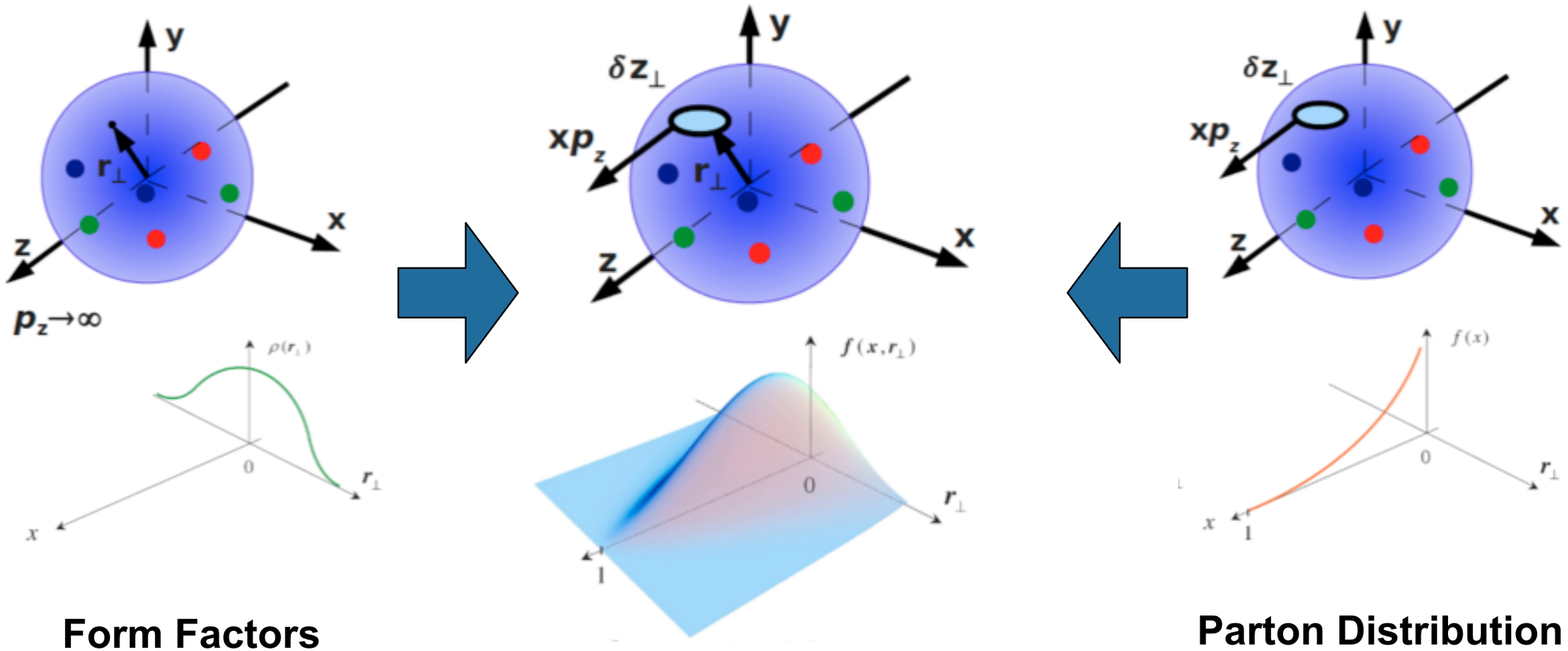
Deeply Virtual Compton Scattering at HERMES

Jennifer Bowles

On behalf of the HERMES collaboration

22nd June 2011

Nucleon Structure



Form Factors

Generalised Parton Distributions

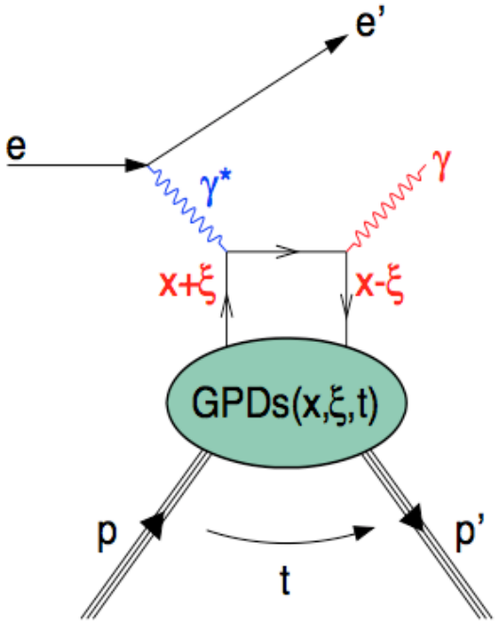
Parton Distribution Functions

There are four spin-1/2 GPDs at leading twist: $H(x, \xi, t)$, $E(x, \xi, t)$, $\tilde{H}(x, \xi, t)$ and $\tilde{E}(x, \xi, t)$
HERMES can provide access to three of them.

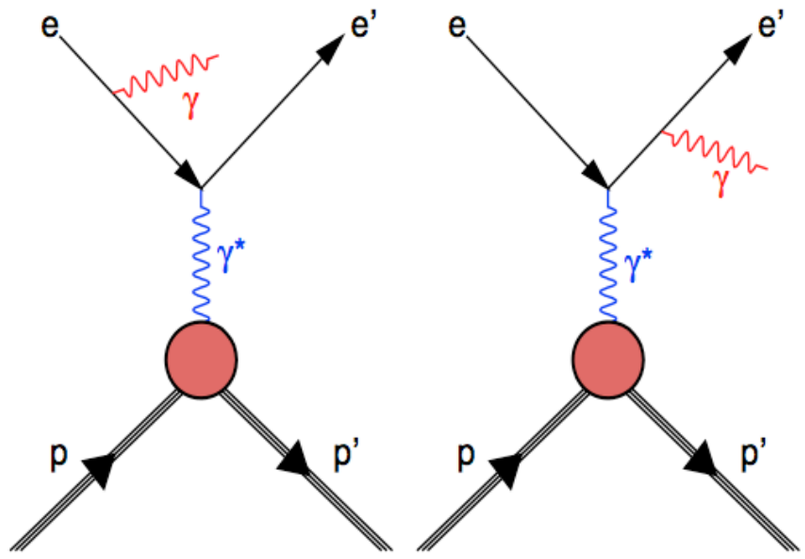
Each GPD has a corresponding Compton Form Factor (CFF) : $\mathcal{H}$, $\mathcal{E}$, $\tilde{\mathcal{H}}$, $\tilde{\mathcal{E}}$

For details about GPDs see the following speaker B. Pire

Deeply Virtual Compton Scattering



DVCS



Bethe-Heitler (BH)

$$d\sigma\left(eN \to eN\gamma\right) \propto |\tau_{BH}|^2 + |\tau_{DVCS}|^2 + \underbrace{\tau_{BH}\tau^*_{DVCS} + \tau^*_{BH}\tau_{DVCS}}_{\mathcal{I}}$$

- BH dominates at HERMES kinematics
- Information on GPDs can be accessed via Compton Form Factors (from the interference of the BH and DVCS cross section.

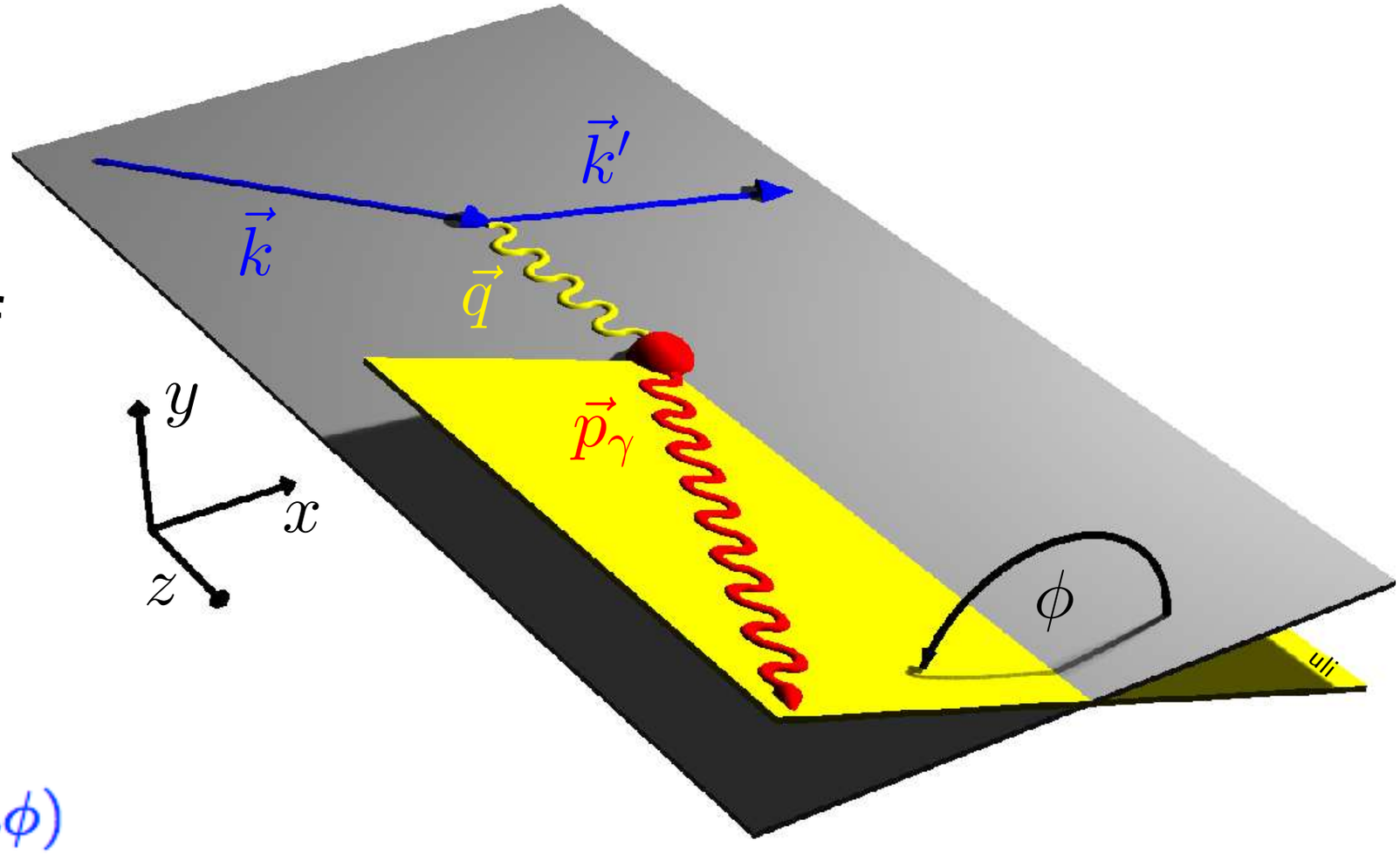
t - Mandelstam variable (squared momentum transfer to nucleon)

x - Fraction of nucleon's longitudinal momentum carried by active quark

ξ - half the change in the longitudinal momentum of the active quark.

Azimuthal Dependence

The $e\,p \to e\,p\,\gamma$ cross section can be expressed in terms of Fourier coefficients:



$$|\tau_{\mathsf{BH}}|^2 \propto \sum_{n=0}^{2} c_n^{\mathsf{BH}} \cos(n\phi)$$

$$|\tau_{\mathsf{DVCS}}|^2 \propto \sum_{n=0}^{2} c_n^{\mathsf{DVCS}} \cos(n\phi) + P_\ell\, s_1^{\mathsf{DVCS}} \sin\phi$$

$$\mathsf{I} \propto \sum_{n=0}^{3} c_n^{\mathsf{I}} \cos(n\phi) + \sum_{n=1}^{2} P_\ell\, s_n^{\mathsf{I}} \sin(n\phi)$$

Azimuthal DVCS Asymmetries

A number of azimuthal asymmetries have been measured at HERMES, e.g

Beam Charge Asymmetry:

$$\mathcal{A}_C(\phi) \equiv \frac{\mathrm{d}\sigma^+(\phi) - \mathrm{d}\sigma^-(\phi)}{\mathrm{d}\sigma^+(\phi) + \mathrm{d}\sigma^-(\phi)}$$

Beam Spin / Target Spin Asymmetries:

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

Beam Unpol. Target Long. pol.

Azimuthal DVCS Asymmetries

A number of azimuthal asymmetries have been measured at HERMES, e.g

Beam Charge Asymmetry:

$$\mathcal{A}_C(\phi) \equiv \frac{\mathrm{d}\sigma^+(\phi) - \mathrm{d}\sigma^-(\phi)}{\mathrm{d}\sigma^+(\phi) + \mathrm{d}\sigma^-(\phi)} \propto \sum_{n=0}^{3} A_C^{\cos(n\phi)} \cos(n\phi)$$

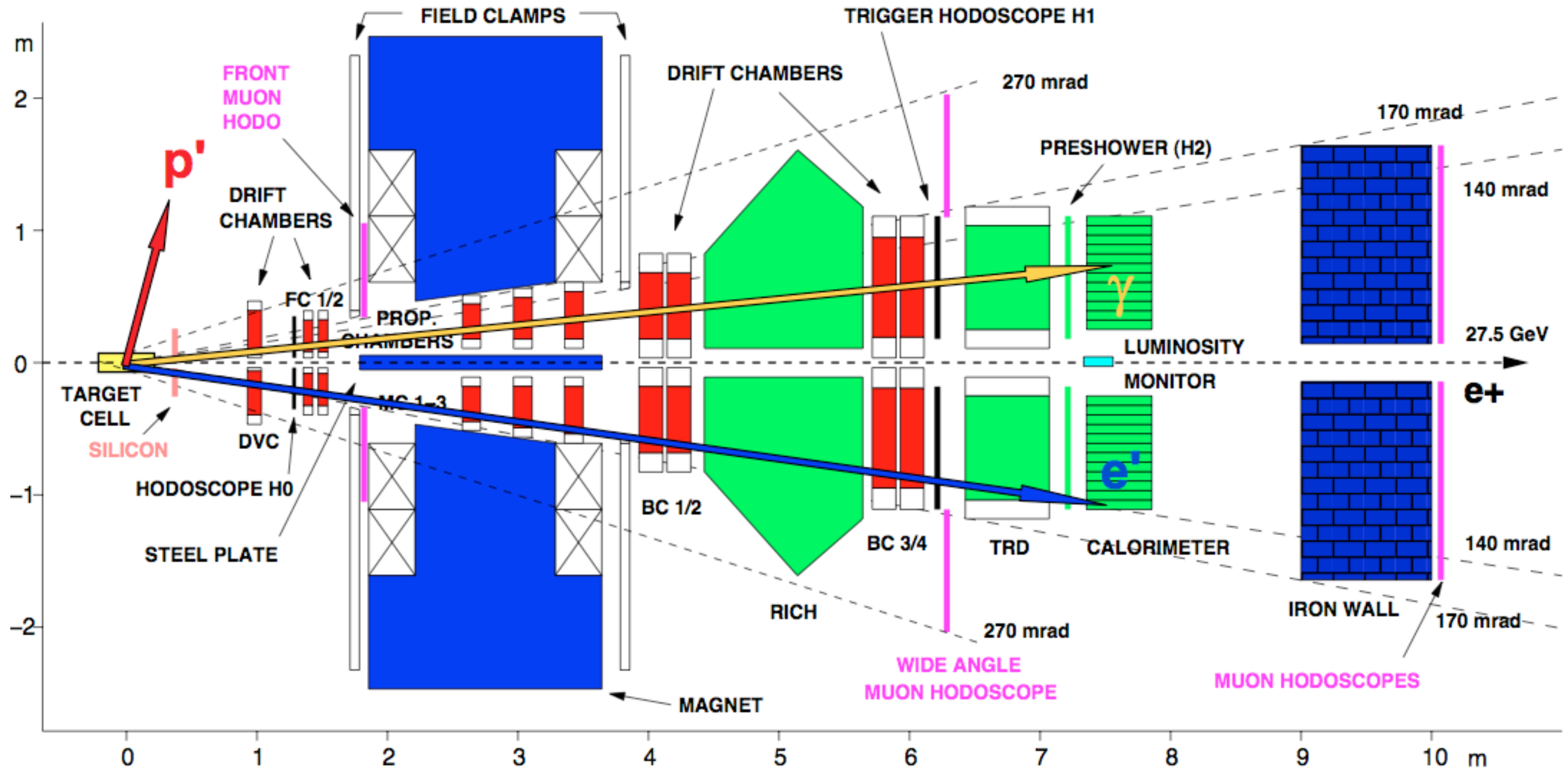
Beam Spin / Target Spin Asymmetries:

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

Beam Unpol. Target Long. pol.

The extracted amplitudes relate to the expansion of the cross section into a Fourier series.

Particle Tracking, Particle Momentum, Particle ID & ϒ detection

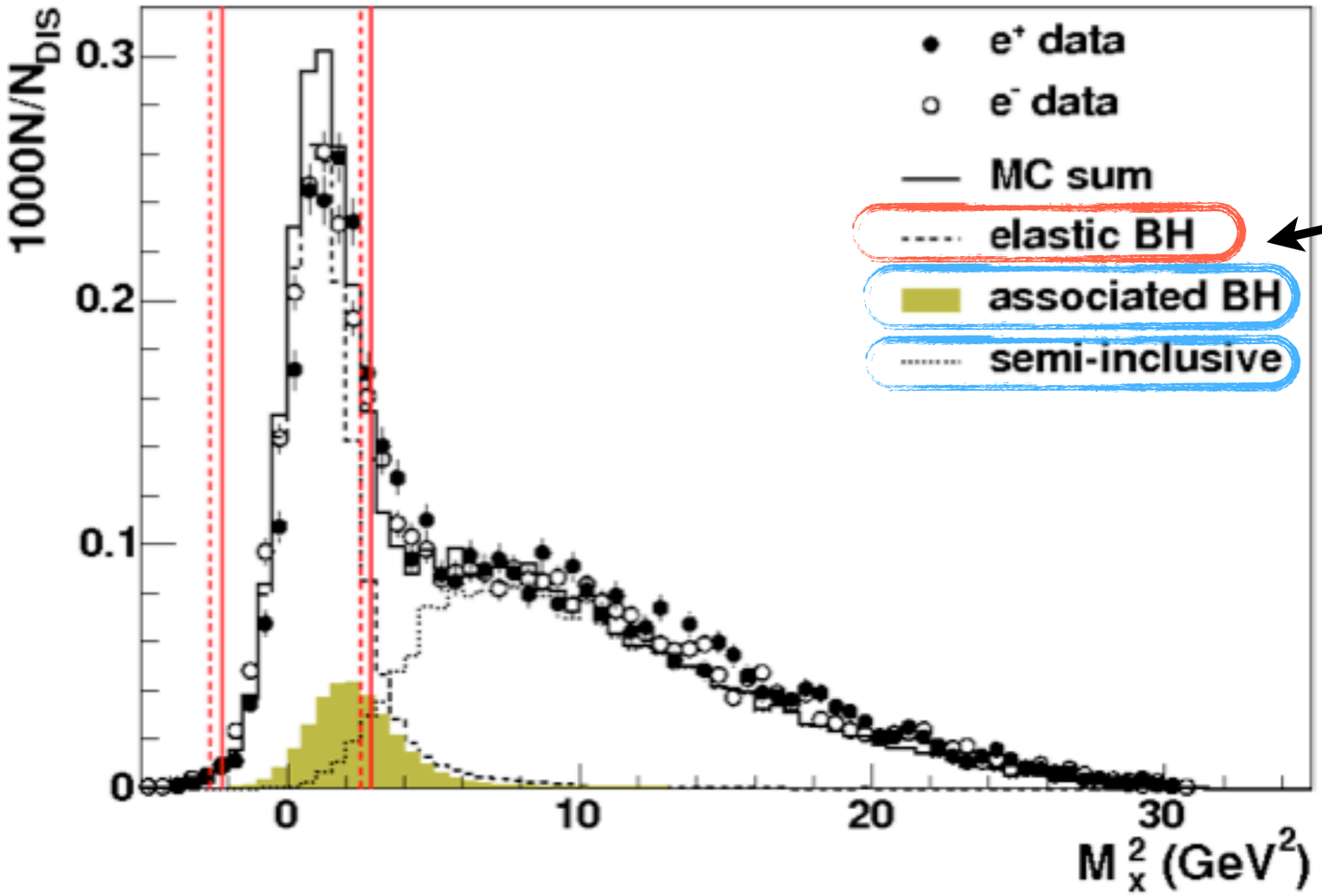


Event selection

★ Measured photon and electron in forward spectrometer.

$$e\,p \rightarrow e\,p\,\gamma$$

★ Selected exclusive events using a missing mass technique

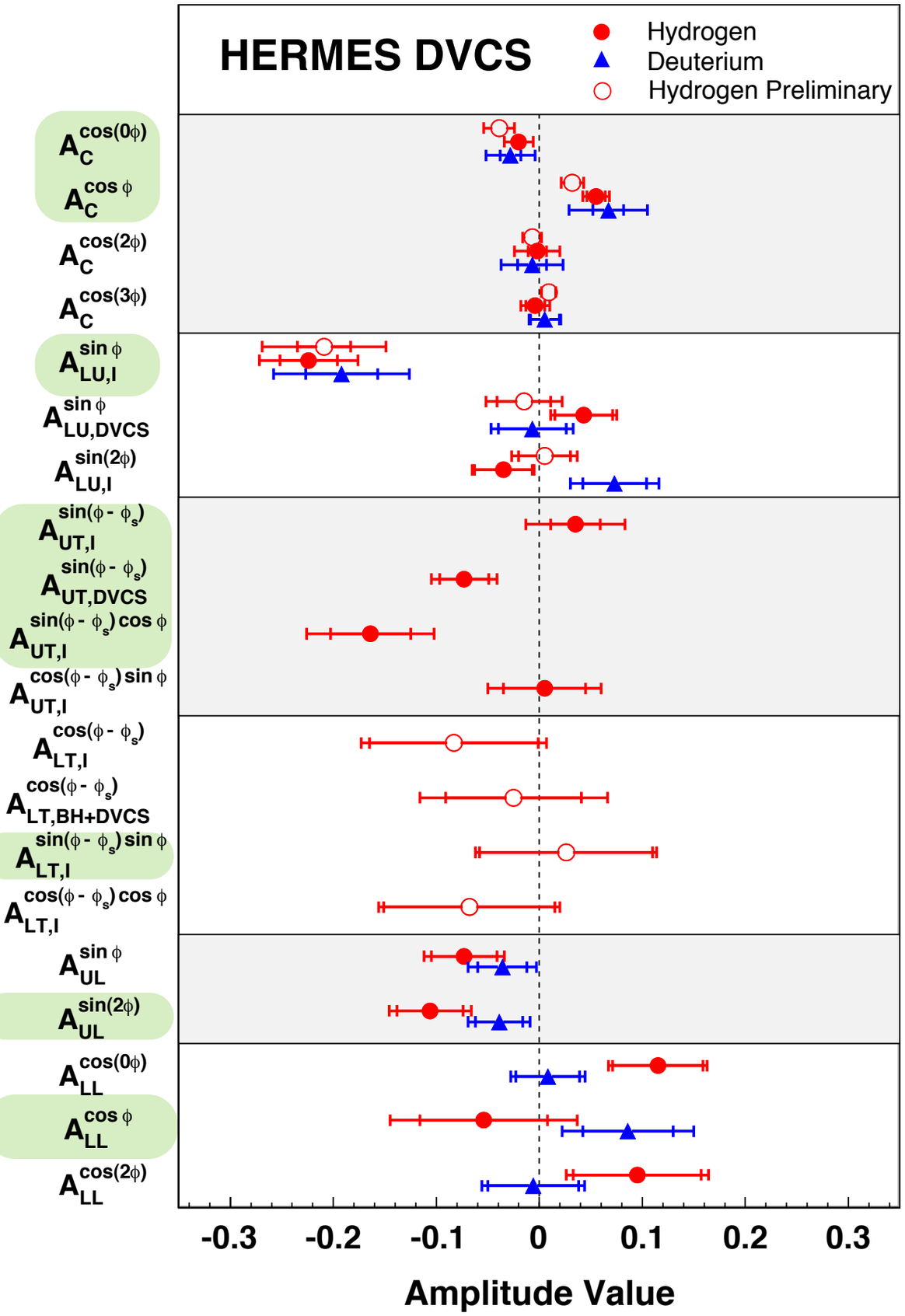


Wanted Signal

DVCS with the Δ

Semi-inclusive DIS

DVCS @ HERMES



Beam-charge asymmetry: Re ($\mathcal{H}$)

JHEP 11 (2009) 083 / Nucl. Phys. B 829 (2010) 1-27

Beam-helicity asymmetry: Im ($\mathcal{H}$)

JHEP 11 (2009) 083 / Nucl. Phys. B 829 (2010) 1-27

Transverse target-spin asymmetry: Im ($\mathcal{H}$-$\mathcal{E}$)

JHEP 06 (2008) 066

Double-spin (LT) asymmetry: Re($\mathcal{H}$+$\mathcal{E}$)

sumbitted to Phys. Lett. B
arXiv: 1106.2990

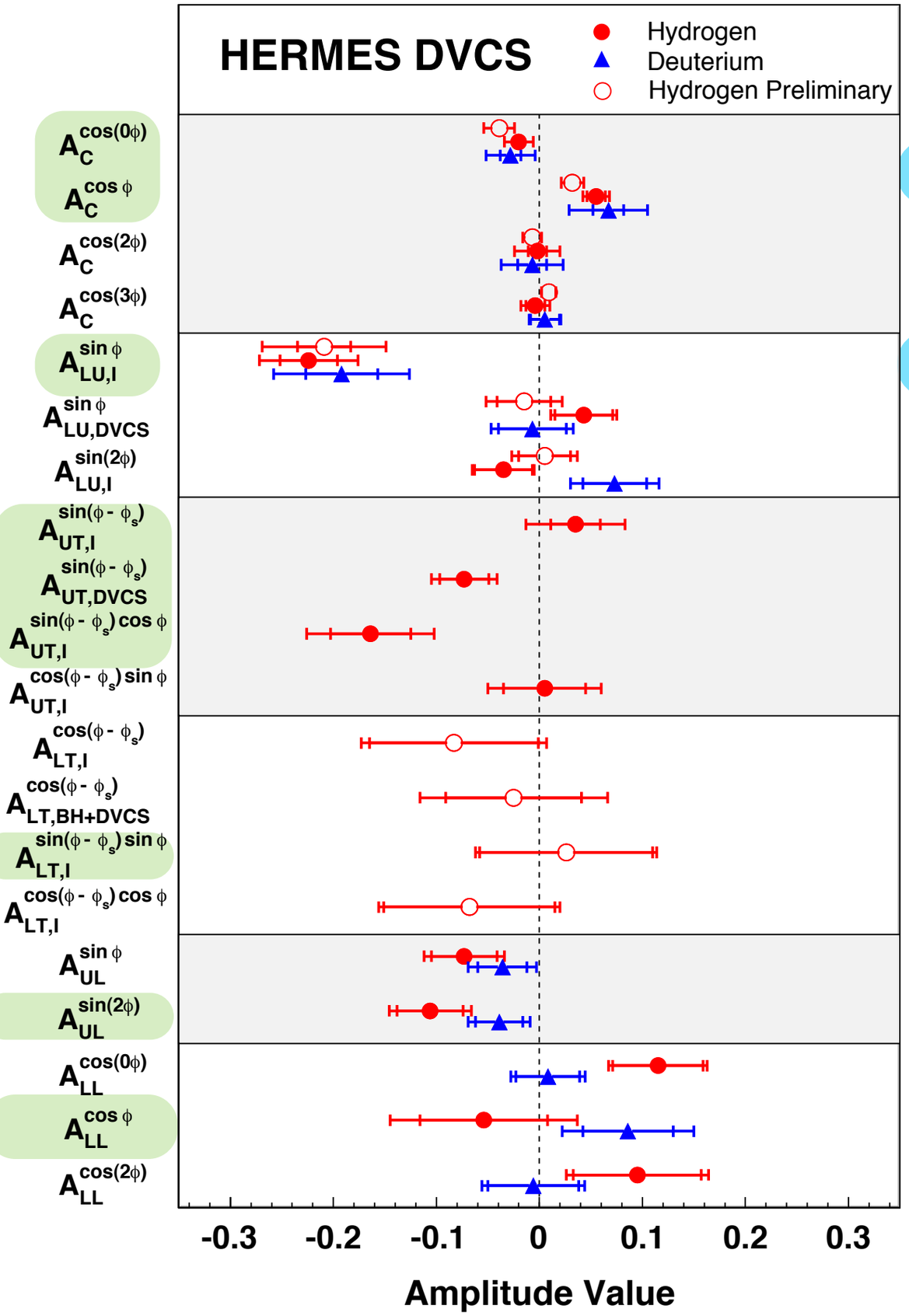
Longitudinal target-spin asymmetry: Im ($\tilde{\mathcal{H}}$)

JHEP 06 (2010) 019 / Nucl. Phys. B 842 (2011) 265-298

Double-spin (LL) asymmetry: Re ($\tilde{\mathcal{H}}$)

JHEP 06 (2010) 019 / Nucl. Phys. B 842 (2011) 265-298

DVCS @ HERMES



Beam-charge asymmetry: Re ($\mathcal{H}$)

JHEP 11 (2009) 083 / Nucl. Phys. B 829 (2010) 1-27

Beam-helicity asymmetry: Im ($\mathcal{H}$)

JHEP 11 (2009) 083 / Nucl. Phys. B 829 (2010) 1-27

Transverse target-spin asymmetry: Im ($\mathcal{H}$-$\mathcal{E}$)

JHEP 06 (2008) 066

Double-spin (LT) asymmetry: Re($\mathcal{H}$+$\mathcal{E}$)

sumbitted to Phys. Lett. B

arXiv: 1106.2990

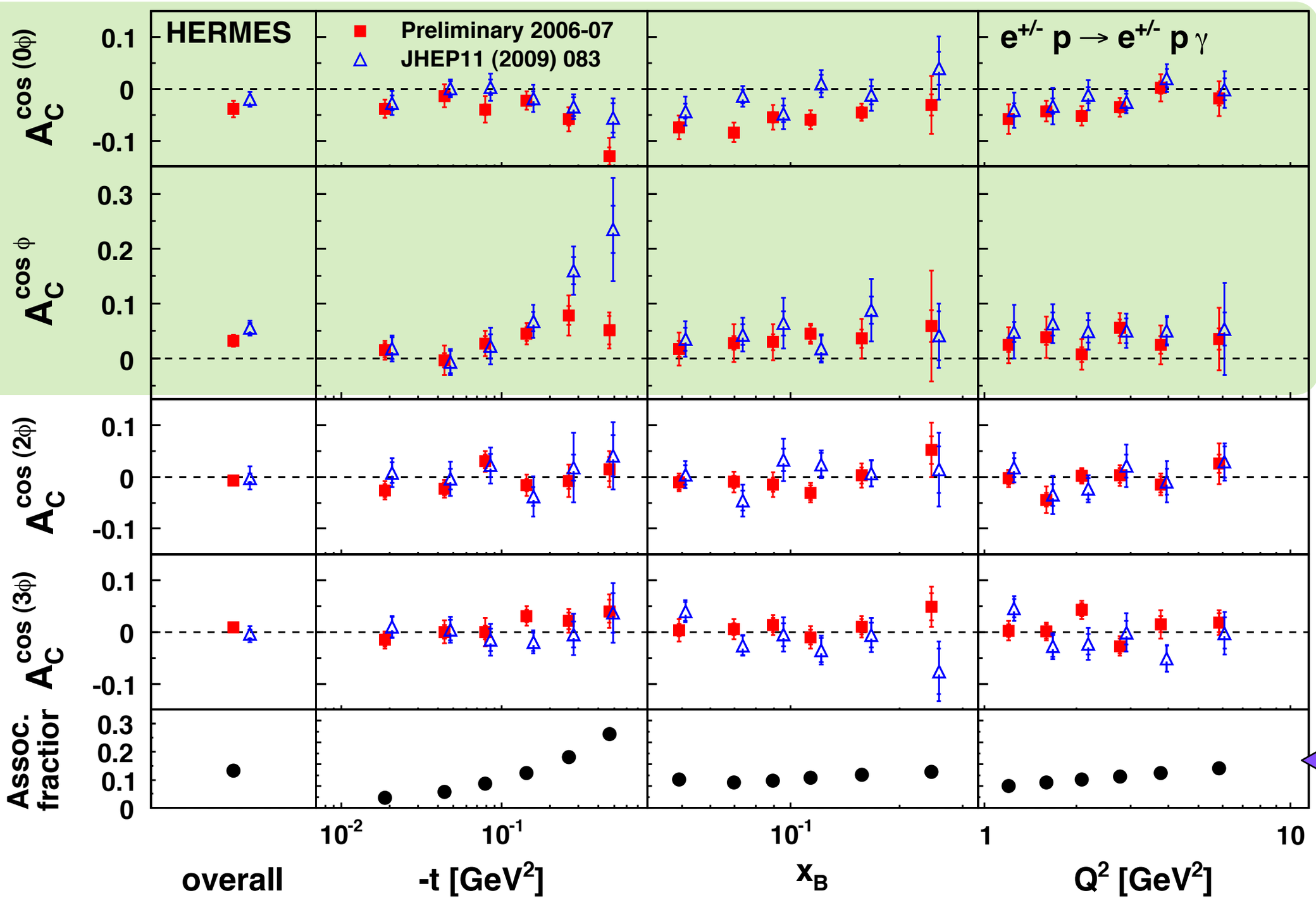
Longitudinal target-spin asymmetry: Im ($\tilde{\mathcal{H}}$)

JHEP 06 (2010) 019 / Nucl. Phys. B 842 (2011) 265-298

Double-spin (LL) asymmetry: Re ($\tilde{\mathcal{H}}$)

JHEP 06 (2010) 019 / Nucl. Phys. B 842 (2011) 265-298

Beam Charge Asymmetry



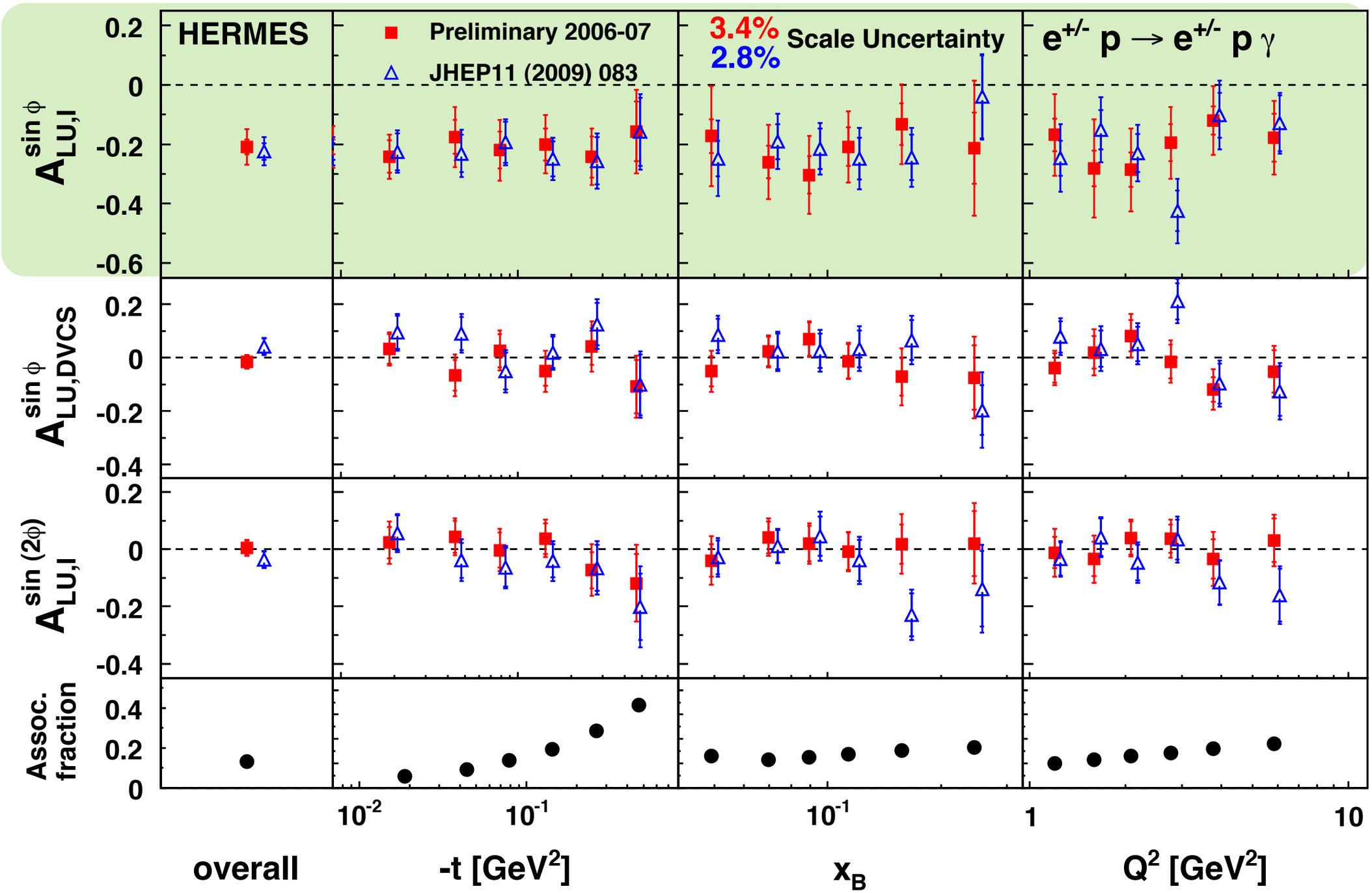
$\propto -A_C \cos\phi$

$\propto \mathrm{Re}(\mathcal{H})$

Fraction of Associated in signal

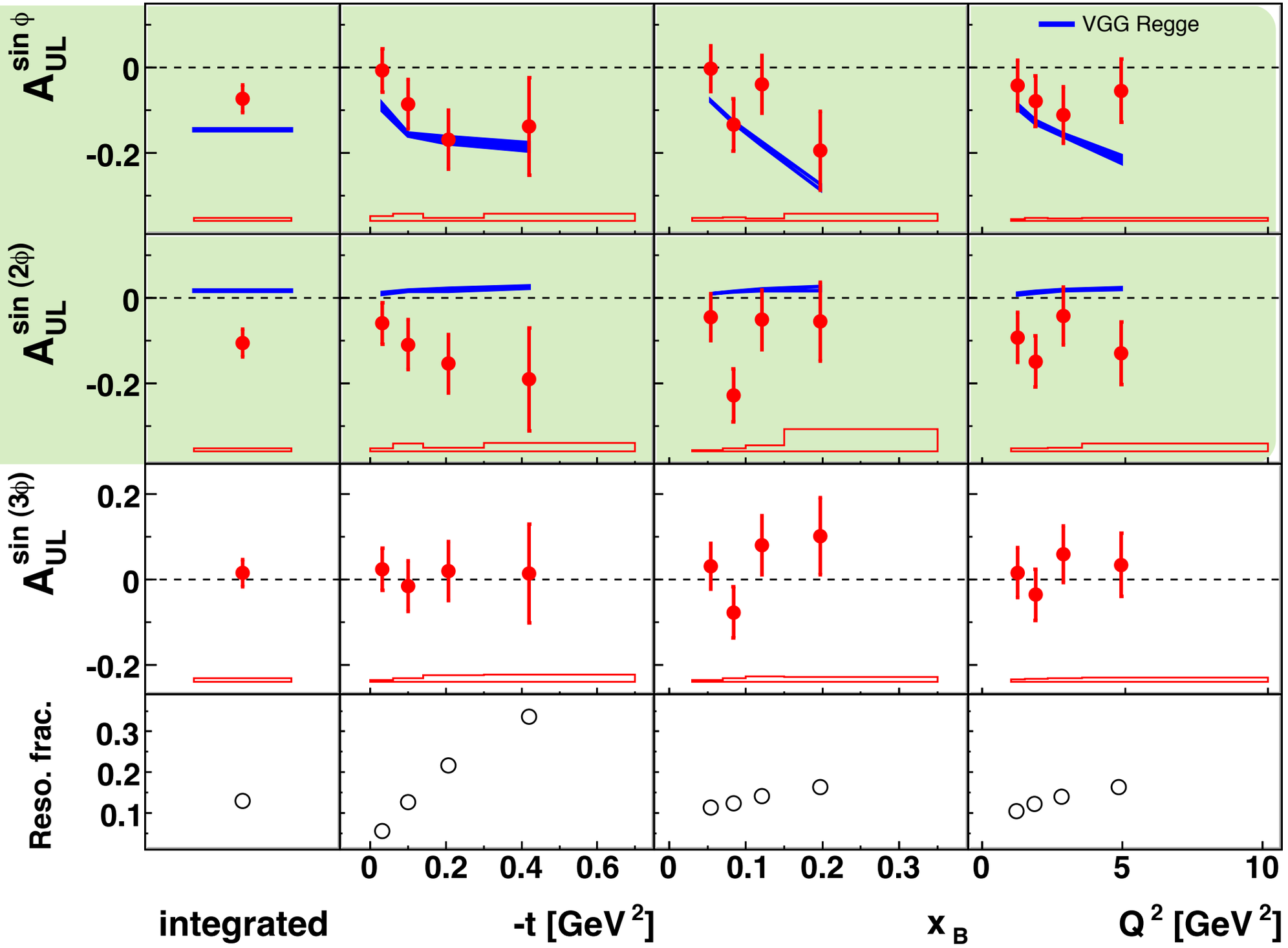
amplitudes binned in $t \equiv (\mathbf{p} - \mathbf{p}')^2 \qquad x_B \equiv \frac{Q^2}{2(\mathbf{p}\cdot\mathbf{q})} \qquad Q \equiv -\mathbf{q}^2$

Beam Helicity Asymmetry



$\propto \mathrm{Im}(\mathcal{H})$

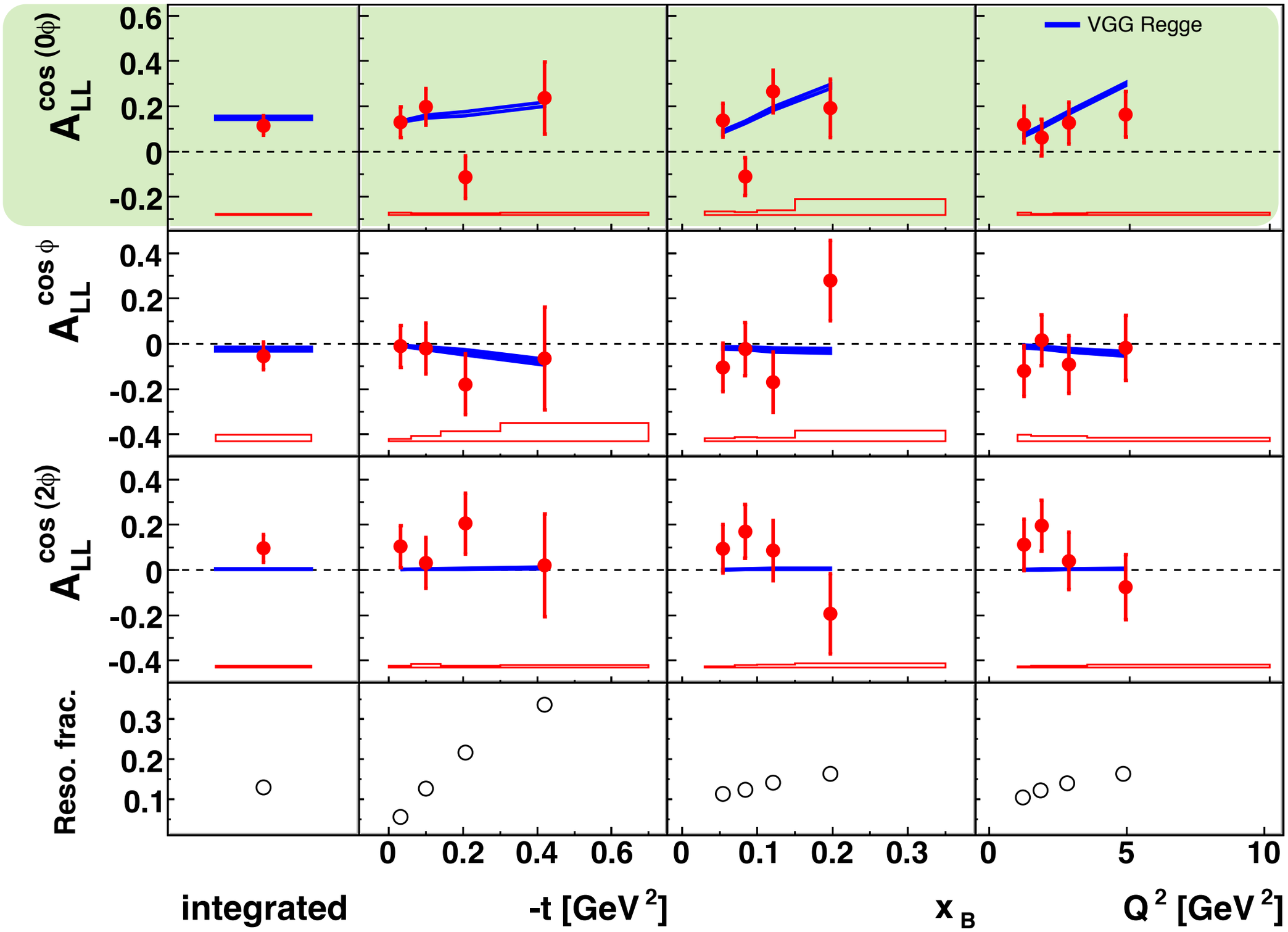
Longitudinal Target Spin Asymmetry



$$\propto \mathrm{Im}(\tilde{\mathcal{H}})$$

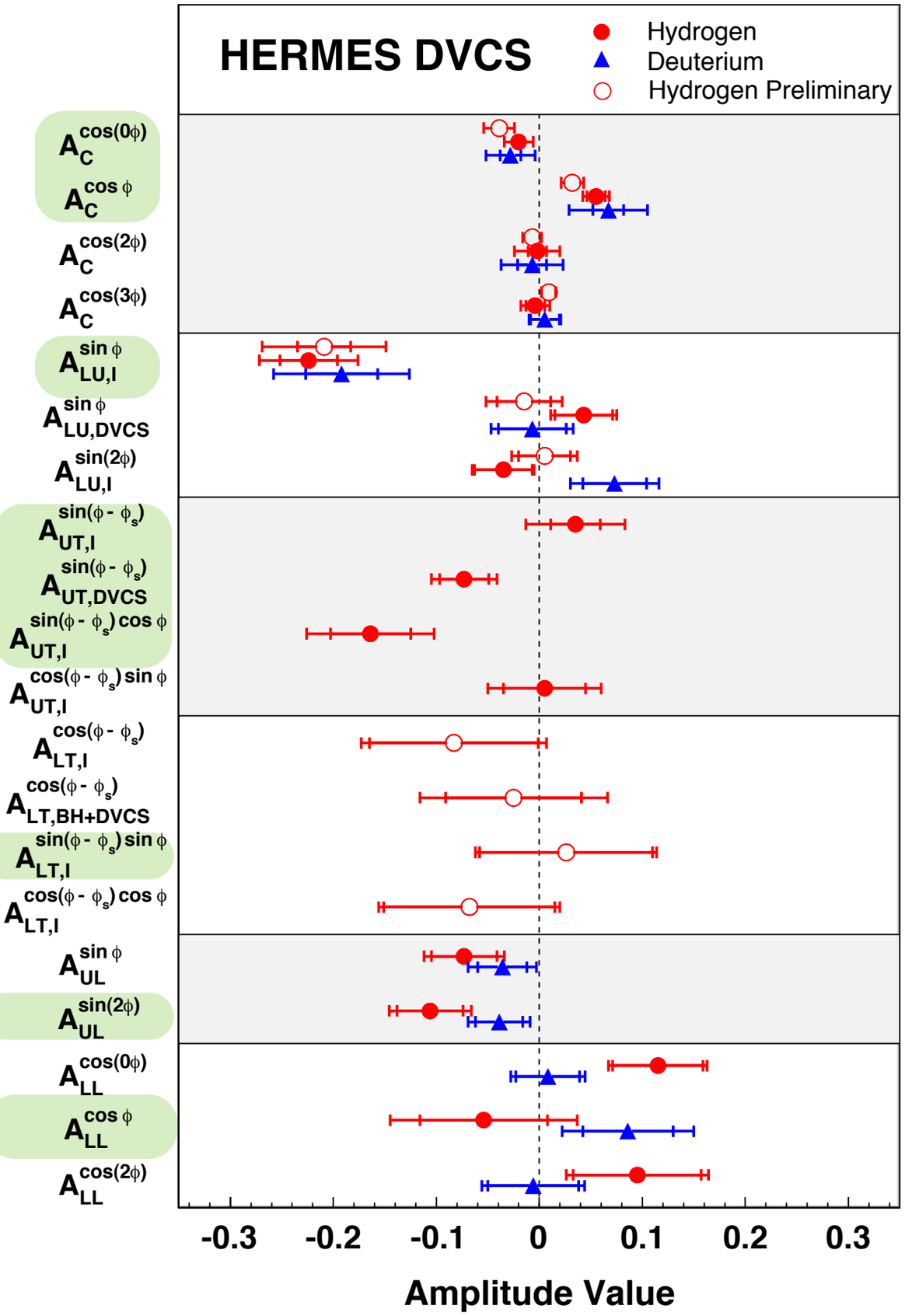
VGG model : Vanderhaegen, Guichon, Guidal
Phys. Rev. D60 (1999) 094017, Prog. Part. Nucl. Phys. 47 (2001) 401

Double spin (LL) spin asymmetry



$\propto \mathrm{Re}(\tilde{\mathcal{H}})$

DVCS @ HERMES



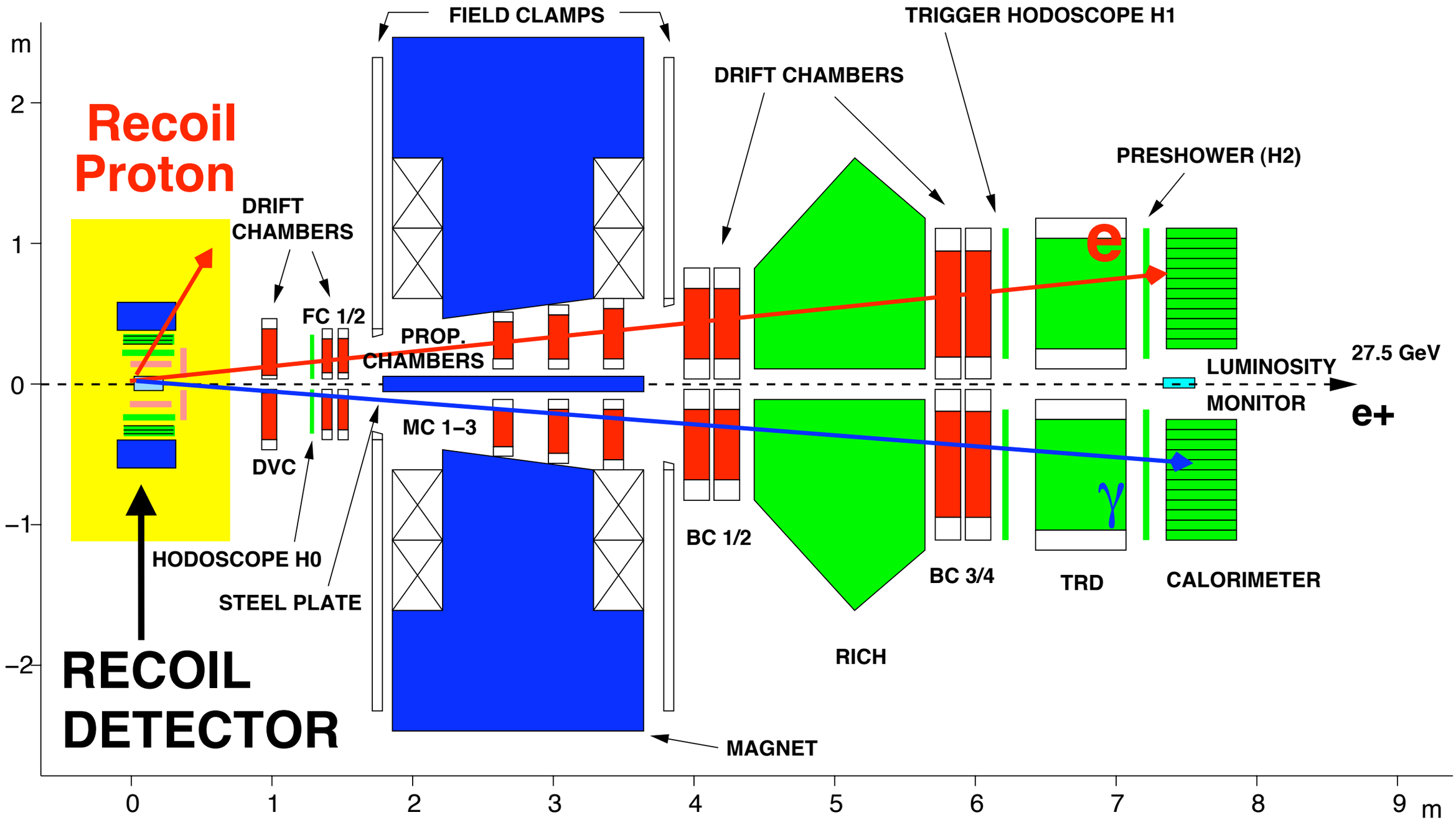
All these include a ~12% background contribution from the associated process (e.g $e\,\Delta \rightarrow e\,\Delta\,\gamma \rightarrow e\,p\,\pi^0\,\gamma$)

Installation of the recoil detector - measure all particles

$$e\,p \rightarrow e\,p\,\gamma$$

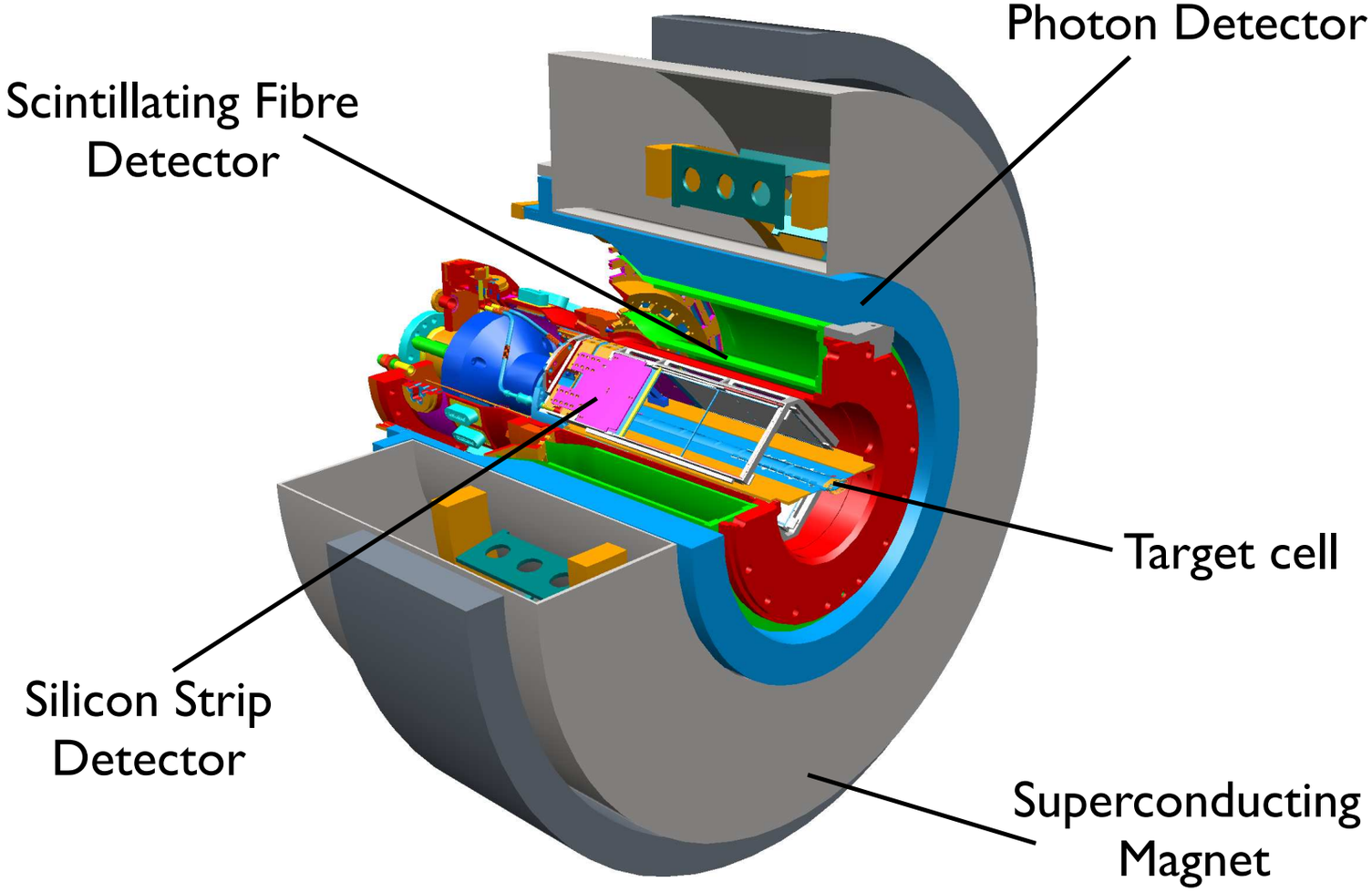
HERMES Spectrometer

Particle Tracking, Particle Momentum, Particle ID & ϒ detection



D_2 and **H_2** unpolarised gas targets 2006-2007

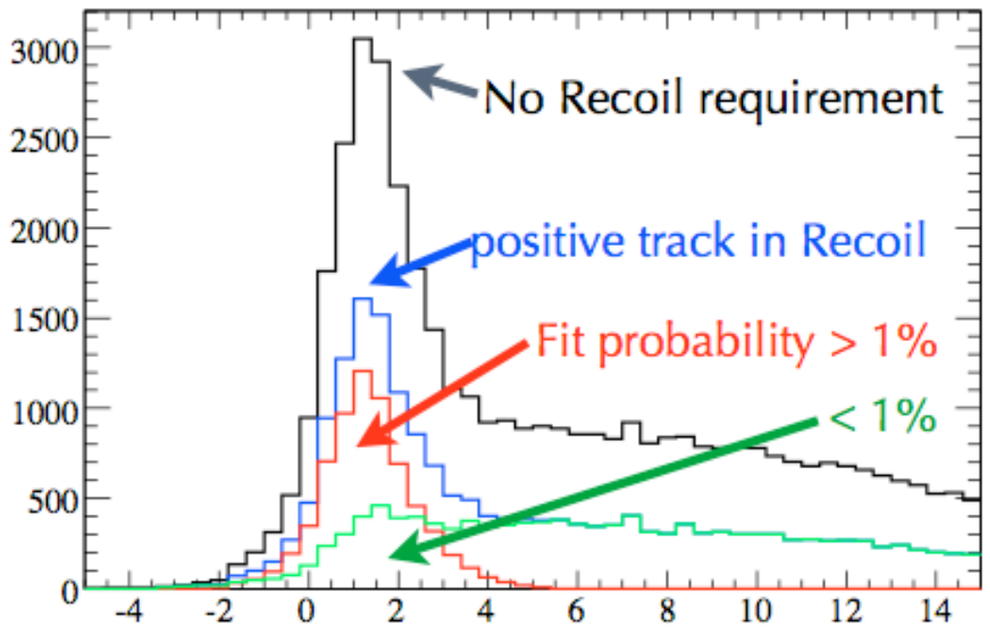
Event selection with the Recoil Detector



Detect a recoil proton!

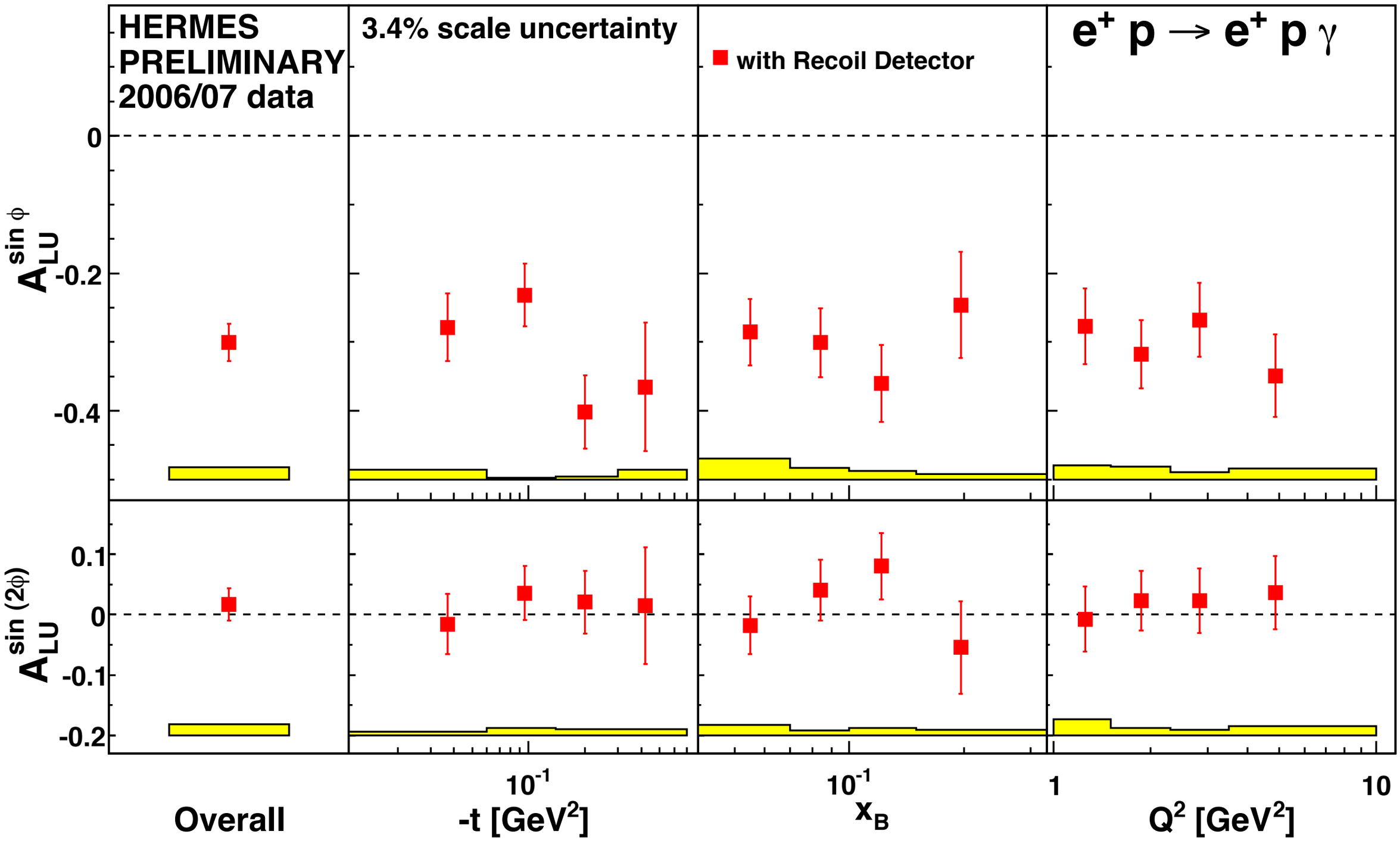
Kinematic event fitting

Background suppressed < 1%

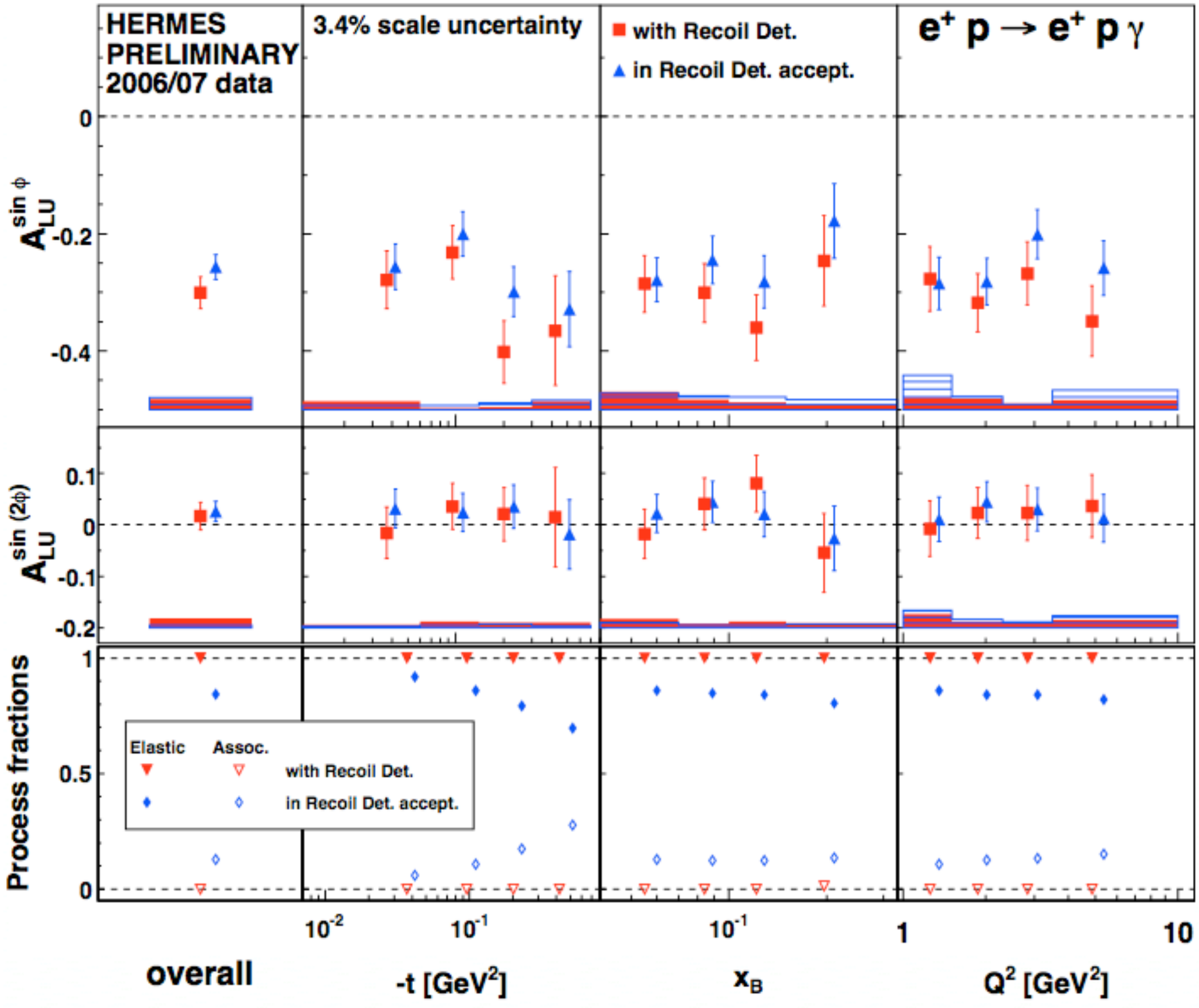


University of Glasgow

Beam Spin Asymmetry



Beam Spin Asymmetry



Conclusions

- **DVCS can provide access to Generalised Parton Distributions**

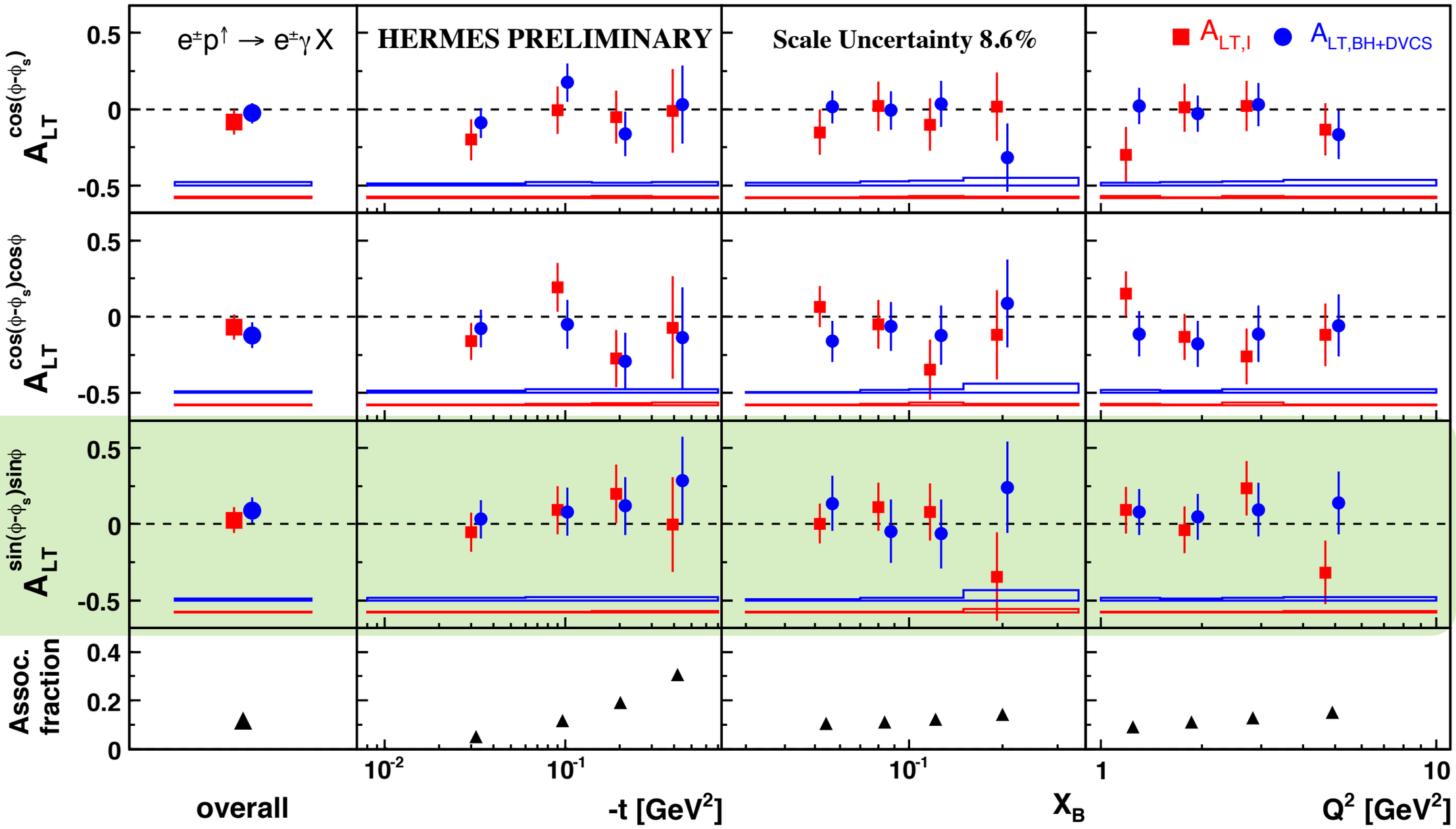
- **HERMES has provided the most diverse set of azimuthal asymmetries**

- **The first result with a pure elastic DVCS signal shown**

- **DVCS results have been used in the first global fits of Compton Form Factors**

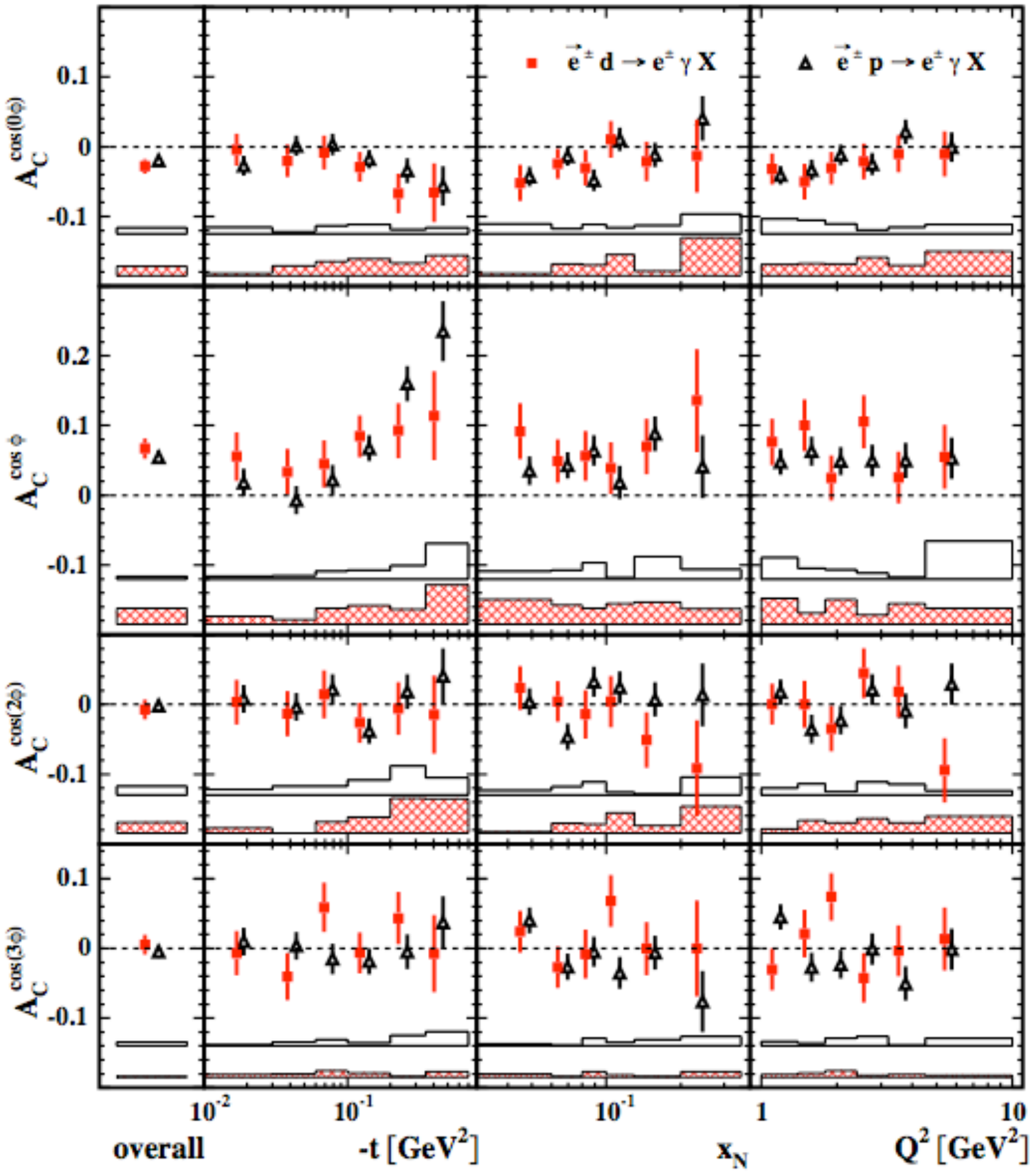
Backup Slides

Double Spin (LT) Asymmetry

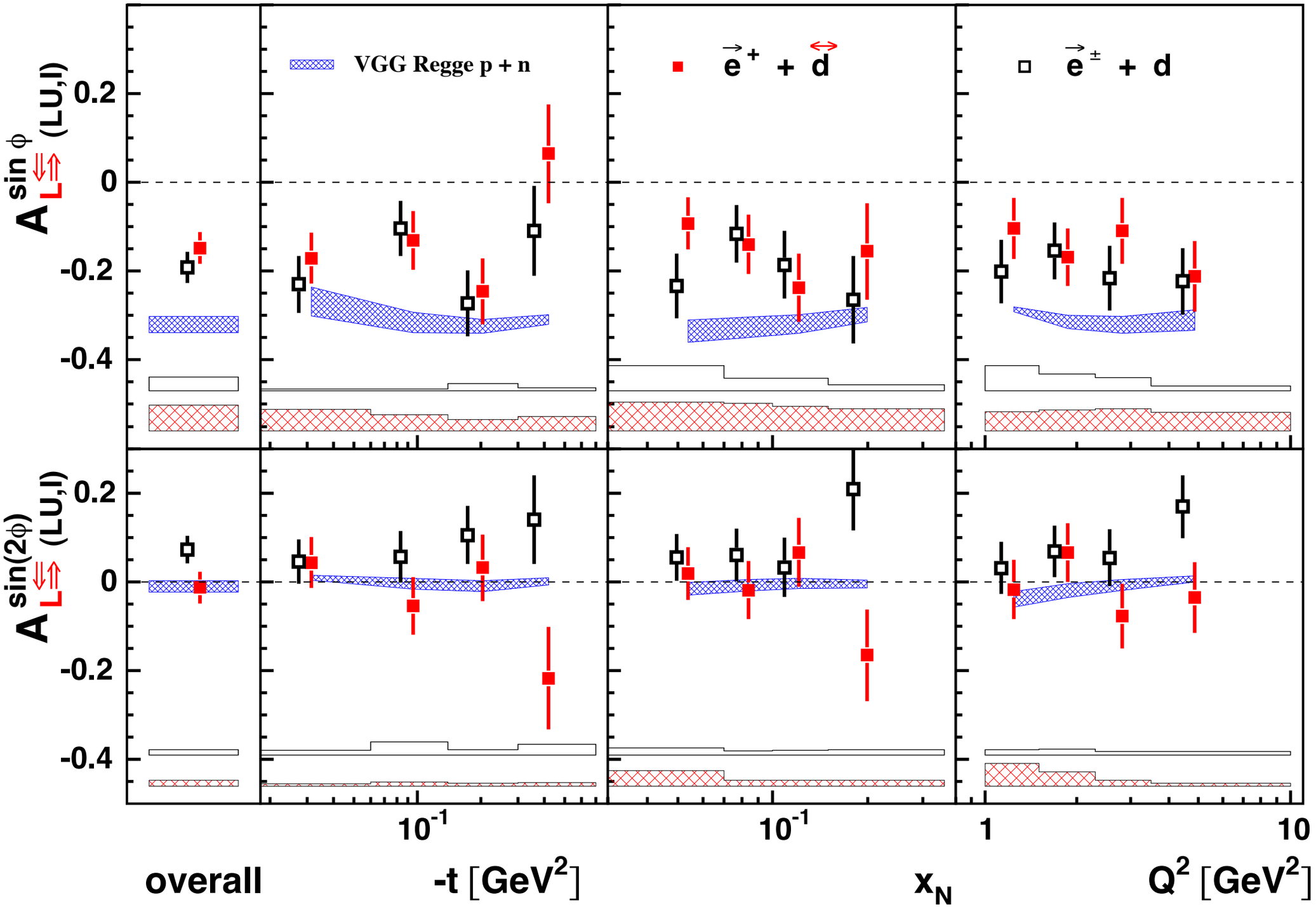


$\propto$ **Re($\mathcal{H}$+$\mathcal{E}$)**

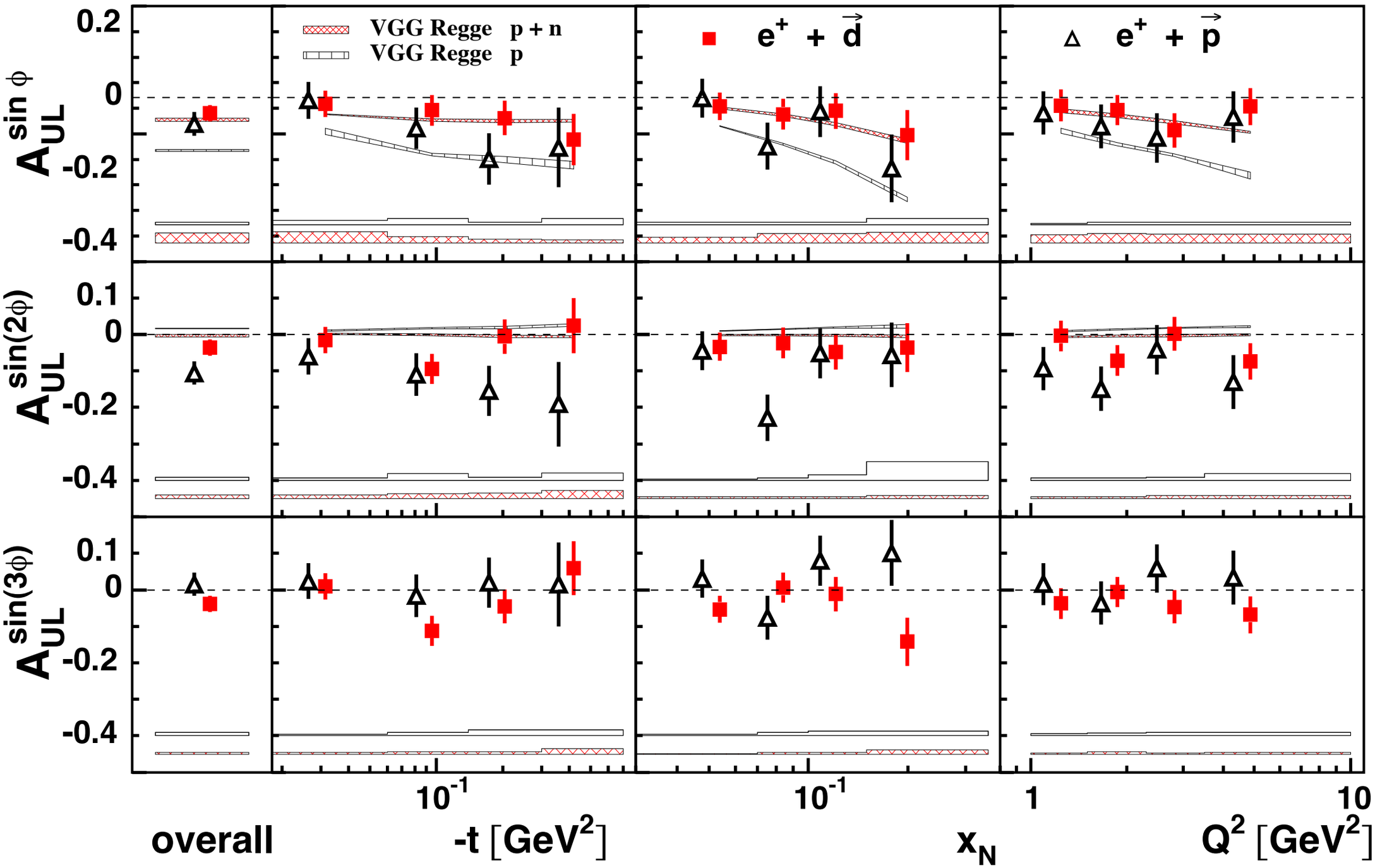
Deuterium BCA

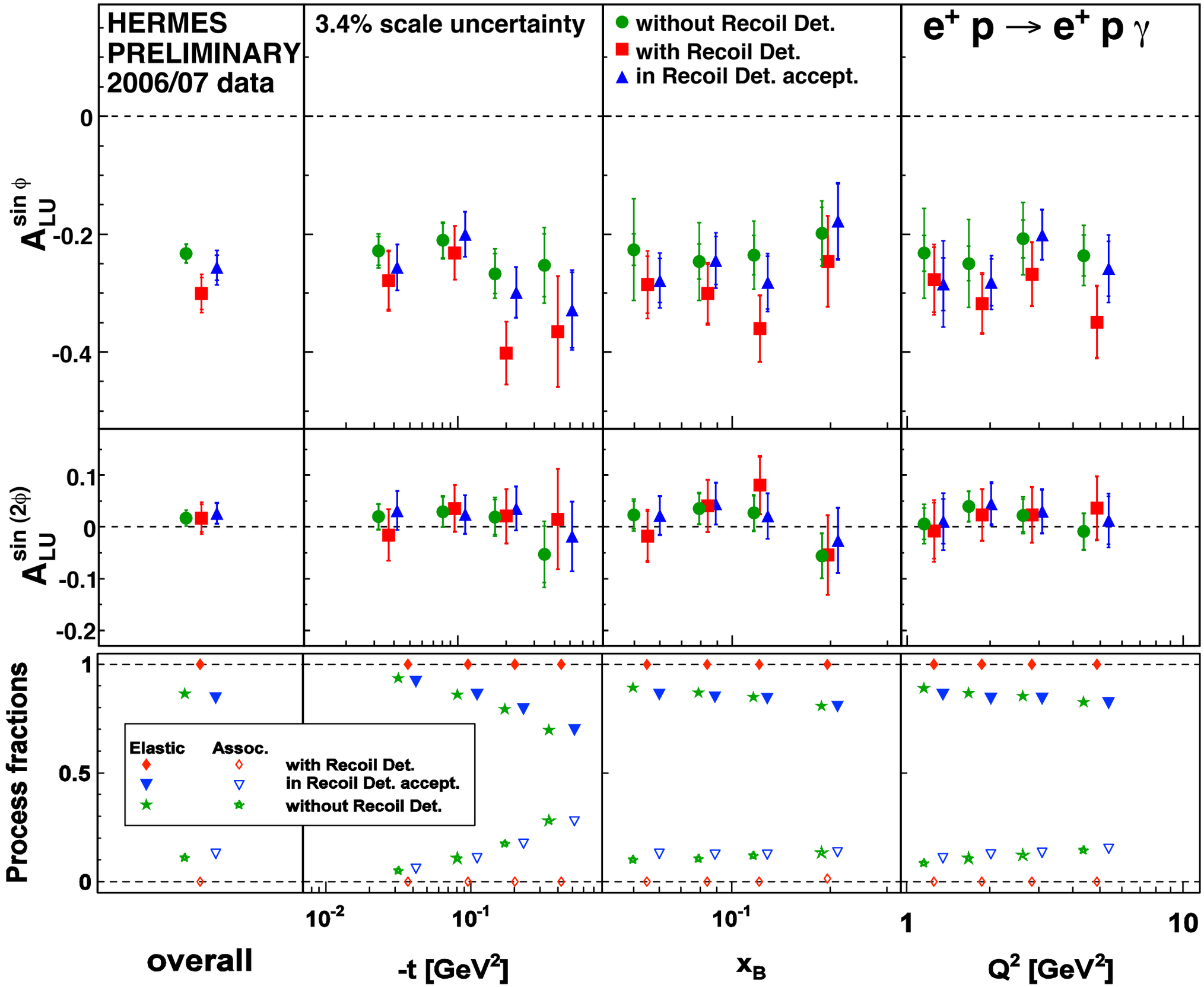


Deuterium BSA



Deuterium BSA




HERMES
PRELIMINARY
2006/07 data
3.4% scale uncertainty
without Recoil Det.
with Recoil Det.
in Recoil Det. accept.
e+ p → e+ p γ
$A_{LU}^{\sin\phi}$
$A_{LU}^{\sin(2\phi)}$
Process fractions
Elastic
Assoc.
with Recoil Det.
in Recoil Det. accept.
without Recoil Det.
overall
-t [GeV²]
x_B
Q^2 [GeV²]