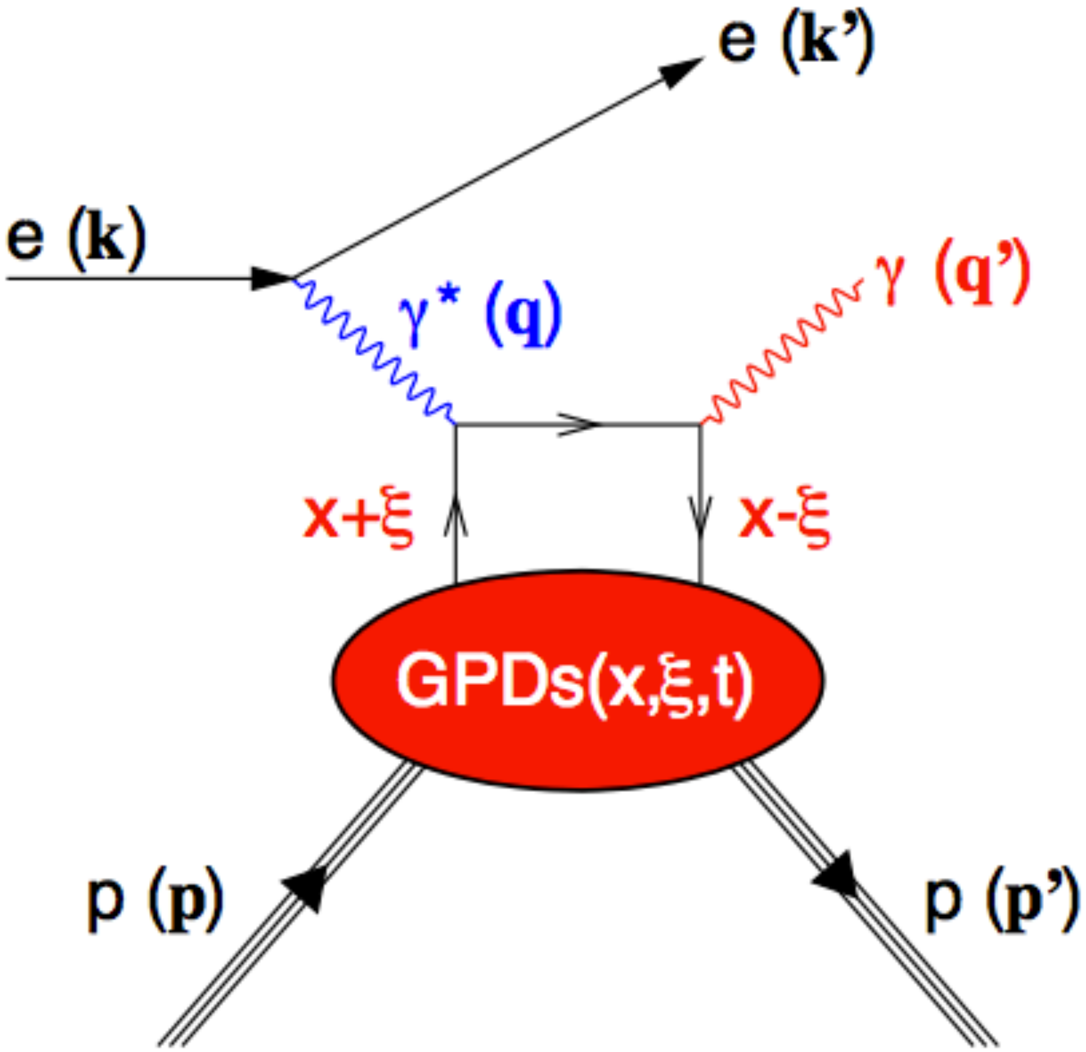
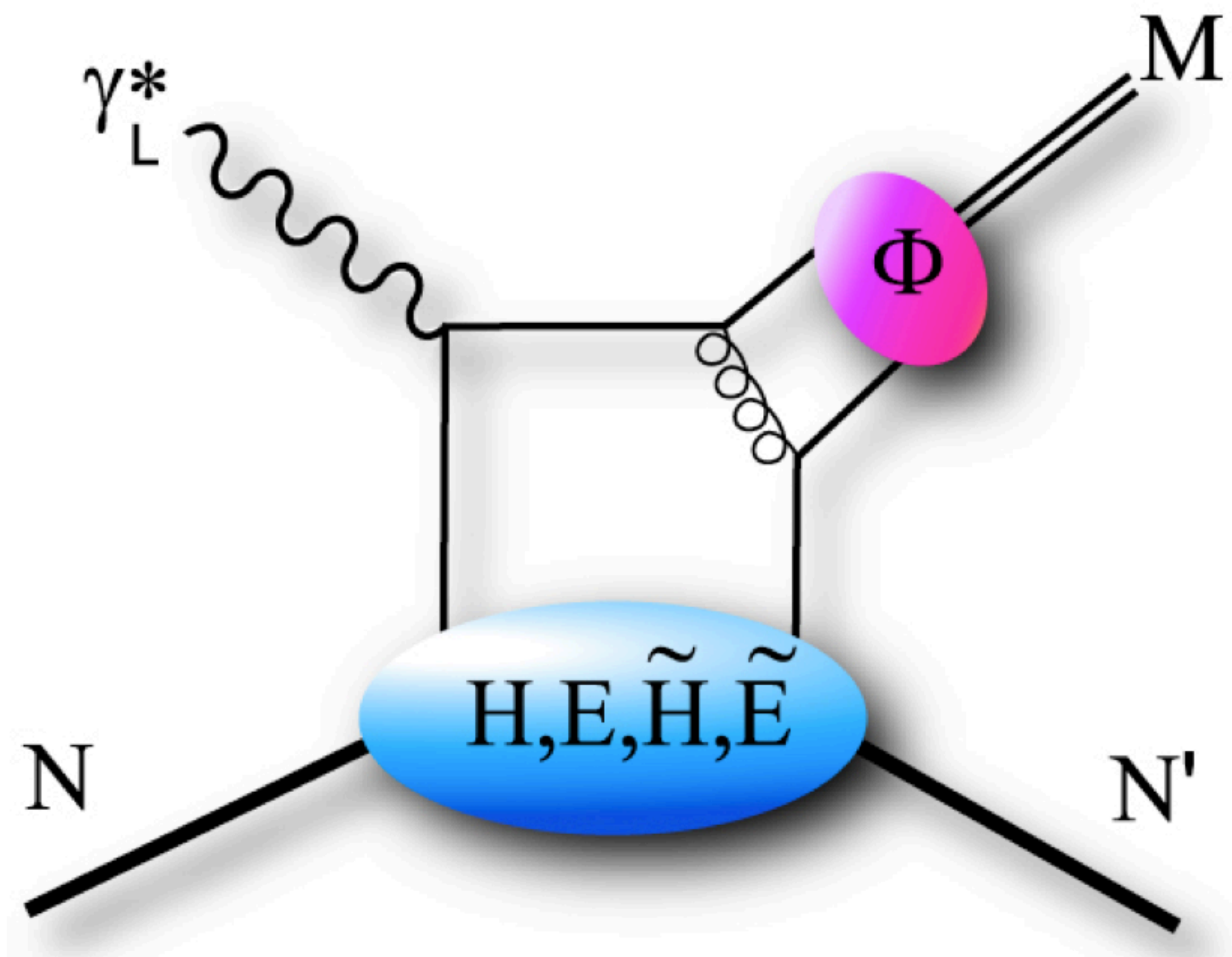
Exclusive Physics @ HERMES

M. MURRAY, UNIVERSITY OF GLASGOW

Baryons 2010

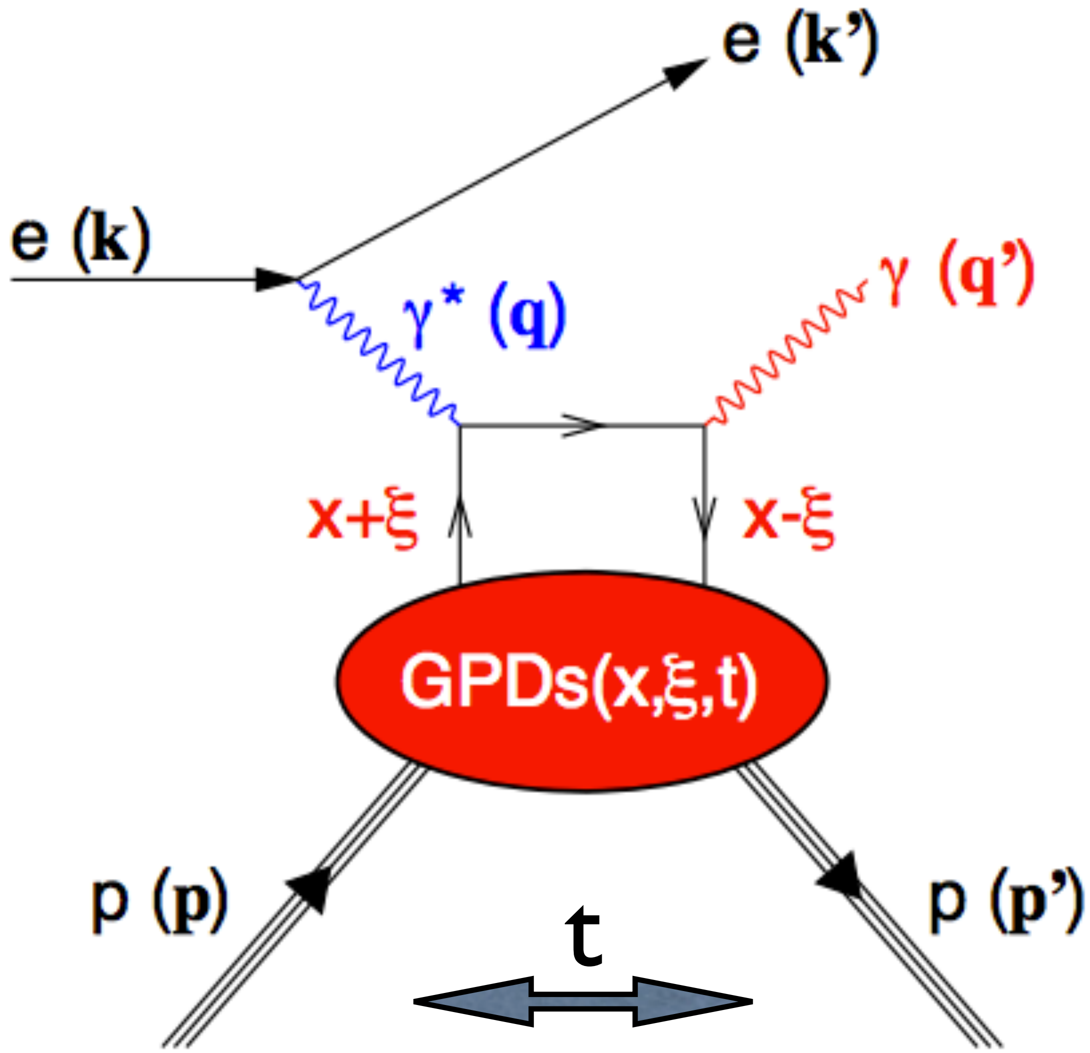
Exclusive Physics





Physics Governed by Generalised Parton Distributions

Generalised Parton Distributions



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.

GPD Physics

Four distributions of interest: H, E, $\tilde{H}$, $\tilde{E}$

H and E integrate over quark helicities
$\tilde{H}$ and $\tilde{E}$ are quark helicity difference distributions

$$J_q = \frac{1}{2} \lim_{t \to 0} \int_{-1}^{1} \left[H^q(x, \xi, t) + E^q(x, \xi, t) \right] x \, dx$$

GPD Physics

Four distributions of interest: H, E, $\tilde{H}$, $\tilde{E}$

H and E integrate over quark helicities

$\tilde{H}$ and $\tilde{E}$ are quark helicity difference distributions

Nucleon helicity inversion

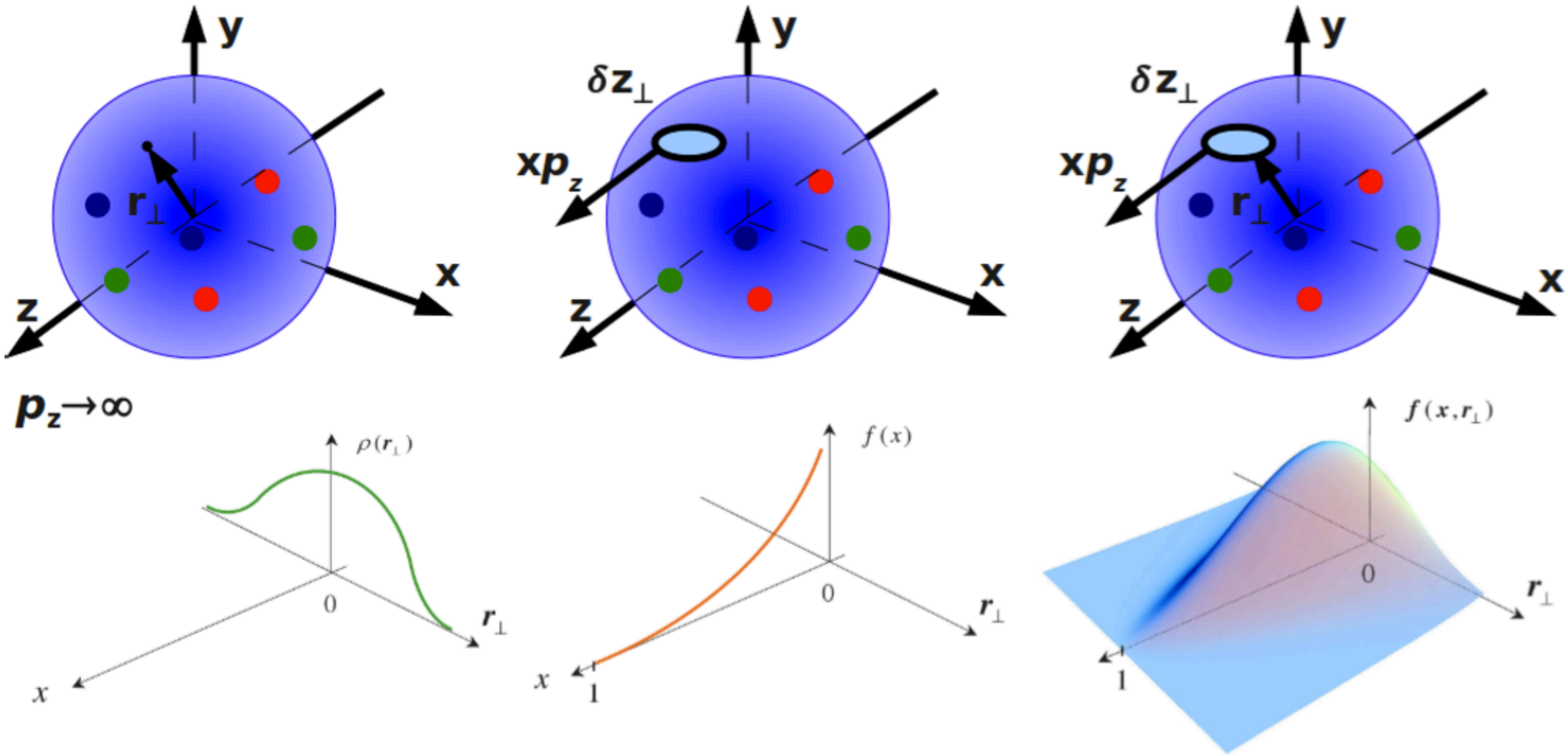
Nucleon helicity conservation

"Ji's Relation"

$$J_q = \frac{1}{2} \lim_{t \to 0} \int_{-1}^{1} \left[H^q(x, \xi, t) + E^q(x, \xi, t) \right] x \, dx$$

Phys. Rev. Lett. 78:610, 1997

GPD Physics

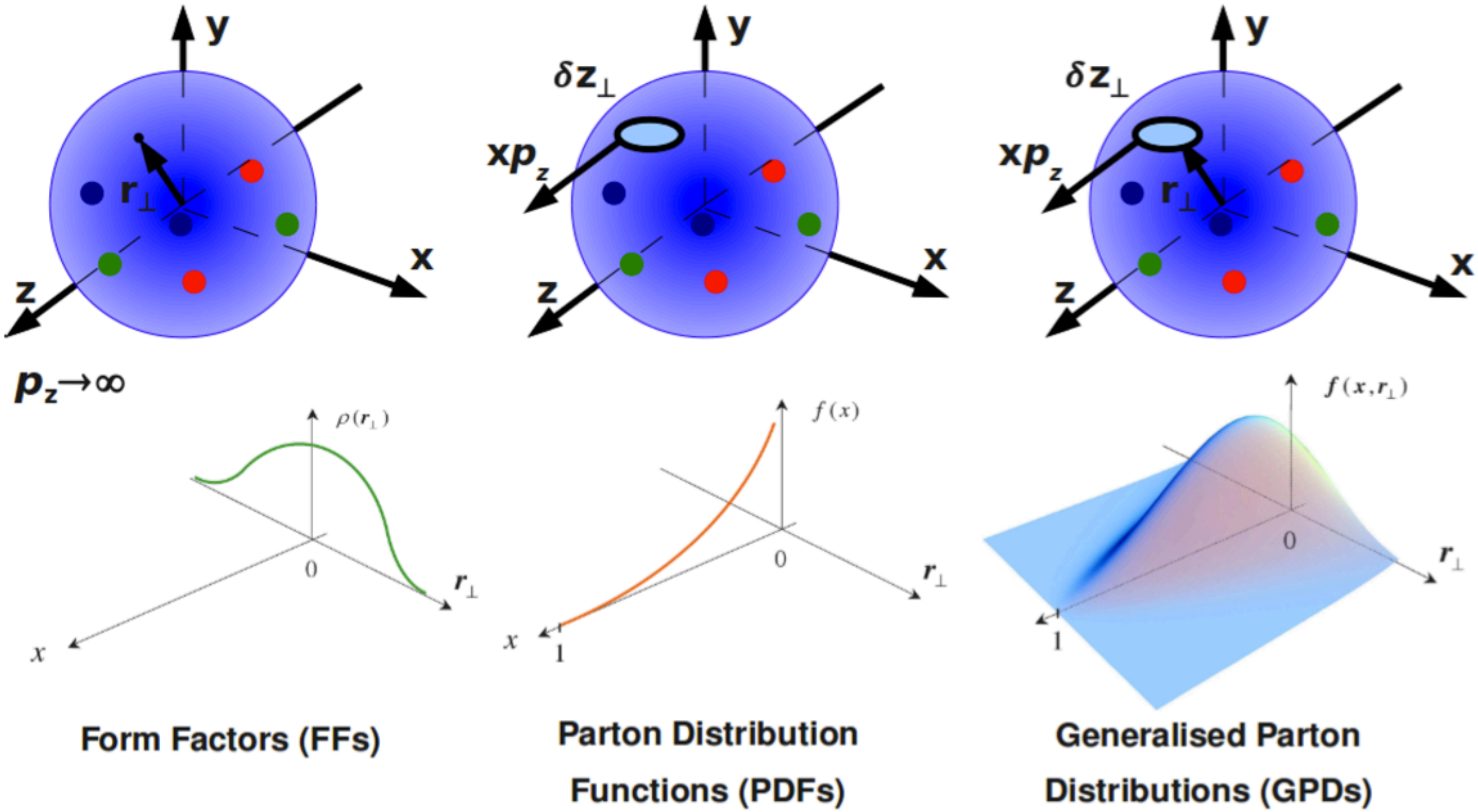


Form Factors (FFs)

Parton Distribution Functions (PDFs)

Generalised Parton Distributions (GPDs)

GPD Physics



H - unpolarised nucleon $\tilde{H}$ - polarised nucleon

GPD Physics

GPDs describe only the soft part of the interaction

Accessed via cross-sections and asymmetries:
requires convolution with a hard scattering kernel

$H \rightarrow \mathcal{H} \qquad \tilde{H} \rightarrow \tilde{\mathcal{H}} \qquad E \rightarrow \mathcal{E} \qquad \tilde{E} \rightarrow \tilde{\mathcal{E}}$

Results in "Compton Form Factors" accessible through
Exclusive Physics, which have real and imaginary parts

GPD Physics

GPDs describe only the soft part of the interaction

Accessed via cross-sections and asymmetries:
requires convolution with a hard scattering kernel

$$\Im m\,\mathcal{F}(\xi,\,t) \;=\; F(\xi,\,\xi,\,t) \pm F(-\xi,\,\xi,\,t)\,,$$

$$\Re e\,\mathcal{F}(\xi,\,t) \;=\; \mathcal{P}_{\mathrm{C}} \int_{-1}^{1} \frac{F(x,\,\xi,\,t)}{x-\xi} \pm \frac{F(x,\,\xi,\,t)}{x+\xi}\, dx$$

GPD Physics

GPDs describe only the soft part of the interaction

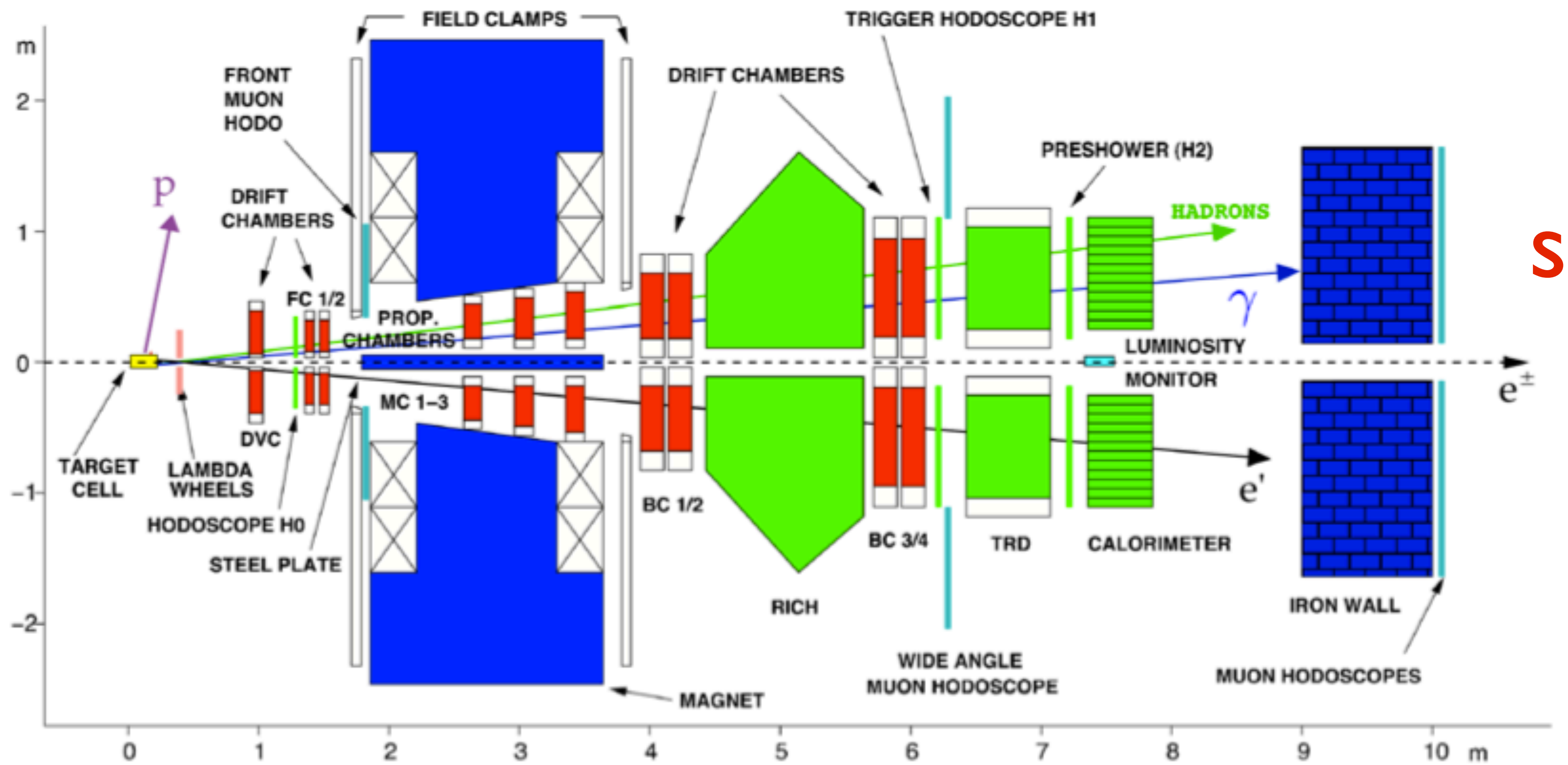
Accessed via cross-sections and asymmetries:
requires convolution with a hard scattering kernel

$$\Im m\,\mathcal{F}(\xi,t) = F(\xi,\xi,t) \pm F(-\xi,\xi,t),$$

$$\Re e\,\mathcal{F}(\xi,t) = \mathcal{P}_C \int_{-1}^{1} \frac{F(x,\xi,t)}{x-\xi} \pm \frac{F(x,\xi,t)}{x+\xi}\,dx$$

Limited *x* access

DVCS @ HERMES



Forward spectrometer ⇒ measure asymmetries directly

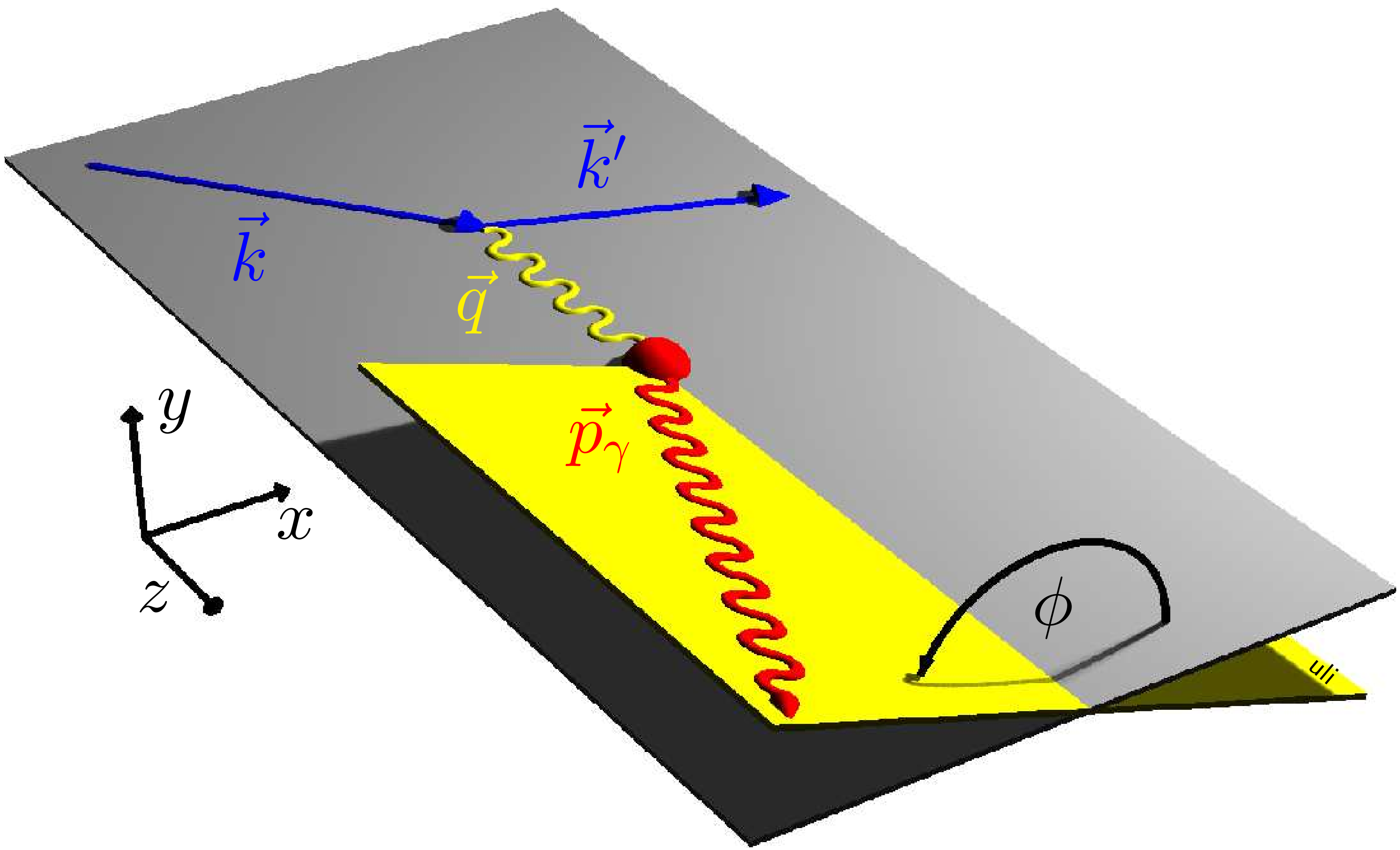
$\langle Q^2 \rangle \cong 2.4\ \mathrm{GeV}^2$

$\langle x_B \rangle \cong 0.1$

$\langle -t \rangle \cong 0.1\ \mathrm{GeV}^2$

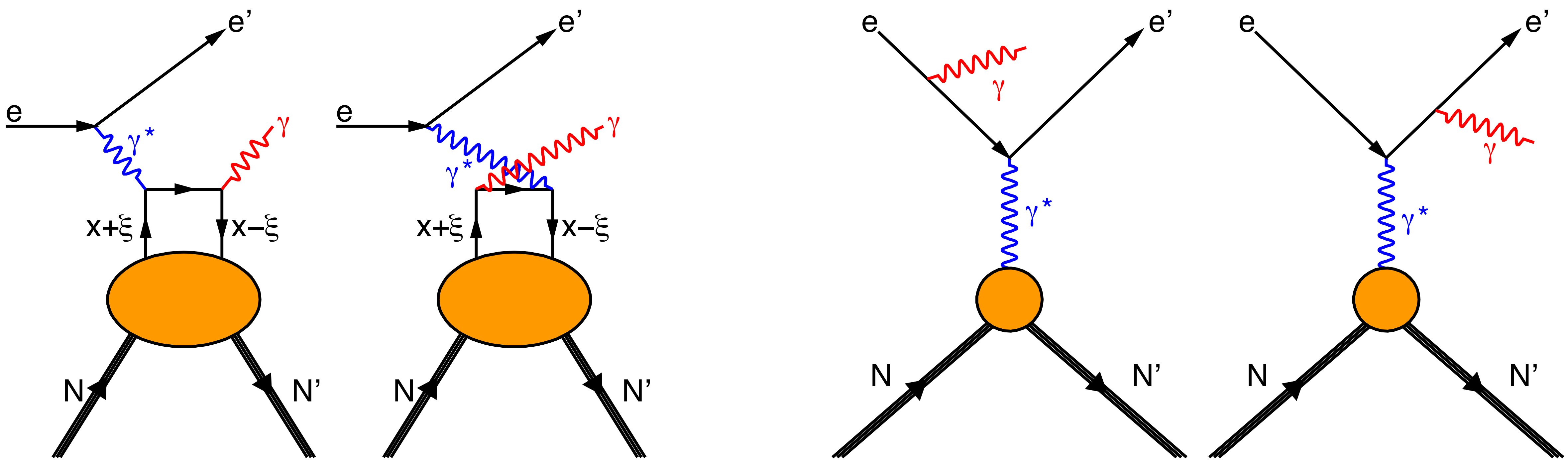
- $1\ \mathrm{GeV}^2 < Q^2 \equiv -q^2 < 10\ \mathrm{GeV}^2$
- $0.03 < x_B < 0.3$
- $0\ \mathrm{GeV}^2 < -t \equiv -(p-p')^2 < 0.7\ \mathrm{GeV}^2$

DVCS @ HERMES



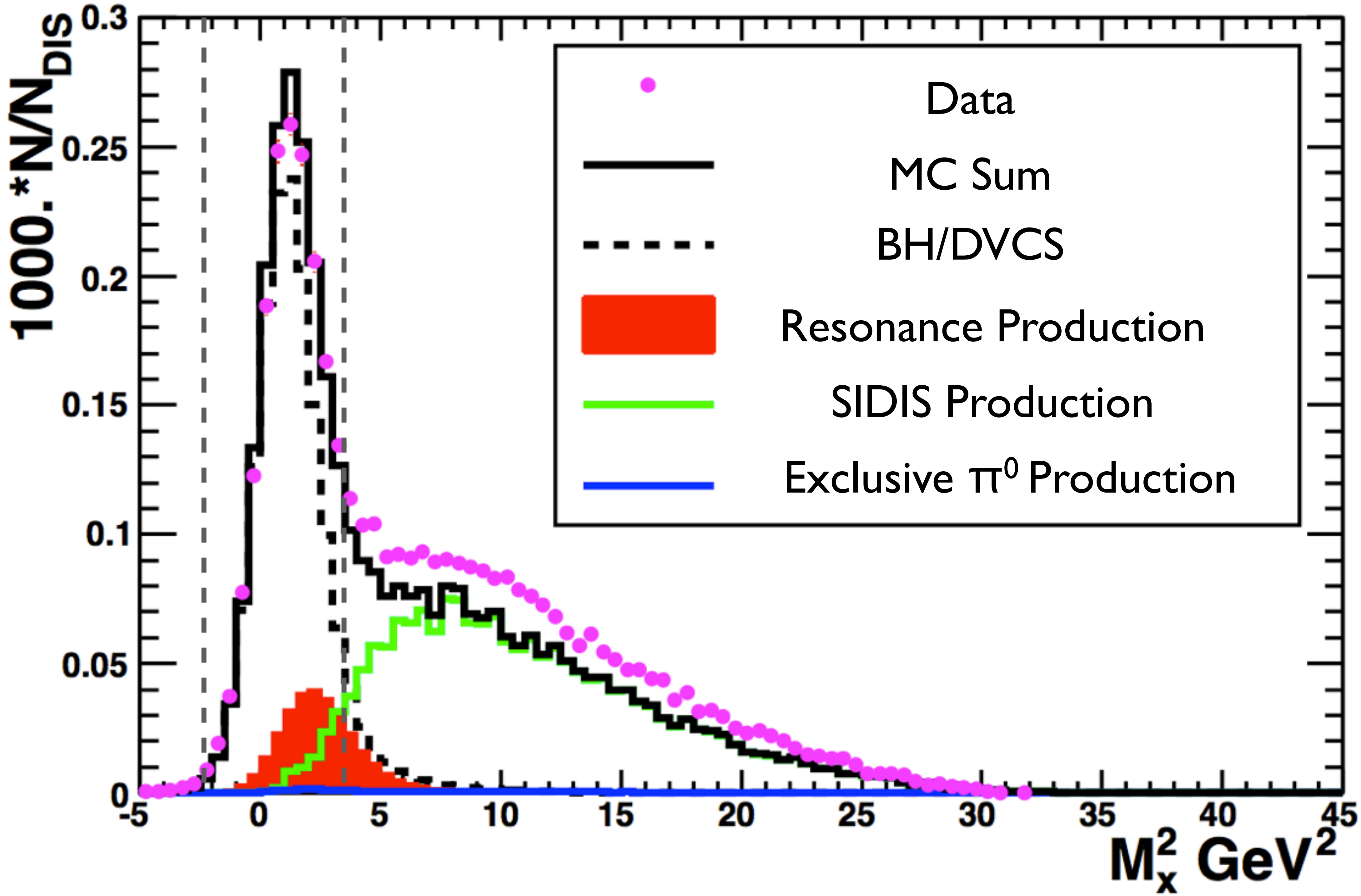
Can also polarize target (anti-)parallel or transverse to γ* direction

DVCS @ HERMES



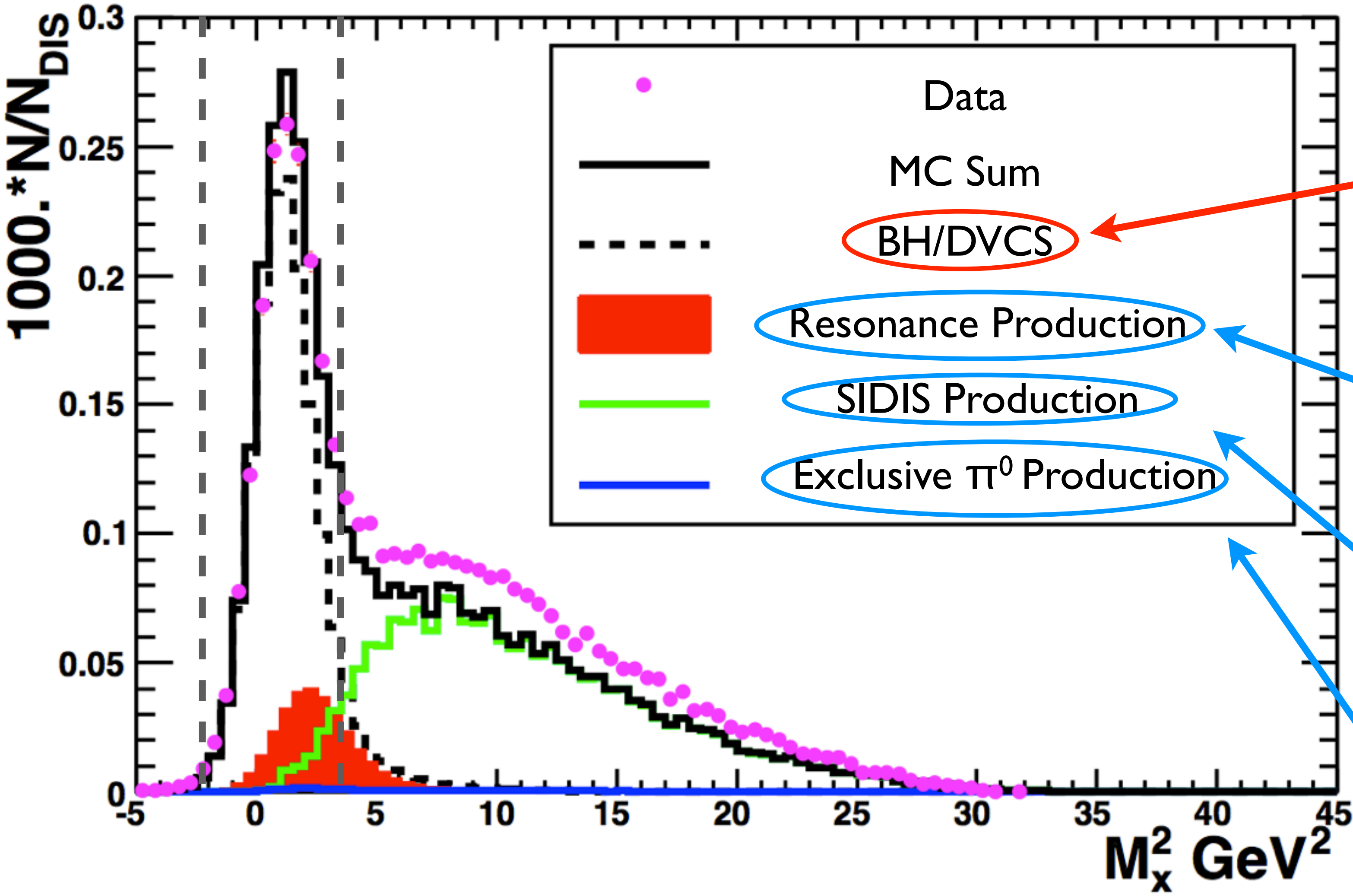
Leptoproduction of real photons has two subprocess: Deeply Virtual Compton Scattering and elastic scattering with Bremsstrahlung.

DVCS @ HERMES



1000.*N/N_DIS
0.3
0.25
0.2
0.15
0.1
0.05
0
-5
0
5
10
15
20
25
30
35
40
45
M_x^2 GeV^2
Data
MC Sum
BH/DVCS
Resonance Production
SIDIS Production
Exclusive π^0 Production

DVCS @ HERMES



Wanted Signal

BH/DVCS from Δ, e.g

$e\,\Delta \rightarrow e\,\Delta\,\gamma \rightarrow e\,p\,\pi^0\,\gamma$

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

$e\,p \rightarrow e\,p\,\pi^0$

DVCS @ HERMES

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

$\longrightarrow$ Beam Spin

$\Longrightarrow$ Target Spin

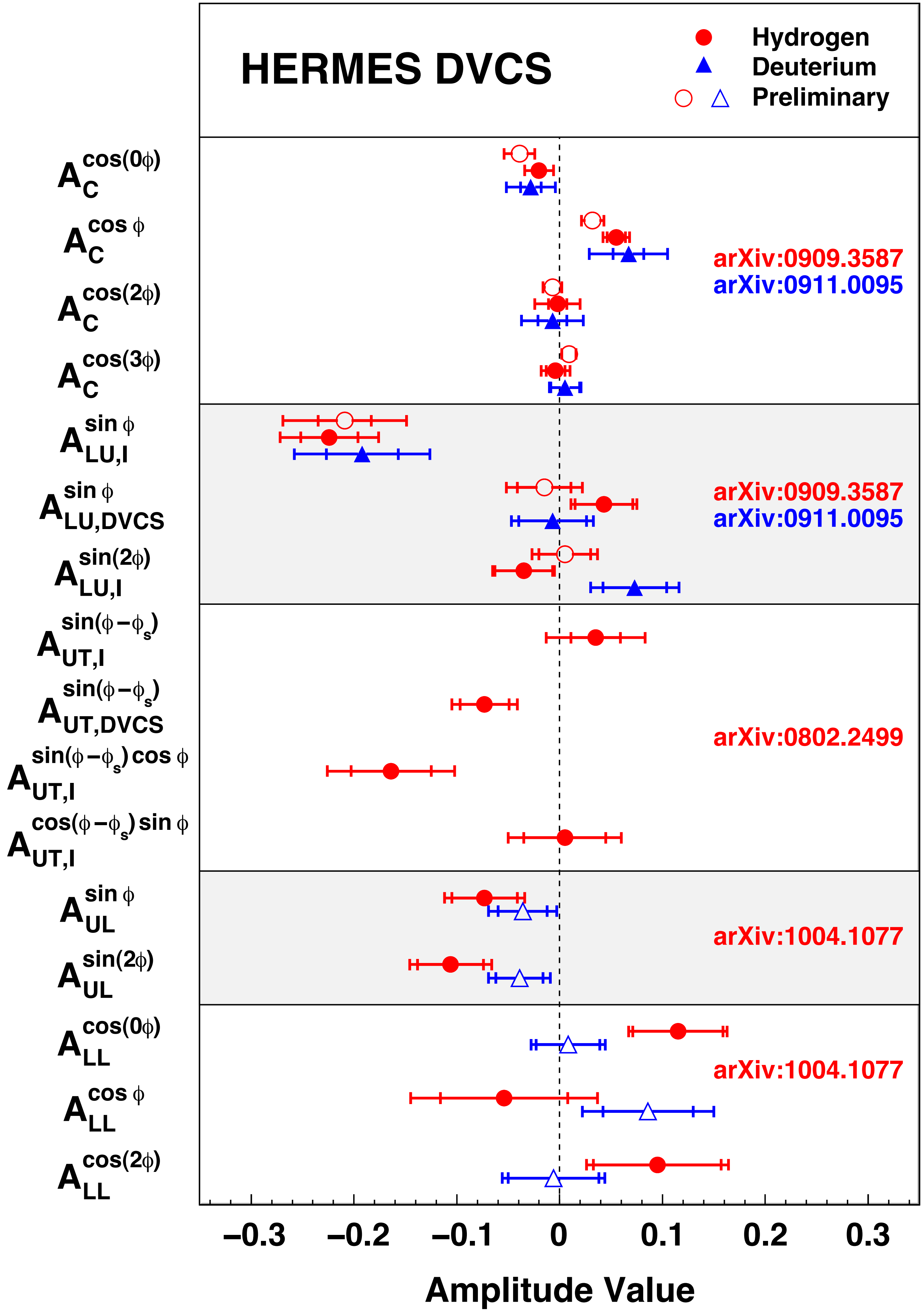
$$\mathcal{A}_{\mathrm{LU}}(\phi) \equiv \frac{[\sigma^{\rightarrow\Leftarrow}(\phi) + \sigma^{\rightarrow\Rightarrow}(\phi)] - [\sigma^{\leftarrow\Leftarrow}(\phi) + \sigma^{\leftarrow\Rightarrow}(\phi)]}{[\sigma^{\rightarrow\Leftarrow}(\phi) + \sigma^{\rightarrow\Rightarrow}(\phi)] + [\sigma^{\leftarrow\Leftarrow}(\phi)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

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

$$\mathcal{A}_{\mathrm{LL}}(\phi) \equiv \frac{[\sigma^{\rightarrow\Rightarrow}(\phi) + \sigma^{\leftarrow\Leftarrow}(\phi)] - [\sigma^{\leftarrow\Rightarrow}(\phi) + \sigma^{\rightarrow\Leftarrow}(\phi)]}{[\sigma^{\rightarrow\Rightarrow}(\phi) + \sigma^{\leftarrow\Leftarrow}(\phi)] + [\sigma^{\leftarrow\Rightarrow}(\phi) + \sigma^{\rightarrow\Leftarrow}(\phi)]} \propto \mathrm{Re}(\tilde{\mathcal{H}})$$

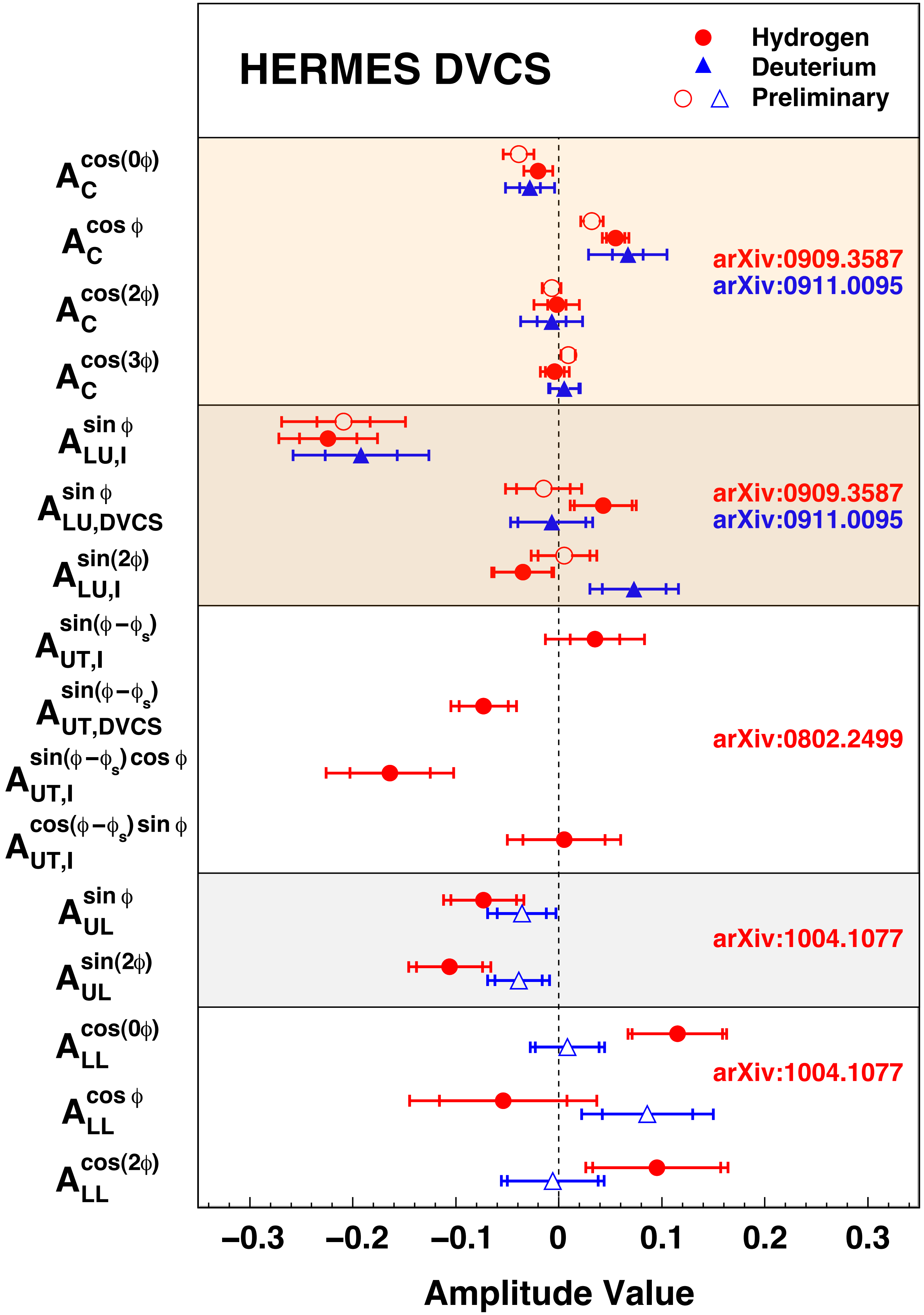
Higher terms in a Fourier decomposition correspond to higher twist and suppression

DVCS @


HERMES DVCS
Hydrogen
Deuterium
Preliminary
arXiv:0909.3587
arXiv:0911.0095
arXiv:0909.3587
arXiv:0911.0095
arXiv:0802.2499
arXiv:1004.1077
arXiv:1004.1077
Amplitude Value
−0.3
−0.2
−0.1
0
0.1
0.2
0.3

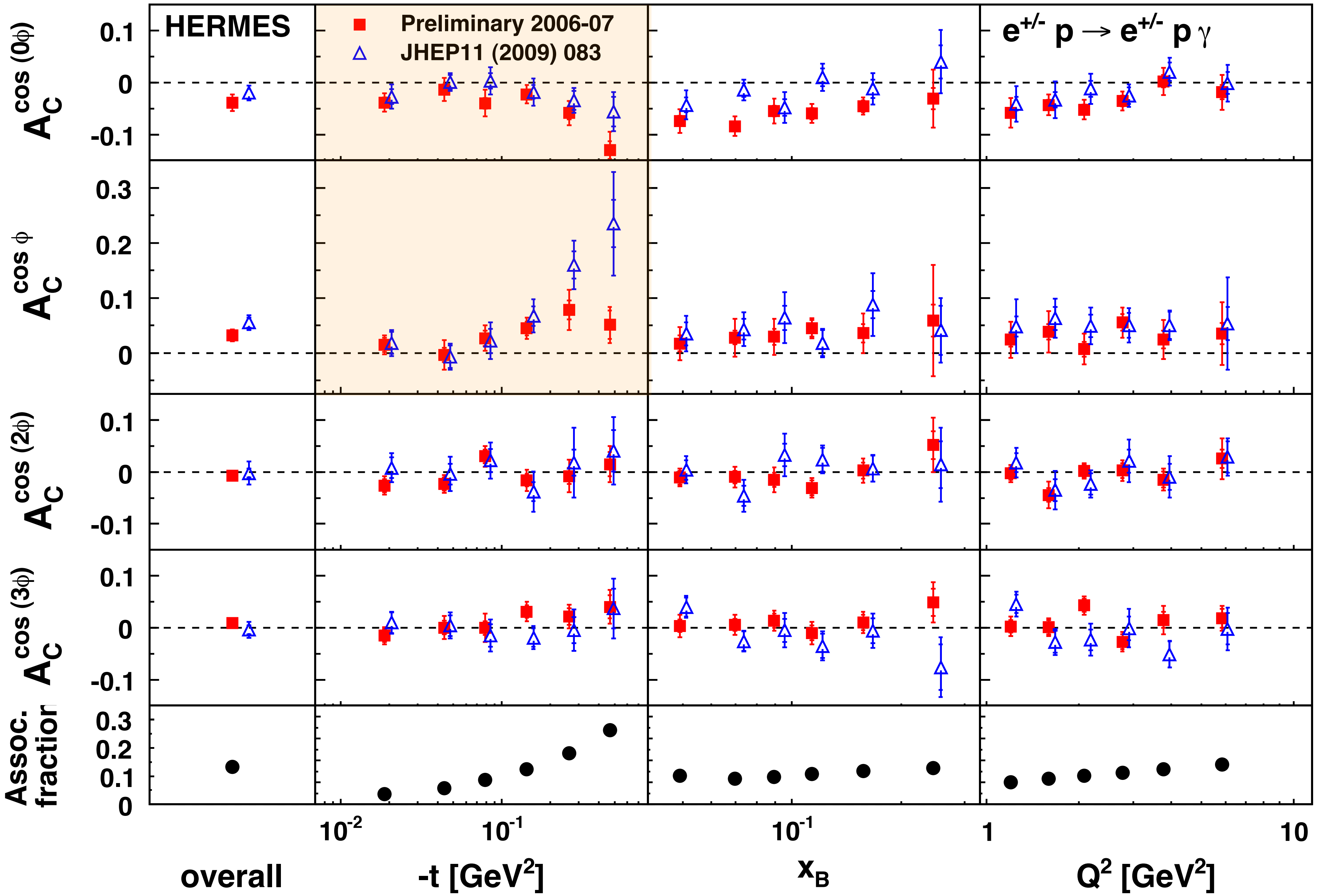
HERMES

DVCS@


HERMES DVCS
Hydrogen
Deuterium
Preliminary
$A_C^{\cos(0\phi)}$
$A_C^{\cos\phi}$
$A_C^{\cos(2\phi)}$
$A_C^{\cos(3\phi)}$
$A_{LU,I}^{\sin\phi}$
$A_{LU,DVCS}^{\sin\phi}$
$A_{LU,I}^{\sin(2\phi)}$
$A_{UT,I}^{\sin(\phi-\phi_s)}$
$A_{UT,DVCS}^{\sin(\phi-\phi_s)}$
$A_{UT,I}^{\sin(\phi-\phi_s)\cos\phi}$
$A_{UT,I}^{\cos(\phi-\phi_s)\sin\phi}$
$A_{UL}^{\sin\phi}$
$A_{UL}^{\sin(2\phi)}$
$A_{LL}^{\cos(0\phi)}$
$A_{LL}^{\cos\phi}$
$A_{LL}^{\cos(2\phi)}$
arXiv:0909.3587
arXiv:0911.0095
arXiv:0909.3587
arXiv:0911.0095
arXiv:0802.2499
arXiv:1004.1077
arXiv:1004.1077
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
Amplitude Value

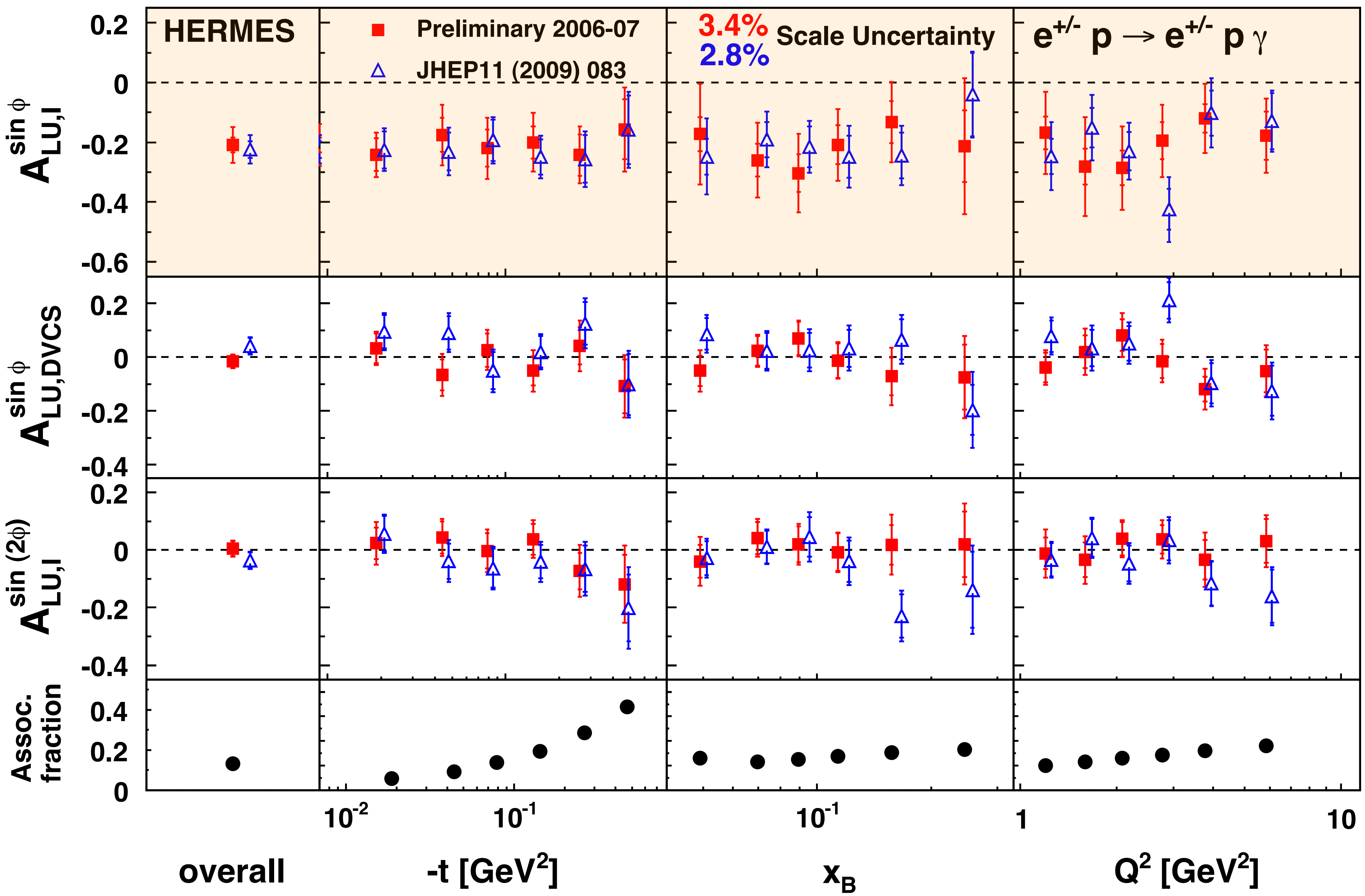
HERMES

Beam Asymmetries



Beam Charge Asymmetries access Re($\mathcal{H}$)

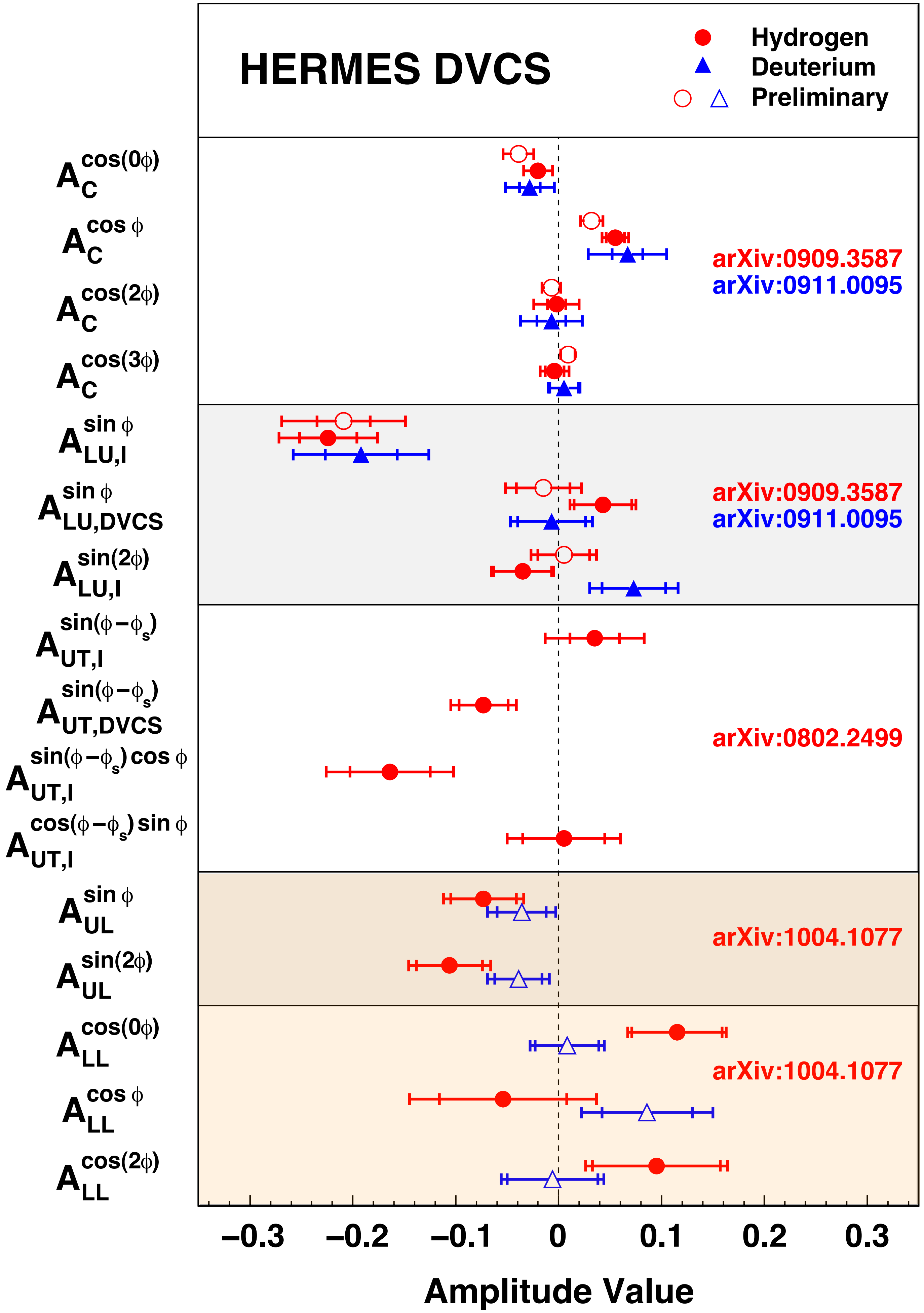
Beam Asymmetries



Beam Helicity Asymmetries access Im($\mathcal{H}$)

Larger values for the BHA than BCA - correlated to the difference in the CFF access?

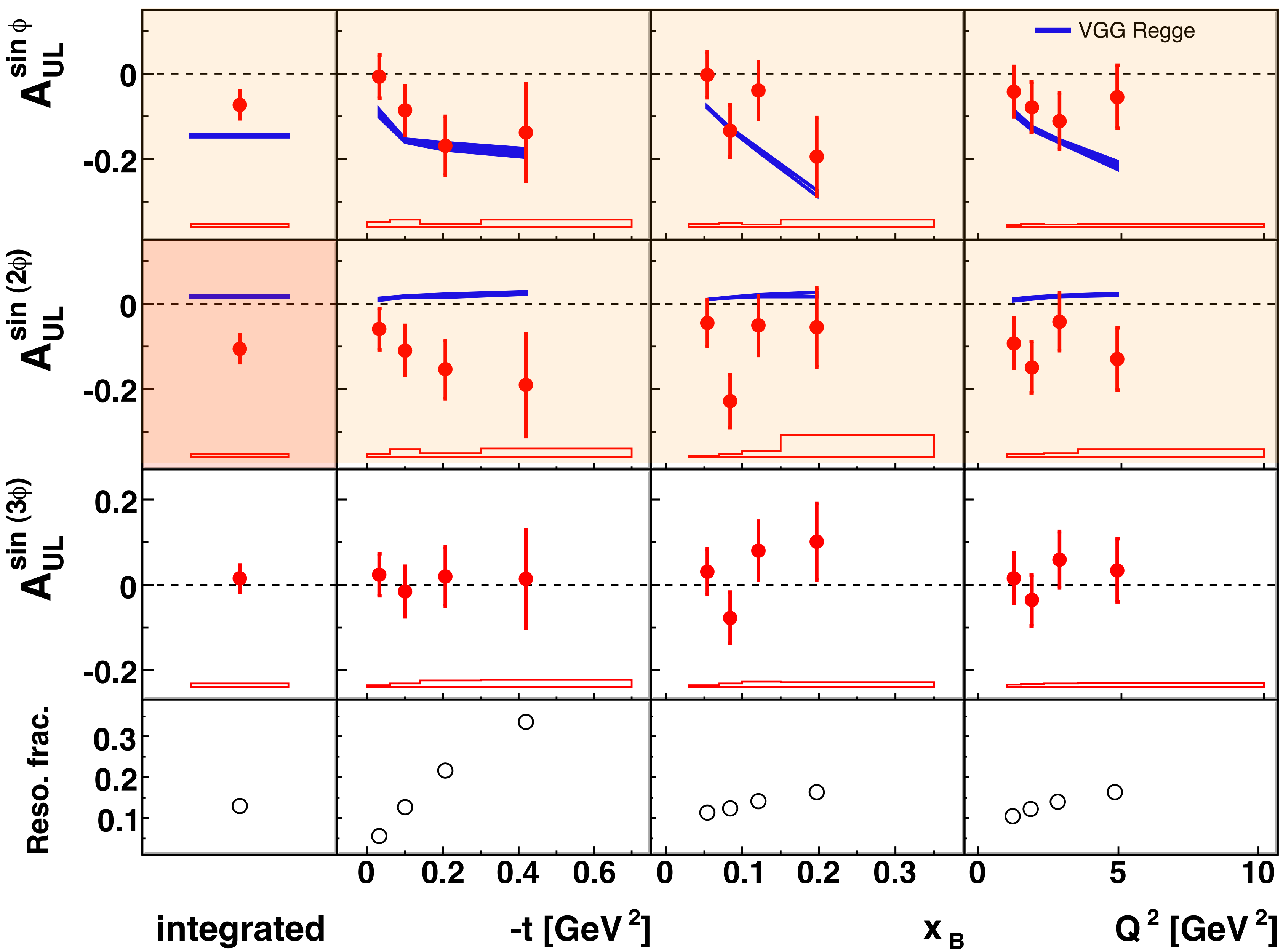
DVCS@



HERMES DVCS
Hydrogen
Deuterium
Preliminary
$A_C^{\cos(0\phi)}$
$A_C^{\cos\phi}$
$A_C^{\cos(2\phi)}$
$A_C^{\cos(3\phi)}$
$A_{LU,I}^{\sin\phi}$
$A_{LU,DVCS}^{\sin\phi}$
$A_{LU,I}^{\sin(2\phi)}$
$A_{UT,I}^{\sin(\phi-\phi_s)}$
$A_{UT,DVCS}^{\sin(\phi-\phi_s)}$
$A_{UT,I}^{\sin(\phi-\phi_s)\cos\phi}$
$A_{UT,I}^{\cos(\phi-\phi_s)\sin\phi}$
$A_{UL}^{\sin\phi}$
$A_{UL}^{\sin(2\phi)}$
$A_{LL}^{\cos(0\phi)}$
$A_{LL}^{\cos\phi}$
$A_{LL}^{\cos(2\phi)}$
arXiv:0909.3587
arXiv:0911.0095
arXiv:0909.3587
arXiv:0911.0095
arXiv:0802.2499
arXiv:1004.1077
arXiv:1004.1077
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
Amplitude Value

HERMES

Target Asymmetries



Long. Pol. target asymmetries access Im($\widetilde{\mathcal{H}}$)

http://arxiv.org/abs/1004.0177

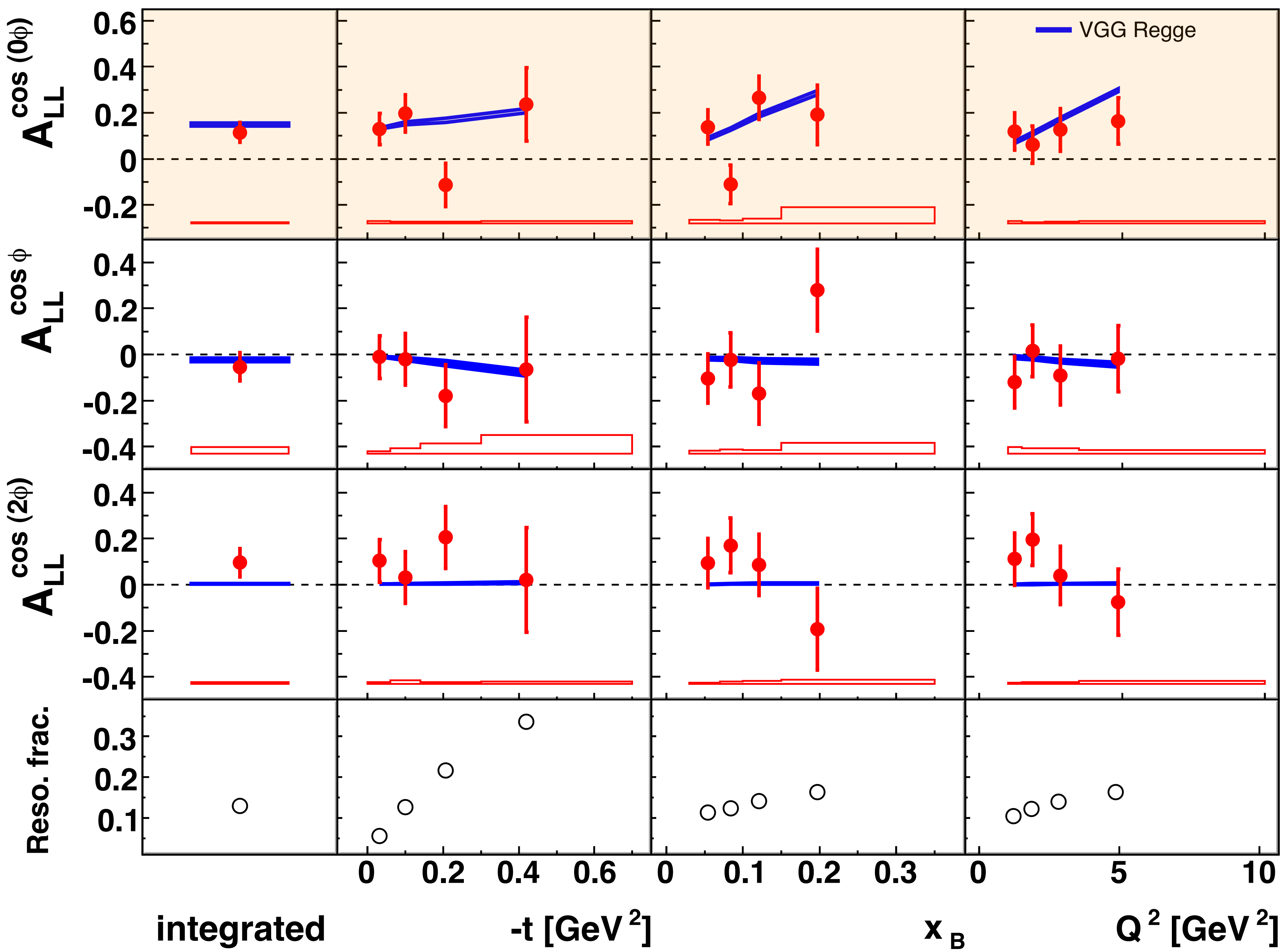
A. Airapetian et al, JHEP 06 (2010) 019

VGG Model:

http://arxiv.org/abs/hep-ph/9905372

Phys.Rev. D60 (1999) 094017

Double Spin Asymmetries



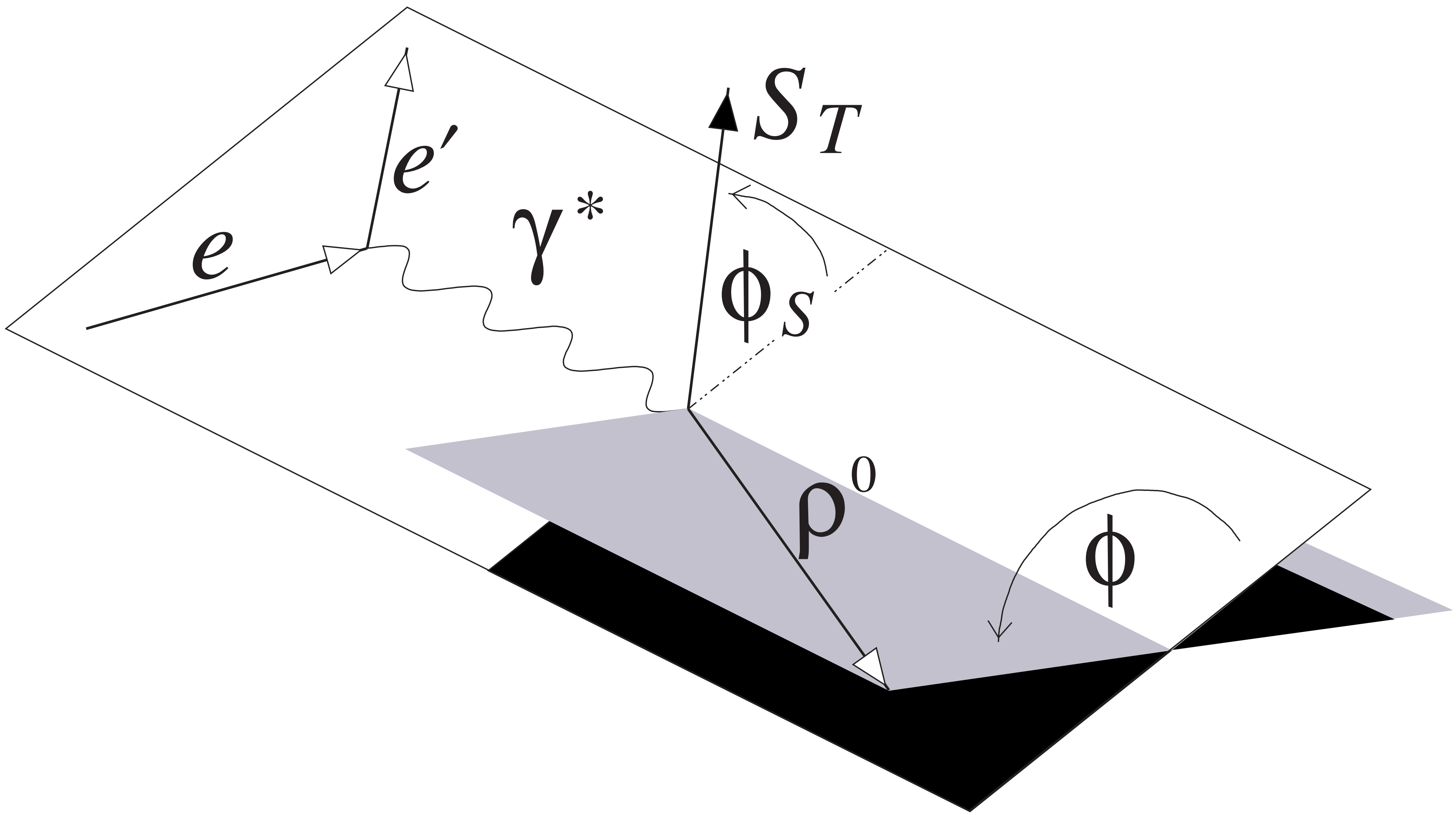
Long. Pol. target / Long. Pol. Beam access Re($\widetilde{\mathcal{H}}$)

Caveat! Relatively large BH contribution to these asymmetries!

http://arxiv.org/abs/1004.0177

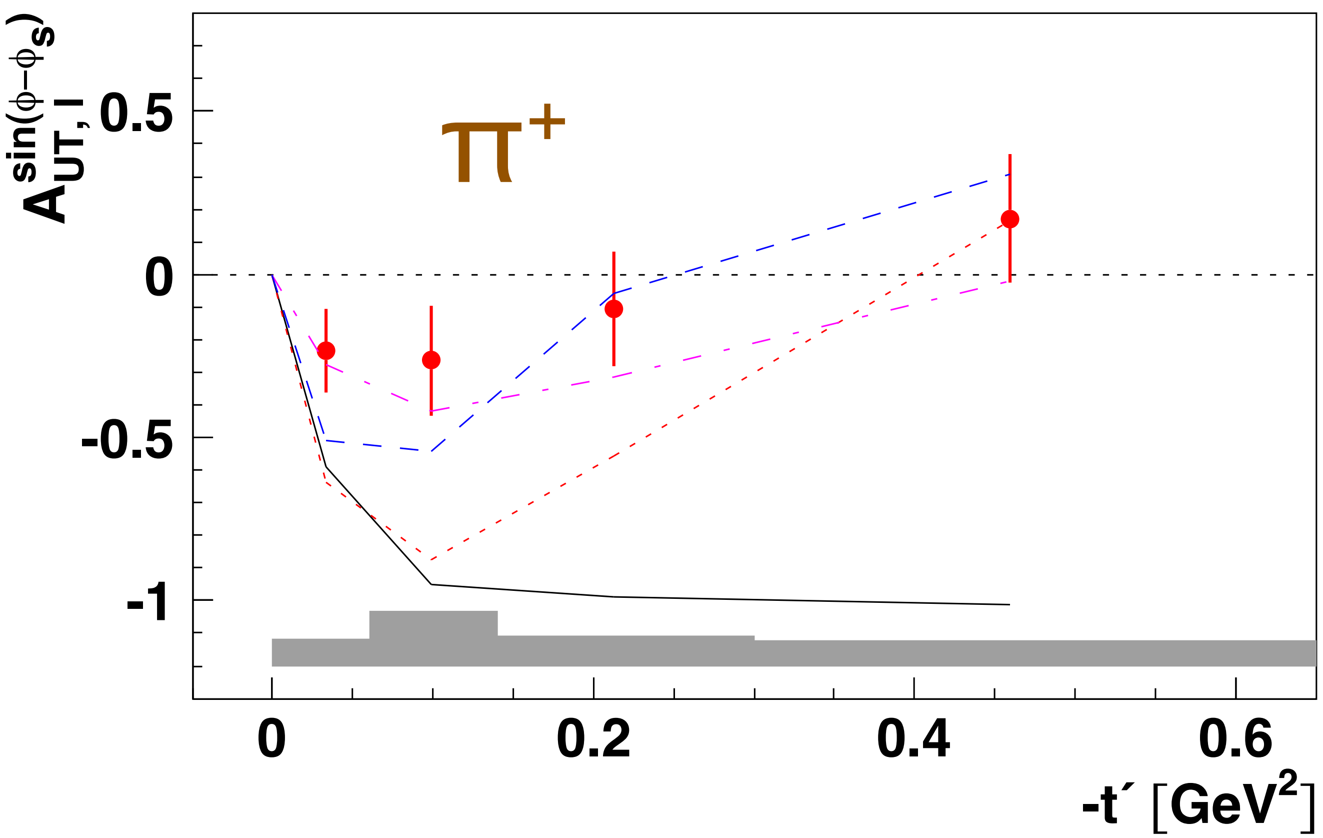
A. Airapetian et al, JHEP 06 (2010) 019

Exclusive Mesons

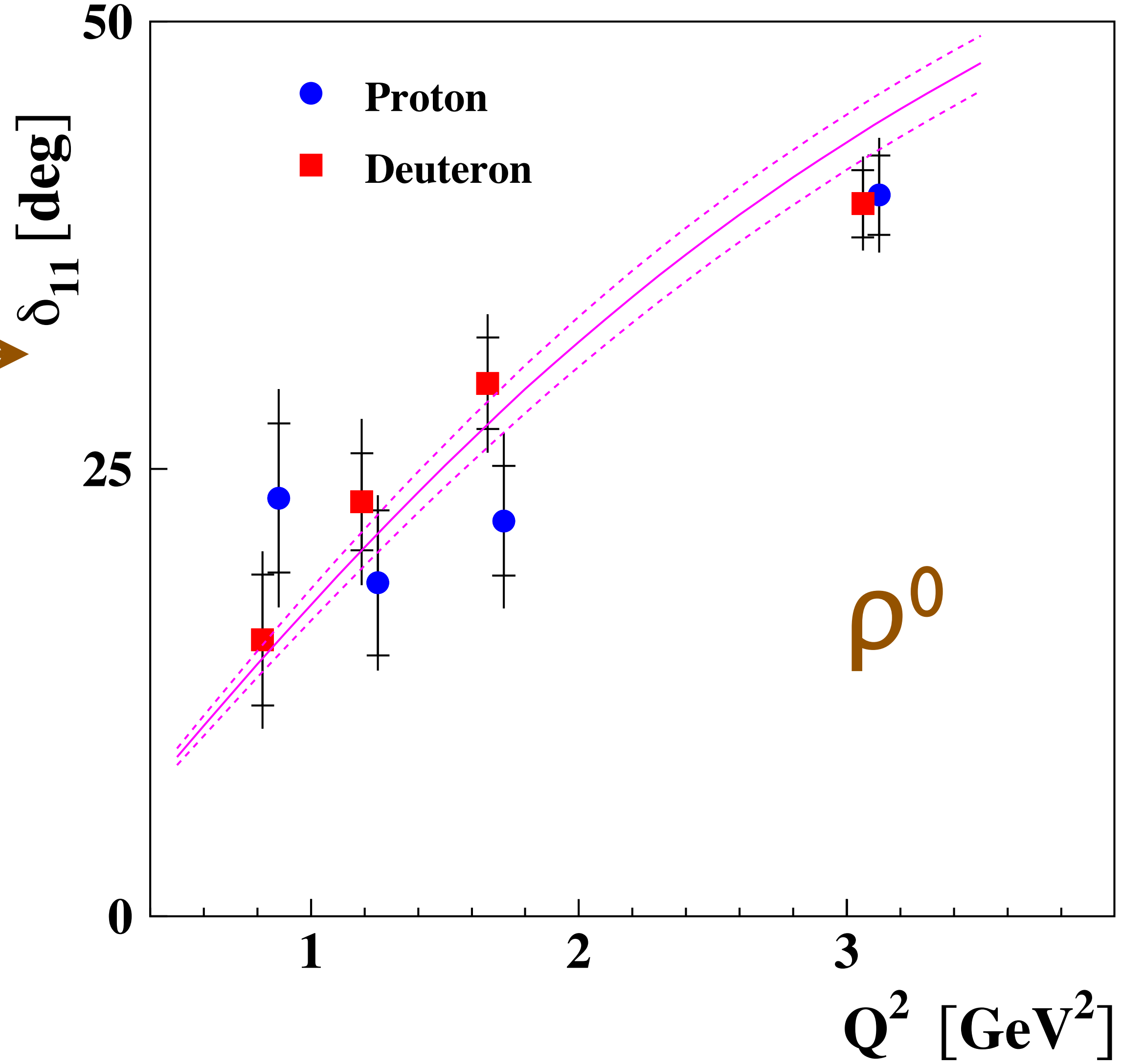


Data taken with all types of polarized targets; average the target polarization to leave unpolarized data

Exclusive Mesons



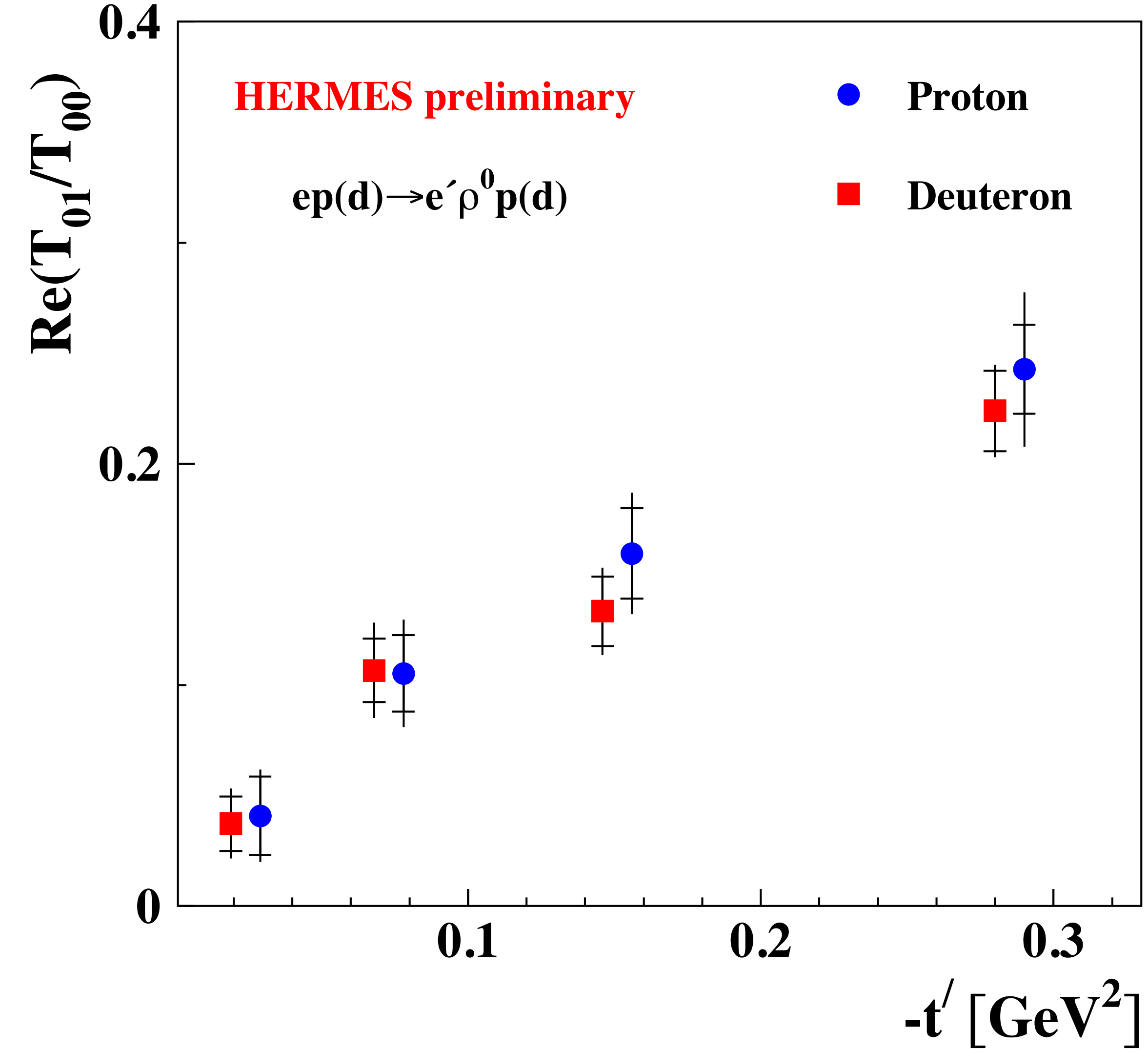
Predictions from GPD models fail to fit the data for polarized targets well.

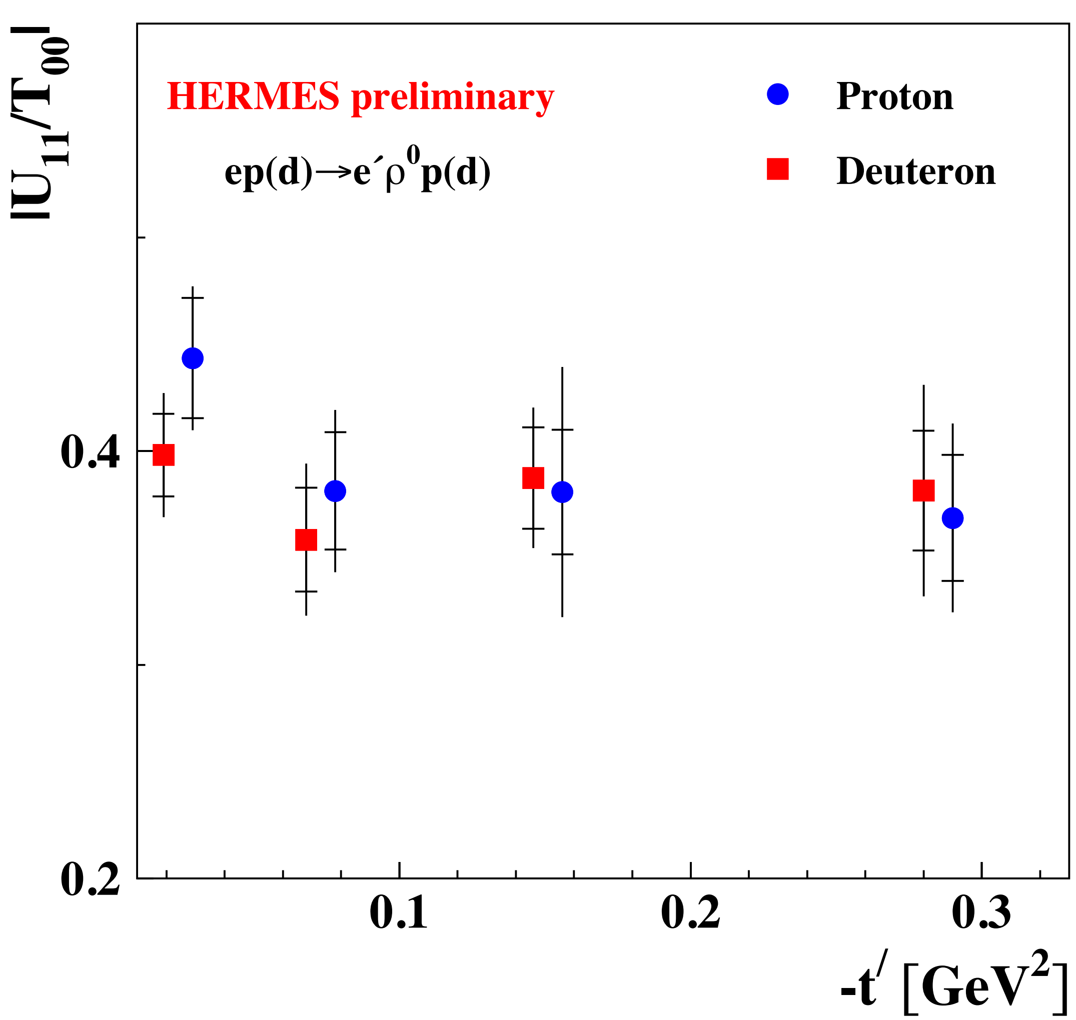


The phase difference between helicity amplitudes T_{11} and T_{00} is much greater than models suggest.

Exclusive Mesons

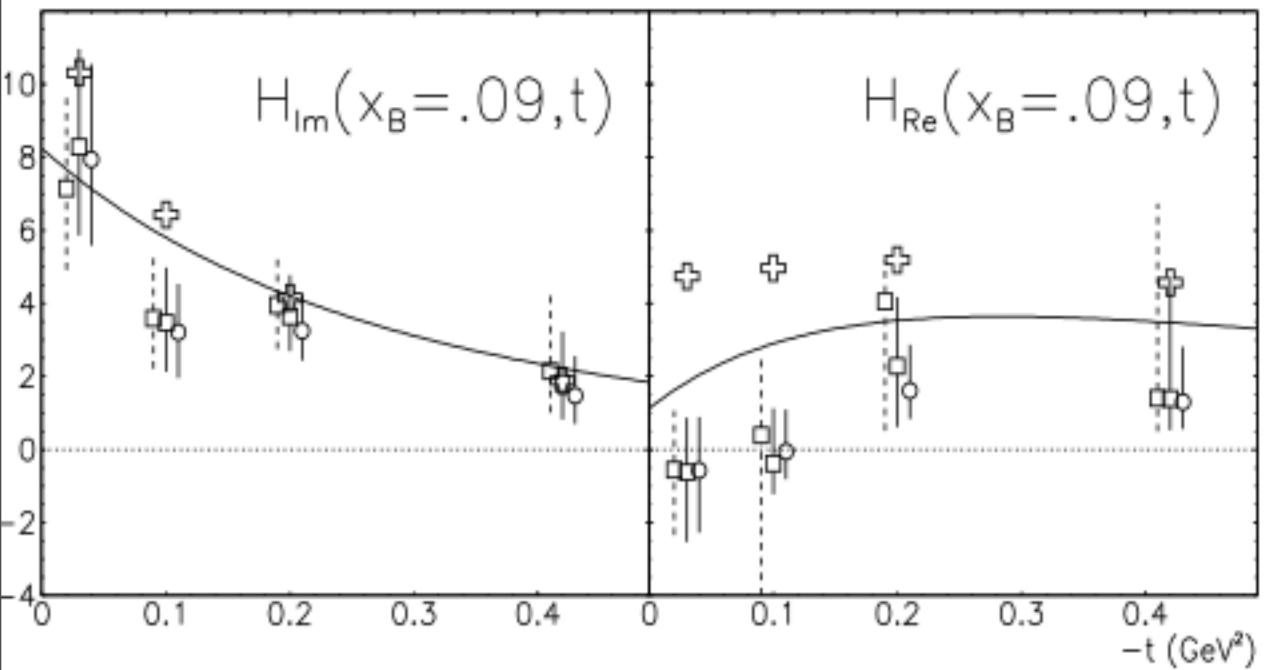
Evidence of S-channel Helicity Conservation violation





Evidence for Unnatural Parity Exchange

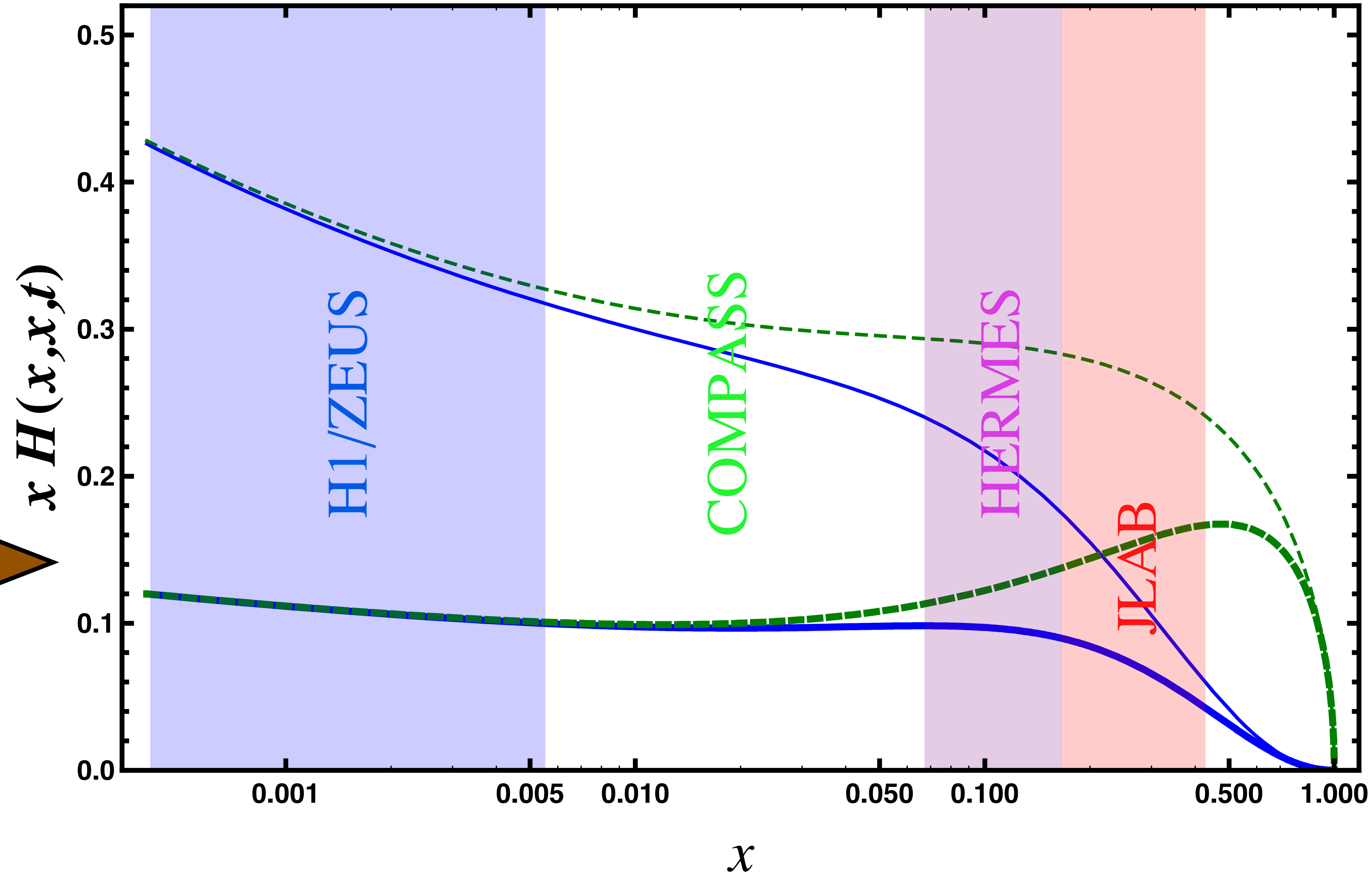
GPD Discovery



http://arxiv.org/abs/1005.4922 *M. Guidal*

New CFF Fit Result incorporating DVCS A_{UL} moments

Postulate GPDs from first principle models



http://arxiv.org/abs/0904.0458

Kumerički and Müller

To appear in Nucl. Phys. B (2010)

Conclusions

- Exclusive Physics can be used to access information on Generalised Parton Distributions
- That information can tell us unique things about nucleon structure
- HERMES' results can help illuminate a path to knowledge of nucleon structure.