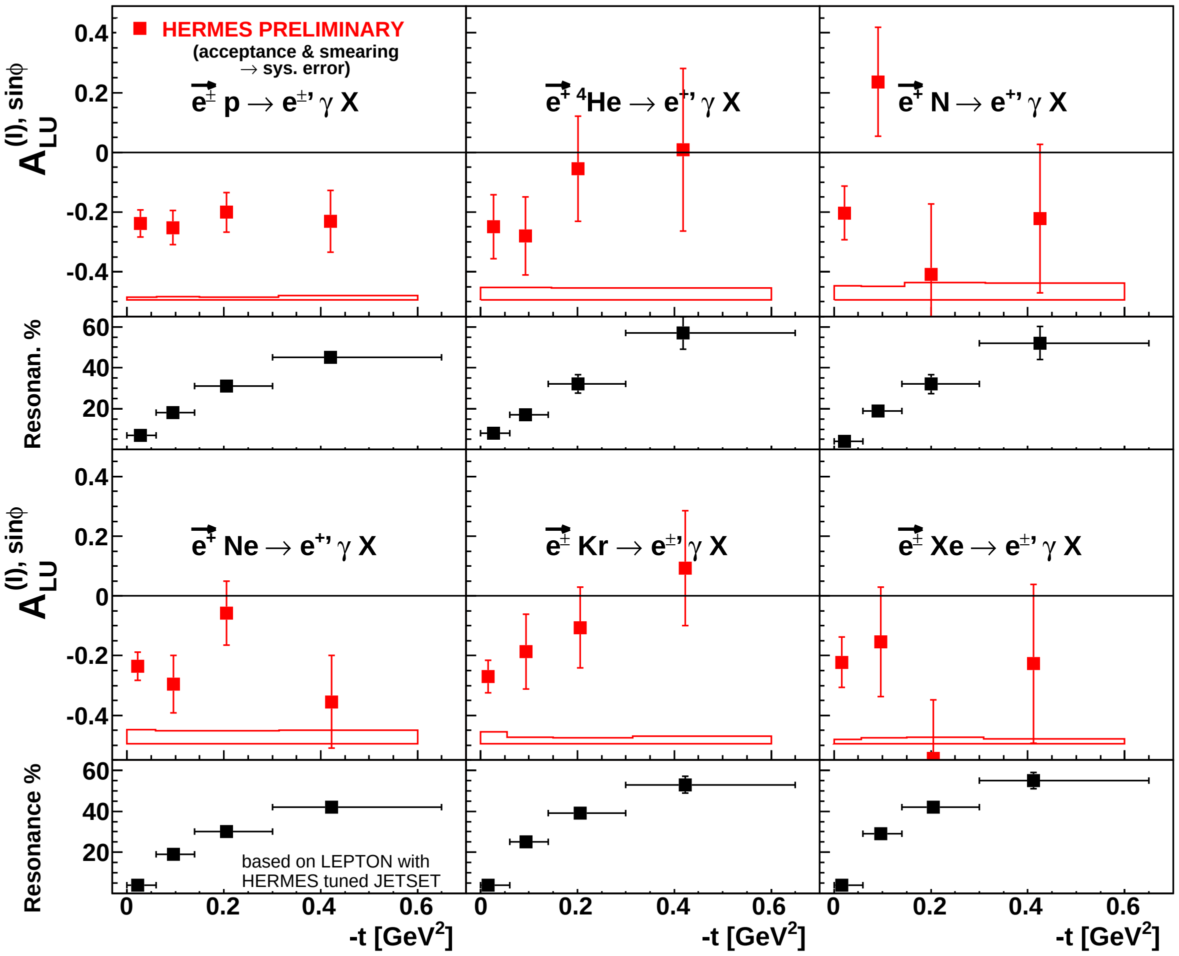
Beam–Helicity Asymmetry Amplitude $A_{LU}^{(I),\sin\phi}$: t dependence

H, Kr, Xe

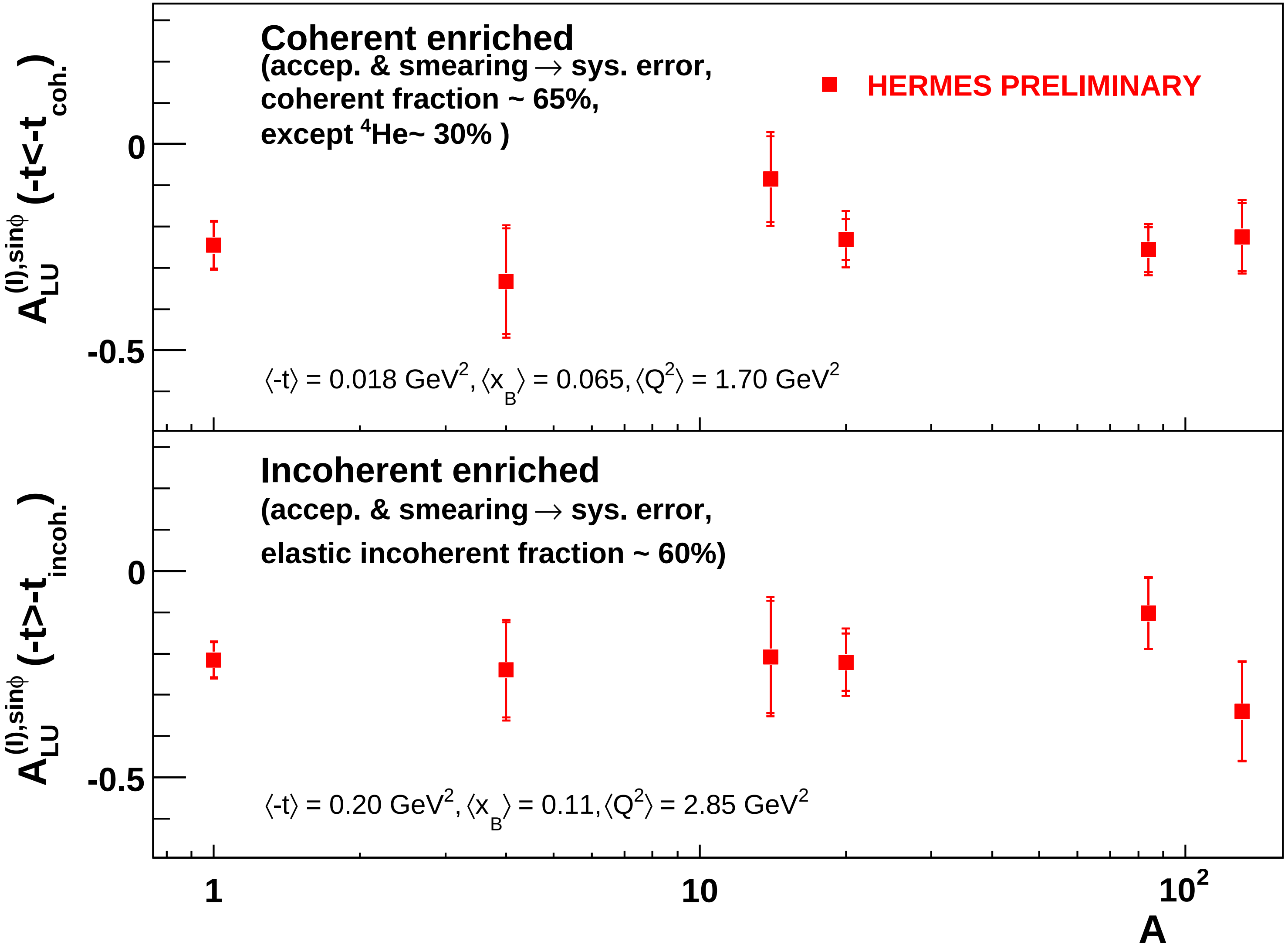
$$A_{LU}^{I}(\phi) = \frac{\sigma^{+\rightarrow} - \sigma^{-\rightarrow} - \sigma^{+\leftarrow} + \sigma^{-\leftarrow}}{\sigma^{+\rightarrow} + \sigma^{-\rightarrow} + \sigma^{-\leftarrow} + \sigma^{+\rightarrow}}$$

$^4He, N, Ne$

$$A_{LU}(\phi) = \frac{\sigma^{\rightarrow} - \sigma^{\leftarrow}}{\sigma^{\rightarrow} + \sigma^{\leftarrow}}$$

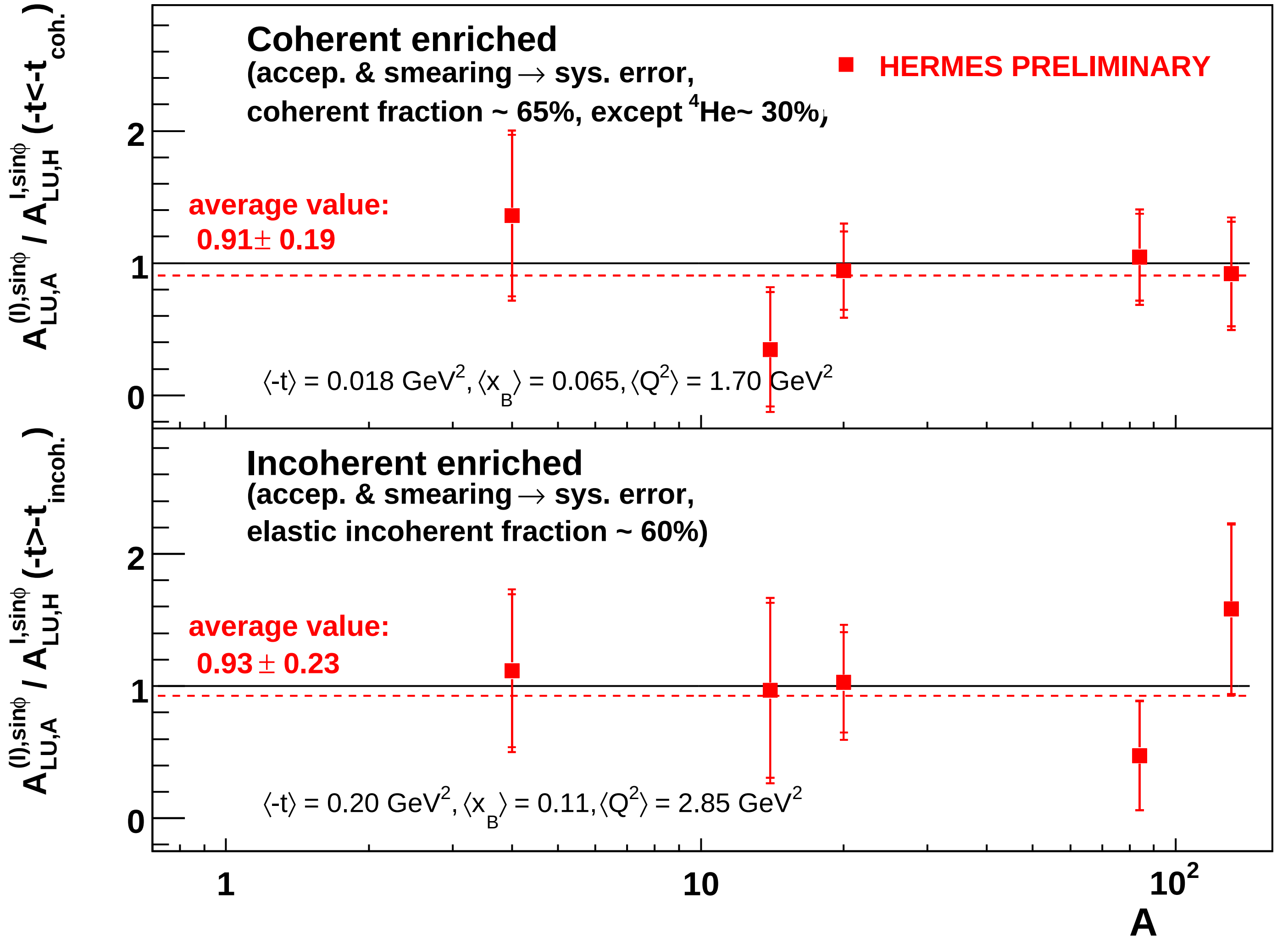


Beam–Helicity Asymmetry Amplitude $A_{LU}^{(I),\sin\phi}$: A- dependence



- $A_{LU}^{(I),\sin\phi}$ AMPLITUDE: NO DEPENDENCE ON A

Ratio of Leading Beam–Helicity Asymmetry Amplitudes



⇐ $R \approx 1$
$R = 1$–1.1 FOR ^4He
LIUTI, TANEJA [PRC(2005)]
$R = 5/3$,
FOR SPIN–0, 1/2
KIRCHNER, MÜLLER [EPJ(2003)]

⇐ $R \approx 1$: AS EXPECTED
BH PROCESS IS SUPPRESSED ON NEUTRON

Summary

- Azimuthal Asymmetries ⇒ DVCS-Amplitudes ⇒ GPDs:
  Contain a wealth of new information on hadron structure at parton level

- The azimuthal asymmetries are measured at HERMES with respect to beam helicity and charge on nuclear targets.

- The Beam-charge and Beam-helicity asymmetry amplitudes $A_C^{\cos\phi}$ and $A_{LU}^{I,\sin\phi}$ do not support models which predict an enhancement of nuclear asymmetries compared to the free proton asymmetry(Kirchner, Müller), (Guzey, Strikmann), (Liuti, Taneja) and (Guzey, Siddikov).

- Data contradict the predicted strong A-dependence of the asymmetries resulting from mesonic degree of freedom in the nuclei(Guzey, Siddikov).

- Data from Deuterium(see talk D. Zeiler) ⇒ possible contribution of quasi-free neutron.

Looking forward to more model calculations for nuclear DVCS

Backup slides!

Beam–Helicity Asymmetry Amplitude $A_{LU}^{(DVCS),\sin\phi}$