Preliminary HERMES results from a combined beam charge and spin analysis of DVCS data

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for the hermes collaboration

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bmb+f - Förderschwerpunkt HERMES

Großgeräte der physikalischen Grundlagenforschung

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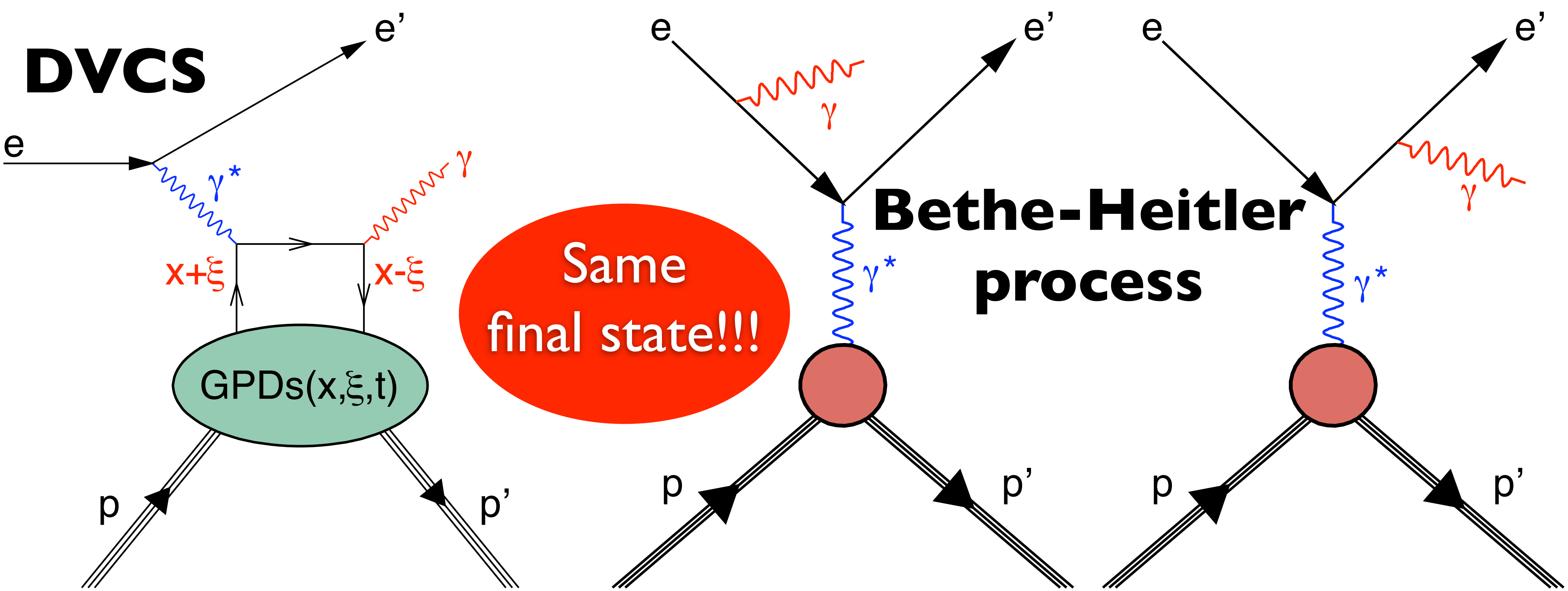
Outline

- Motivation for interest in DVCS and definition of observables.
- The DVCS analysis at HERMES.
- Corrections and systematic uncertainties.
- Results on proton target.
- Comparison to results on Deuterium target.

Deeply virtual Compton Scattering



The (differential) cross section:

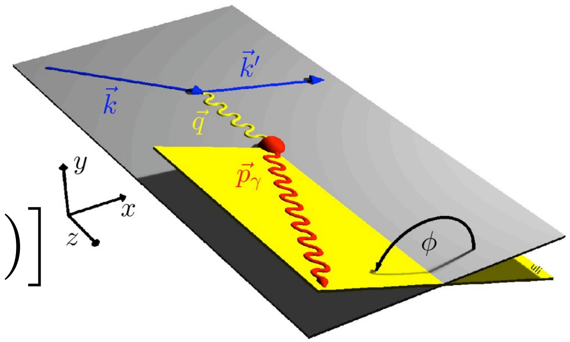
$$\frac{d\sigma}{dx_{\mathrm{B}}\ dQ^2\ dt\ d\phi} = \frac{\alpha_{\mathrm{em}}^3 x_{\mathrm{B}} y}{16\pi^2 Q^2 e^6} \frac{|\mathcal{T}_{\mathrm{BH}}|^2 + |\mathcal{T}_{\mathrm{DVCS}}|^2 + \mathcal{I}}{\sqrt{1 + 4x_{\mathrm{B}}^2 M^2/Q^2}}$$

DVCS amplitude measurable despite $|\mathcal{T}_{\mathrm{BH}}|^2 \gg |\mathcal{T}_{\mathrm{DVCS}}|^2$ at HERMES kinematics.

Azimuthal dependencies

Signatures for different azimuthal amplitudes:

Beam polarization λ, beam charge e_l;



$$|\mathcal{T}_{\mathrm{BH}}|^2 = \frac{K_{\mathrm{BH}}}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left[c_0^{\mathrm{BH}} + c_1^{\mathrm{BH}} cos(\phi) + c_2^{\mathrm{BH}} cos(2\phi)\right]$$

$$|\mathcal{T}_{\mathrm{DVCS}}|^2 = K_{\mathrm{DVCS}}\left[c_0^{\mathrm{DVCS}} + c_1^{\mathrm{DVCS}} cos(\phi) + c_2^{\mathrm{DVCS}} cos(2\phi)\right]$$

$$+ \lambda K_{\mathrm{DVCS}}\; s_1^{\mathrm{DVCS}} sin(\phi)$$

Beam spin asymmetry

$$\mathcal{I} = e_l \frac{K_{\mathrm{Int}}}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left[c_0^{\mathcal{I}} + c_1^{\mathcal{I}} cos(\phi) + c_2^{\mathcal{I}} cos(2\phi) + c_3^{\mathcal{I}} cos(3\phi)\right]$$

Beam charge asymmetry

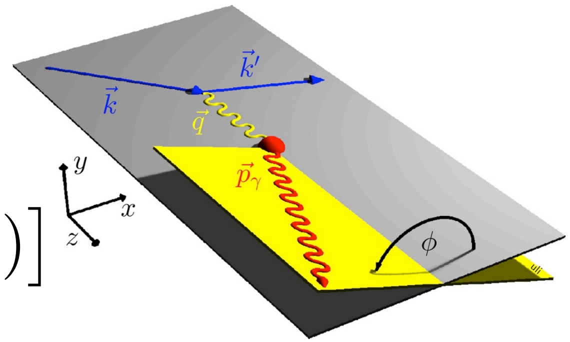
$$+ e_l \lambda \frac{K_{\mathrm{Int}}}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left[s_1^{\mathcal{I}} sin(\phi) + s_2^{\mathcal{I}} sin(3\phi)\right]$$

Beam charge/spin asymmetry

Azimuthal dependencies

Signatures for different azimuthal amplitudes:

Beam polarization λ, beam charge e_l;



$$|\mathcal{T}_{\rm BH}|^2 = \frac{K_{\rm BH}}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \left[c_0^{\rm BH} + c_1^{\rm BH} cos(\phi) + c_2^{\rm BH} cos(2\phi)\right]$$

$$|\mathcal{T}_{\rm DVCS}|^2 = K_{\rm DVCS} \left[c_0^{\rm DVCS} + c_1^{\rm DVCS} cos(\phi) + c_2^{\rm DVCS} cos(2\phi)\right] + \lambda K_{\rm DVCS}\, s_1^{\rm DVCS} sin(\phi)$$

Beam spin asymmetry

$$\mathcal{I} = e_l \frac{K_{\rm Int}}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \left[c_0^{\mathcal{I}} + c_1^{\mathcal{I}} cos(\phi) + c_2^{\mathcal{I}} cos(2\phi) + c_3^{\mathcal{I}} cos(3\phi)\right]$$

Beam charge asymmetry

$$+ e_l \lambda \frac{K_{\rm Int}}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \left[s_1^{\mathcal{I}} sin(\phi) + s_2^{\mathcal{I}} sin(3\phi)\right]$$

Beam charge/spin asymmetry

Propagators include additional azimuthal dependence! The unpolarized terms stay as dilution in the asymmetries!

Relation to Compton Formfactors

$$c_1^{\mathcal{I}} \propto \frac{\sqrt{-t}}{Q} Re \left[F_1 \mathcal{H} + \xi (F_1 + F_2) \tilde{\mathcal{H}} - \frac{t}{4M^2} F_2 \mathcal{E} \right]$$

$$c_0^{\mathcal{I}} \propto -\frac{\sqrt{-t}}{Q} c_1^{\mathcal{I}}$$

Both, real and imaginary part of CFF H can be extracted.

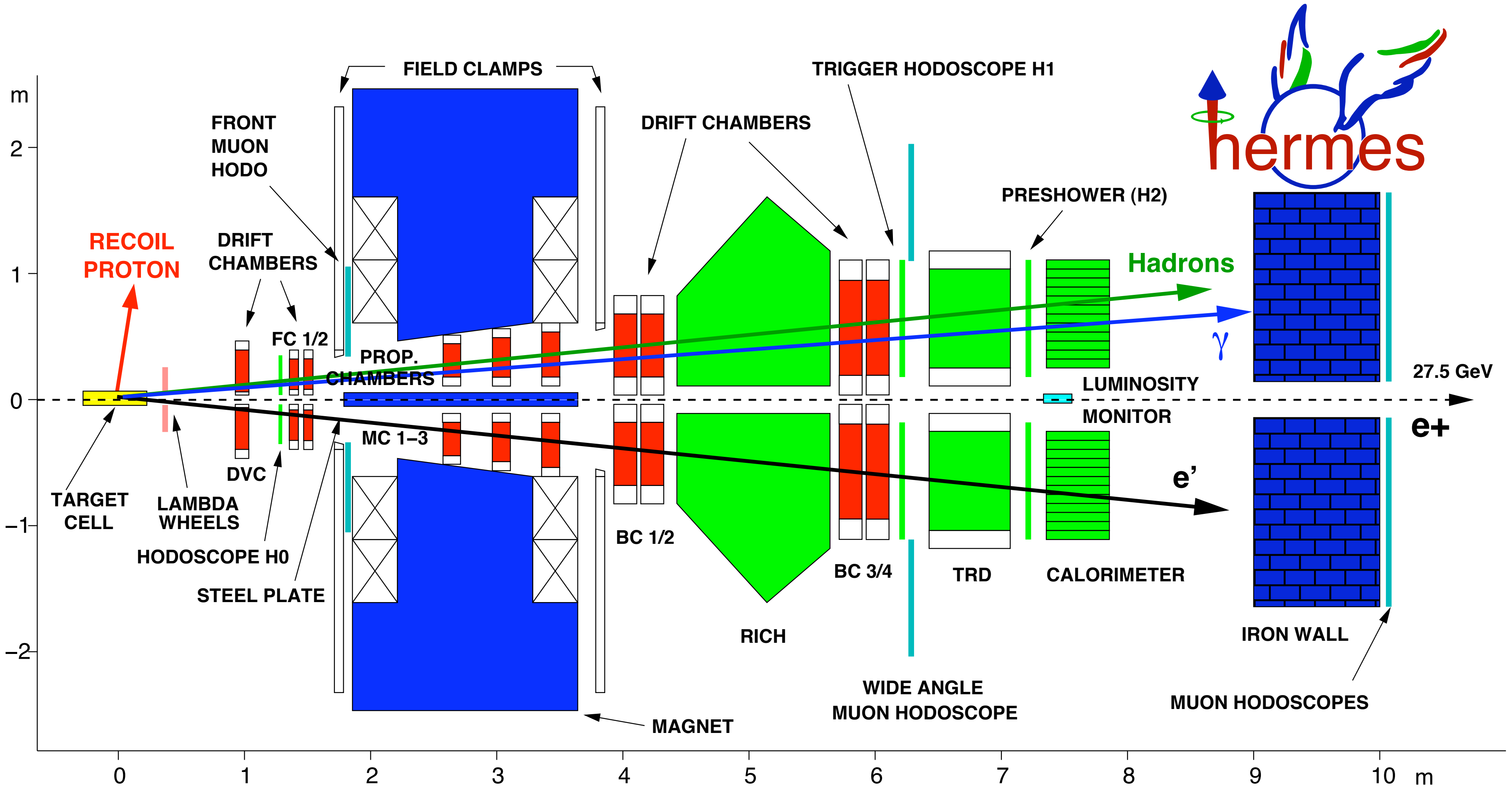
$$s_1^{\mathcal{I}} \propto \frac{\sqrt{-t}}{Q} Im \left[F_1 \mathcal{H} + \xi (F_1 + F_2) \tilde{\mathcal{H}} - \frac{t}{4M^2} F_2 \mathcal{E} \right]$$

BUT we can only measure effective asymmetries:

$$A_{\mathrm{C}}(\phi) = -\frac{\frac{x_{\mathrm{B}}}{y} \sum_{n=0}^{3} c_n^I cos(n\phi)}{\frac{\sum_{n=0}^{2} c_n^{BH} cos(n\phi)}{(1+\epsilon^2)^2} + \frac{x_{\mathrm{B}}^2 t \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}{Q^2} \sum_{n=0}^{2} c_n^{DVCS} cos(n\phi)}$$

In the analysis data with different beam charges and helicities are combined and simultaneously fit to extract the different asymmetry amplitudes.

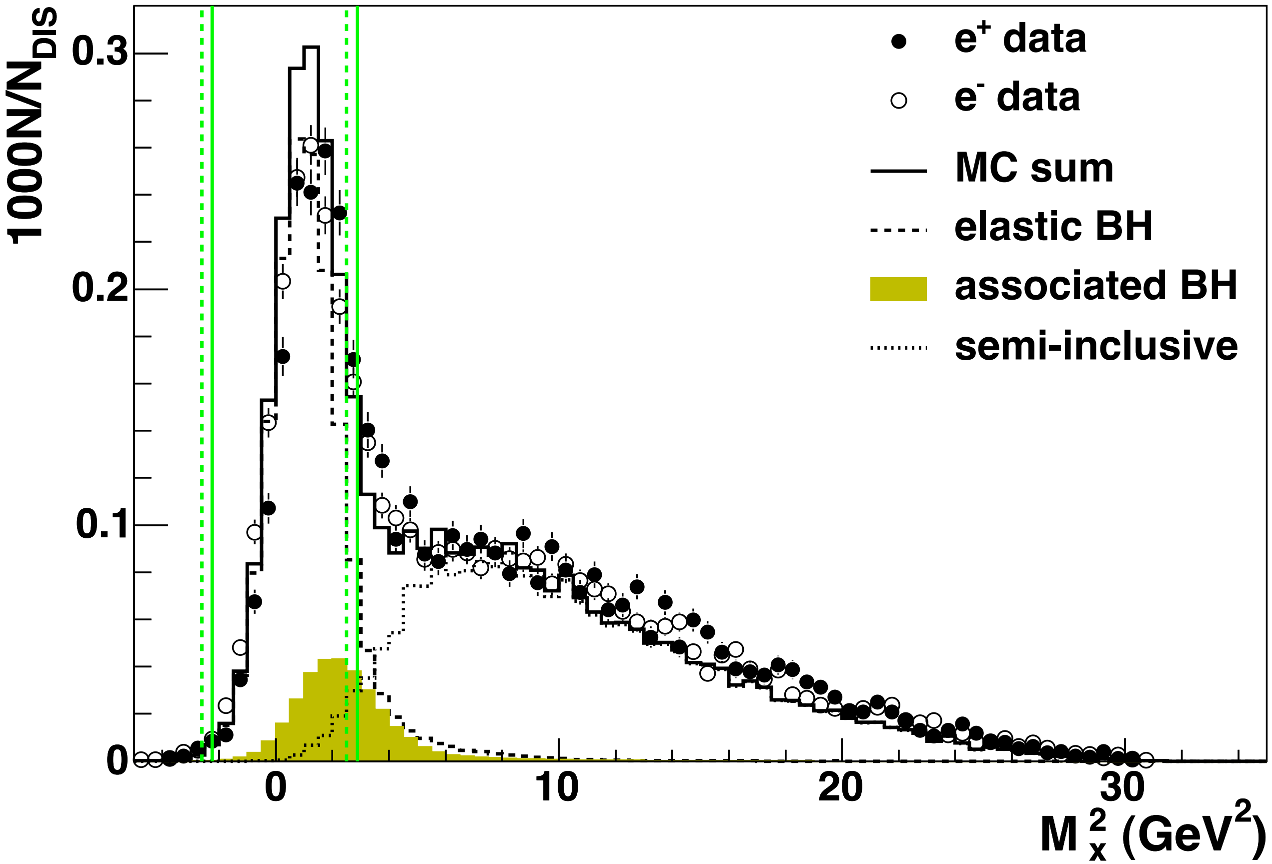
The HERMES experiment



All data has been taken without the Recoil Detector.

Corrections and Uncertainties

Identification by missing mass technique: $(e + p \rightarrow e' + \gamma + X)$



After all cuts:

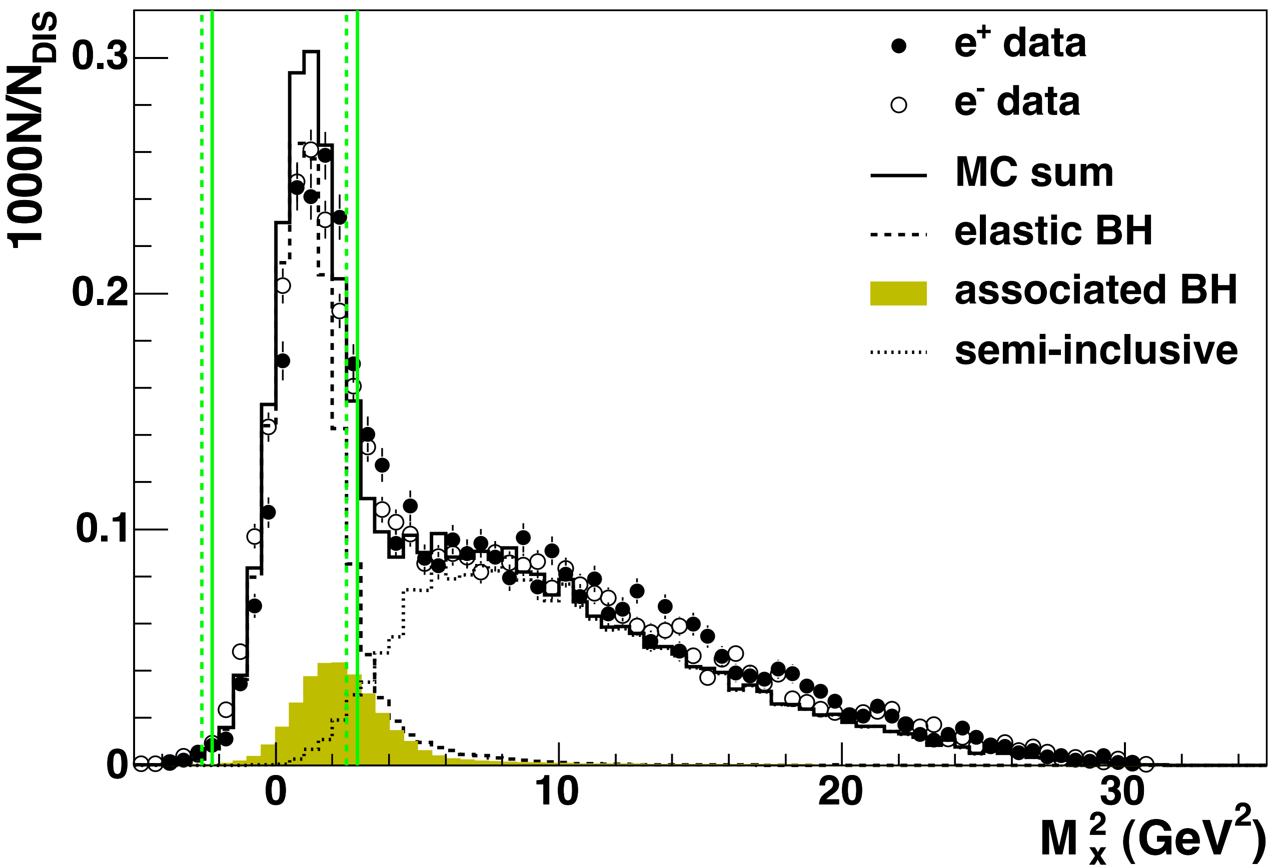
~ 12 %

Not possible to separate associated from elastic production.
Treated as part of the signal and not corrected for.

➡ Possible with Recoil Detector for 2006/2007 data.

Corrections and Uncertainties

Identification by missing mass technique: $(e + p \rightarrow e' + \gamma + X)$



After all cuts:

~ 12 %

~ 3 %

(mainly pion production)

corrected for:

$$A_{\text{excl.}} = \frac{1}{1 - f_{\text{i}}} \left[A_{\text{meas.}} - f_{\text{i}} A_{\text{i}} \right]$$

Semi-inclusive pion production corrected as dilutions for charge dependent asymmetries. For pure DVCS term, asymmetry extracted from π^0 ($z_\pi > 0.8$)data. Fractional contributions taken from MC.

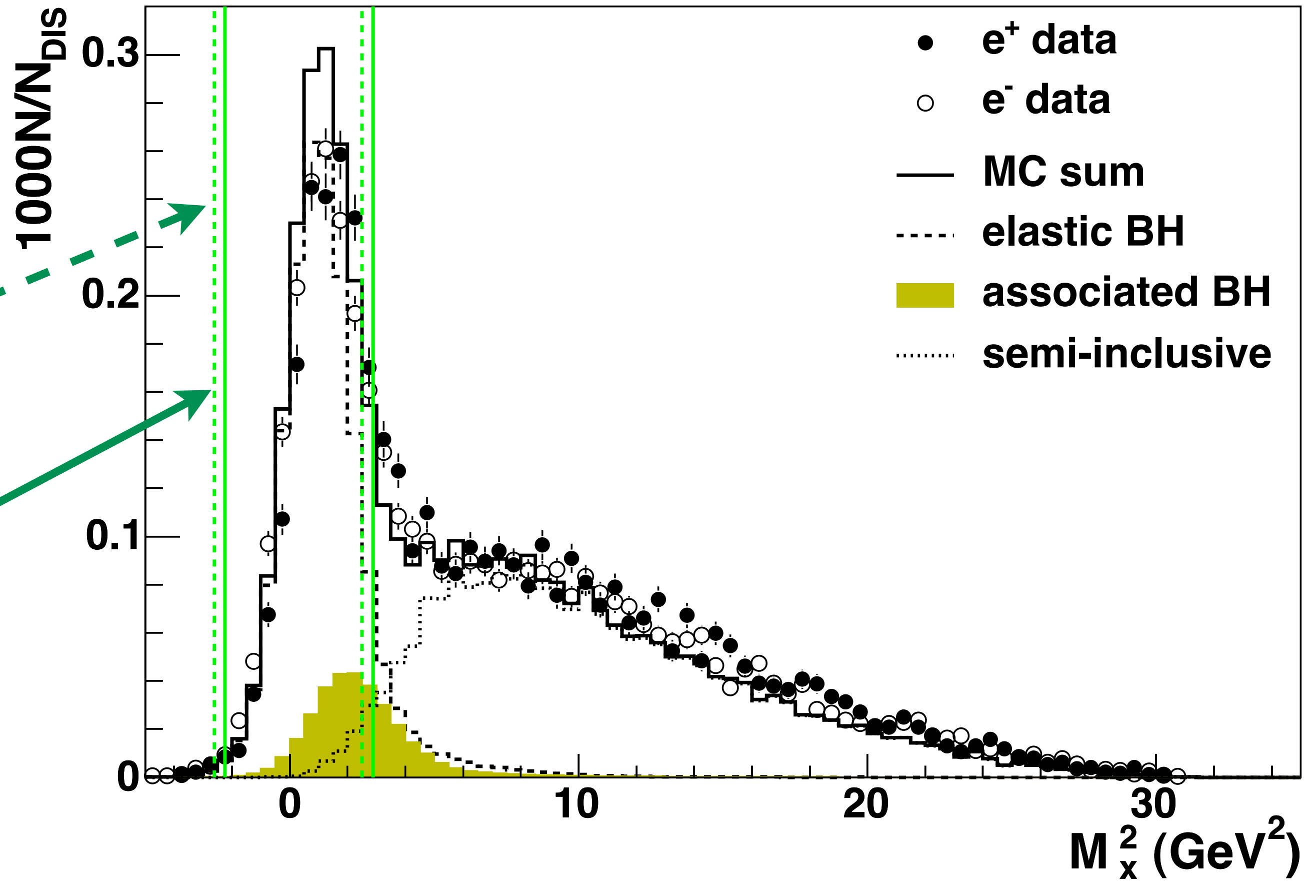
Corrections and uncertainties (cont')

The position of the exclusive peak in the missing mass distribution changes with the beam charge:

Different windows chosen:

Exclusive window for e^- data.

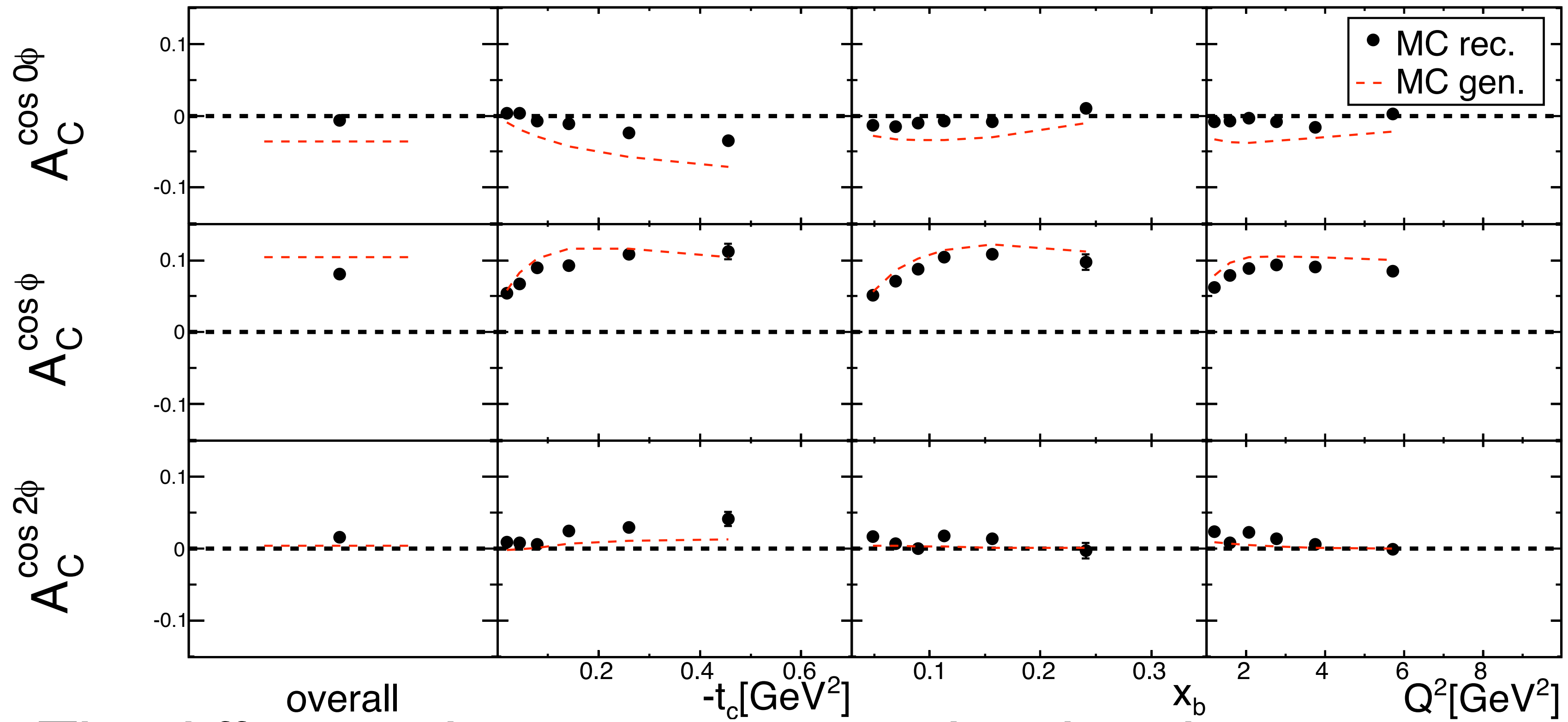
Exclusive window for e^+ data.

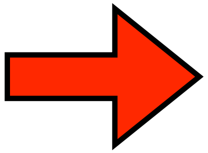


One quarter of the effect of the shift has been added to the systematic error. Only a small contribution overall.

Corrections and uncertainties (cont')

MC study to estimate the effect of the acceptance, bin-width, smearing and mis-alignments between lepton beam and spectrometer:





The difference between generated and in the acceptance reconstructed asymmetry amplitudes are added to the systematics. Different theoretical models are combined. Gives main contribution to systematics.

GPD Models

"VGG" model: **(Vanderhaeghen, Guichon, Guidal 1999)**

★ Based on double distributions.

★ Includes a D-term to restore full polynomiality.

★ Includes a Regge inspired and a factorized t-ansatz.

★ Skewness depending on free parameters b_{val} & b_{sea}.

★ Includes twist-three contributions.

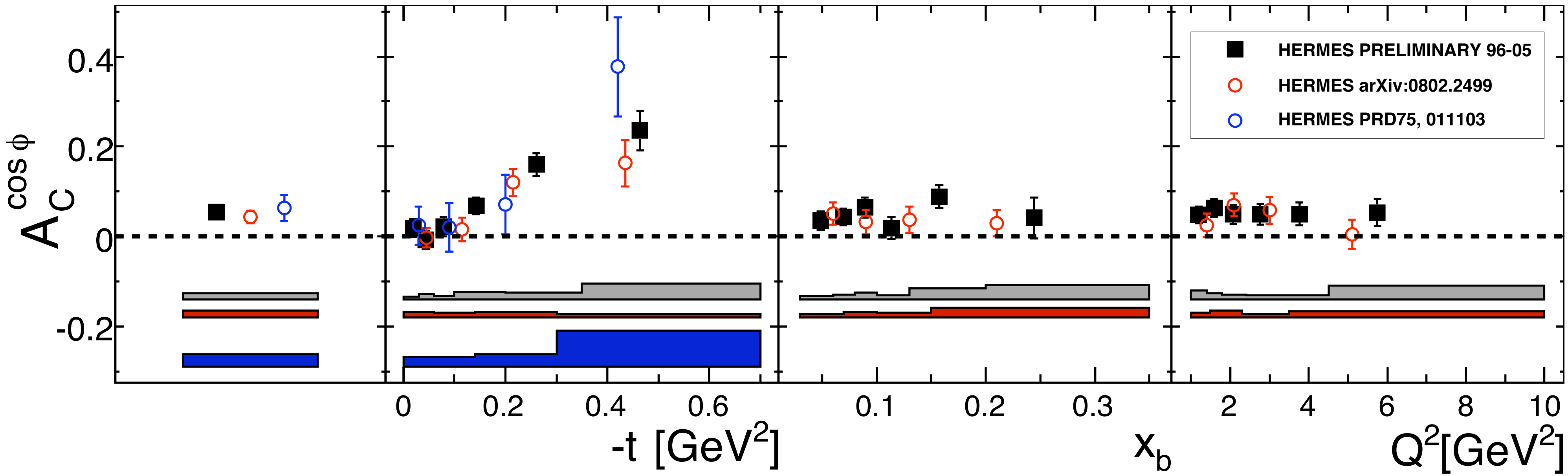
"Dual" model: **(Guzey, Teckentrup 2006)**

★ GPDs based on an infinite sum of t-channel resonances.

★ Includes a Regge inspired and a factorized t-ansatz.

★ Does not include twist-three.

Beam charge asymmetries

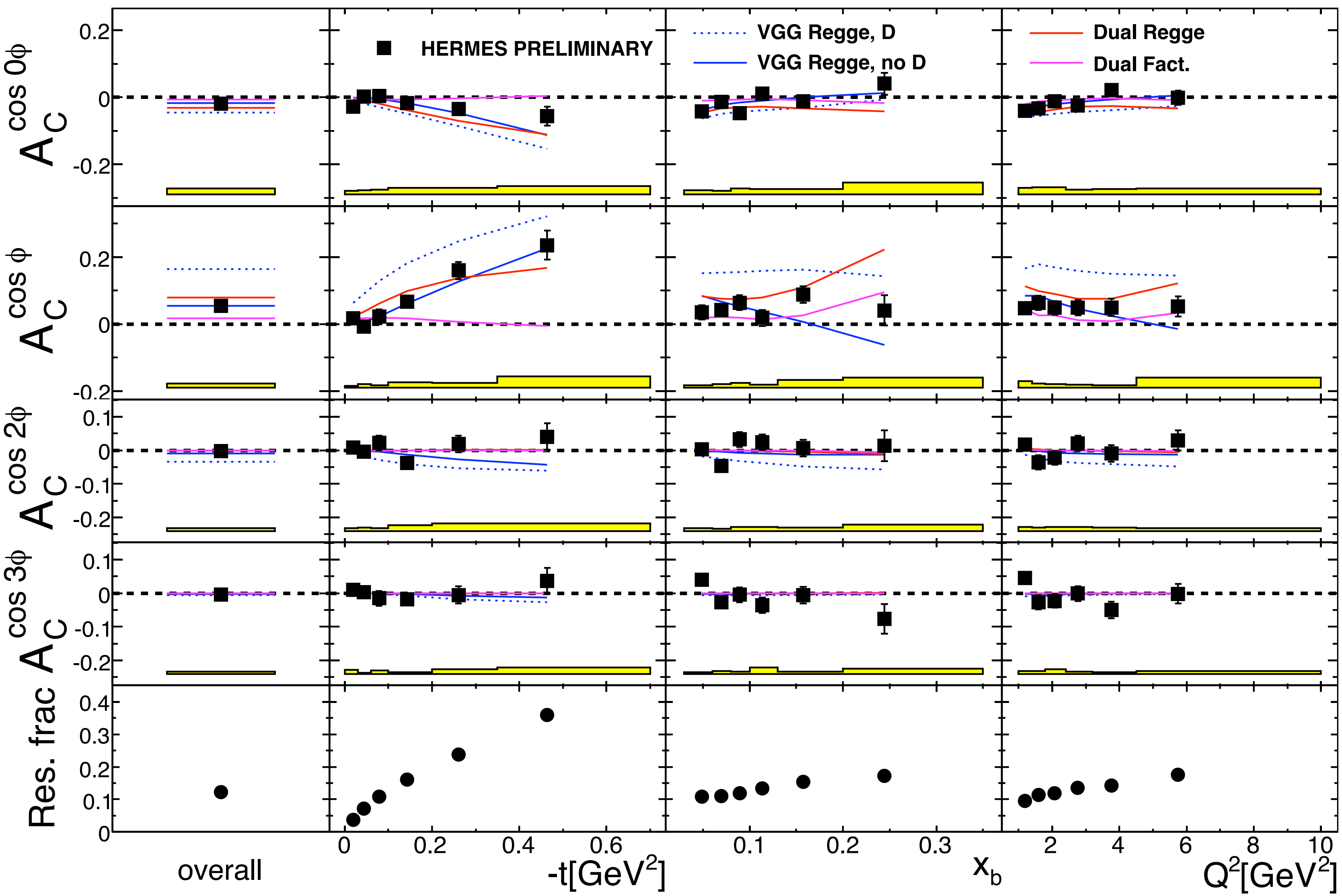


<u>Changes in the new analysis:</u>

- ✦ 2.5 times the statistics than in the previous publications.
- ✦ 6 bins in all kinematic variables.
- ✦ The systematic error includes new model-dependent studies.

➡ Results agree with former publications with higher statistical precision.

Beam Charge Asymmetries



$\propto -A_C^{cos\phi}$

$\propto \mathrm{Re}[F_1\mathcal{H}]$

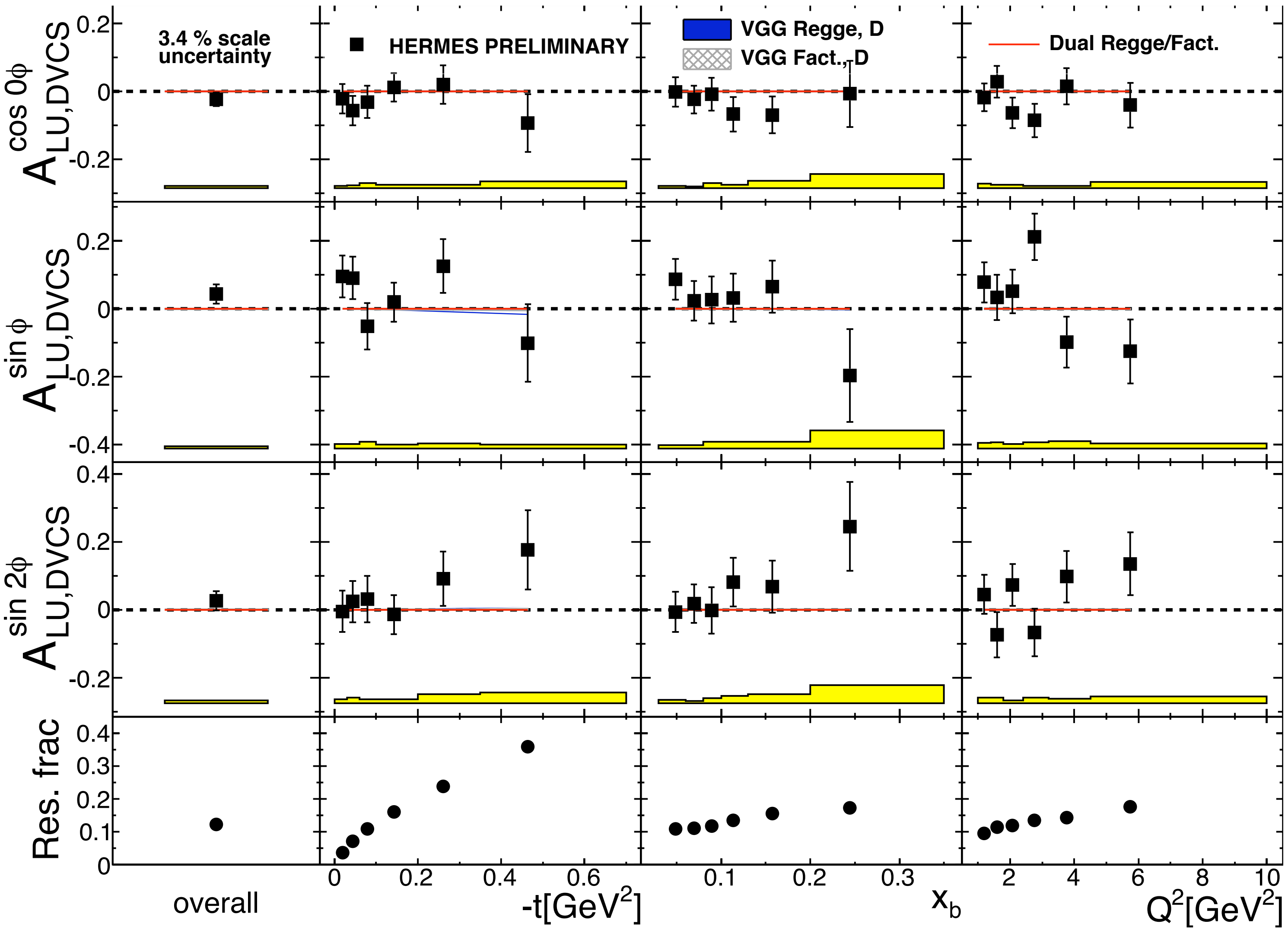
(higher twist)

(gluon leading twist)

Bin-wise fractions of associated production.

The factorized ansatz and the VGG variant with a D-term is dis-favored by the beam charge asymmetry.

Beam Spin Asymmetries



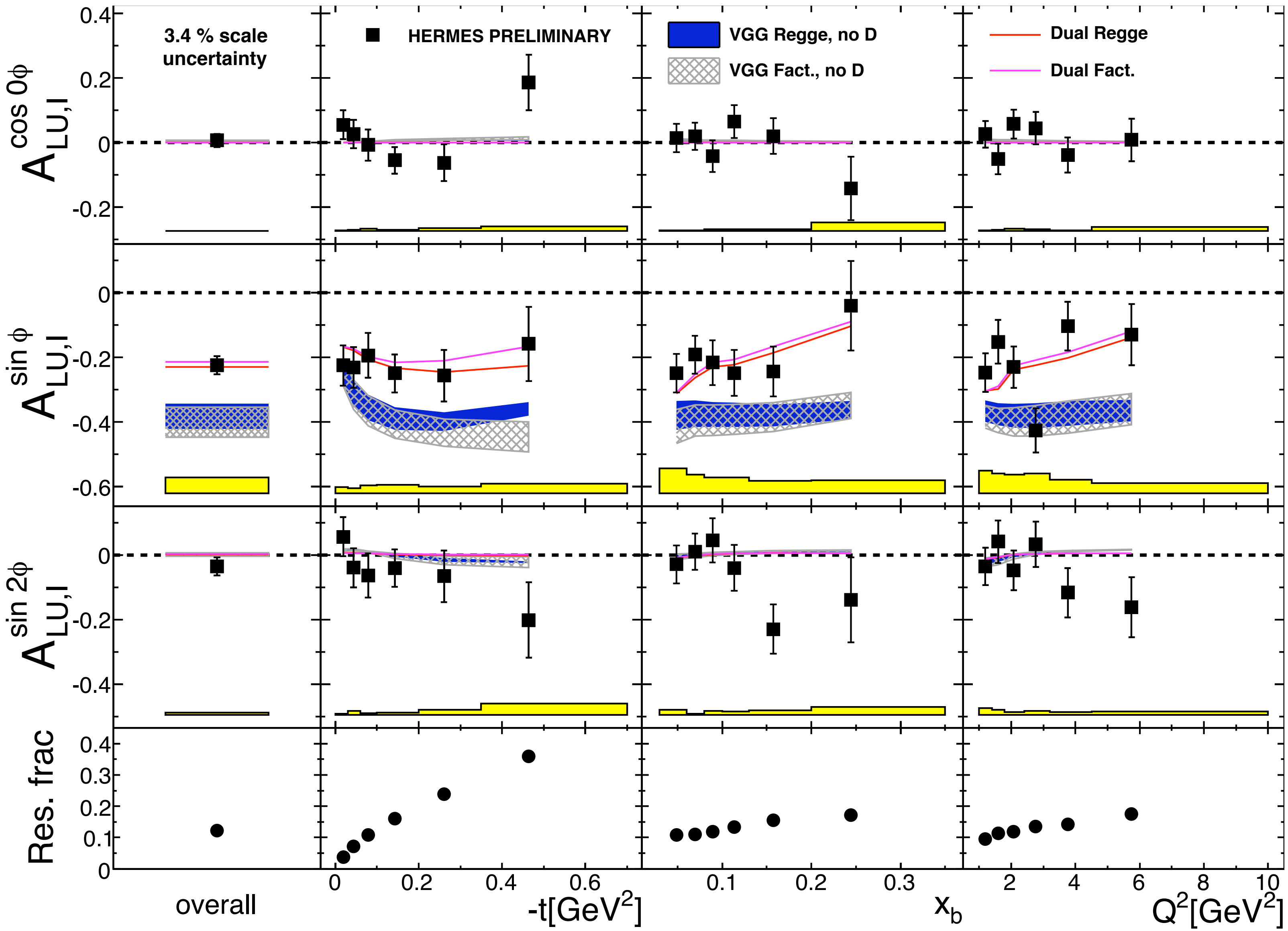
$\propto \left[\mathcal{H}\mathcal{H}^* + \tilde{\mathcal{H}}\tilde{\mathcal{H}}^*\right]$

(higher twist)

Bin-wise fractions of associated production.

Pure DVCS squared asymmetries are compatible with zero, in agreement with model assumptions. VGG bands obtained by varying input parameters b_{val} & b_{sea}.

Beam Spin Asymmetries



$\propto \; \mathrm{Re}[F_1\mathcal{H}]$

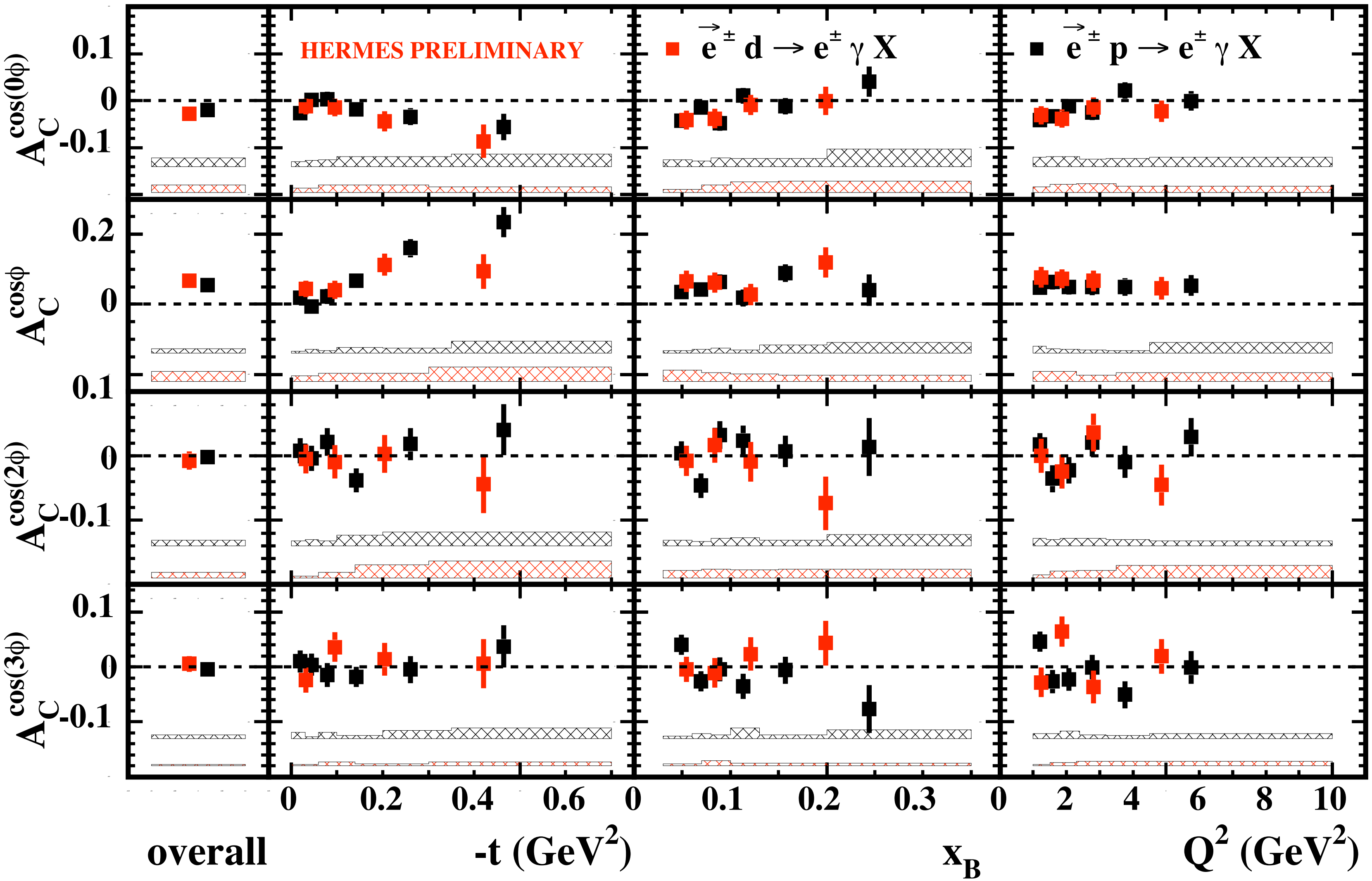
$\propto \; Im[F_1\mathcal{H}]$

(higher twist)

Bin-wise fractions of associated production.

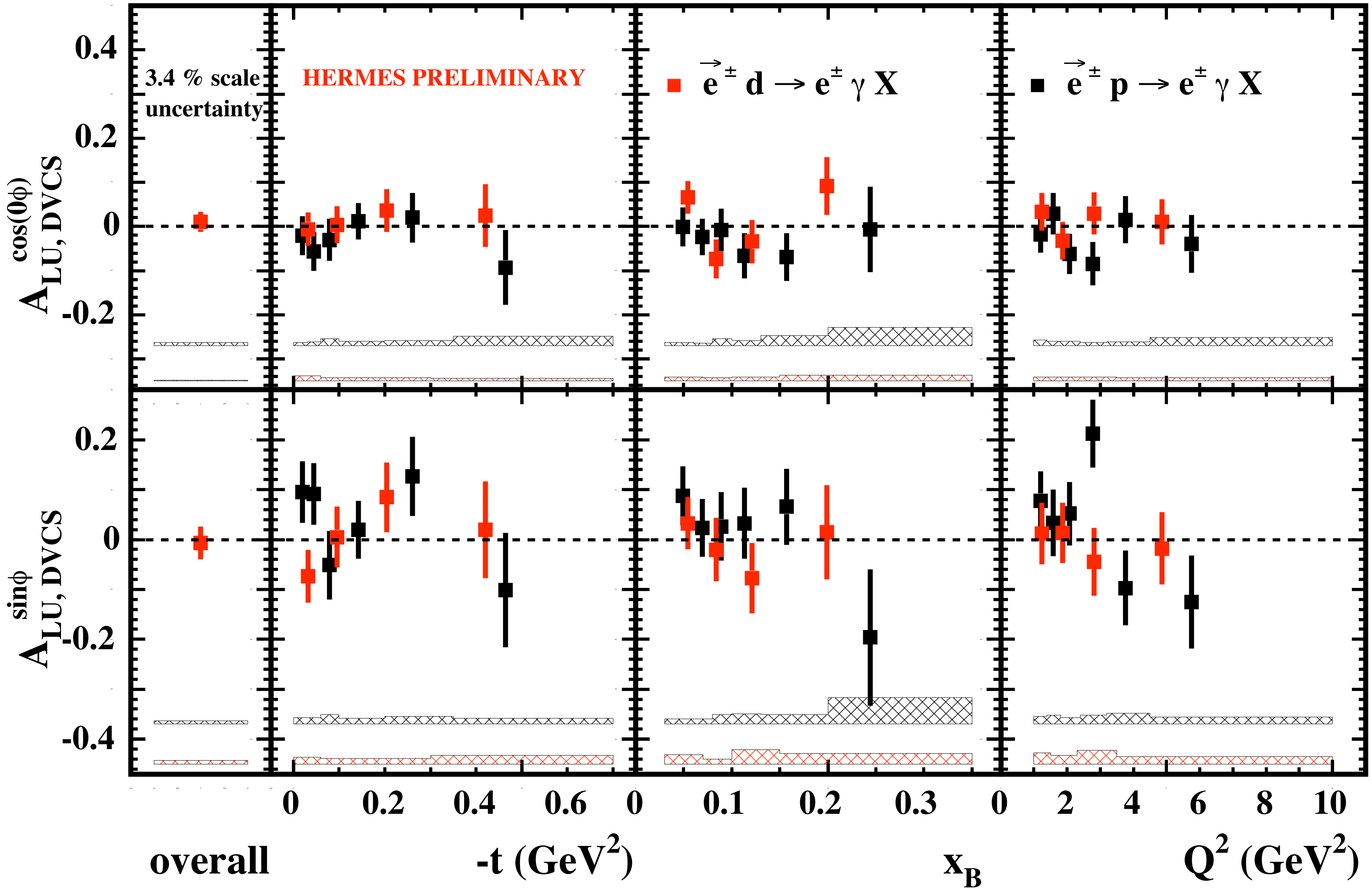
➡ Result agrees with Dual model predictions, but fractions of associated productions are not corrected for.

Comparison to Deuterium Data



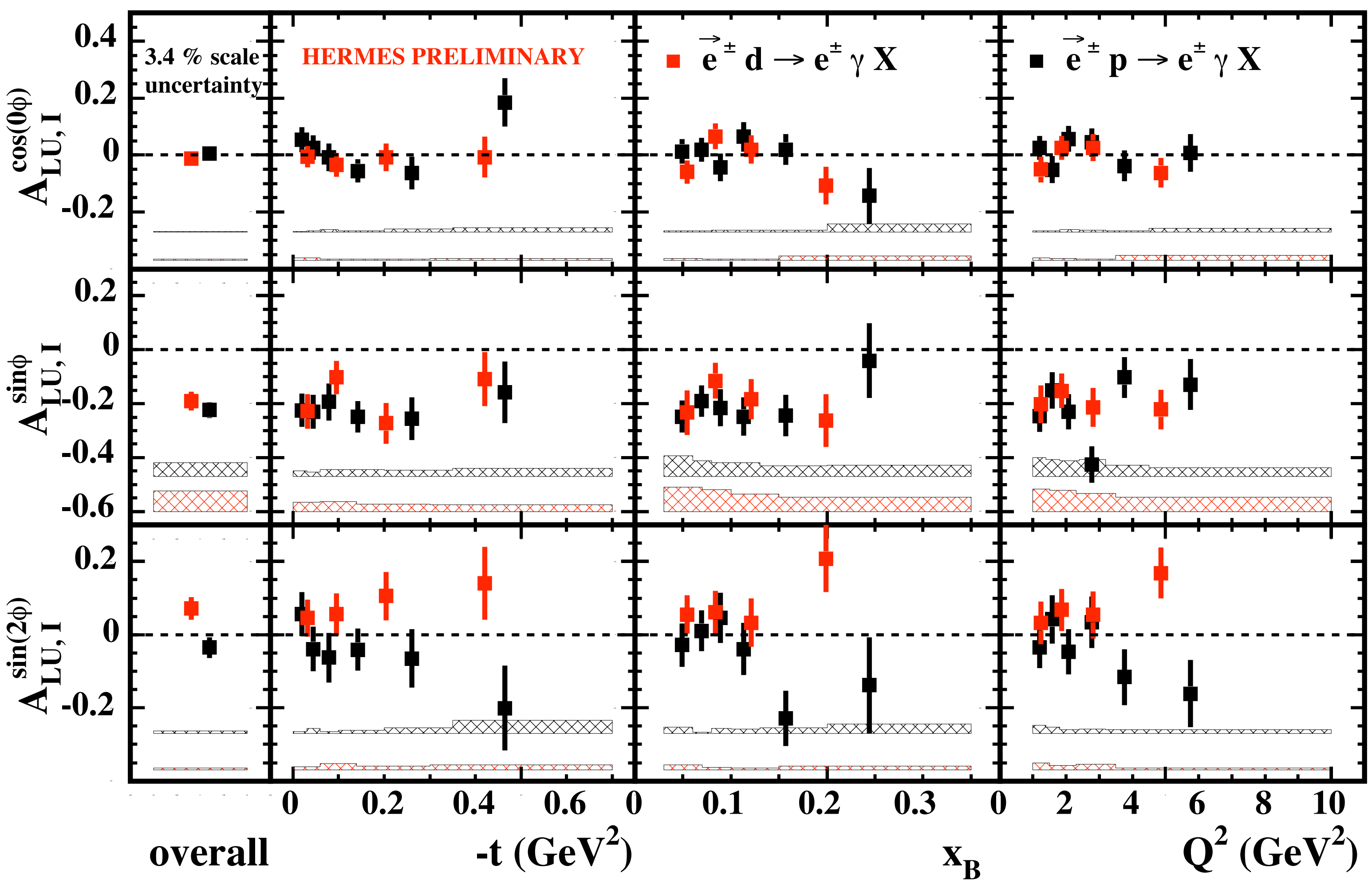
Proton and deuterium results are compatible. Both, in low t ($t<0.06$ GeV^2; 40% coherent) and high t (incoherent) region.

Comparison to Deuterium Data



Proton and deuterium sin ϕ moment of the DVCS[2] term are compatible with zero. Different beam charges have same BSA amplitude, but different signs!

Comparison to Deuterium Data



The sin ϕ moment from the interference term is significantly negative over the whole kinematic range for both targets.

Summary

- HERMES released new preliminary results on BCA and BSA from a analysis on the proton with much more statistics than in previous publications.
- The BCA clearly disfavors all factorized model variants and the inclusion of a D-term in VGG.
- The associated production needs to be accounted for in the BSA. The statistical precision allows for strong constraints on GPDs.
- In the 2006/2007 data the associated process can be separated with the information from the Recoil Detector.
- Very recently a combined analysis of the deuterium data has been released as well. The results on the different targets agree very well for all leading twist amplitudes.

Backup

Fractional contributions