DVCS at HERMES

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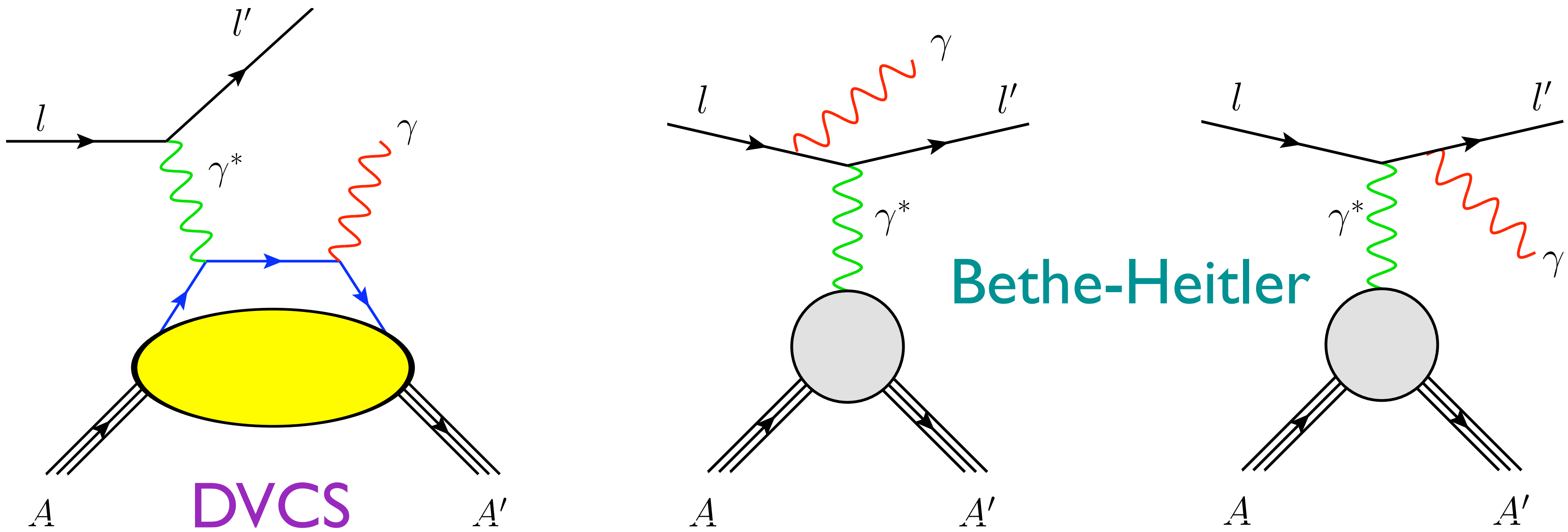
for the HERMES collaboration

DIS Newport News, 14.04.2011



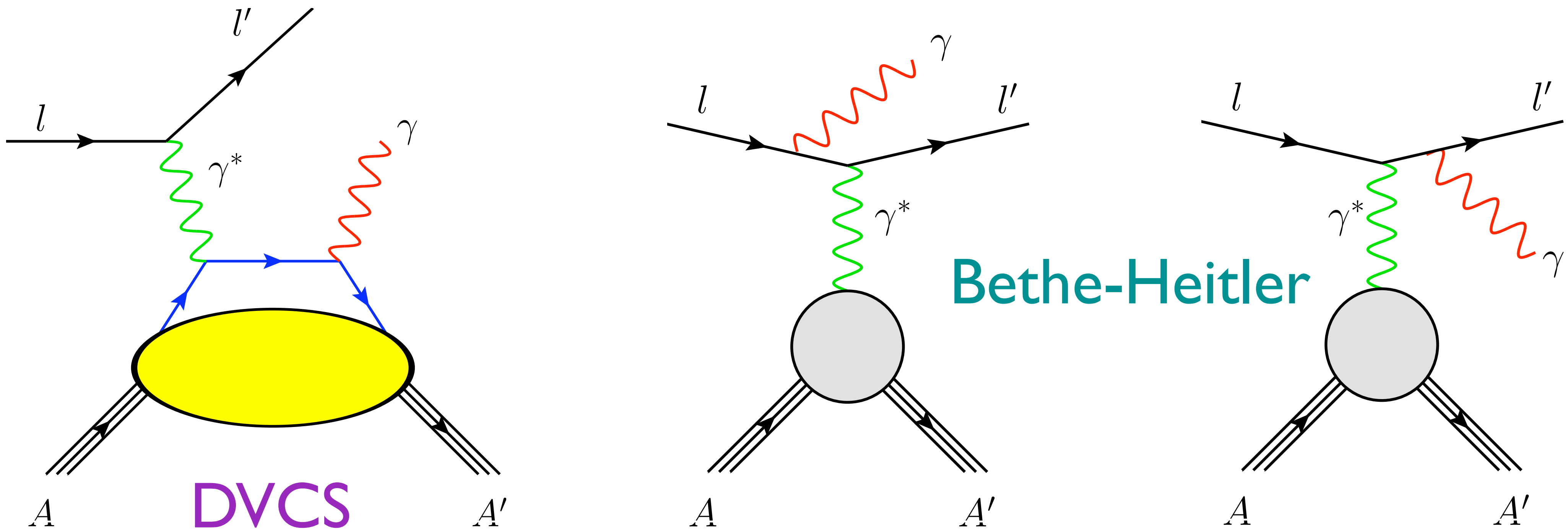
DVCS and Bethe-Heitler ⇒ Same final state ⇒ Interference

$$\frac{d\sigma}{dx_B dQ^2 d|t| d\phi} \propto |\mathcal{T}_{BH}|^2 + |\mathcal{T}_{DVCS}|^2 + \underbrace{\mathcal{T}_{DVCS}\mathcal{T}_{BH}^* + \mathcal{T}_{BH}\mathcal{T}_{DVCS}^*}_{I}$$

At HERMES kinematics $|\mathcal{T}_{DVCS}|^2 << |\mathcal{T}_{BH}|^2$

DVCS amplitudes can be accessed trough Interference

Interference ⇒ non-zero azimuthal asymmetries



$$\frac{d\sigma}{dx_B dQ^2 d|t| d\phi} \propto |\mathcal{T}_{BH}|^2 + |\mathcal{T}_{DVCS}|^2 + \underbrace{\mathcal{T}_{DVCS}\mathcal{T}^*_{BH} + \mathcal{T}_{BH}\mathcal{T}^*_{DVCS}}_{I}$$

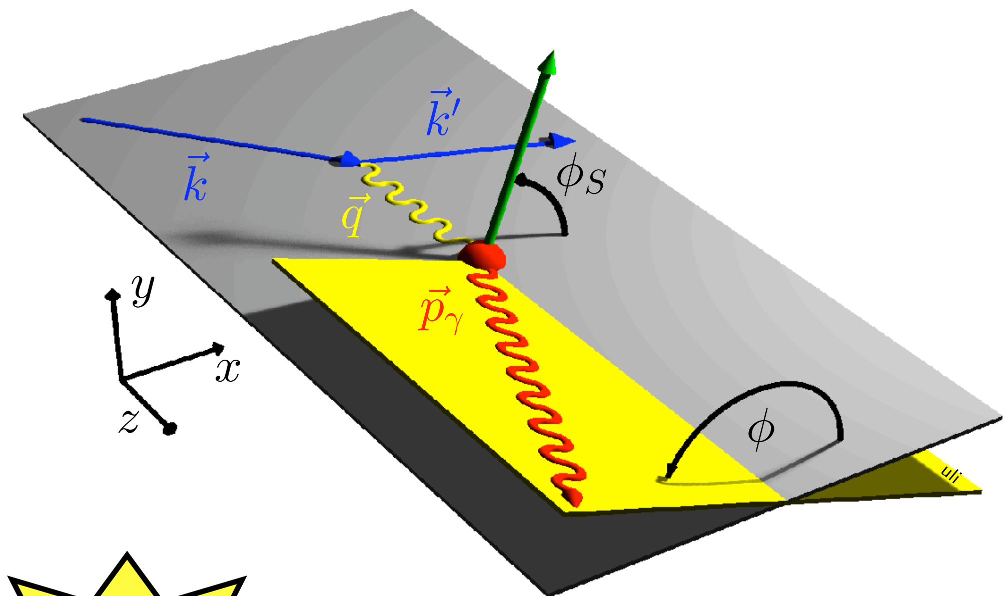
Bethe-Heitler is parametrized in terms of electromagnetic Form-Factors

$$\left.\begin{array}{ll} F_1, F_2 & Nucleons \\ G_1, G_2, G_3 & Deuteron \end{array}\right\} \Rightarrow$$ BH is calculable in QED

DVCS is parametrized in terms of Compton Form-Factors

$$\left.\begin{array}{ll} \mathcal{H}, \mathcal{E}, \tilde{\mathcal{H}}, \tilde{\mathcal{E}} & Nucleons \\ \mathcal{H}, \mathcal{H}_1, \cdots \mathcal{H}_5, \tilde{\mathcal{H}}_1, \cdots \tilde{\mathcal{H}}_4 & Deuteron \end{array}\right\} =$$

= convolutions of hard scattering amplitudes and GPD's



- Beam-Charge asymmetry

$$\sigma(e^+,\phi)-\sigma(e^-,\phi)\propto Re[F_1\mathcal{H}]\,(Re[G_1\mathcal{H}_1])$$

- Beam-Spin Asymmetry

$$\sigma(\overrightarrow{e},\phi)-\sigma(\overleftarrow{e},\phi)\propto Im[F_1\mathcal{H}]\,(Im[G_1\mathcal{H}_1])$$

- Longitudinal Target-Spin Asymmetry

New

$$\sigma(\overset{\Rightarrow}{P},\phi)-\sigma(\overset{\Leftarrow}{P},\phi)\propto Im[F_1\widetilde{\mathcal{H}}]\,(Im[G_1\widetilde{\mathcal{H}}_1])$$

- Longitudinal Double-Spin Asymmetry

New

$$\sigma(\overset{\Rightarrow}{P},\overrightarrow{e},\phi)-\sigma(\overset{\Rightarrow}{P},\overleftarrow{e},\phi)\propto Re[F_1\widetilde{\mathcal{H}}]\,(Re[G_1\widetilde{\mathcal{H}}_1])$$

- Transverse Target-Spin Asymmetry

$$\sigma(\phi,\phi_S)-\sigma(\phi,\phi_S+\pi)\propto Im[F_2\mathcal{H}-F_1\mathcal{E}]$$

- Transverse Double-Spin Asymmetry

$$\sigma(\overrightarrow{e},\phi,\phi_S)-\sigma(\overleftarrow{e},\phi,\phi_S+\pi)\propto Re[F_2\mathcal{H}-F_1\mathcal{E}]$$

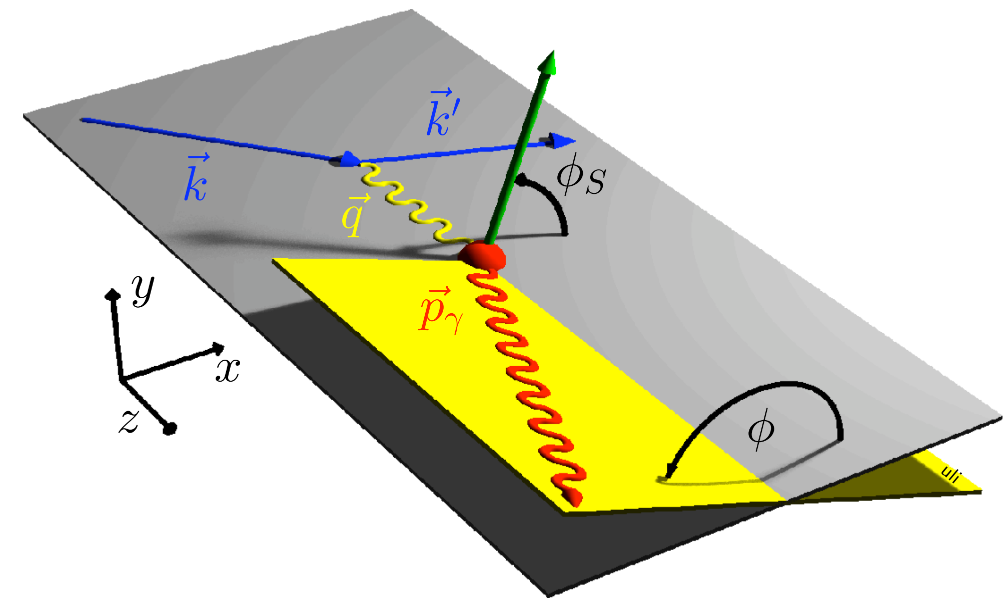
New

Azimuthal Dependences

$$|\mathcal{T}_{\rm BH}|^2 = \frac{K_{\rm BH}}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left\{\sum_{n=0}^{2} c_n^{\rm BH}\cos(n\phi) + s_1^{BH}\sin(\phi)\right\}$$

$$|\mathcal{T}_{\rm DVCS}|^2 = K_{\rm DVCS}\left\{\sum_{n=0}^{2} c_n^{\rm DVCS}\cos(n\phi) + \sum_{n=1}^{2} s_n^{\rm DVCS}\sin(n\phi)\right\}$$

$$\mathcal{I} = -\frac{K_{\rm I}e_\ell}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left\{\sum_{n=0}^{3} c_n^{\rm I}\cos(n\phi) + \sum_{n=1}^{3} s_n^{\rm I}\sin(n\phi)\right\}$$



Longitudinally polarized target:

$$\left.\begin{aligned} c_n &= c_{n,unp} + \lambda\Lambda c_{n,LP} \\ s_n &= \lambda s_{n,unp} + \Lambda s_{n,LP} \end{aligned}\right\}$$ **Spin - 1/2**

$$\left.\begin{aligned} c_n &= \frac{3}{2}\Lambda^2 c_{n,unp} + \lambda\Lambda c_{n,LP} + (1-\frac{3}{2}\Lambda^2)c_{n,LLP} \\ s_n &= \frac{3}{2}\lambda\Lambda^2 s_{n,unp} + \Lambda s_{n,LP} + (1-\frac{3}{2}\Lambda^2)\lambda s_{n,LLP} \end{aligned}\right\}$$ **Spin - 1**

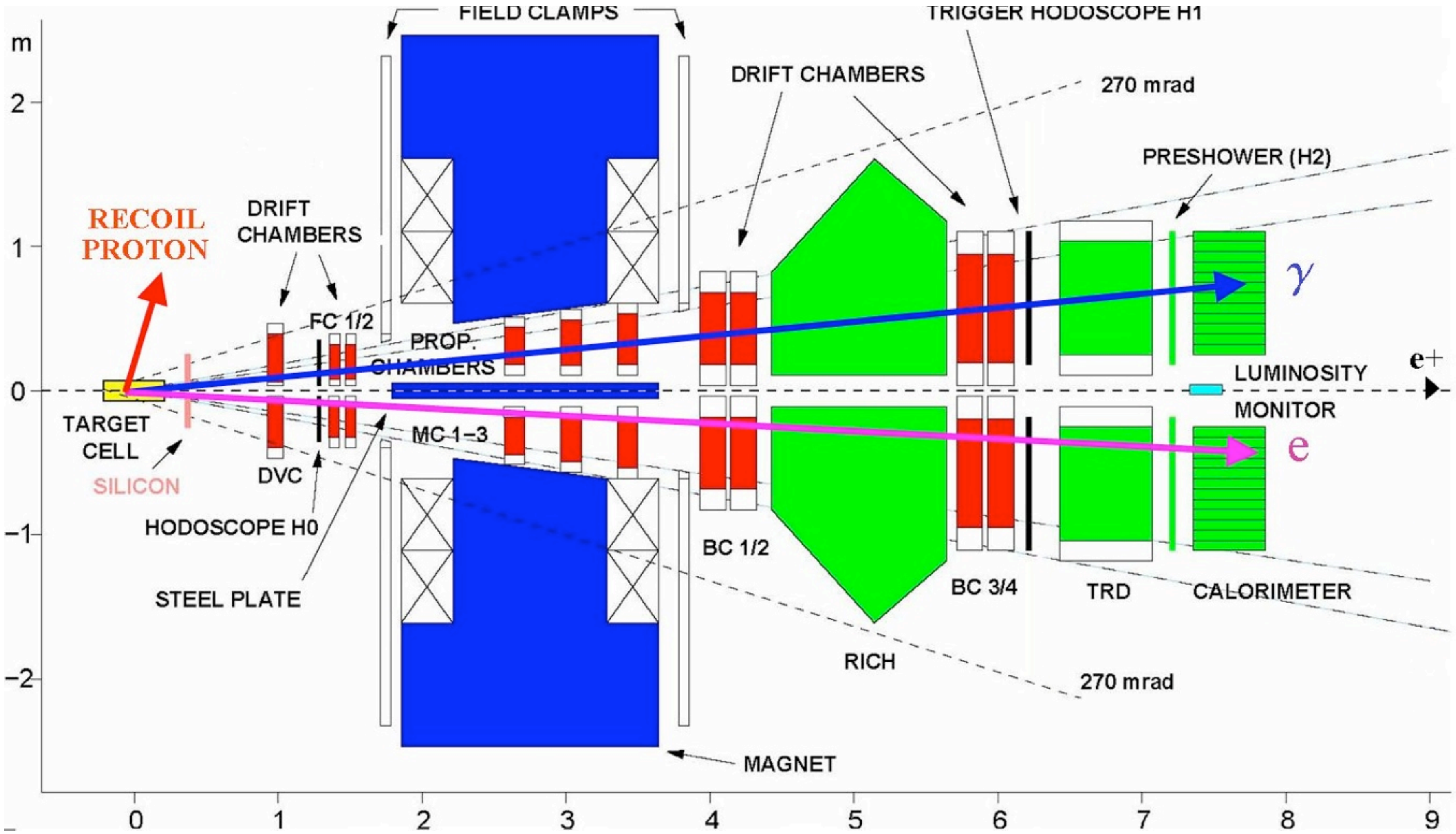
λ - Beam helicity

Λ - Target spin projection

e_ℓ - Beam charge

Transversely polarized target:

$$\left.\begin{aligned} c_n &= c_{n,unp} + \Lambda c_{n,UT} + \lambda\Lambda c_{n,LT} \\ s_n &= \lambda s_{n,unp} + \Lambda s_{n,UT} + \lambda\Lambda s_{n,LT} \end{aligned}\right\}$$ **Spin - 1/2**



Longitudinally polarized
e^+/e^- Beam
27.6 GeV

- 1996-1997 Longitudinally Polarized Hydrogen (e^+ Beam) ≈ 3 M DIS
- 2002-2005 Transversely Polarized Hydrogen (e^+/e^- Beam) ≈ 10 M DIS
- 1998-2000 Longitudinally Polarized Deuterium (e^+/e^- Beam) ≈ 6 M DIS
- 1996-2005 Unpolarized Hydrogen (e^+/e^- Beam) ≈ 17 M DIS
- 1996-2005 Unpolarized Deuterium (e^+/e^- Beam) ≈ 10 M DIS
- 2006-2007 Unpolarized Hydrogen (e^+/e^- Beam) ≈ 40 M DIS

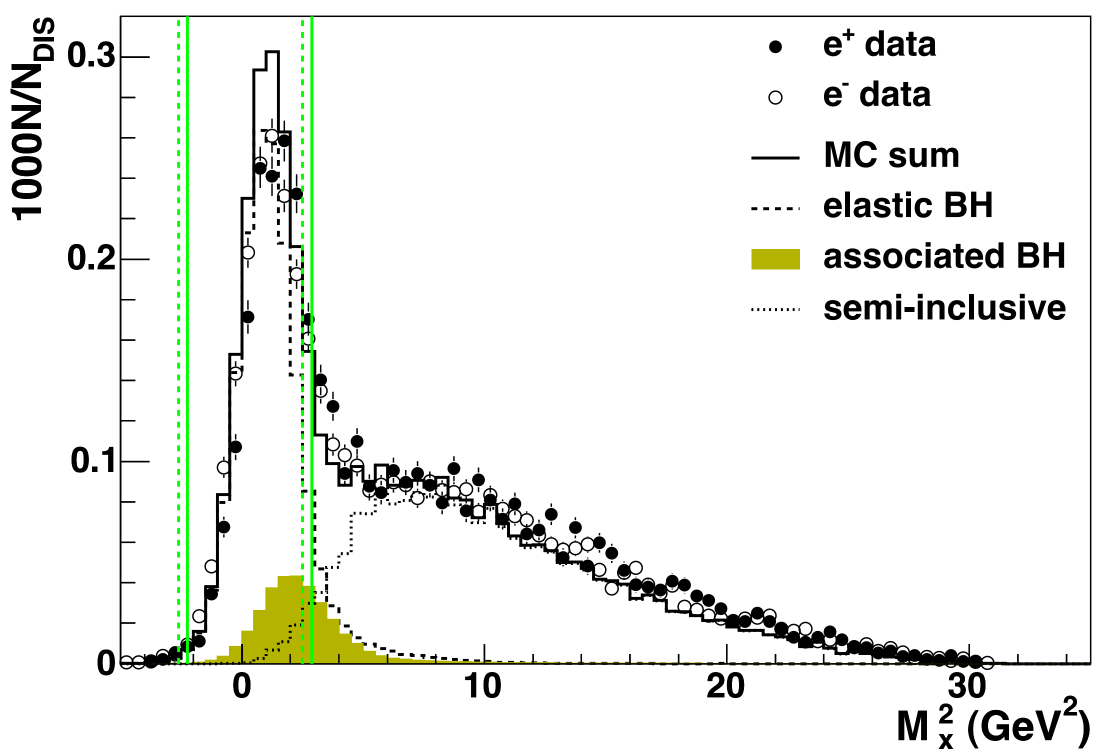
- Events with one DIS lepton and one trackless cluster in the calorimeter.
- Recoiling nucleon/nucleus was not detected

$\Longrightarrow$ Exclusivity via missing mass technique: $M_x^2 = (P + q - q')^2$

$$W^2 > 9\,GeV^2, \quad \nu < 22\,GeV$$

$$0.03 < x_B < 0.35,\ 1 < Q^2 < 10\,GeV^2$$

$$-t < 0.7\,GeV^2, \quad E_\gamma > 5\,GeV$$



Proton:
- Elastic; $ep \rightarrow ep\gamma$
- Associated; mainly $ep \rightarrow e\Delta^+\gamma$
- Semi-Inclusive; mainly $ep \rightarrow e\pi^0 X$

$$-2.25\,GeV^2 < M_x^2 < 2.89\,GeV^2$$

Associated cannot be resolved $\longrightarrow$ defined as a part of signal.

- Events with one DIS lepton and one trackless cluster in the calorimeter.
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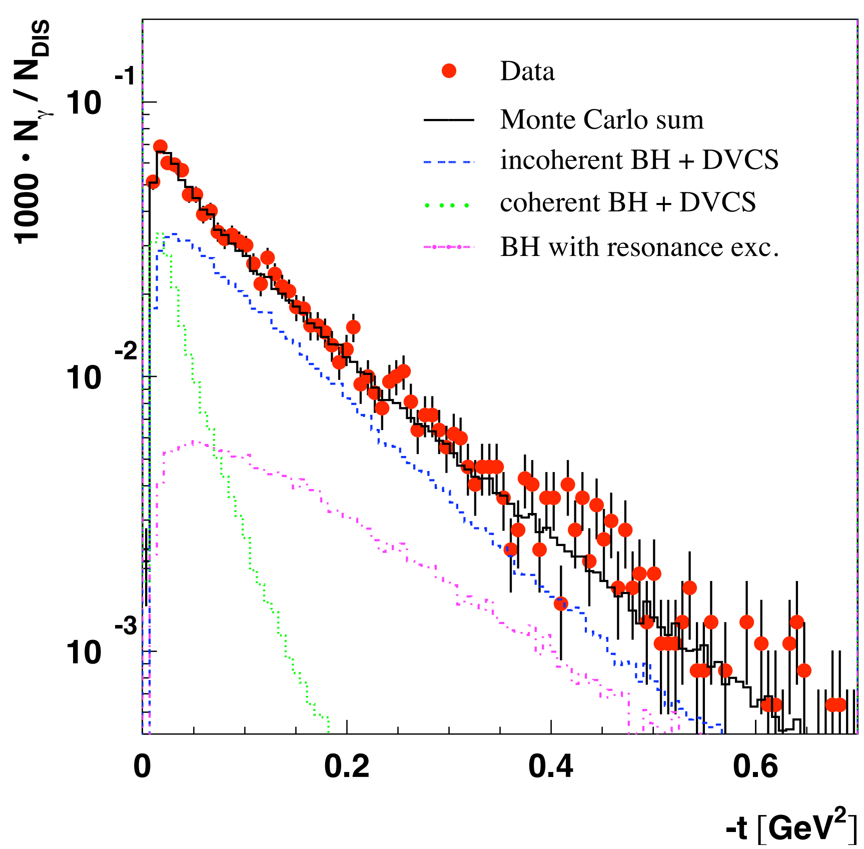

Proton:

- Elastic; $ep \longrightarrow ep\gamma$
- Associated; mainly $ep \longrightarrow e\Delta^+\gamma$
- Semi-Inclusive; mainly $ep \longrightarrow e\pi^0 X$

Deuteron:

- Elastic (Coherent); $ed \longrightarrow ed\gamma$
- Quasi-Elastic; $ed \longrightarrow epn\gamma$
- Associated; $eN \longrightarrow eN^*\gamma$
- Semi-Inclusive; $eN \longrightarrow e\pi^0 X$

$$-2.25\,GeV^2 < M_x^2 < 2.89\,GeV^2$$

Associated cannot be resolved $\longrightarrow$ defined as a part of signal.

Distribution in the expectation value of measured yield

$$\langle \mathcal{N}(e_\ell, P_l, S_t, \phi, \phi_S)\rangle \propto \sigma_{UU}(\phi)[1 + e_\ell \mathcal{A}_C + P_l \mathcal{A}_{LU}^{DVCS} + e_\ell P_l \mathcal{A}_{LU}^{I} + S_t \mathcal{A}_{UT}^{DVCS} + e_\ell S_t \mathcal{A}_{UT}^{I} + P_l S_t \mathcal{A}_{LT}^{BH+DVCS} + e_\ell P_l S_t \mathcal{A}_{LT}^{I}]$$

Combined e^+ and e^- data => allow to separate pure beam(target) polarization dependent parts of the cross section from that convoluted with beam charge .

e_ℓ - Beam Charge

P_l - Beam Polarization

S_t - Target Polarization

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Combined e⁺ and e⁻ data => allow to separate pure beam(target) polarization dependent parts of the cross section from that convoluted with beam charge .

Expansion of the asymmetries:

$$\mathcal{A} \approx \sum_{n=0}^{N} A^{\cos(n\phi)} \cos(n\phi) \quad or \quad \mathcal{A} \approx \sum_{n=1}^{N} A^{\sin(n\phi)} \sin(n\phi)$$

e_ℓ - Beam Charge

P_l - Beam Polarization

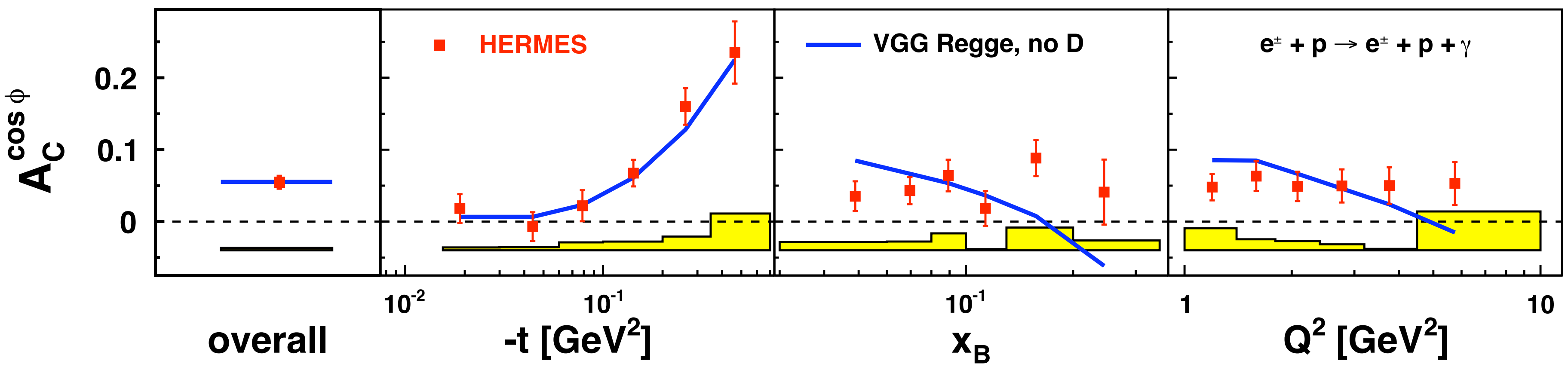
S_t - Target Polarization

Asymmetry amplitudes are extracted simultaneously with maximum likelihood method.

JHEP 11 (2009) 083

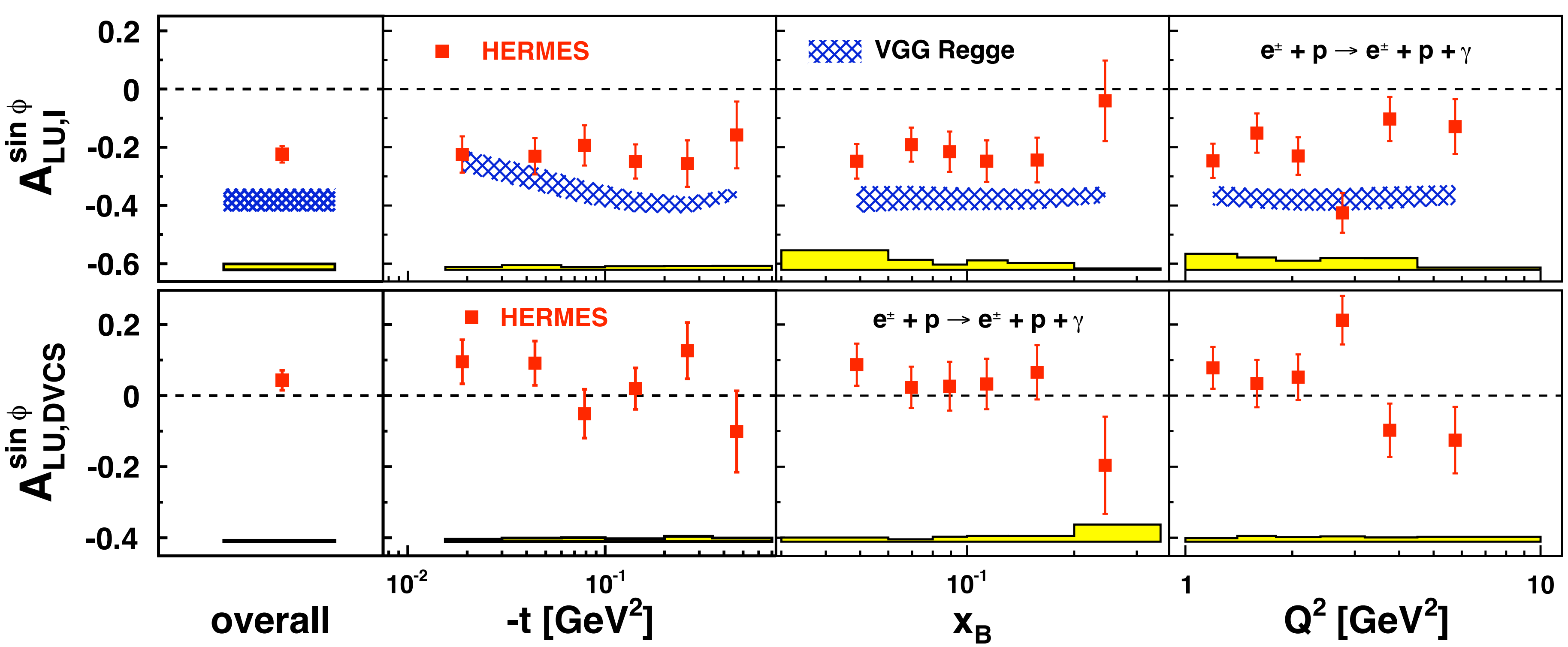
Beam-charge & Beam-helicity asymmetries (H)

$$\mathcal{A}_C(\phi) = \frac{(\sigma^{+\rightarrow} + \sigma^{+\leftarrow}) - (\sigma^{-\rightarrow} + \sigma^{+\leftarrow})}{(\sigma^{+\rightarrow} + \sigma^{+\leftarrow}) + (\sigma^{-\rightarrow} + \sigma^{+\leftarrow})}$$



$\propto \mathcal{R}e\left[F_1 \mathcal{H}\right]$

$$\mathcal{A}_{LU}^{I,DVCS}(\phi) = \frac{(\sigma^{+\rightarrow} - \sigma^{+\leftarrow}) \pm (\sigma^{-\rightarrow} - \sigma^{-\leftarrow})}{(\sigma^{+\rightarrow} + \sigma^{+\leftarrow}) + (\sigma^{-\rightarrow} + \sigma^{-\leftarrow})}$$



$\propto \mathcal{I}m\left[F_1 \mathcal{H}\right]$

$\propto \mathcal{I}m\left[\mathcal{H}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{H}}^*\right]$

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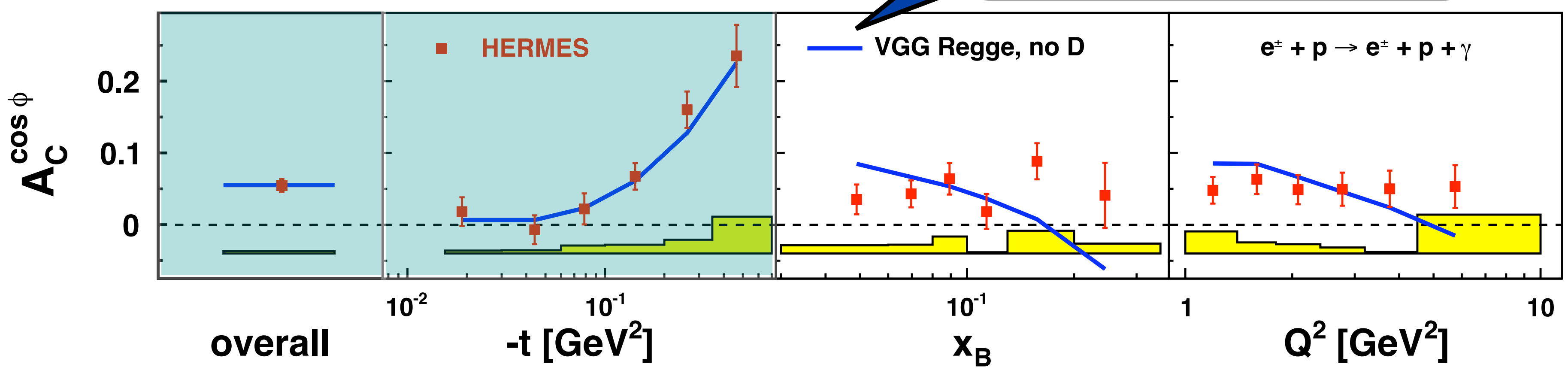
Model: VGG
Phys..Rev.D (1999) 094017
Prog. Nucl. Phys, 47 (2001) 401

Beam charge asymmetry
- strong -t dependence
- no x_B and Q^2 dependencies
- good agreement with model predictions



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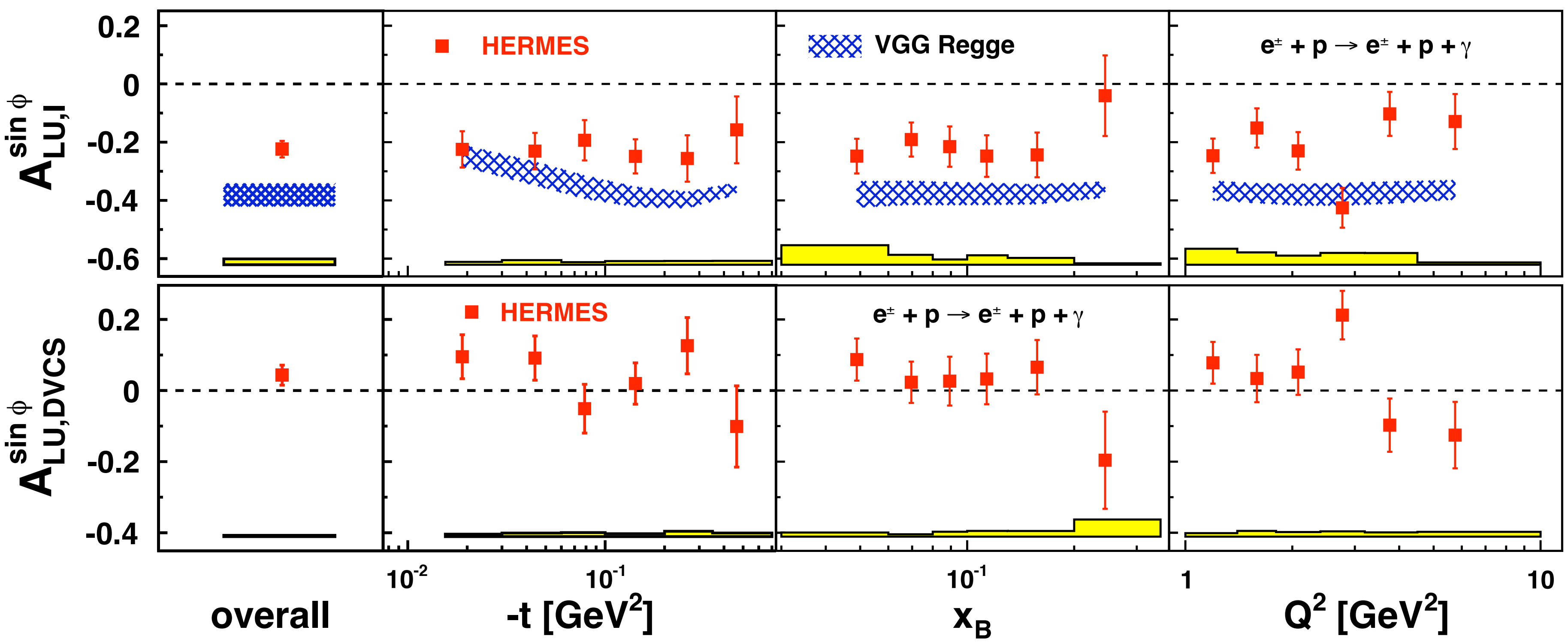

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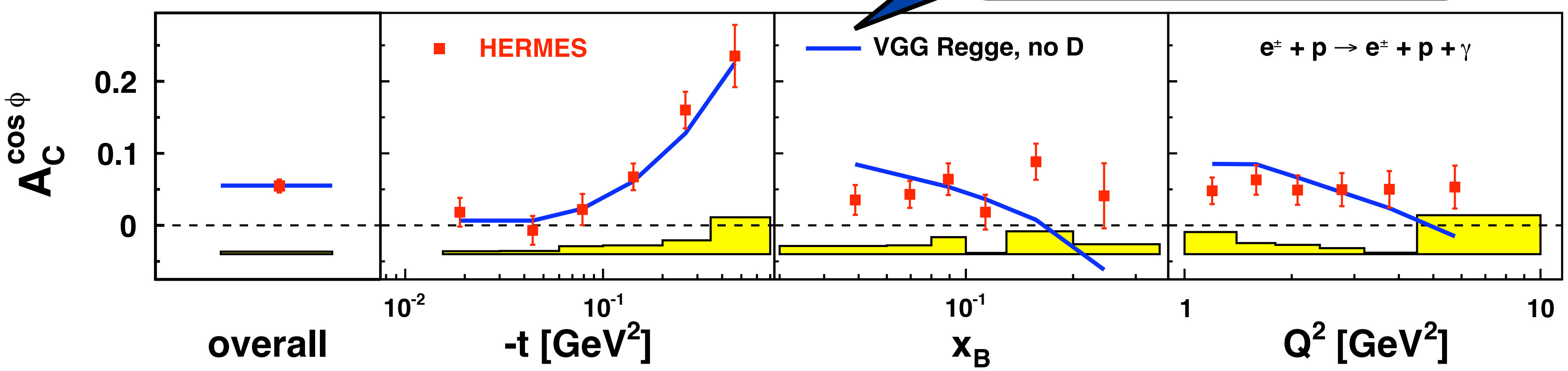

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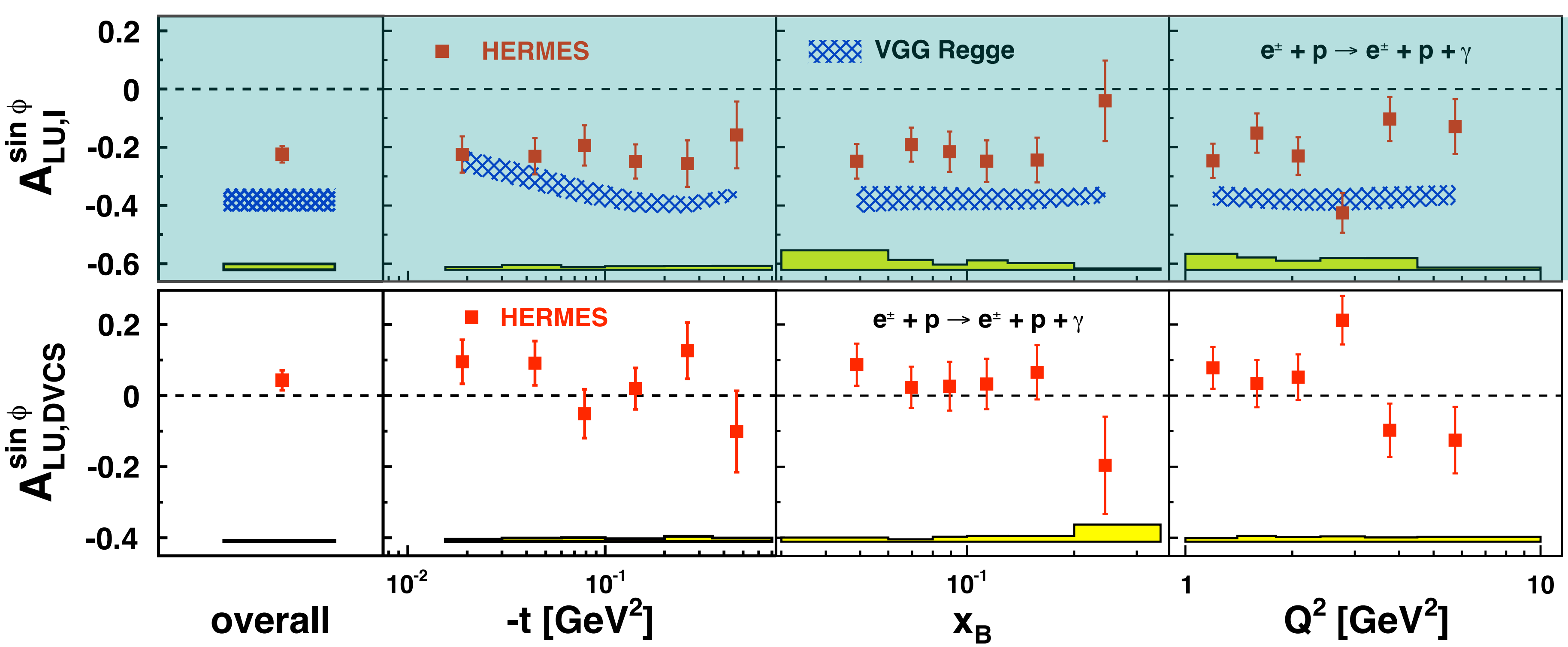

$\propto \mathcal{I}m\left[F_1\mathcal{H}\right]$

$\propto \mathcal{I}m\left[\mathcal{H}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{H}}^*\right]$

Charge-difference beam-helicity asymmetry
- significant negative value
- no kinematic dependencies
- model predictions overshot the data

JHEP 11 (2009) 083

Beam-charge & Beam-helicity asymmetries (H)

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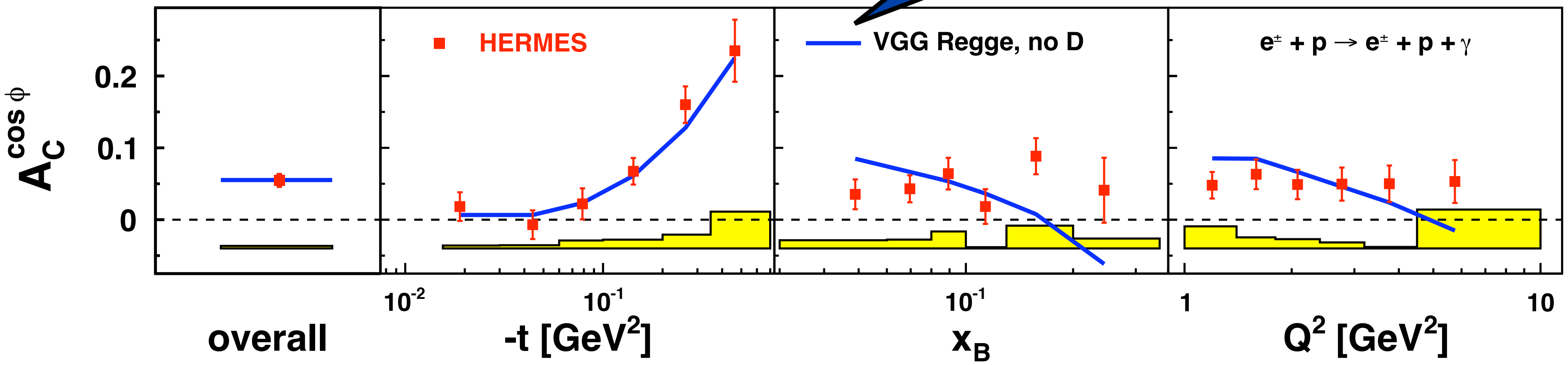

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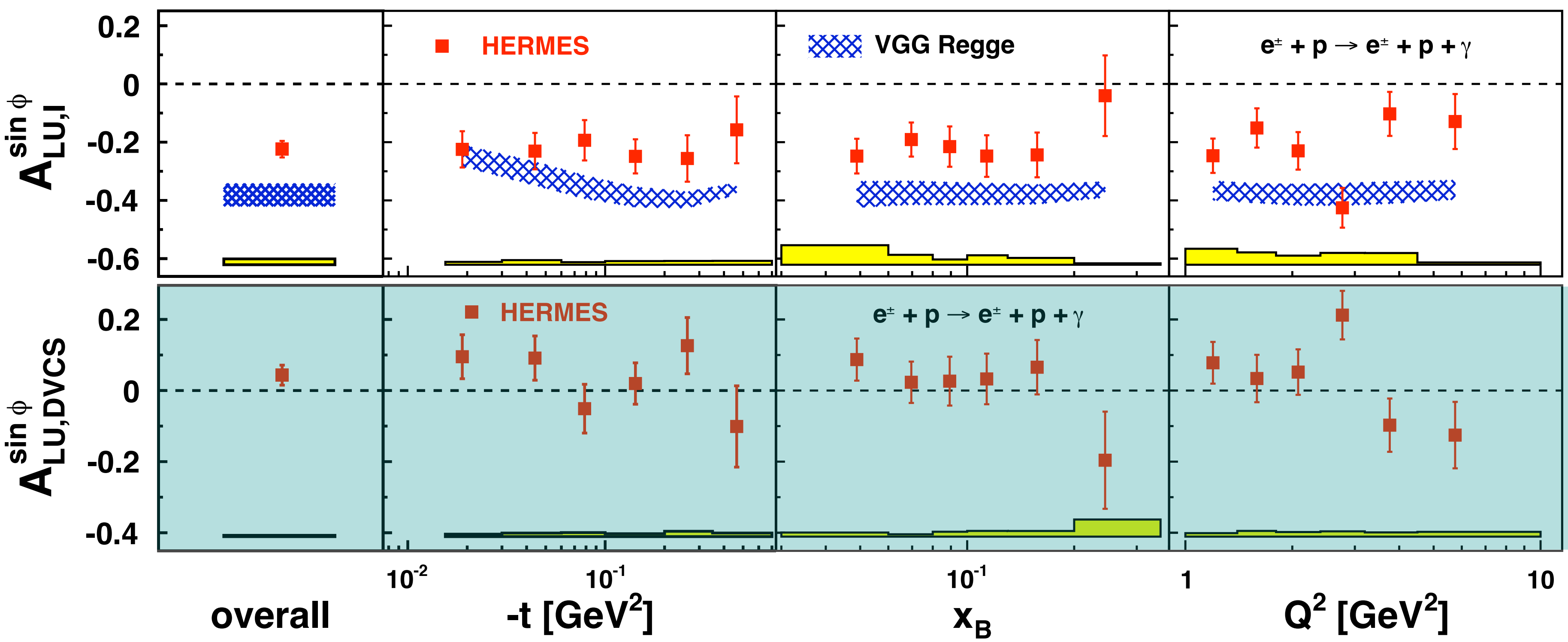


Charge-difference beam-helicity asymmetry
- significant negative value
- no kinematic dependencies
- model predictions overshot the data

$\propto \mathcal{I}m[F_1\mathcal{H}]$

Charge-averaged beam-helicity asymmetry
- consistent with zero

$\propto \mathcal{I}m[\mathcal{H}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{H}}^*]$

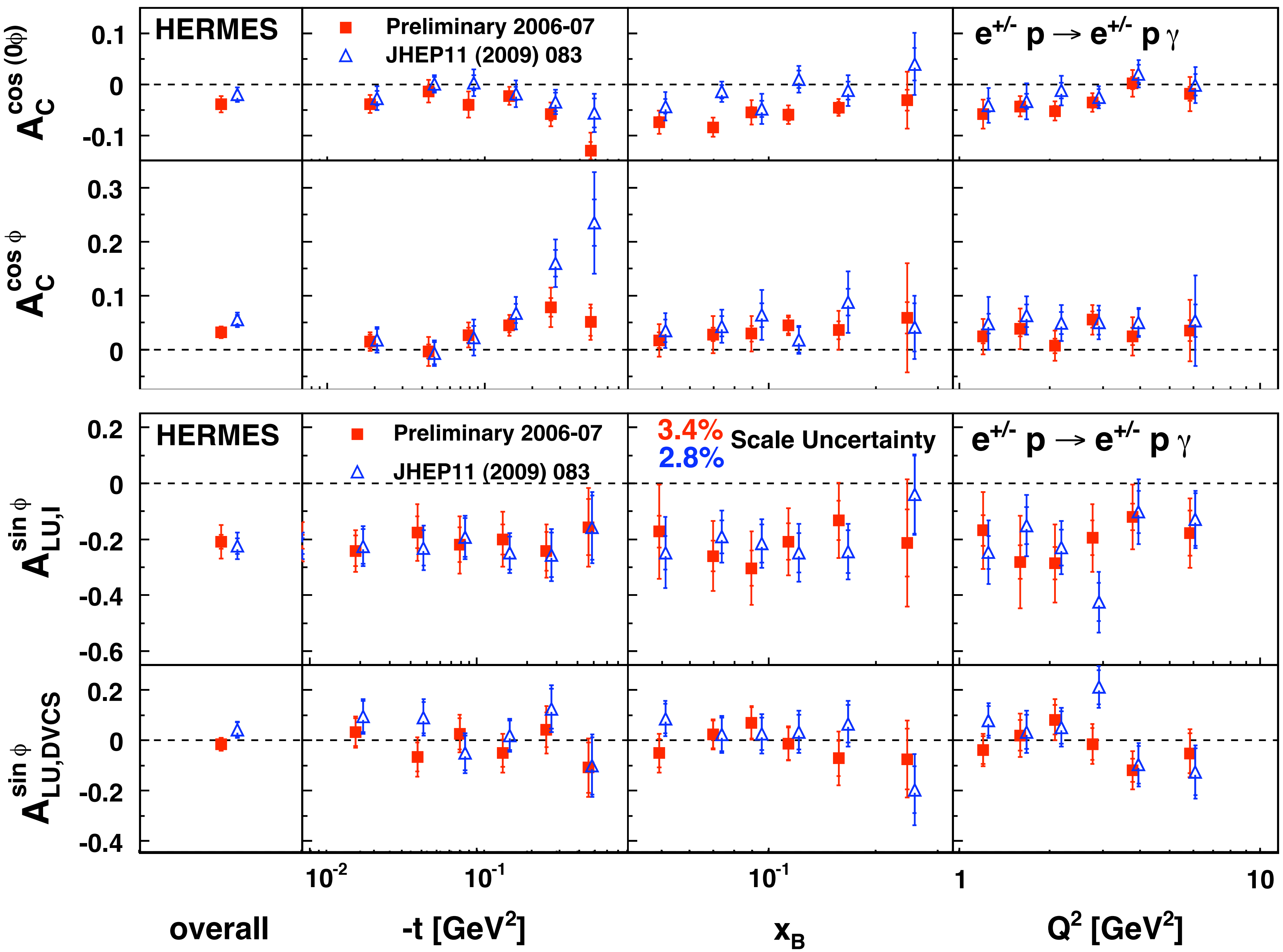
2 - dimensional (x_B, -t) binning also available

Beam-charge & Beam-helicity asymmetries (H)

1996-2005: JHEP 11 (2009) 083

2006-2007: Preliminary

- improved precision 1996/2005 + 2006/2007 data



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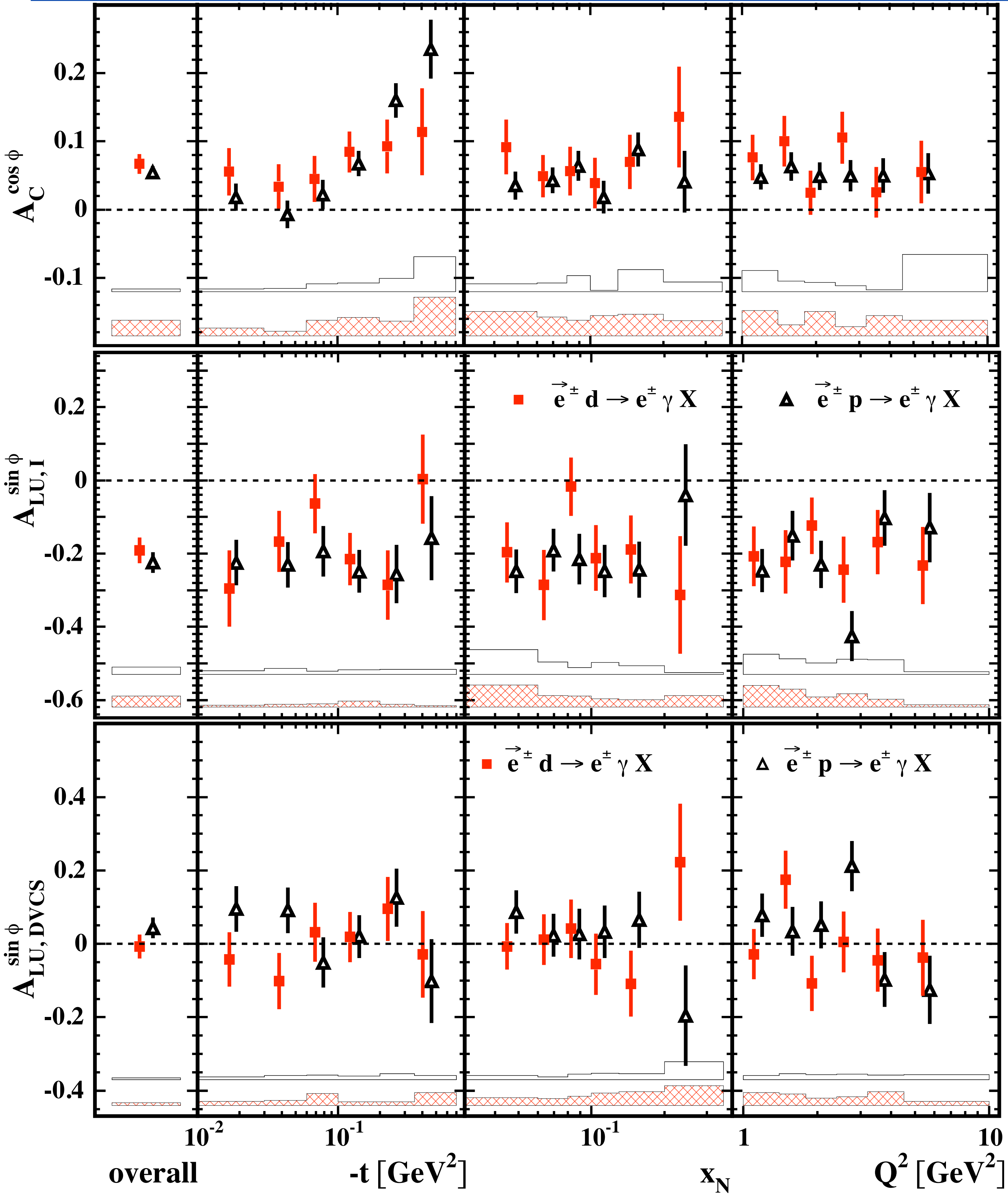
$$\mathcal{A}_{LU}^{I}(\phi) = \frac{(\sigma^{+\rightarrow} - \sigma^{+\leftarrow}) - (\sigma^{-\rightarrow} - \sigma^{-\leftarrow})}{(\sigma^{+\rightarrow} + \sigma^{+\leftarrow}) + (\sigma^{-\rightarrow} + \sigma^{-\leftarrow})}$$

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

Nucl. Phys. B829 (2010) 1 Beam-charge & Beam-helicity asymmetries (D,H)



$\propto \mathcal{R}e[F_1\mathcal{H}]$, $\mathcal{R}e[G_1\mathcal{H}_1]$

$\propto \mathcal{I}m[F_1\mathcal{H}]$, $\mathcal{I}m[G_1\mathcal{H}_1]$

$\propto \mathcal{I}m[\mathcal{H}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{H}}^*]$, $\mathcal{I}m[\mathcal{H}_1\mathcal{H}_1^* + \ldots]$

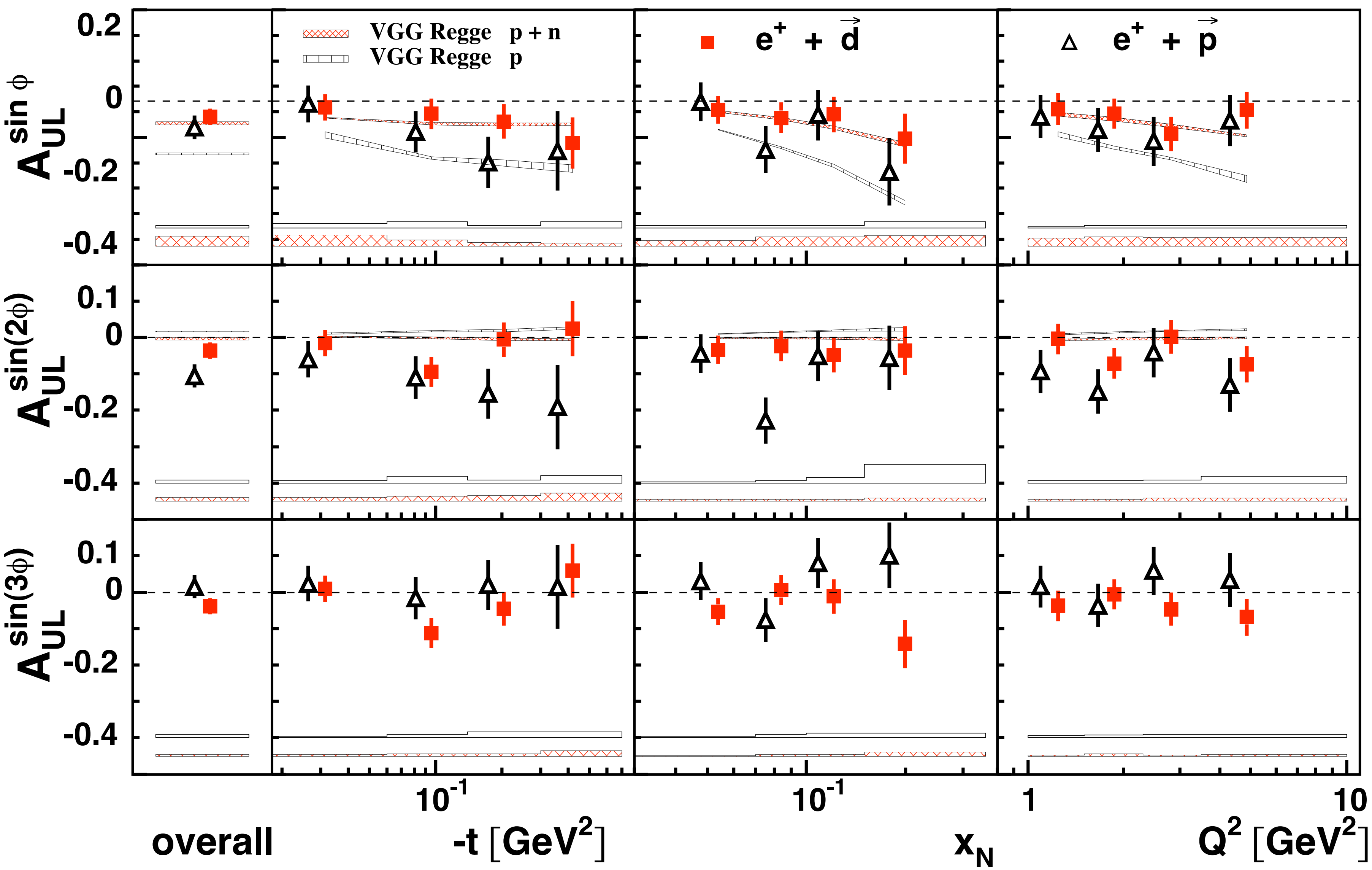
Beam-charge & Beam-Helicity asymmetries

- Proton and Deuteron results are compatible at low and intermediate -t regions.
- No clear signatures of 40% contribution from coherent process at low -t.
- no significant x_B and Q^2 dependencies.
- Difference at large -t (for beam-charge asymmetry) might be caused by additional contributions from Neutron and its resonances.

Longitudinal Target-Spin Asymmetry (D,H)

Data collected with positron beam

$$\mathcal{A}_{UL}(\phi) = \frac{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\leftarrow\Rightarrow}) - (\sigma^{\rightarrow\Leftarrow} + \sigma^{\leftarrow\Leftarrow})}{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\leftarrow\Rightarrow}) + (\sigma^{\rightarrow\Leftarrow} + \sigma^{\leftarrow\Leftarrow})}$$



$\propto \begin{array}{l} \mathcal{I}m\left[F_1\widetilde{\mathcal{H}}\right] \\ \mathcal{I}m\left[G_1\widetilde{\mathcal{H}}_1\right] \end{array}$

$\propto$ Higher twist

Model predictions for deuteron: Sum of incoherent processes on the proton and neutron

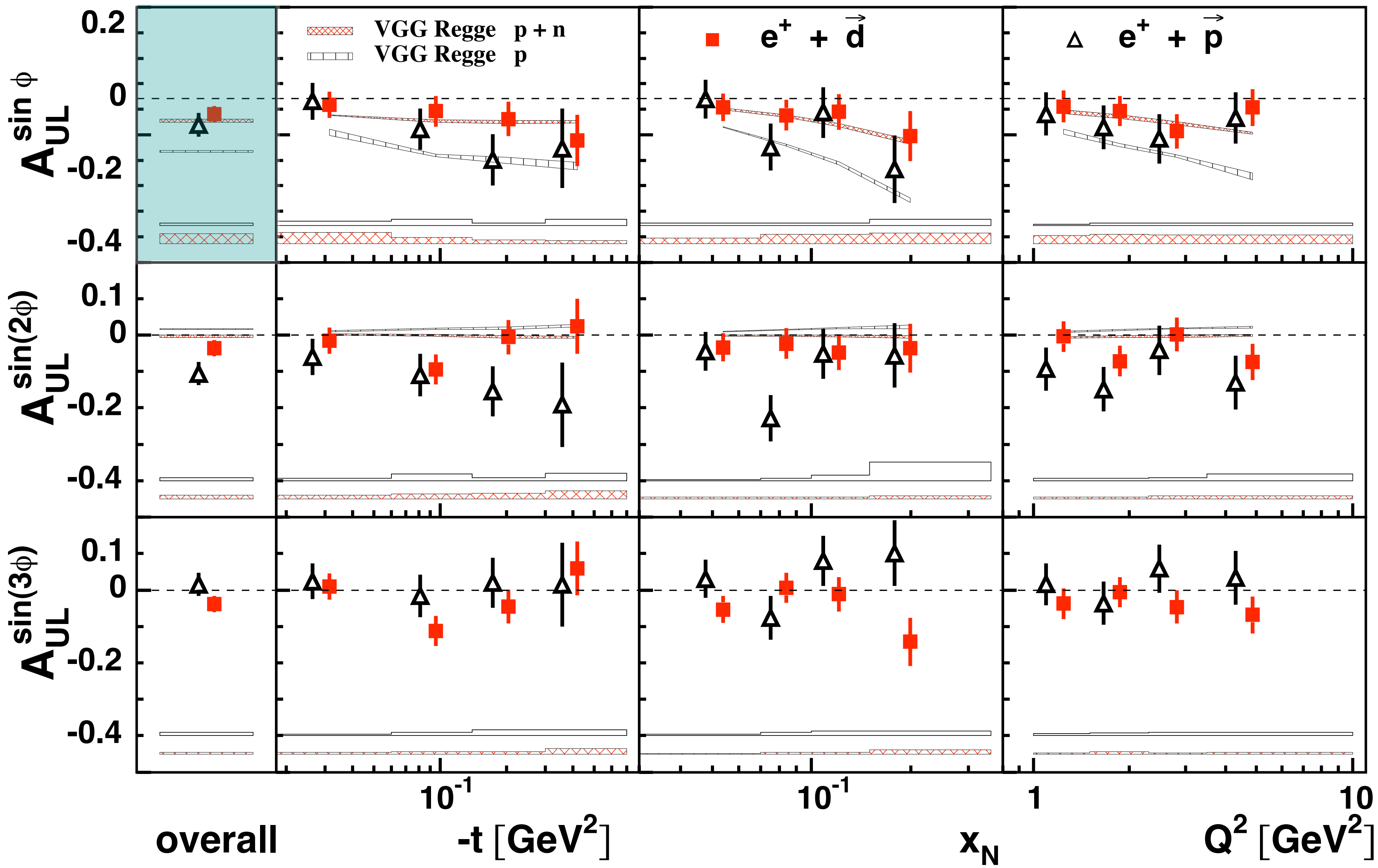
Longitudinal Target-Spin Asymmetry (D,H)

Data collected with positron beam

$$\mathcal{A}_{UL}(\phi) = \frac{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\leftarrow\Rightarrow}) - (\sigma^{\rightarrow\Leftarrow} + \sigma^{\leftarrow\Leftarrow})}{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\leftarrow\Rightarrow}) + (\sigma^{\rightarrow\Leftarrow} + \sigma^{\leftarrow\Leftarrow})}$$

Longitudinal Target-Spin asymmetry

- Non-zero negative value of leading sin(ϕ) amplitude on both targets.



$\propto \mathcal{I}m[F_1\widetilde{\mathcal{H}}]$

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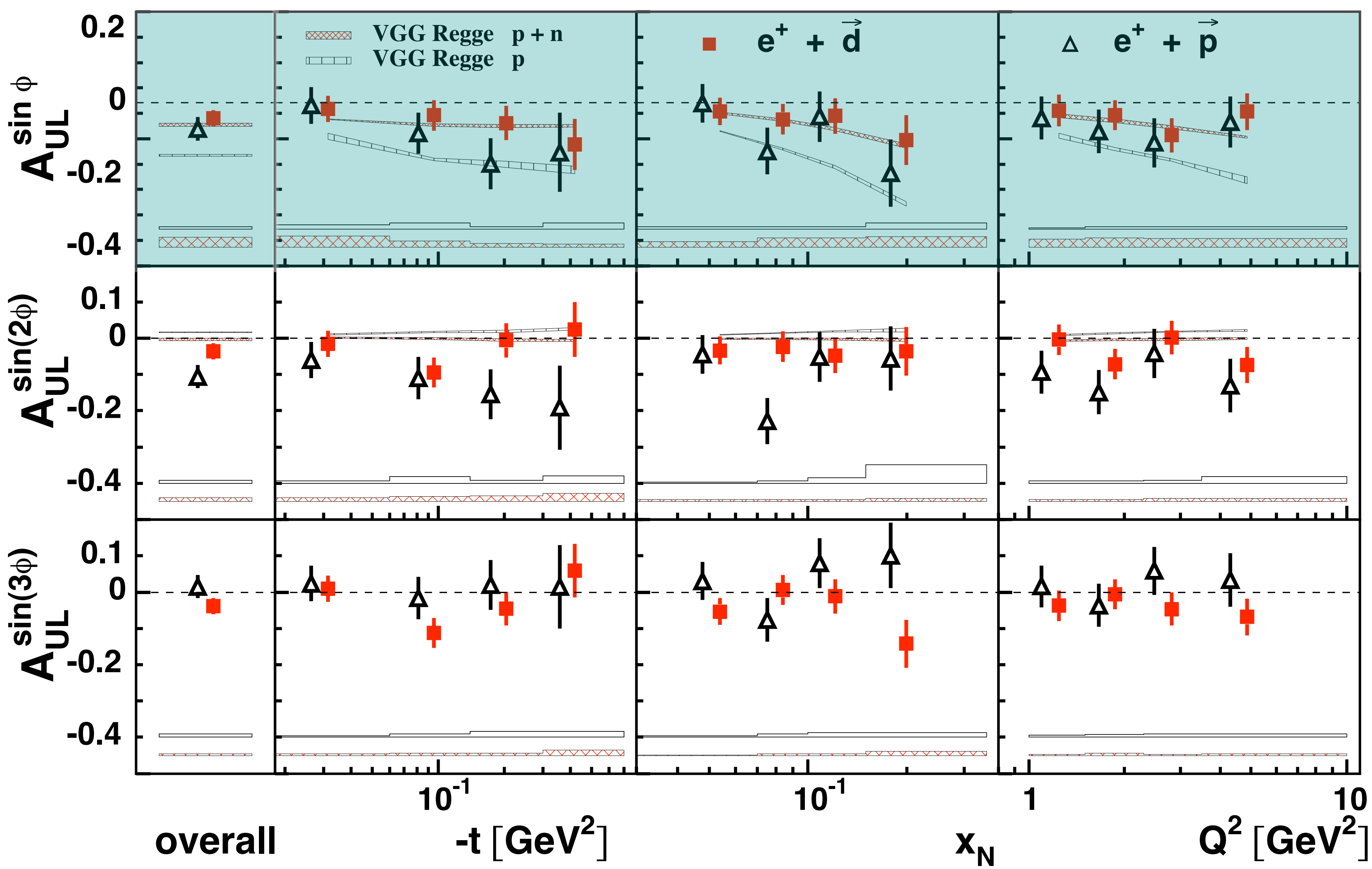

$\propto \begin{array}{l}\mathcal{I}m[F_1\widetilde{\mathcal{H}}] \\ \mathcal{I}m[G_1\widetilde{\mathcal{H}}_1]\end{array}$

- Results on deuteron neither support nor disfavor large contribution from neutron, predicted by the model.
- Results on proton and deuteron targets are compatible.

$\propto$ Higher twist

Model predictions for deuteron: Sum of incoherent processes on the proton and neutron

Longitudinal Target-Spin Asymmetry (D,H)

Data collected with positron beam

$$\mathcal{A}_{UL}(\phi) = \frac{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\leftarrow\Rightarrow}) - (\sigma^{\rightarrow\Leftarrow} + \sigma^{\leftarrow\Leftarrow})}{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\leftarrow\Rightarrow}) + (\sigma^{\rightarrow\Leftarrow} + \sigma^{\leftarrow\Leftarrow})}$$

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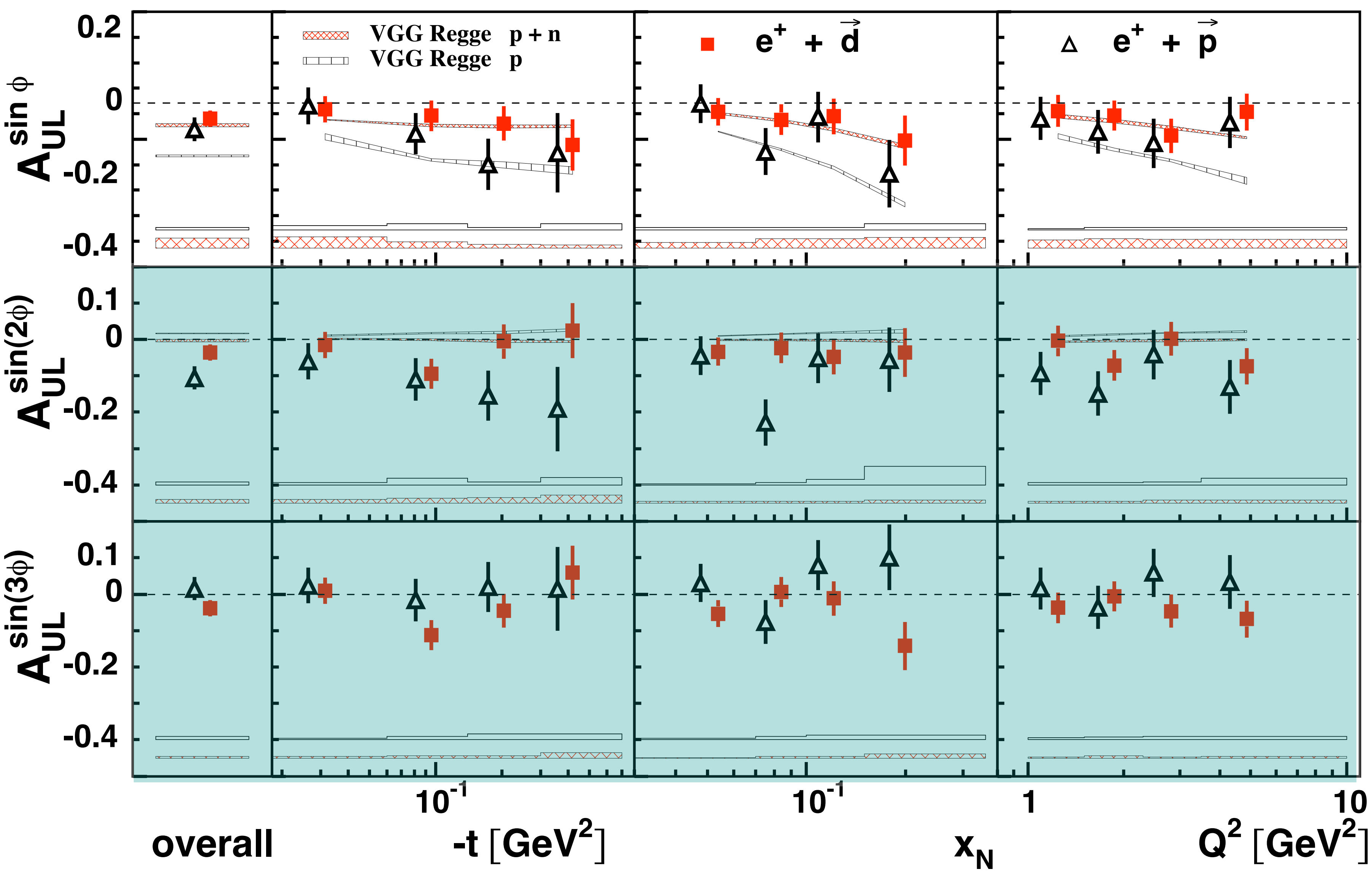

$\propto \mathcal{I}m[F_1\widetilde{\mathcal{H}}]$

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- Results on deuteron neither support nor disfavor large contribution from neutron, predicted by the model.
- Results on proton and deuteron targets are compatible.

$\propto$ Higher twist

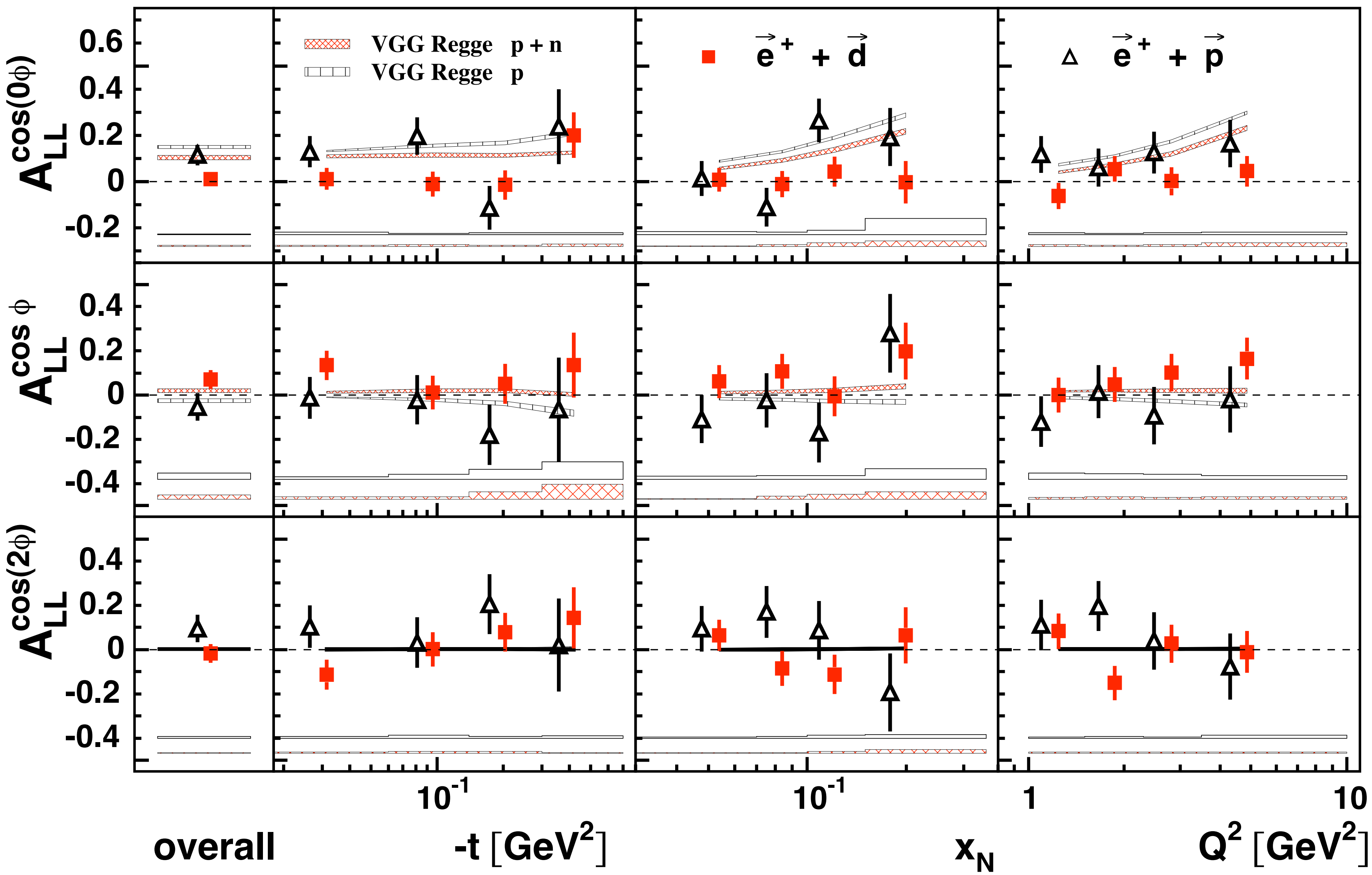
- Amplitudes related to the Higher twist contributions are consistent with zero.

Model predictions for deuteron: Sum of incoherent processes on the proton and neutron

Longitudinal Double-Spin Asymmetry (D,H)

Data collected with positron beam

$$\mathcal{A}_{LL}(\phi) = \frac{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\leftarrow\Leftarrow}) - (\sigma^{\rightarrow\Leftarrow} + \sigma^{\leftarrow\Rightarrow})}{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\leftarrow\Leftarrow}) + (\sigma^{\rightarrow\Leftarrow} + \sigma^{\leftarrow\Rightarrow})}$$



$\propto -A_{LL}^{\cos(\phi)}$

$\propto \mathcal{R}e\left[F_1\widetilde{\mathcal{H}}\right]$ $\mathcal{R}e\left[G_1\widetilde{\mathcal{H}}_1\right]$

$\propto$ Higher twist

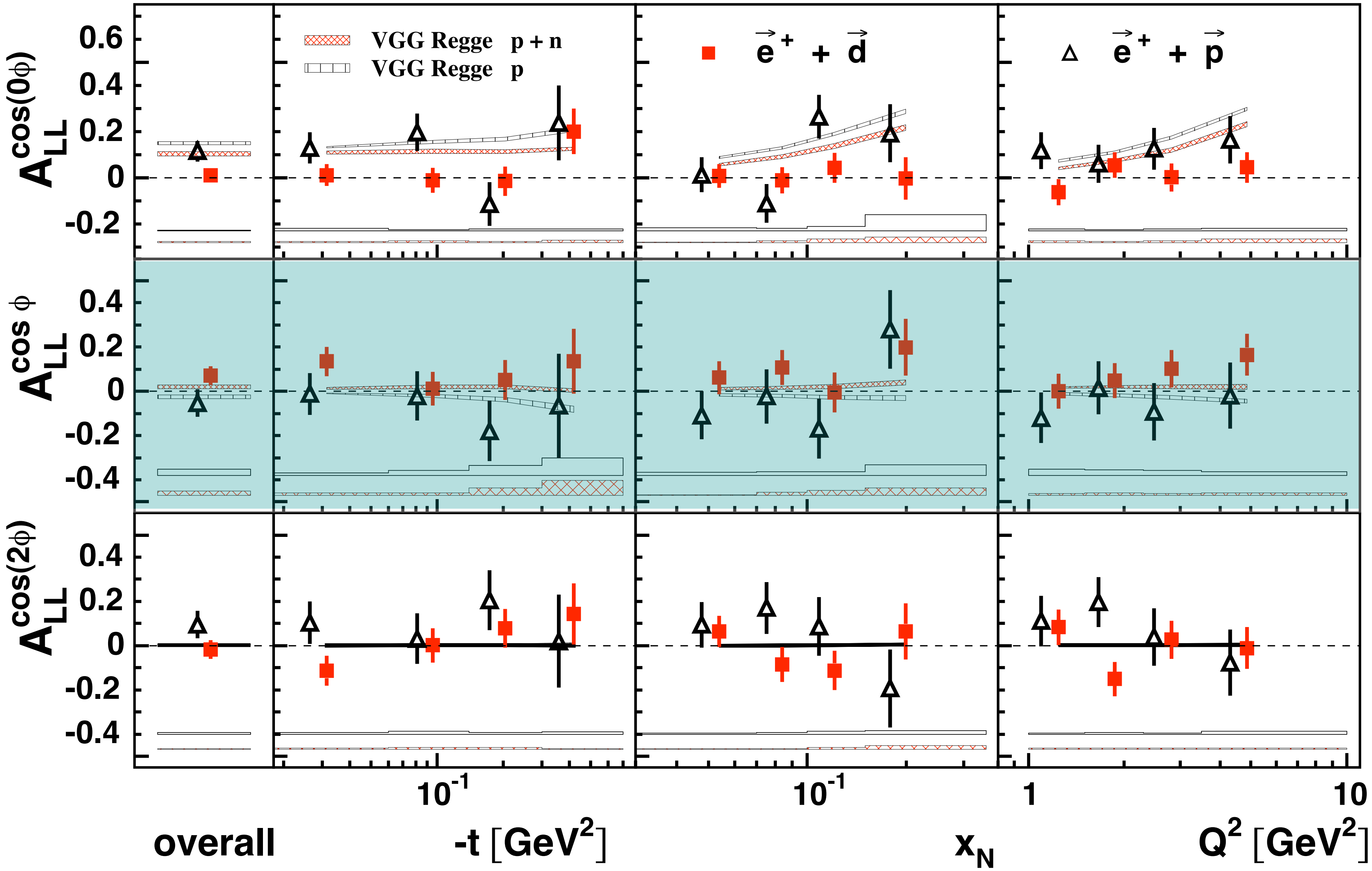
Asymmetry amplitudes are attributed not only to squared DVCS or Interference term, but also to squared Bethe-Heitler term.

Longitudinal Double-Spin Asymmetry (D,H)

Data collected with positron beam

$$\mathcal{A}_{LL}(\phi) = \frac{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\leftarrow\Leftarrow}) - (\sigma^{\rightarrow\Leftarrow} + \sigma^{\leftarrow\Rightarrow})}{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\leftarrow\Leftarrow}) + (\sigma^{\rightarrow\Leftarrow} + \sigma^{\leftarrow\Rightarrow})}$$

Longitudinal Double-Spin asymmetry
- Leading cos(ϕ) amplitude is compatible with zero for both targets.



$\propto -A_{LL}^{\cos(\phi)}$

$\propto \mathcal{R}e[F_1\widetilde{\mathcal{H}}]$ $\mathcal{R}e[G_1\widetilde{\mathcal{H}}_1]$

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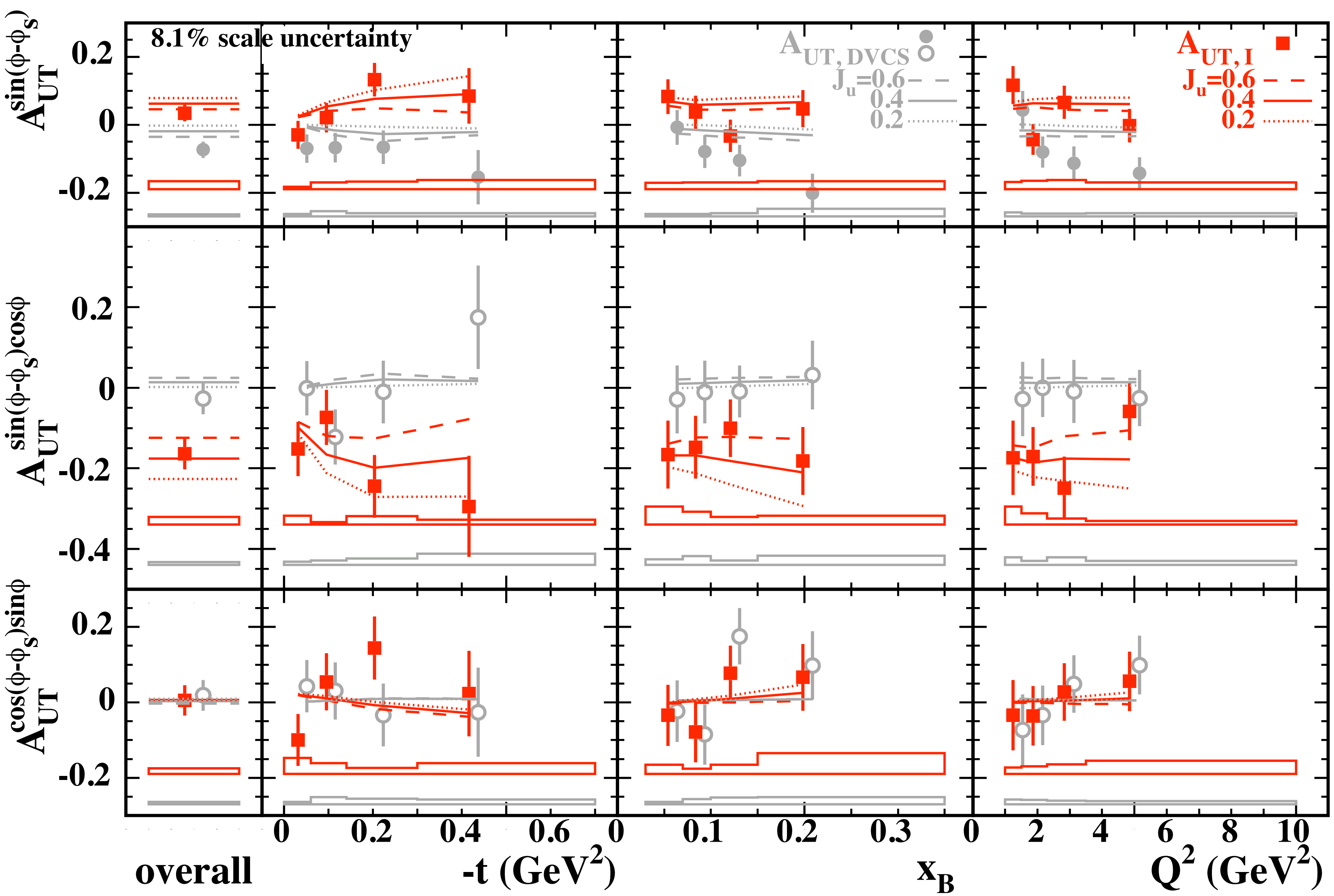
Asymmetry amplitudes are attributed not only to squared DVCS or Interference term, but also to squared Bethe-Heitler term.

Transverse Target-Spin Asymmetries (H)

$$\mathcal{A}_{UT}^{I,DVCS}(\phi,\phi_S) = \frac{(\sigma^{+\Uparrow} - \sigma^{+\Downarrow}) \pm (\sigma^{-\Uparrow} - \sigma^{-\Downarrow})}{(\sigma^{+\Uparrow} + \sigma^{+\Downarrow}) + (\sigma^{-\Uparrow} + \sigma^{-\Downarrow})}$$



$\propto A_{UT}^{\sin(\phi-\phi_S)\cos(\phi)}$

$\propto \mathcal{I}m\left[F_2\mathcal{H} - F_1\mathcal{E}\right]$
$\mathcal{I}m\left[\mathcal{H}\mathcal{E}^* - \mathcal{E}\mathcal{H}^* - \xi(\widetilde{\mathcal{H}}\widetilde{\mathcal{E}}^* - \widetilde{\mathcal{E}}\widetilde{\mathcal{H}}^*)\right]$

$\propto \mathcal{I}m\left[F_2\tilde{\mathcal{H}} - (F_1 + \xi F_2)\tilde{\mathcal{E}}\right]$
$\mathcal{I}m\left[-\widetilde{\mathcal{H}}\mathcal{E}^* - \widetilde{\mathcal{H}}^*\mathcal{E} + \xi(\mathcal{H}\widetilde{\mathcal{E}}^* + \widetilde{\mathcal{E}}\mathcal{H}^*)\right]$

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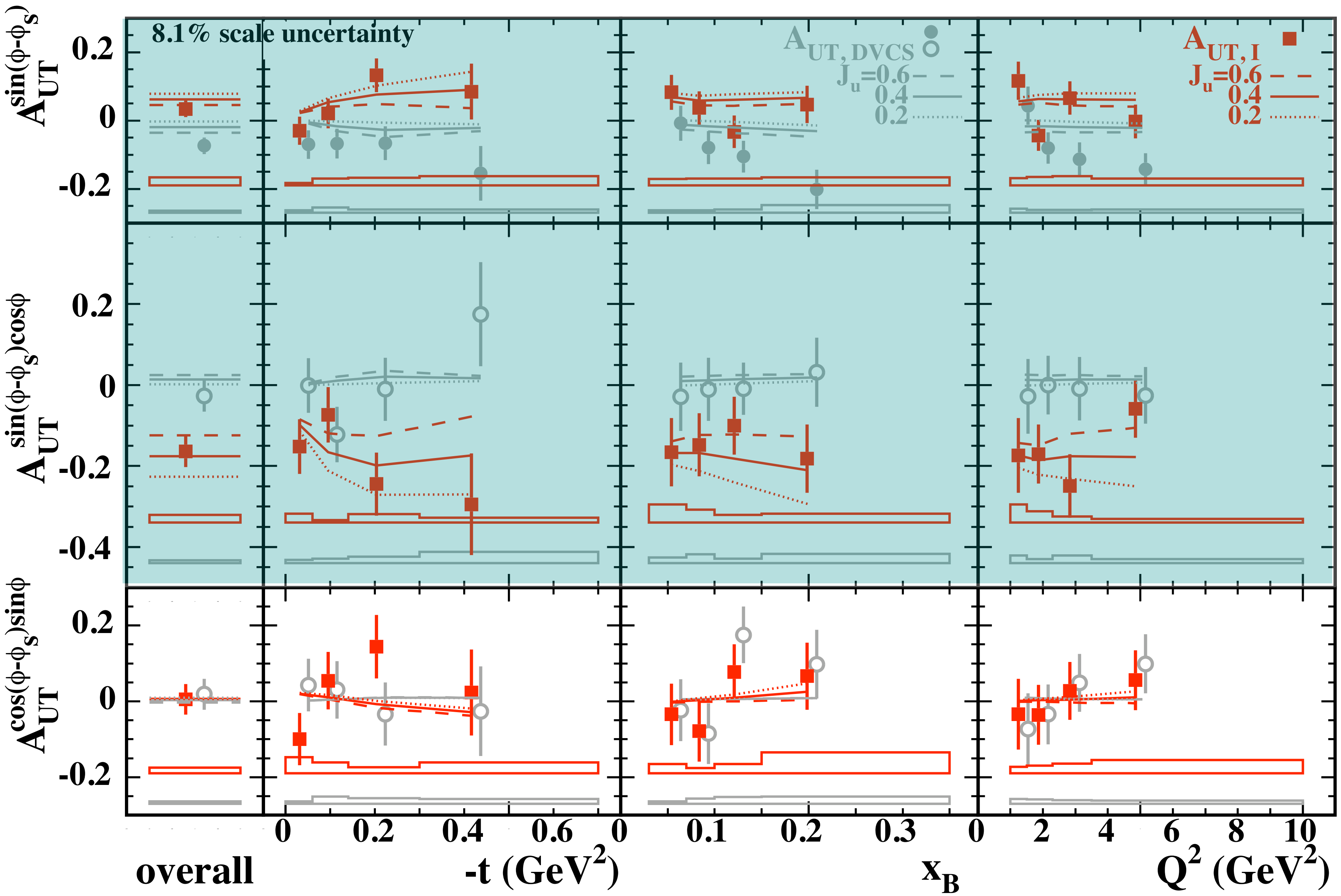
Transverse Target-Spin Asymmetries (H)

$$\mathcal{A}_{UT}^{I,DVCS}(\phi,\phi_S) = \frac{(\sigma^{+\Uparrow} - \sigma^{+\Downarrow}) \pm (\sigma^{-\Uparrow} - \sigma^{-\Downarrow})}{(\sigma^{+\Uparrow} + \sigma^{+\Downarrow}) + (\sigma^{-\Uparrow} + \sigma^{-\Downarrow})}$$

Charge-difference Transverse Target-Spin asymmetry

- Non-zero leading cos(nϕ) amplitudes.



$$\propto A_{UT}^{\sin(\phi-\phi_S)\cos(\phi)}$$

$$\propto \begin{array}{l} \mathcal{I}m\left[F_2\mathcal{H} - F_1\mathcal{E}\right] \\ \mathcal{I}m\left[\mathcal{H}\mathcal{E}^* - \mathcal{E}\mathcal{H}^* - \xi(\widetilde{\mathcal{H}}\widetilde{\mathcal{E}}^* - \widetilde{\mathcal{E}}\widetilde{\mathcal{H}}^*)\right] \end{array}$$

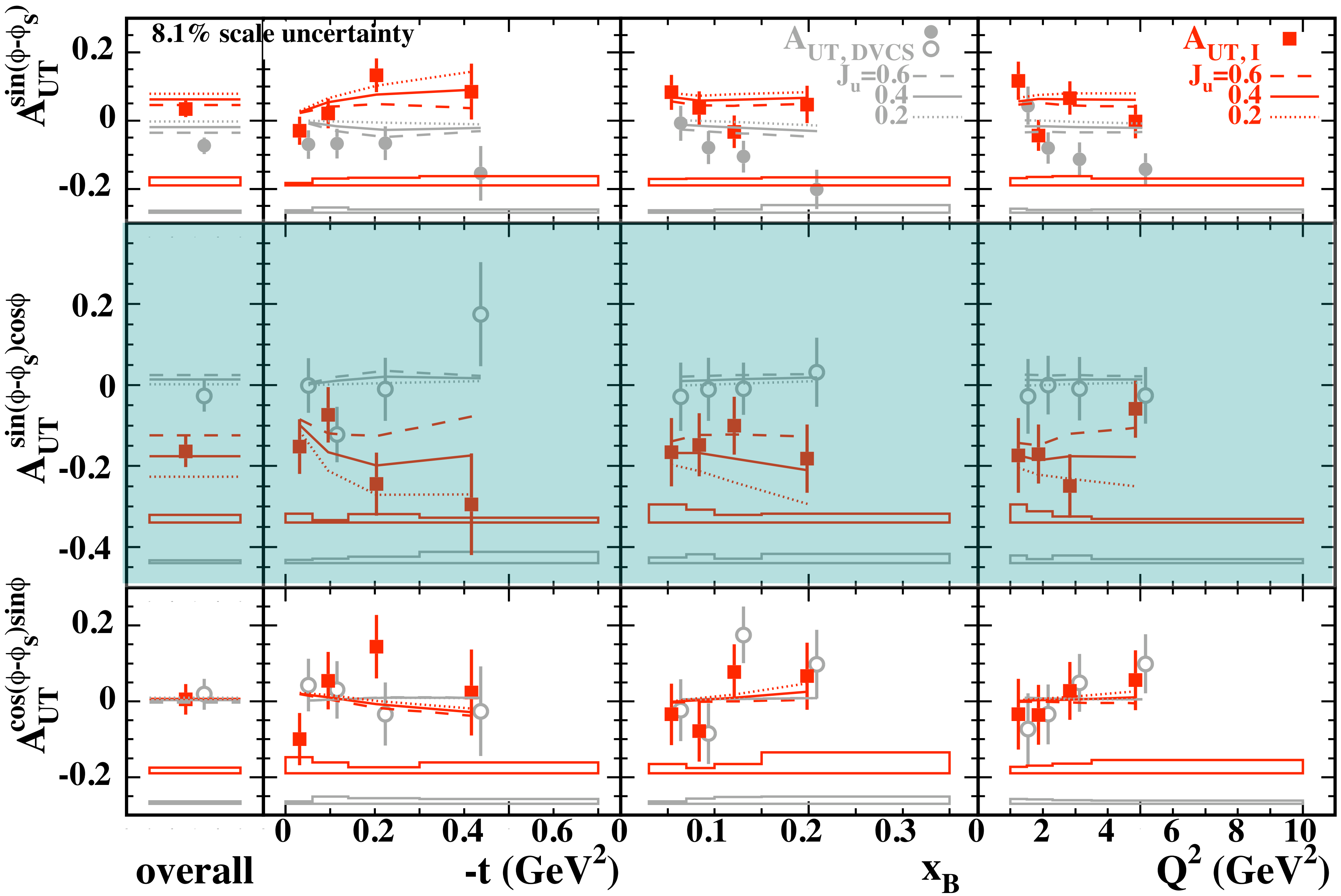
$$\propto \begin{array}{l} \mathcal{I}m\left[F_2\widetilde{\mathcal{H}} - (F_1 + \xi F_2)\widetilde{\mathcal{E}}\right] \\ \mathcal{I}m\left[-\widetilde{\mathcal{H}}\mathcal{E}^* - \widetilde{\mathcal{H}}^*\mathcal{E} + \xi(\mathcal{H}\widetilde{\mathcal{E}}^* + \widetilde{\mathcal{E}}\mathcal{H}^*)\right] \end{array}$$

Transverse Target-Spin Asymmetries (H)

$$\mathcal{A}_{UT}^{I,DVCS}(\phi,\phi_S) = \frac{(\sigma^{+\Uparrow} - \sigma^{+\Downarrow}) \pm (\sigma^{-\Uparrow} - \sigma^{-\Downarrow})}{(\sigma^{+\Uparrow} + \sigma^{+\Downarrow}) + (\sigma^{-\Uparrow} + \sigma^{-\Downarrow})}$$

Charge-difference Transverse Target-Spin asymmetry

- Non-zero leading cos(nϕ) amplitudes.



$\propto A_{UT}^{\sin(\phi-\phi_S)\cos(\phi)}$

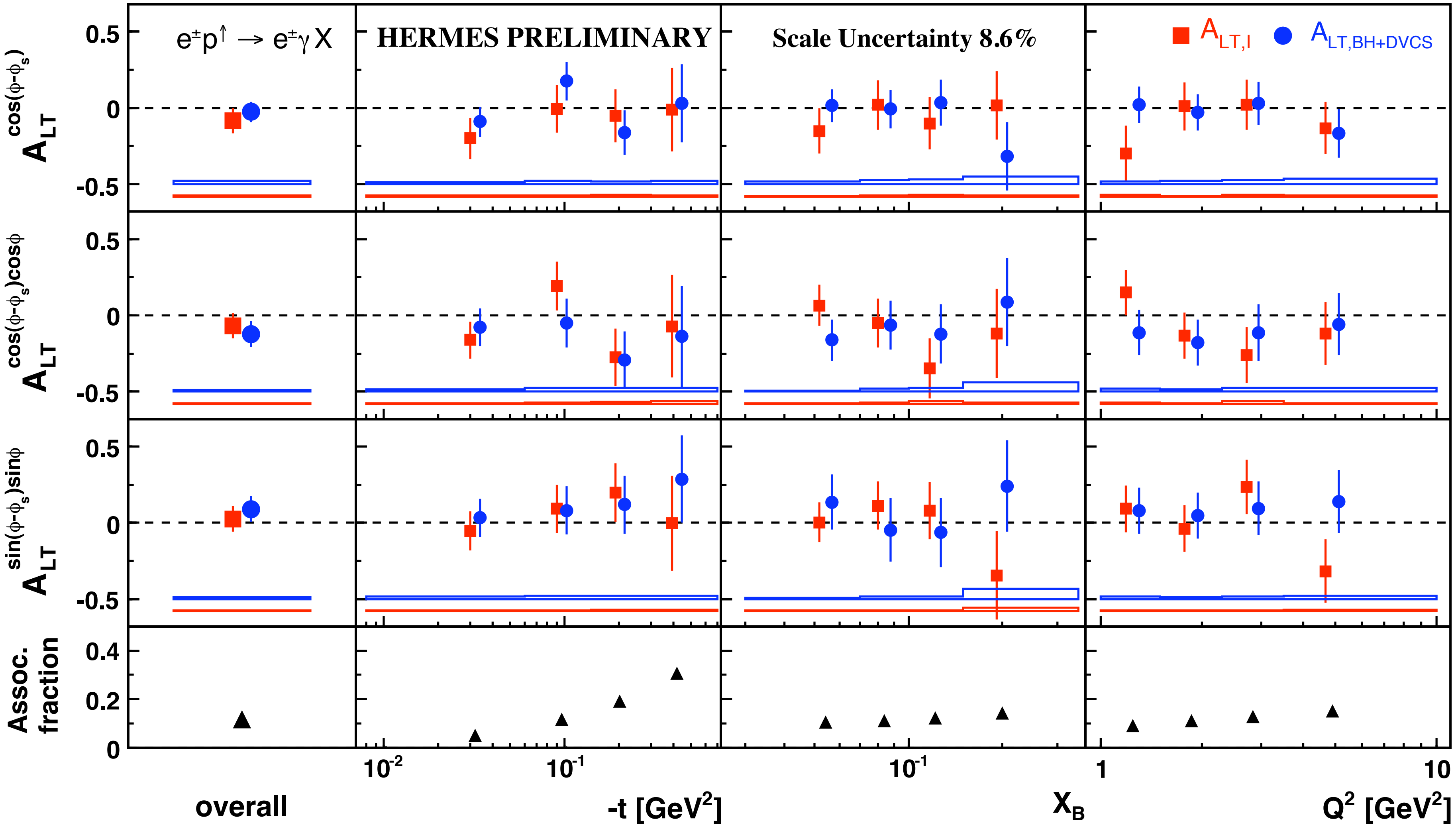
$\propto \mathcal{I}m\left[F_2\mathcal{H} - F_1\mathcal{E}\right]$
$\mathcal{I}m\left[\mathcal{H}\mathcal{E}^* - \mathcal{E}\mathcal{H}^* - \xi(\widetilde{\mathcal{H}}\widetilde{\mathcal{E}}^* - \widetilde{\mathcal{E}}\widetilde{\mathcal{H}}^*)\right]$

$\propto \mathcal{I}m\left[F_2\tilde{\mathcal{H}} - (F_1 + \xi F_2)\tilde{\mathcal{E}}\right]$
$\mathcal{I}m\left[-\widetilde{\mathcal{H}}\mathcal{E}^* - \widetilde{\mathcal{H}}^*\mathcal{E} + \xi(\mathcal{H}\widetilde{\mathcal{E}}^* + \widetilde{\mathcal{E}}\mathcal{H}^*)\right]$

Leading cos(ϕ) amplitude of charge-difference target-spin asymmetry A^I_{UT} is sensitive to CFF $\mathcal{E}$, therefore J_u .

Transverse Target-Spin Asymmetries (H)

$$\mathcal{A}_{LT}^{I,BH+DVCS}(\phi,\phi_S) = \frac{(\overrightarrow{\sigma}^{+\Uparrow} + \overleftarrow{\sigma}^{+\Downarrow} - \overrightarrow{\sigma}^{+\Downarrow} - \overleftarrow{\sigma}^{+\Uparrow}) \pm (\overrightarrow{\sigma}^{-\Uparrow} + \overleftarrow{\sigma}^{-\Downarrow} - \overrightarrow{\sigma}^{-\Downarrow} - \overleftarrow{\sigma}^{-\Uparrow})}{(\overrightarrow{\sigma}^{+\Uparrow} + \overleftarrow{\sigma}^{+\Downarrow} + \overrightarrow{\sigma}^{+\Downarrow} + \overleftarrow{\sigma}^{+\Uparrow}) + (\overrightarrow{\sigma}^{+\Uparrow} + \overleftarrow{\sigma}^{+\Downarrow} + \overrightarrow{\sigma}^{+\Downarrow} + \overleftarrow{\sigma}^{+\Uparrow})}$$

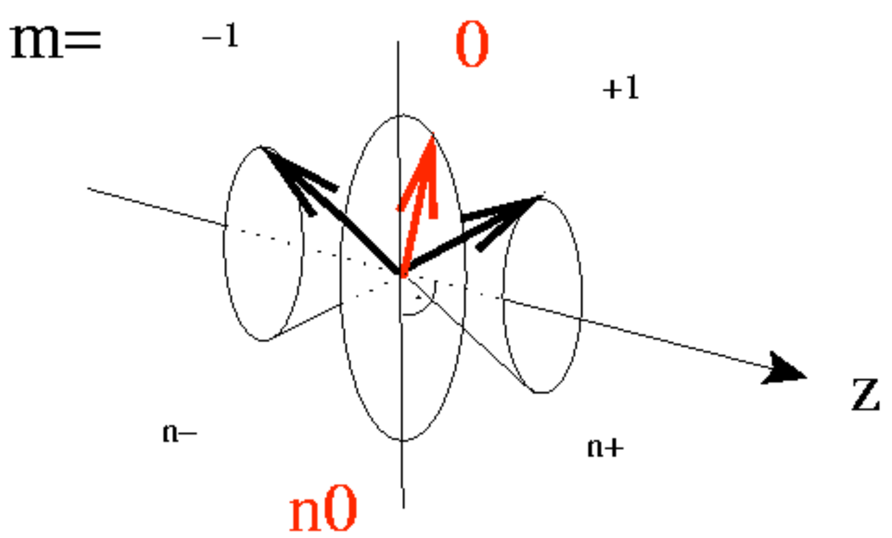


$$\propto A_{LT}^{\cos(\phi-\phi_S)\cos(\phi)}$$

$$\propto \frac{\mathcal{R}e\left[F_2\widetilde{\mathcal{H}} - (F_1+\xi F_2)\widetilde{\mathcal{E}}\right]}{\mathcal{R}e\left[\mathcal{H}\mathcal{E}^* - \mathcal{E}\mathcal{H}^* - \xi(\widetilde{\mathcal{H}}\widetilde{\mathcal{E}}^* - \widetilde{\mathcal{E}}\widetilde{\mathcal{H}}^*)\right]}$$

$$\propto \frac{\mathcal{R}e\left[F_2\mathcal{H} - F_1\mathcal{E}\right]}{\mathcal{R}e\left[-\widetilde{\mathcal{H}}\mathcal{E}^* - \widetilde{\mathcal{H}}^*\mathcal{E} + \xi(\mathcal{H}\widetilde{\mathcal{E}}^* + \widetilde{\mathcal{E}}\mathcal{H}^*)\right]}$$

Leading amplitudes of charge-difference and charge-averaged transverse double-spin asymmetries are compatible with zero over all kinematic regions.
Sensitivity to J_u is suppressed by kinematic pre-factor.



Beam-Spin and Beam-Charge Asymmetries
on longitudinally polarized Deuterium
with vanishing vector polarization
(non-vanishing tensor polarization)

Coherent contribution :
small -t $\simeq$ 40%

$$\mathcal{A}_{L\stackrel{\Leftarrow}{\Rightarrow}}(\phi) = \frac{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\rightarrow\Leftarrow}) - (\sigma^{\leftarrow\Leftarrow} + (\sigma^{\leftarrow\Rightarrow})}{(\sigma^{\rightarrow\Rightarrow} + \sigma^{\rightarrow\Leftarrow}) + (\sigma^{\leftarrow\Leftarrow} + (\sigma^{\leftarrow\Rightarrow})}$$

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

$$\left.\right\} \begin{array}{l} \mathcal{I}m[G_1(\mathcal{H}_1 - \frac{1}{3}\mathcal{H}_5)] \\ \mathcal{I}m[G_1\mathcal{H}_1] \end{array}$$

$$\mathcal{A}_{\stackrel{C}{\leftarrow}\stackrel{\Leftarrow}{\Rightarrow}}(\phi) = \frac{(\sigma^{+\Rightarrow} + \sigma^{+\Leftarrow}) - (\sigma^{-\Leftarrow} + (\sigma^{-\Rightarrow})}{(\sigma^{+\Rightarrow} + \sigma^{+\Leftarrow}) + (\sigma^{-\Leftarrow} + (\sigma^{-\Rightarrow})}$$

$$\mathcal{A}_C(\phi) = \frac{\sigma^{+} - \sigma^{-}}{\sigma^{+} - \sigma^{-}}$$

$$\left.\right\} \begin{array}{l} \mathcal{R}e[G_1(\mathcal{H}_1 - \frac{1}{3}\mathcal{H}_5)] \\ \mathcal{R}e[G_1\mathcal{H}_1] \end{array}$$

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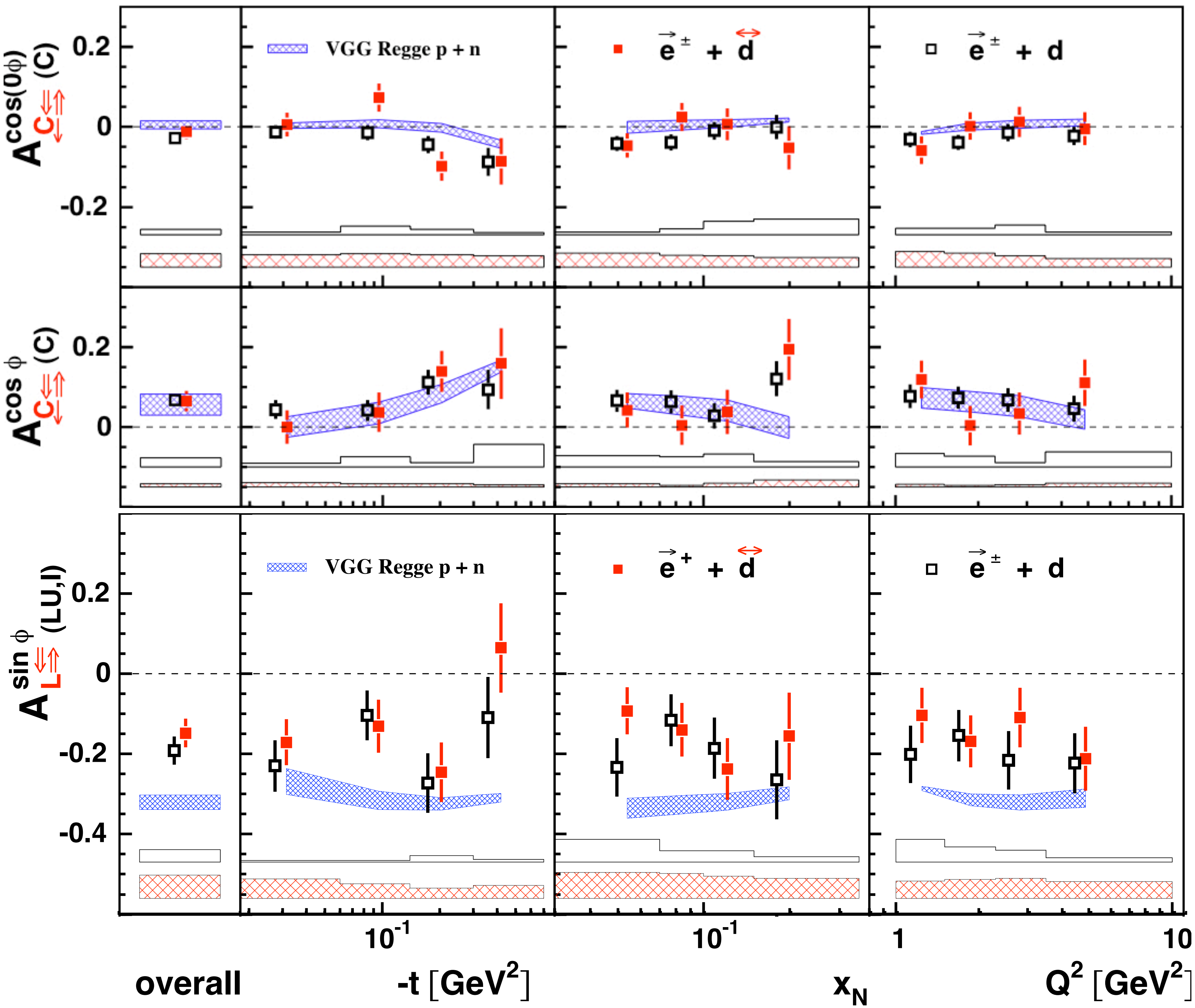
Beam-Charge & Beam helicity Asymmetries (D)



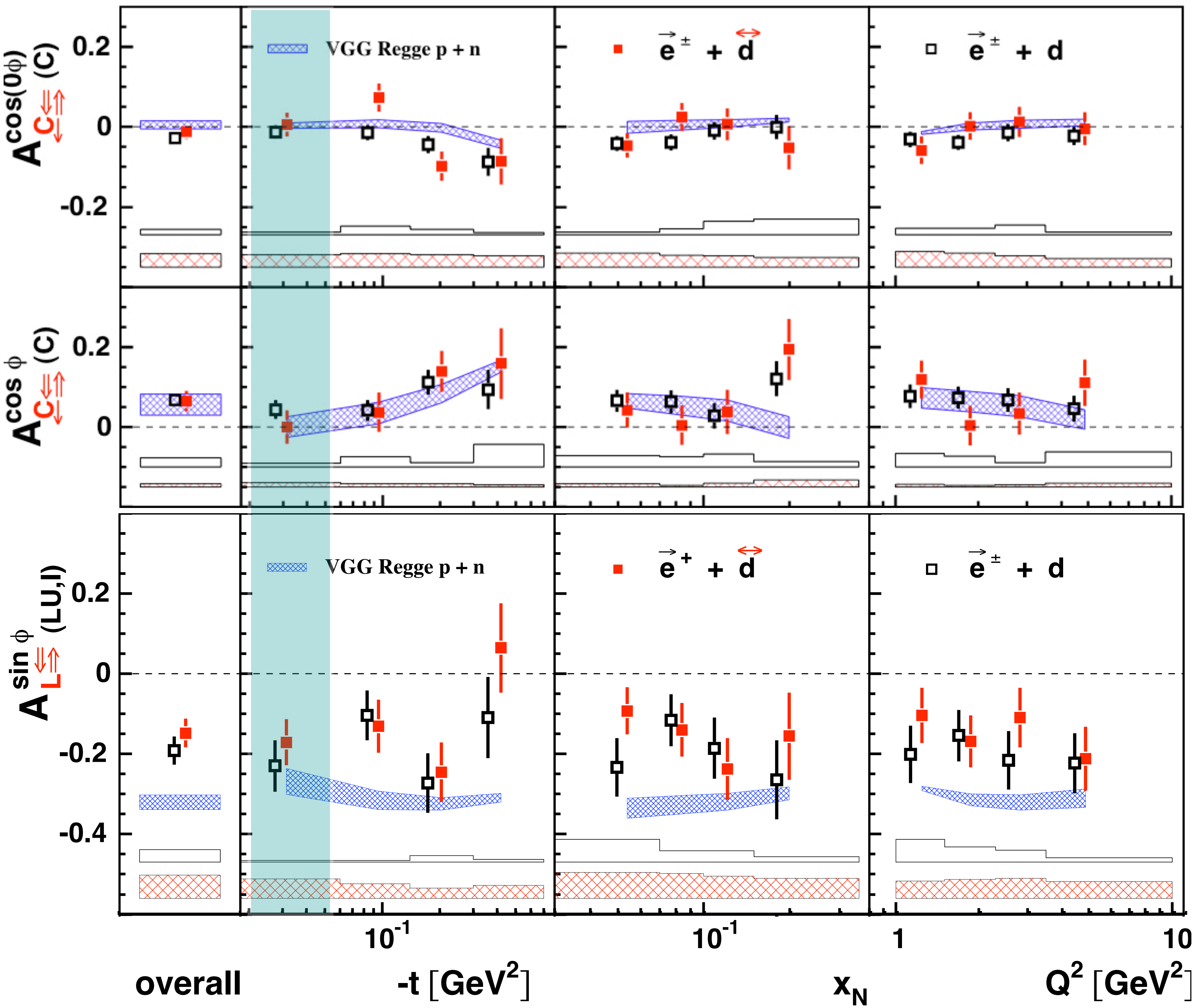
$$\propto -A^{\cos(\phi)}$$

$$\propto \begin{array}{l} \mathcal{R}e[G_1(\mathcal{H}_1 - \frac{1}{3}\mathcal{H}_5)] \\ \mathcal{R}e[G_1\mathcal{H}_1] \end{array}$$

$$\propto \begin{array}{l} \mathcal{I}m[G_1(\mathcal{H}_1 - \frac{1}{3}\mathcal{H}_5)] \\ \mathcal{I}m[G_1\mathcal{H}_1] \end{array}$$

- Results on an unpolarized and longitudinally polarized deuterium targets are consistent over all kinematic region.
- Comparison at low -t does not reveal signatures of tensor effects.
  Small contribution from CFF $\mathcal{H}_5$

Beam-Charge & Beam helicity Asymmetries (D)



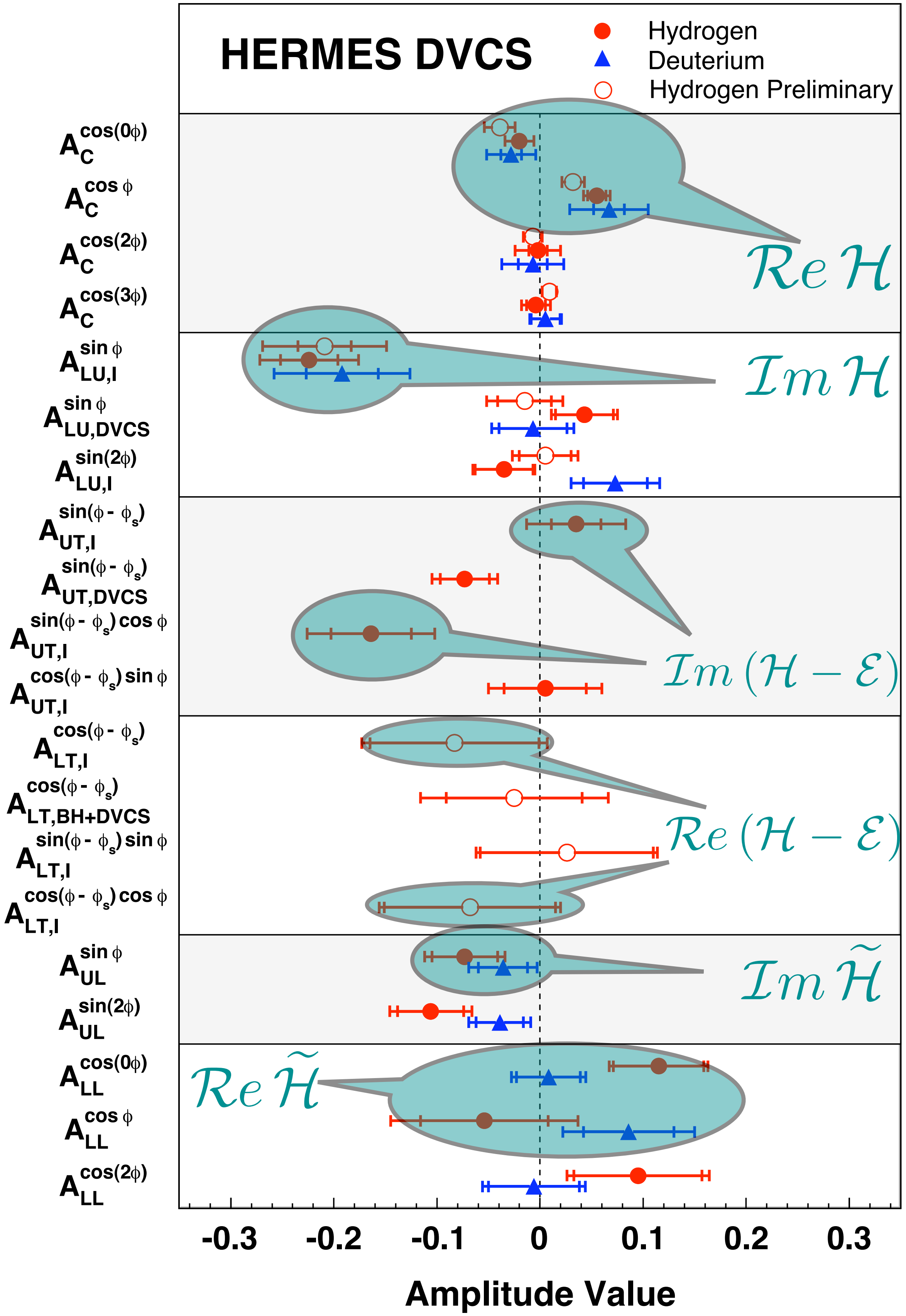
$\propto -A^{\cos(\phi)}$

$\propto \dfrac{\mathcal{R}e[G_1(\mathcal{H}_1 - \frac{1}{3}\mathcal{H}_5)]}{\mathcal{R}e[G_1\mathcal{H}_1]}$

$\propto \dfrac{\mathcal{I}m[G_1(\mathcal{H}_1 - \frac{1}{3}\mathcal{H}_5)]}{\mathcal{I}m[G_1\mathcal{H}_1]}$

- Results on an unpolarized and longitudinally polarized deuterium targets are consistent over all kinematic region.
- Comparison at low -t does not reveal signatures of tensor effects. Small contribution from CFF $\mathcal{H}_5$

Summary



Beam-Charge Asymmetry

Beam-Spin Asymmetry

Transverse Target-Spin Asymmetry

Transverse Double-Spin Asymmetry

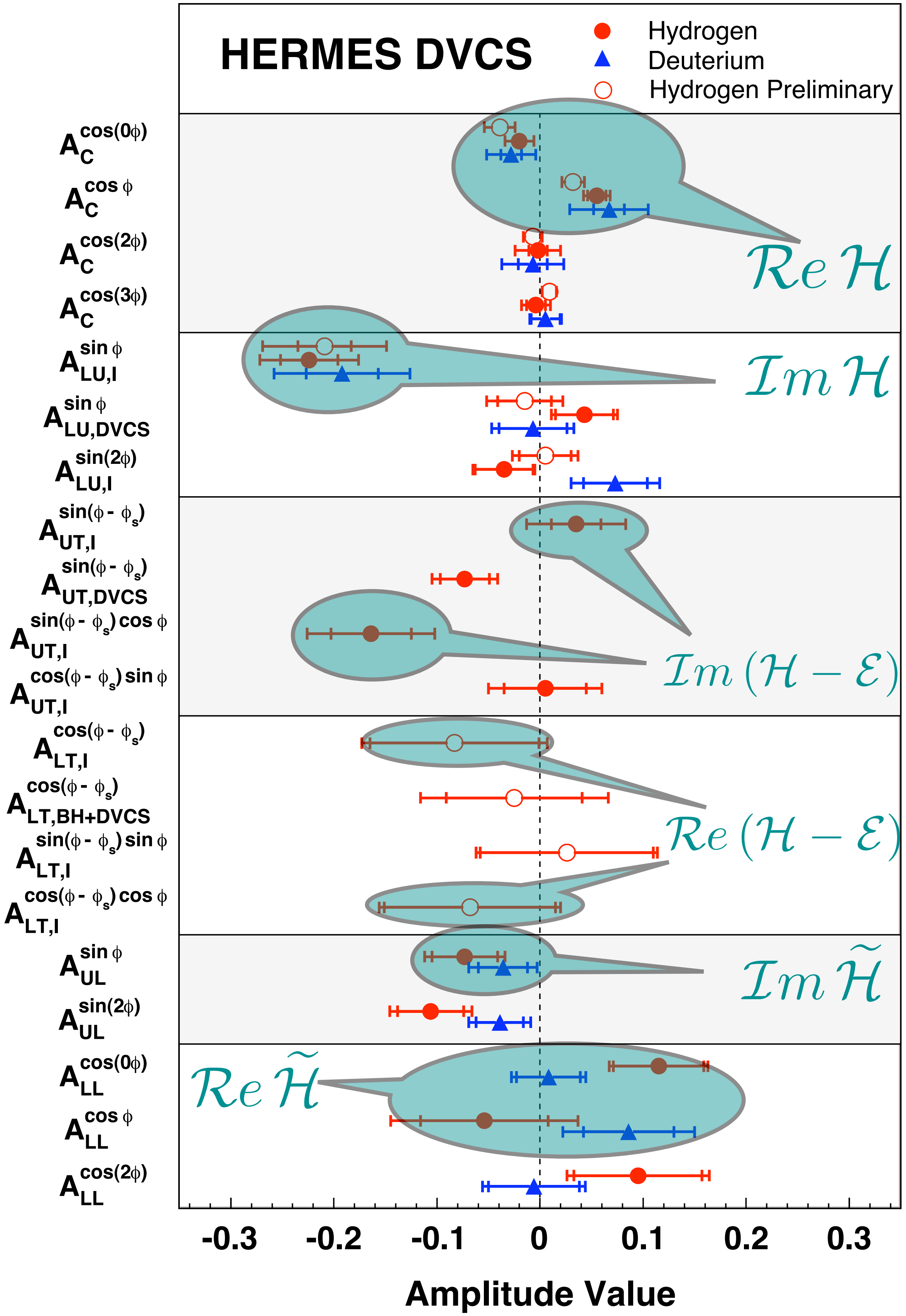
Longitudinal Target-Spin Asymmetry

Longitudinal Double-Spin Asymmetry

+ BCA and BSA on nuclear targets

First results with Recoil measurement: See talk by S. Yaschenko

Summary



Beam-Charge Asymmetry

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Beam-Spin Asymmetry

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Transverse Target-Spin Asymmetry

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Transverse Double-Spin Asymmetry

Preliminary

Longitudinal Target-Spin Asymmetry

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Longitudinal Double-Spin Asymmetry

JHEP 06 (2010) 019

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+ BCA and BSA on nuclear targets

Phys. Rev. C81, 035202 (2010)

First results with Recoil measurement: See talk by S. Yaschenko