New More Precise Results on DVCS from Nuclear Targets

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Hongxue Ye

(for the HERMES Collaboration)

yehx@hep.pku.edu.cn

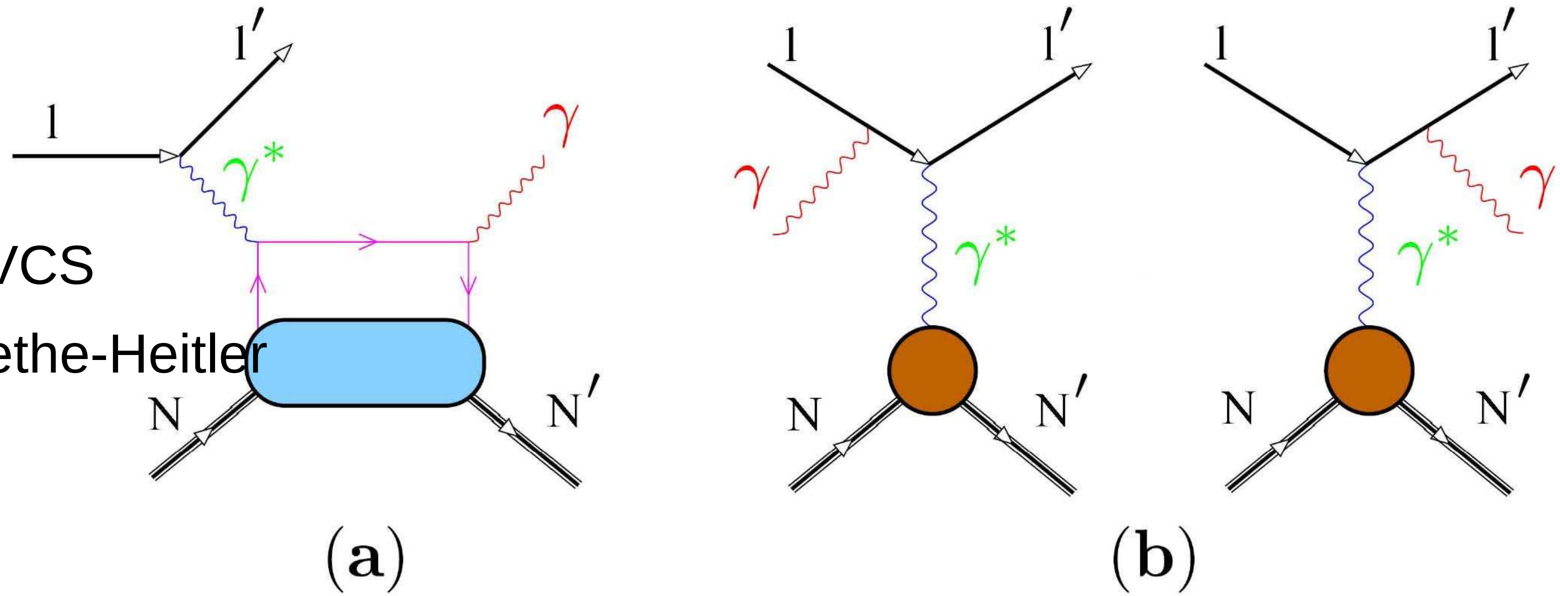
outline

- Introduction and Motivation
- Deeply Virtual Compton Scattering and the Asymmetries
- The HERMES Experiment and Preliminary Results
- Summary and Outlook

Why Deeply Virtual Compton Scattering?

(a) DVCS

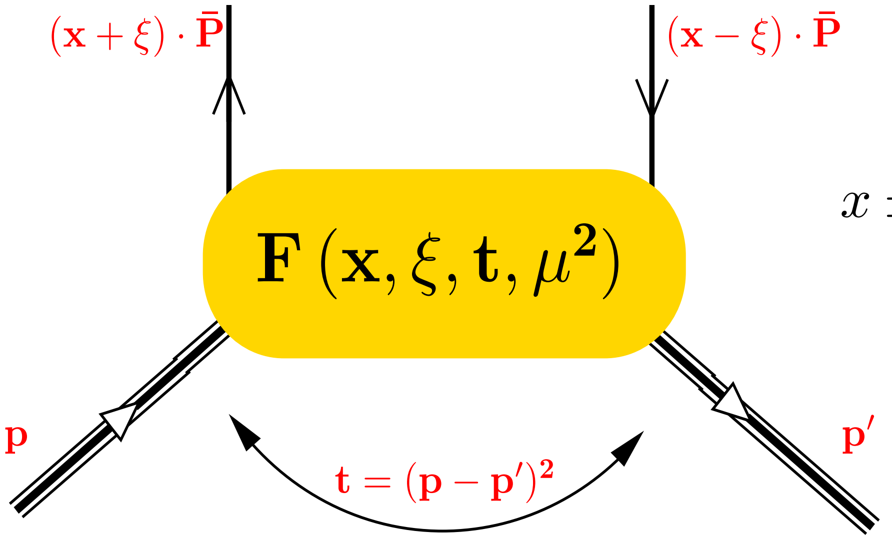
(b) Bethe-Heitler



- hard exclusive lepton-production of a real photon and leaving the target intact:
  $l(k) + N(p) \rightarrow l'(k') + N'(p') + \gamma(q')$
- Physical observables come from DVCS + BH + interference
- Theoretical cleanest tool to study GPDs

Why Generalized Parton Distribution?

- GPDs: defined through matrix elements $\langle p', S' | \mathcal{O} | p, S \rangle$



F	:	GPDs
$x \pm \xi$	:	Parton long. momentum fraction
t	:	invariant momentum transfer
μ	:	renormalization scale

- Form Factors: transverse spatial information $\Leftarrow$ Elastic scattering
- PDFs: Longitudinal momentum distribution $\Leftarrow$ DIS
- GPDs: Access to the transverse position and longitudinal momentum distribution at the same time, 2+1 -D picture $\Leftarrow$ DVCS

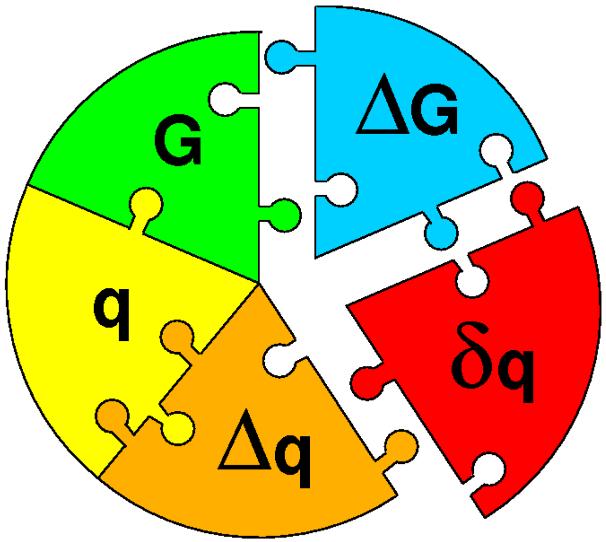
Why GPDs(II)?

- GPDs can be related to known quantities

FFs	$\int_{-1}^{1} dx H_q(x,\xi,t,\mu^2) = F_1^q(t)$	$\int_{-1}^{1} dx E_q(x,\xi,t,\mu^2) = F_2^q(t)$
PDFs	$H_q(x,0,0,\mu^2) = q(x,\mu^2)$	E_q not measurable through DIS

- GPDs $\Rightarrow J_{q,g} = \frac{1}{2}\Delta\Sigma(\Delta G) + L_q(g)$ (Ji, 1997)

$$J_{q,g} = \frac{1}{2}\lim_{t\to 0}\int dx\, x[H_{q,g}(x,\xi,t,\mu^2) + E_{q,g}(x,\xi,t,\mu^2)]$$



to access the last pieces of nucleon spin structure:

$$1/2 = \underbrace{1/2\overbrace{\Delta\Sigma}^{30\%} + L_q}_{J_q=?} + \underbrace{\Delta G + L_g}_{J_g=?}$$

Why Nuclear DVCS?

- Several measurements on the cross section and various asymmetries published for the proton or deuterium target
- No publication about heavier nuclear targets
  - get access to the nuclear GPDs
  - constrain theoretical models attempting to describe nuclear structure
  - provide a better understanding of the nature of nuclear force

hermes has the unique nuclear DVCS data available now

(He-4, Nitrogen, Neon, Krypton and Xenon)

$\Rightarrow$ Let's do something!

Deeply Virtual Compton Scattering

- The same final state in DVCS and Bethe-Heitler $\Rightarrow$interference

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

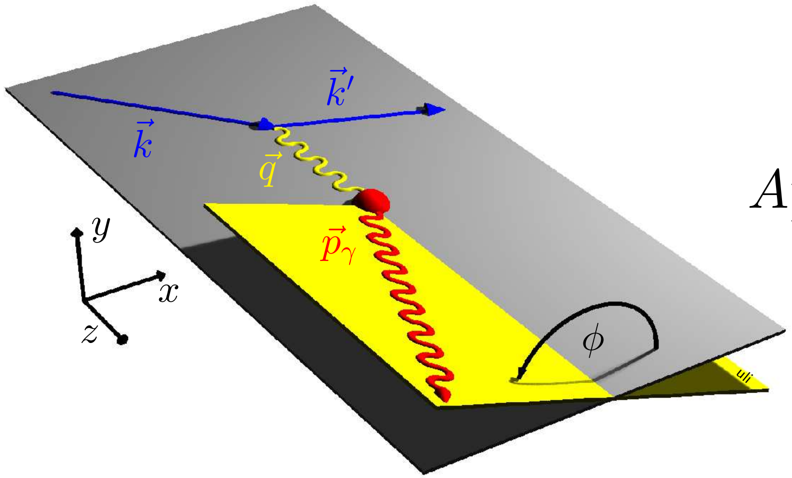
- At HERMES, $\mathcal{T}_{\rm BH} \gg \mathcal{T}_{\rm DVCS} \Rightarrow \mathcal{T}_{\rm DVCS}$ can be accessed through $\mathcal{I}$: both its amplitude and phase
- For longitudinal polarized beam with beam polarization P_b and charge e_l, and unpolarized target, the cross section can be factorized as

$$\sigma_{LU} = \sigma^0_{UU}(\phi)\left[1 + e_l\ A_C(\phi) + P_b\ A^{DVCS}_{LU}(\phi) + e_l\ P_b\ A^{\mathcal{I}}_{LU}(\phi)\right]$$

σ^0_{UU}: neither dependent on beam charge nor beam polarization
A_C : the traditional Beam Charge Asymmetry $\Rightarrow c^{\mathcal{I}}_{0/1/2,unp}$
A^{DVCS}_{LU}: only dependent on beam polarization $P_b \Rightarrow s^{DVCS}_{1,unp}$
$A^{\mathcal{I}}_{LU}$: dependent on P_b and beam charge $\Rightarrow s^{\mathcal{I}}_{1/2,unp}$

The Measured Asymmetries

- The All HERMES nuclear data(1997-2005) is included; The hydrogen data from 2000+2005 is included
- The *Combined analysis* for Hydrogen/Krypton/Xenon using both beam charges data



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

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

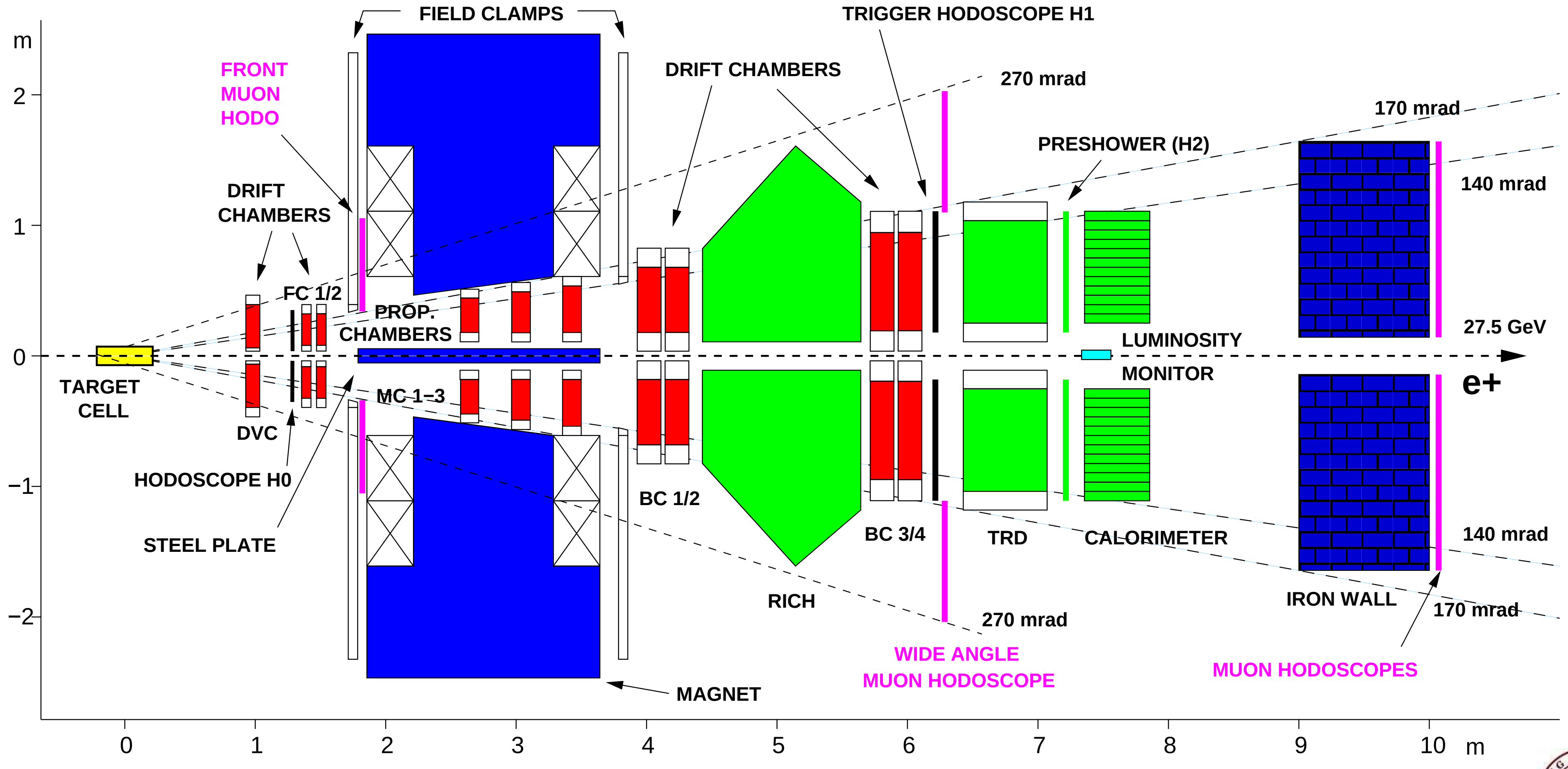
$$A_{LU}^{\mathcal{I}}(\phi) = \frac{\sigma^{+\rightarrow} - \sigma^{-\rightarrow} - \sigma^{+\leftarrow} + \sigma^{-\leftarrow}}{\sigma^{+\rightarrow} + \sigma^{-\rightarrow} + \sigma^{+\leftarrow} + \sigma^{-\leftarrow}}$$

- The *single-BSA analysis* for Helium-4/Nitrogen/Neon: e^+ data $\Rightarrow$ traditional single beam charge Beam Spin Asymmetry

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

The HERMES Experiment

- the scattering lepton and real γ are detected
- recoiling nucleon/nuclei is not detected

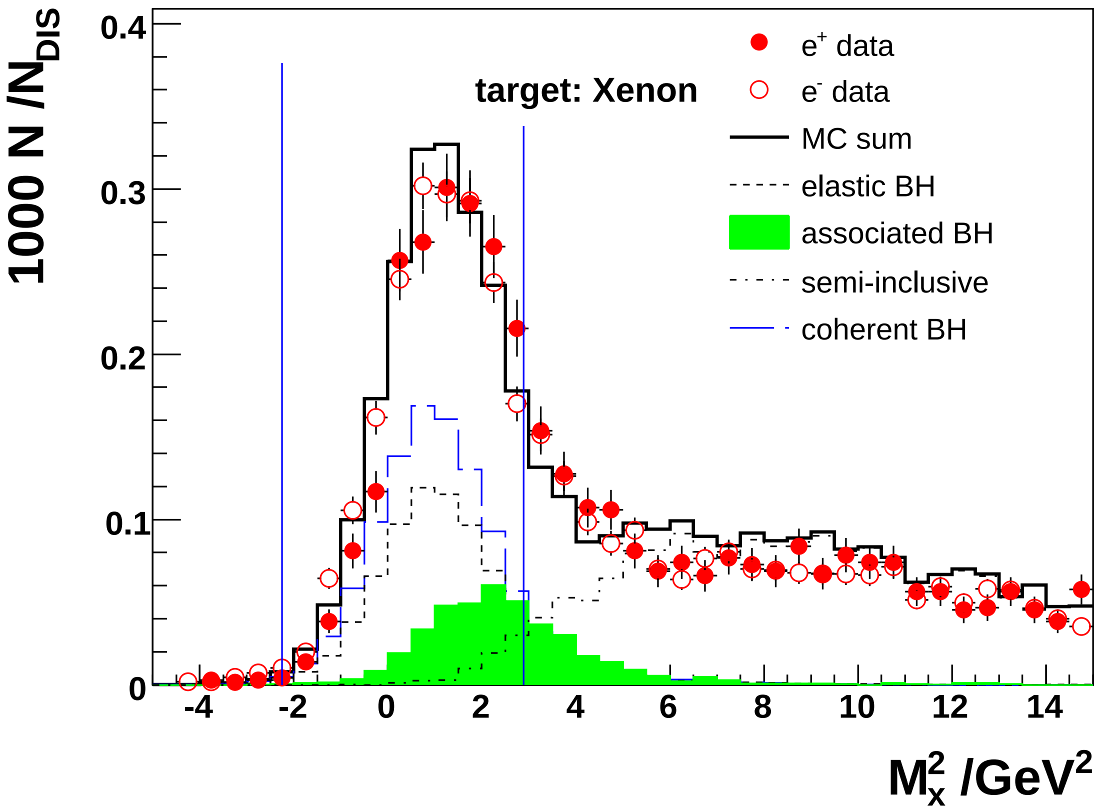


The HERMES Experiment(II)

- Missing mass is used to select the exclusive sample

$$M_x^2 = (P_e + P_p - P_{e'} - P_\gamma)^2$$

- π^0 background is estimated ∼5% and corrected for the results

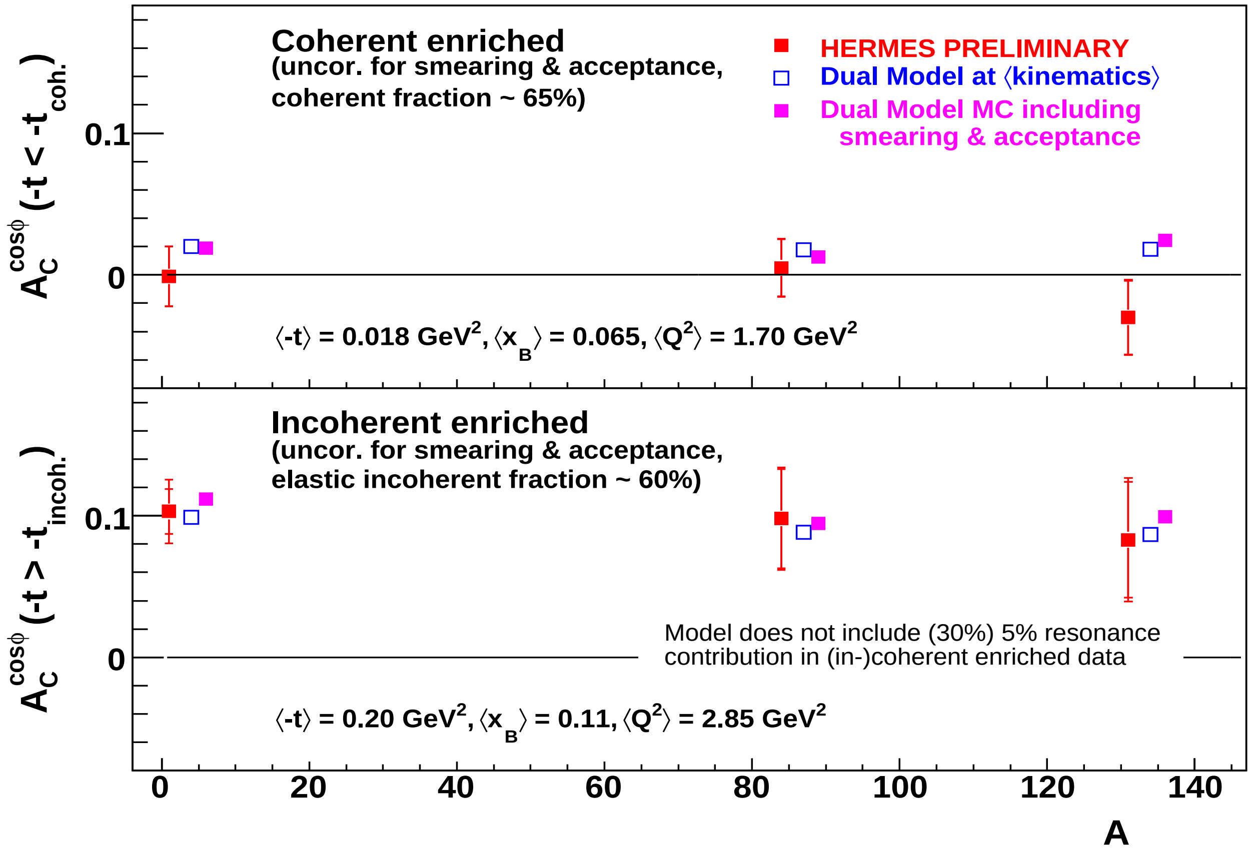


Coherent/incoherent separation

- nuclear DVCS involves 2 contributions:
  1. Coherent process: nuclear target stays intact
  2. Incoherent process: nuclear target breaks up, the γ is emitted by a particular proton or neutron
- Separate coherent/incoherent part by a t cutoff value
- Given the t dependence of the asymmetries $\Rightarrow$ to get the same $\langle t \rangle$ for all the targets $\Rightarrow$ differences for $\langle x_B \rangle$, $\langle Q^2 \rangle$ are also quite small

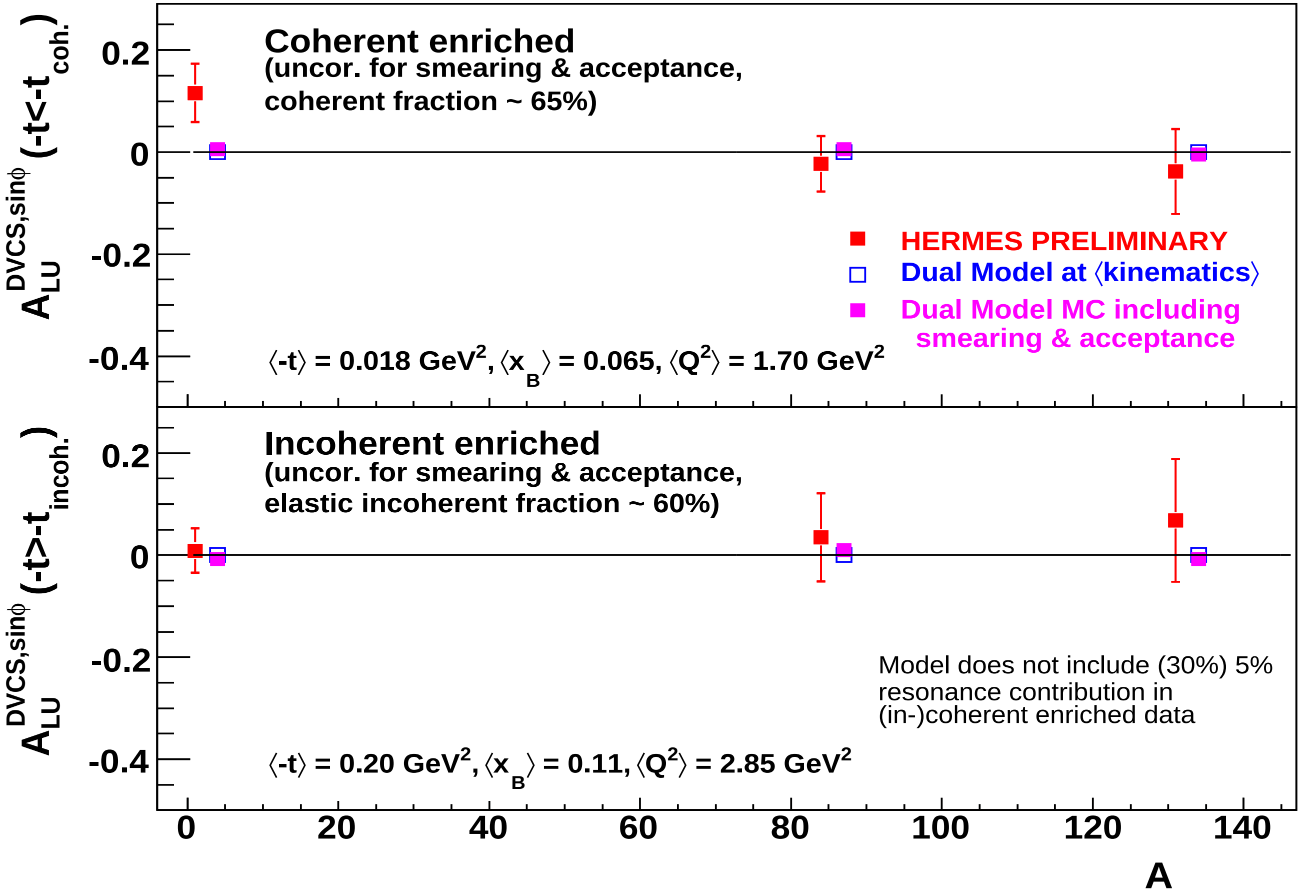
Target	t cutoff	estimated %elas. coh. incoh. (by MC)	$\langle t \rangle$ (RMS)	$\langle x_B \rangle$ (RMS)	$\langle Q^2 \rangle$ (RMS)
H	$-t < -t_{coh.}$	–	-0.018(0.008)	0.070(0.023)	1.81(0.75)
	$-t > -t_{incoh.}$	–	-0.200(0.120)	0.109(0.059)	2.89(1.62)
Kr	$-t < -t_{coh.}$	70	-0.018(0.015)	0.064(0.023)	1.63(0.68)
	$-t > -t_{incoh.}$	58	-0.200(0.125)	0.108(0.058)	2.84(1.61)
Xenon	$-t < -t_{coh.}$	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)

Preliminary Results: Beam Charge Asymmetry $A_C^{\cos\phi}$



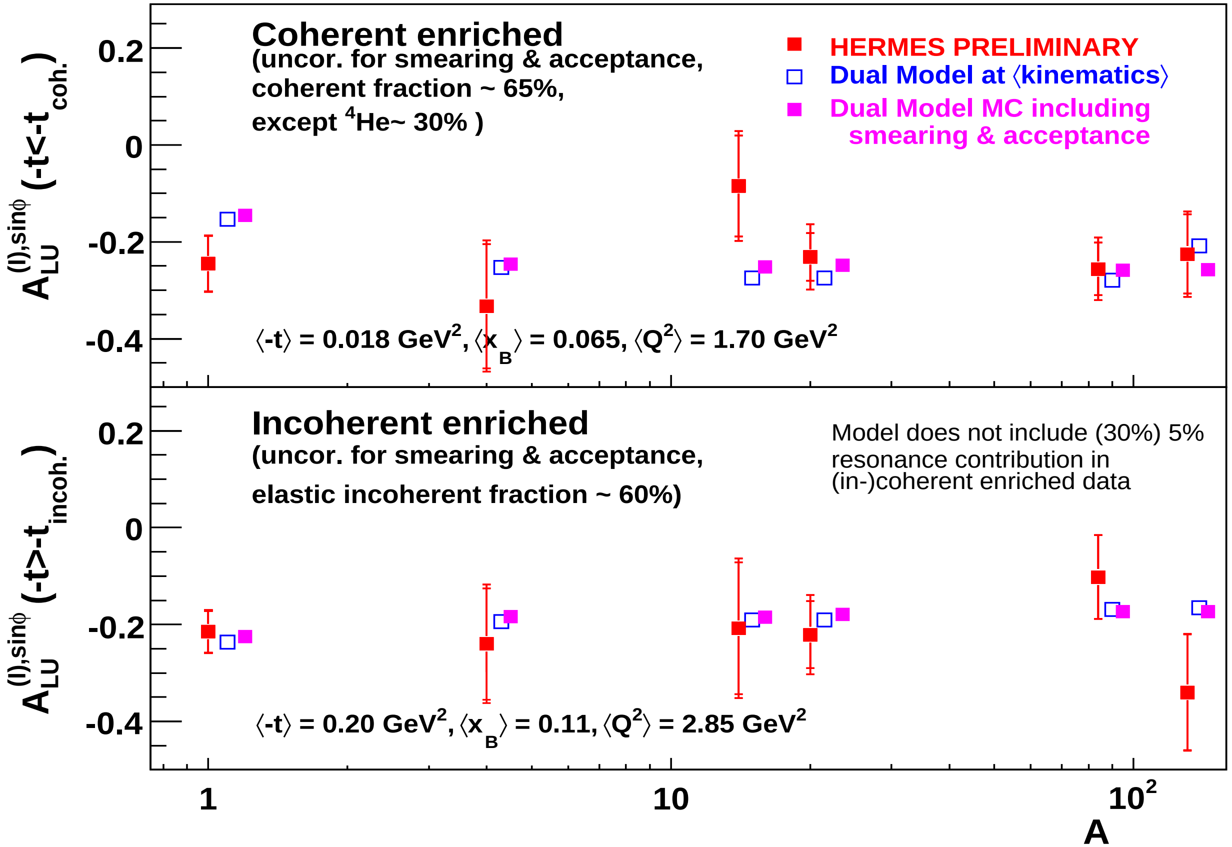
- The measured $A_C^{\cos\phi}$(shown as red points) in coherent enriched part is quite small
- Double error bars denote stat. uncertainty only and total experimental uncertainty
- Smearing (always small) and acceptance effect is not included in error bar yet, but demonstrated with the Dual Model (V. Guzey, arXiv:0801.3235 [hep-ph])

DVCS Term of Beam Spin Asymmetry: $A_{LU}^{DVCS,\sin\phi}$



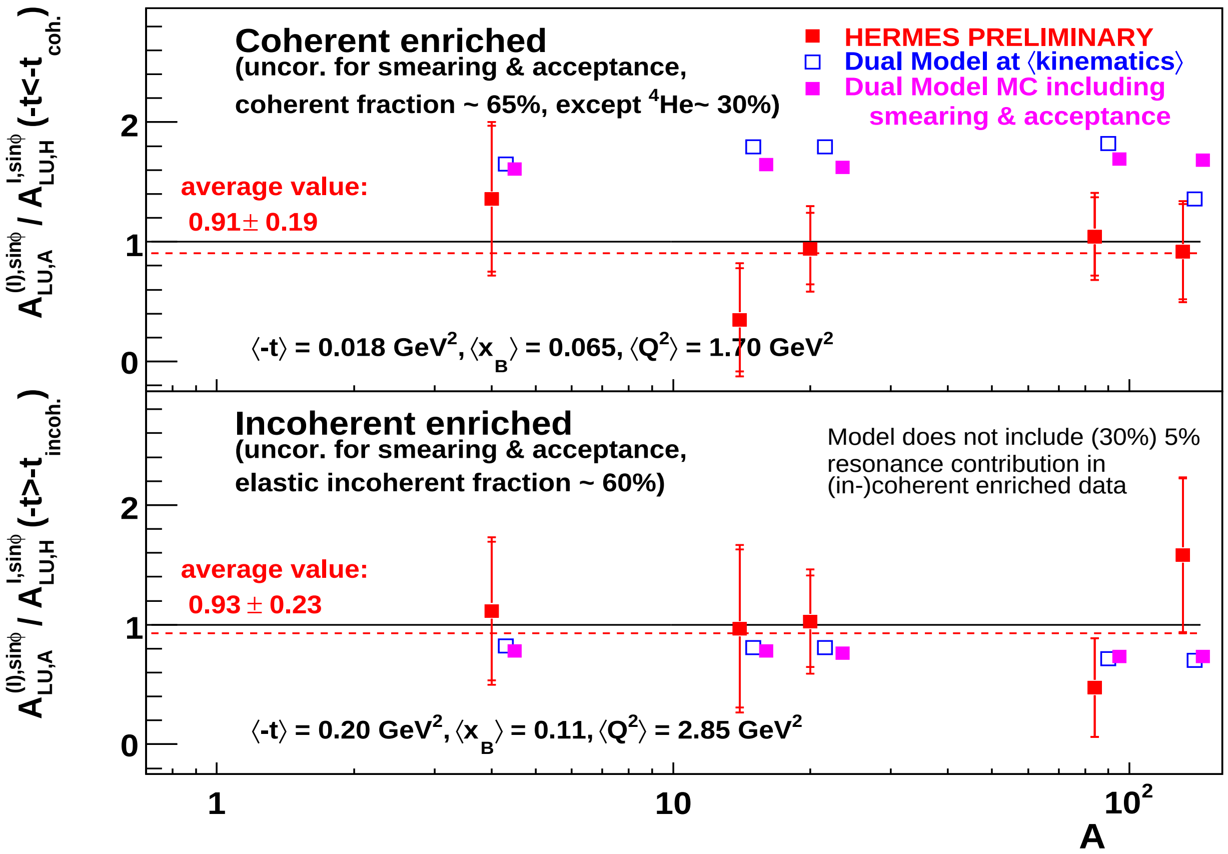
- The measured $A_{LU}^{DVCS,\sin\phi}$ are comparable with zero, except for the coherent enriched Hydrogen
- Acceptance effect is demonstrated with the Dual Model

Leading Beam Spin Asymmetry Amplitude: $A_{LU}^{(I),\sin\phi}$



- H/Kr/Xenon⇐combined analysis; He4/N/Neon $\Leftarrow e^+$ beam single-BSA fit
- From Hydrogen data, the expected small asymmetry at small t is not seen
- For Xenon small t sample, large acceptance effect due to (a). steep asymmetry t-dependence (b). the remaining incoherent contribution has a sizeable different t contribution $\Rightarrow$ Model dependent

Ratio of Leading BSA Amplitude: $A_{LU,A}^{(I),\sin\phi}/A_{LU,H}^{I,\sin\phi}$



- The measured ratio of $A_{LU,A}^{(I),\sin\phi}/A_{LU,H}^{I,\sin\phi}$ is comparable with unity in both (in-)coherent enriched sample
- The results have been corrected for the background and other experimental effects, but not for the smearing (small effect, $\sim$0.01) and acceptance effect

Summary and Outlook

Summary

- All the HERMES nuclear target data are analyzed, and all the possible asymmetries are extracted
- Preliminary results of $A_{LU,A}^{(I),sin\phi}/A_{LU,H}^{I,sin\phi}$ are found to be comparable with unity, for both coherent enriched and incoherent enriched data
- ’Discrepancy’ with Dual Model might be due to its assumption of same neutron and proton matter distribution in nuclei (Thanks, Moskov)

Outlook

- The Deuterium data are under analyzing; the comparison of nuclear results and Deuterium will be given soon and shown possible contribution of quasi-free neutron

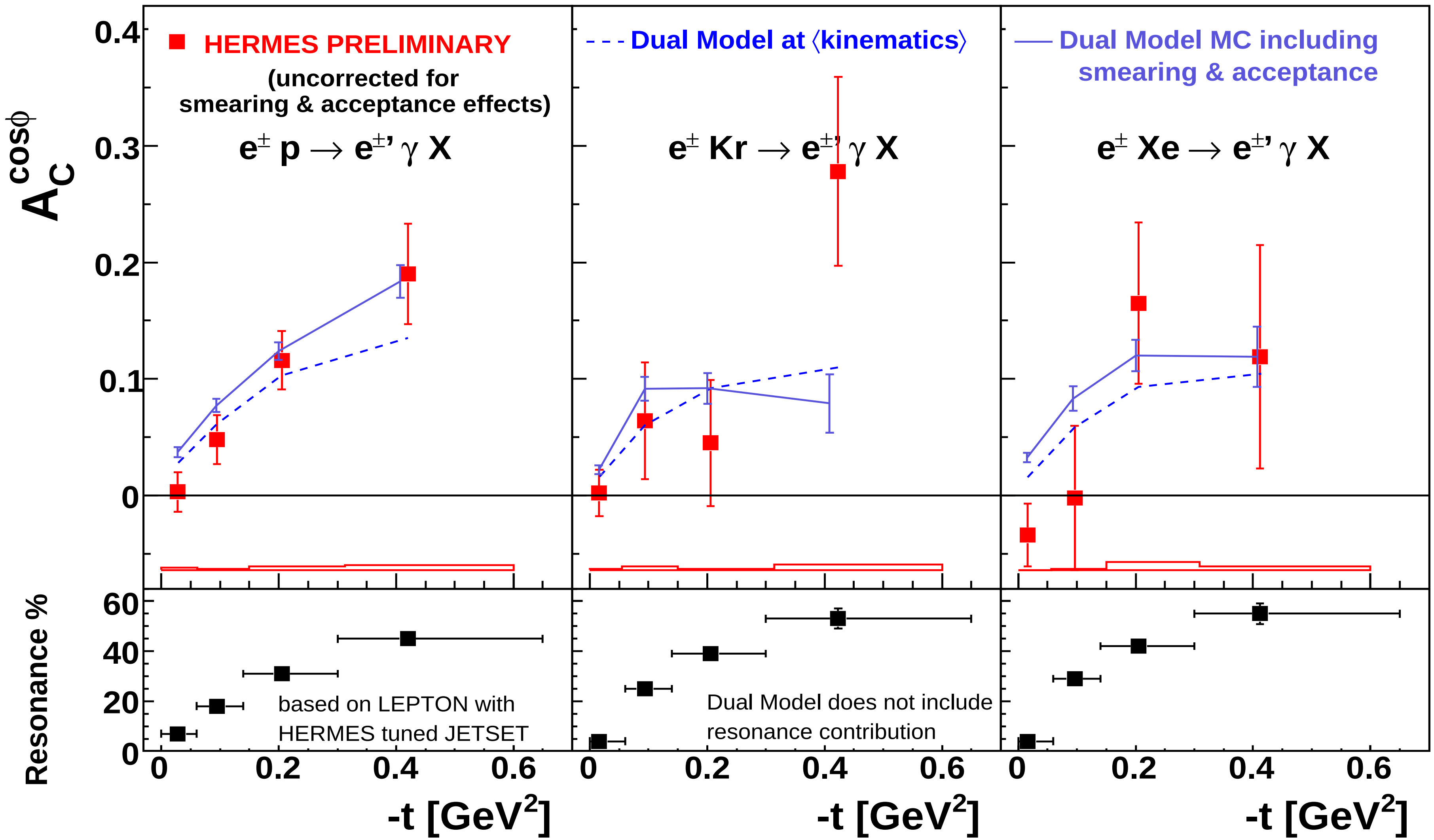
Thanks

Thank you !

BACK UP PLOTS

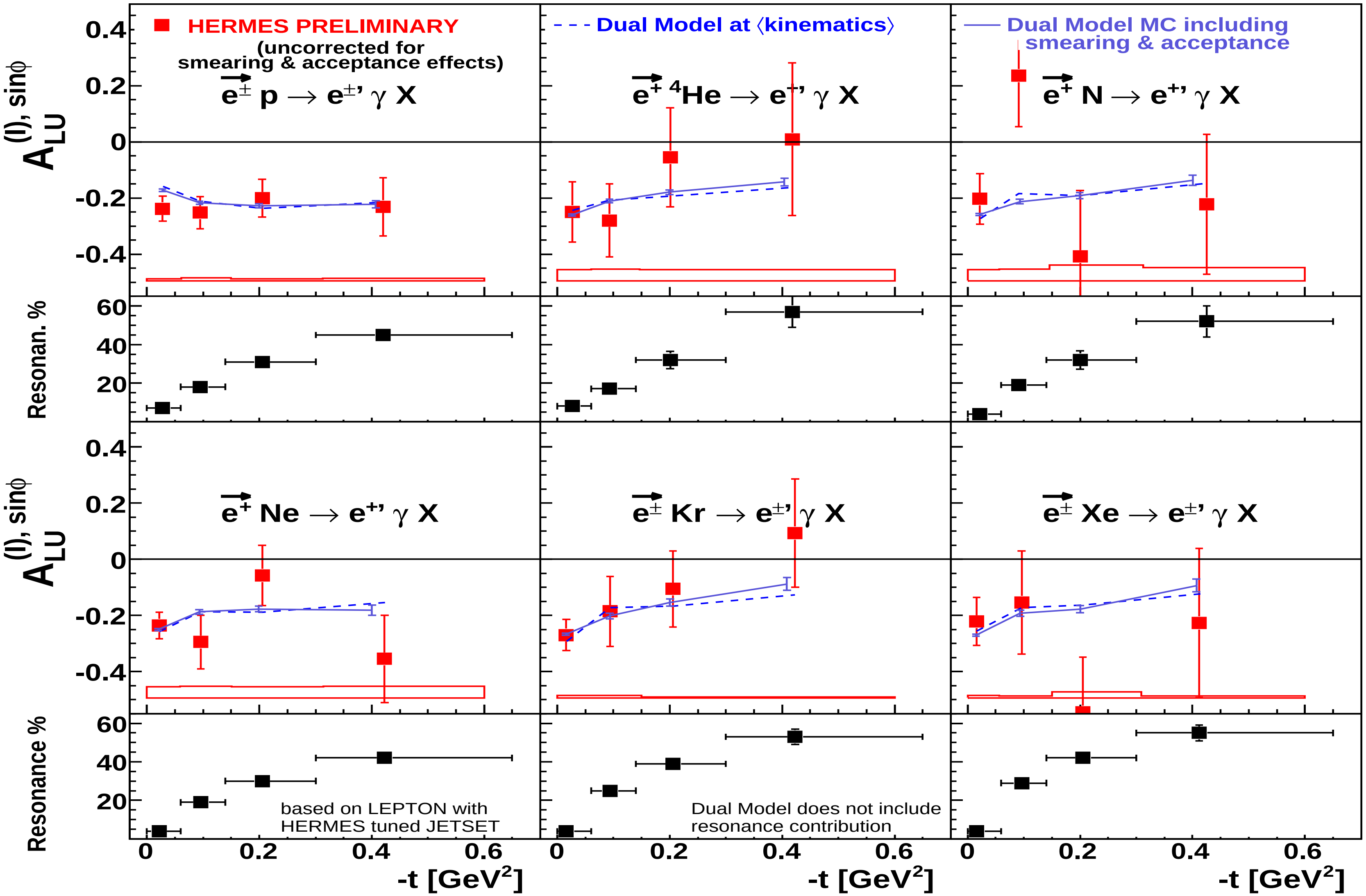
t_c dependence of Beam Charge Asymmetry: $A_C^{\cos\phi}$

– Measured $A_C^{\cos\phi}$ vs. t, with the estimated resonance fraction shown for each t bin



t_c dependence of Leading BSA Amplitude: $A_{LU}^{(I),\sin\phi}$

– Measured $A_{LU}^{(I),\sin\phi}$ vs. t, with the estimated resonance fraction shown for each t bin



M_x^2 Distribution

– M_x^2 Distribution compared between MC and data, with different process contributions shown