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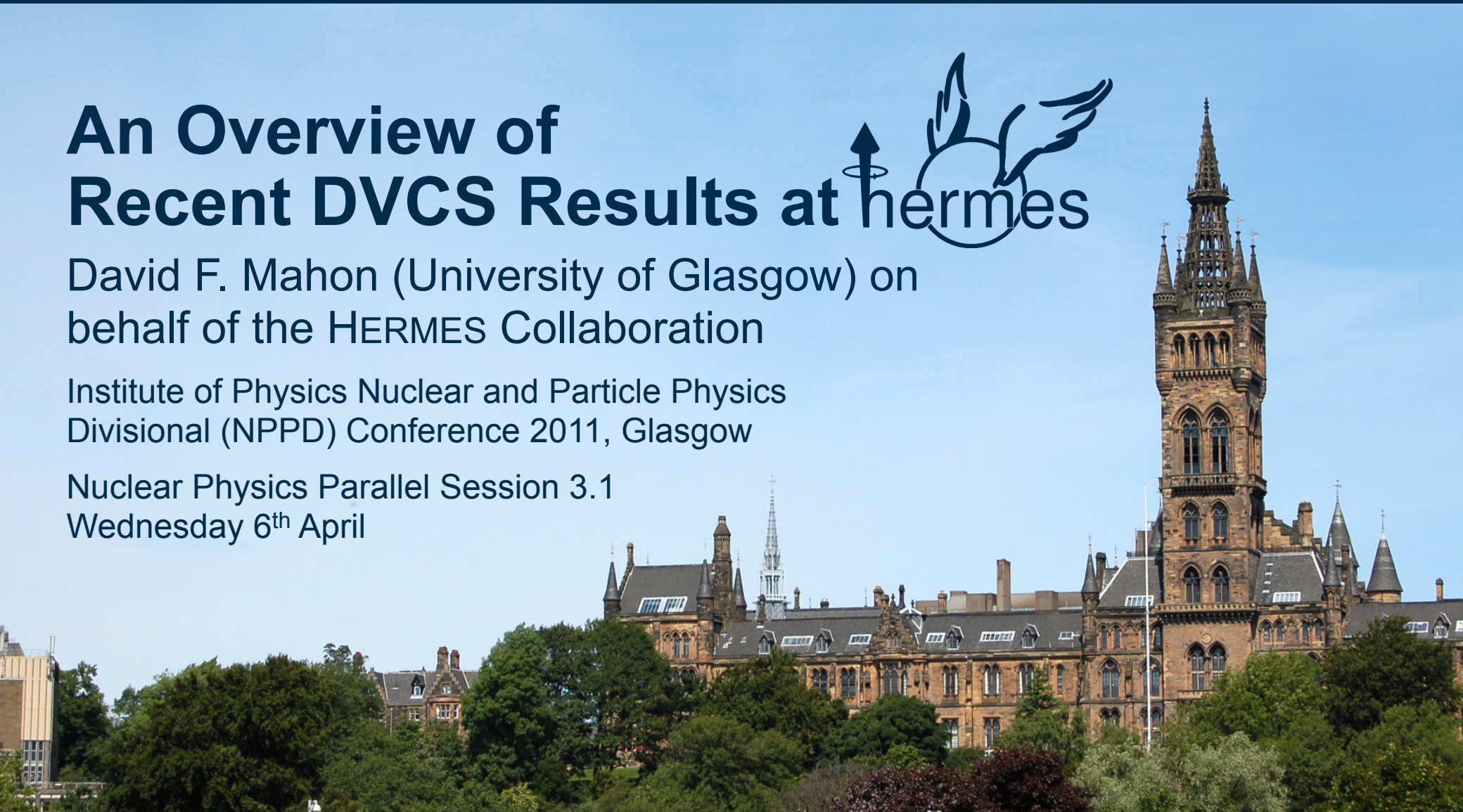
# An Overview of Recent DVCS Results at HERMES

David F. Mahon (University of Glasgow) on behalf of the HERMES Collaboration

Institute of Physics Nuclear and Particle Physics Divisional (NPPD) Conference 2011, Glasgow

Nuclear Physics Parallel Session 3.1
Wednesday 6th April



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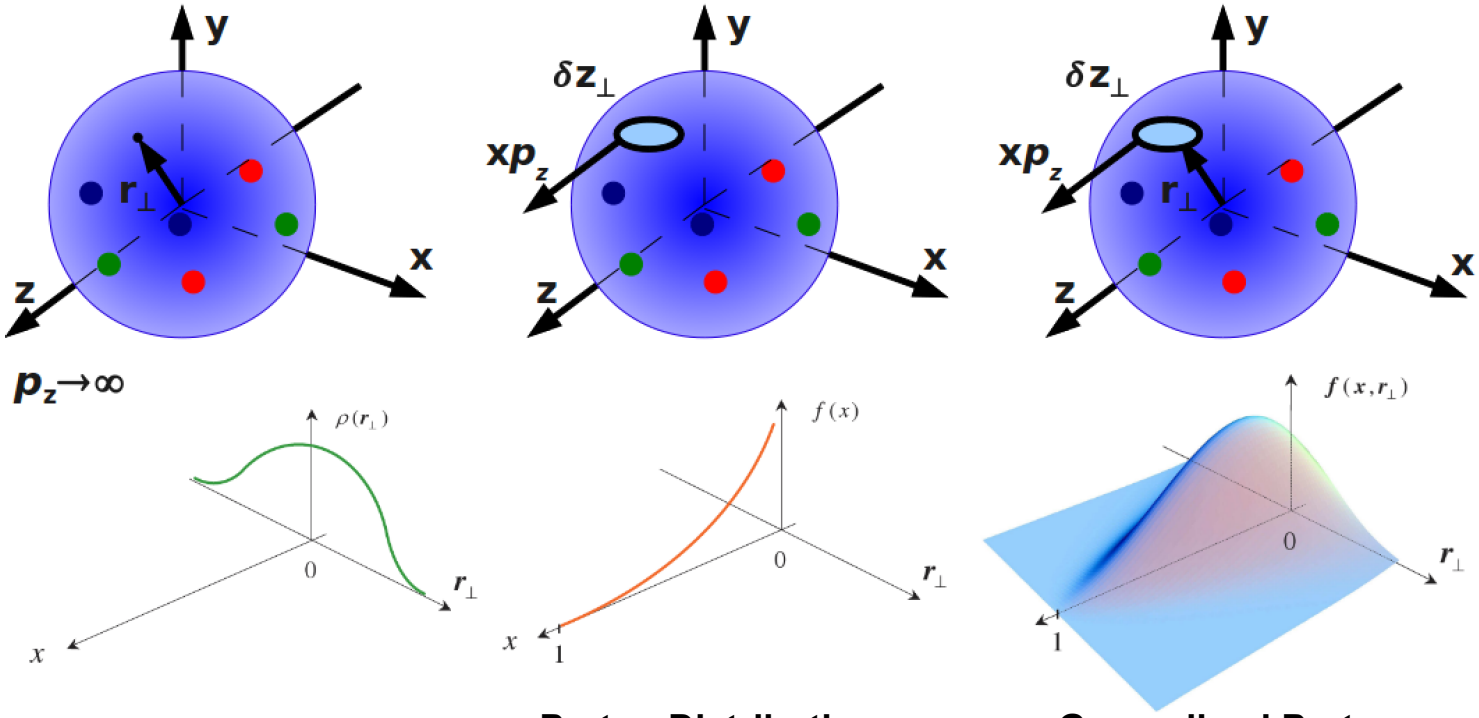
# Generalised Parton Distributions




**Form Factors**

**Parton Distribution Functions**

**Generalised Parton Distributions (GPDs)**

There are four spin-½ GPDs at leading-twist: $H(x, \xi, t)$, $E(x, \xi, t)$, $\widetilde{H}(x, \xi, t)$ and $\widetilde{E}(x, \xi, t)$.
Results of Deeply Virtual Compton Scattering at HERMES can provide information on three of them.

Ji Relation:
*Phys. Rev. Lett.* **78** (1997) 610

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

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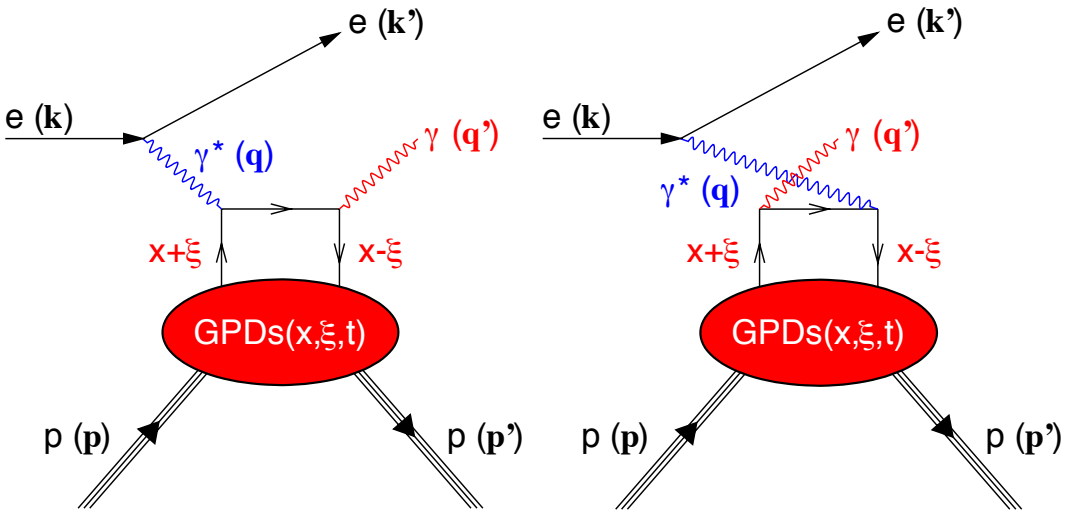
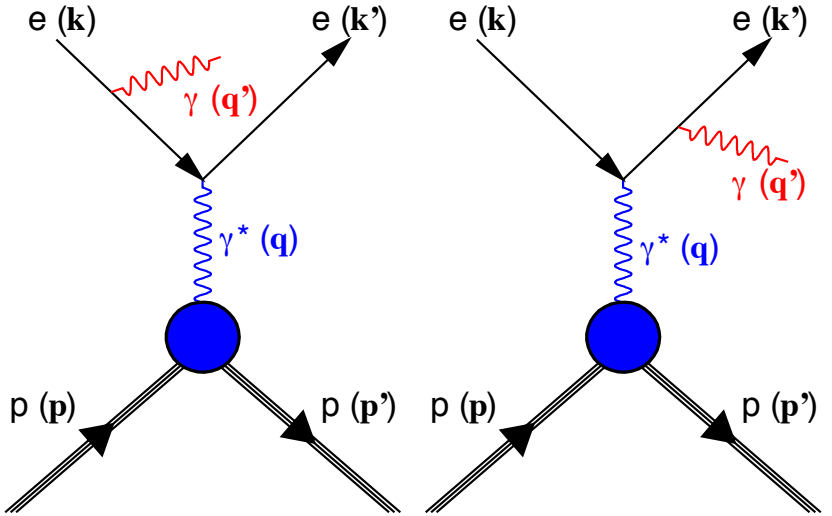
# The ep→epγ Interaction




**Deeply Virtual Compton Scattering**




**Bethe-Heitler**

$$\frac{d\sigma}{dx_{\mathrm{B}}\,dQ^2\,d|t|\,d\phi} = \frac{x_{\mathrm{B}}e^6\left|\tau_{\mathrm{DVCS}}+\tau_{\mathrm{BH}}\right|^2}{32(2\pi)^4Q^4\sqrt{1+\epsilon^2}}$$

$$t \equiv (\mathbf{p}-\mathbf{p}')^2$$
$$Q \equiv -\mathbf{q}^2$$
$$\xi \simeq \frac{x_{\mathrm{B}}}{2-x_{\mathrm{B}}}$$
$$x_{\mathrm{B}} \equiv \frac{Q^2}{2(\mathbf{p}\cdot\mathbf{q})}$$

- Bethe-Heitler (BH) is the dominant contribution at HERMES kinematics.
- From the interference term, information relating to Compton Form Factors (CFFs) can be accessed via cross-section asymmetries.
- These CFFs each relate to a corresponding GPD via a convolution with the hard-scattering kernel.

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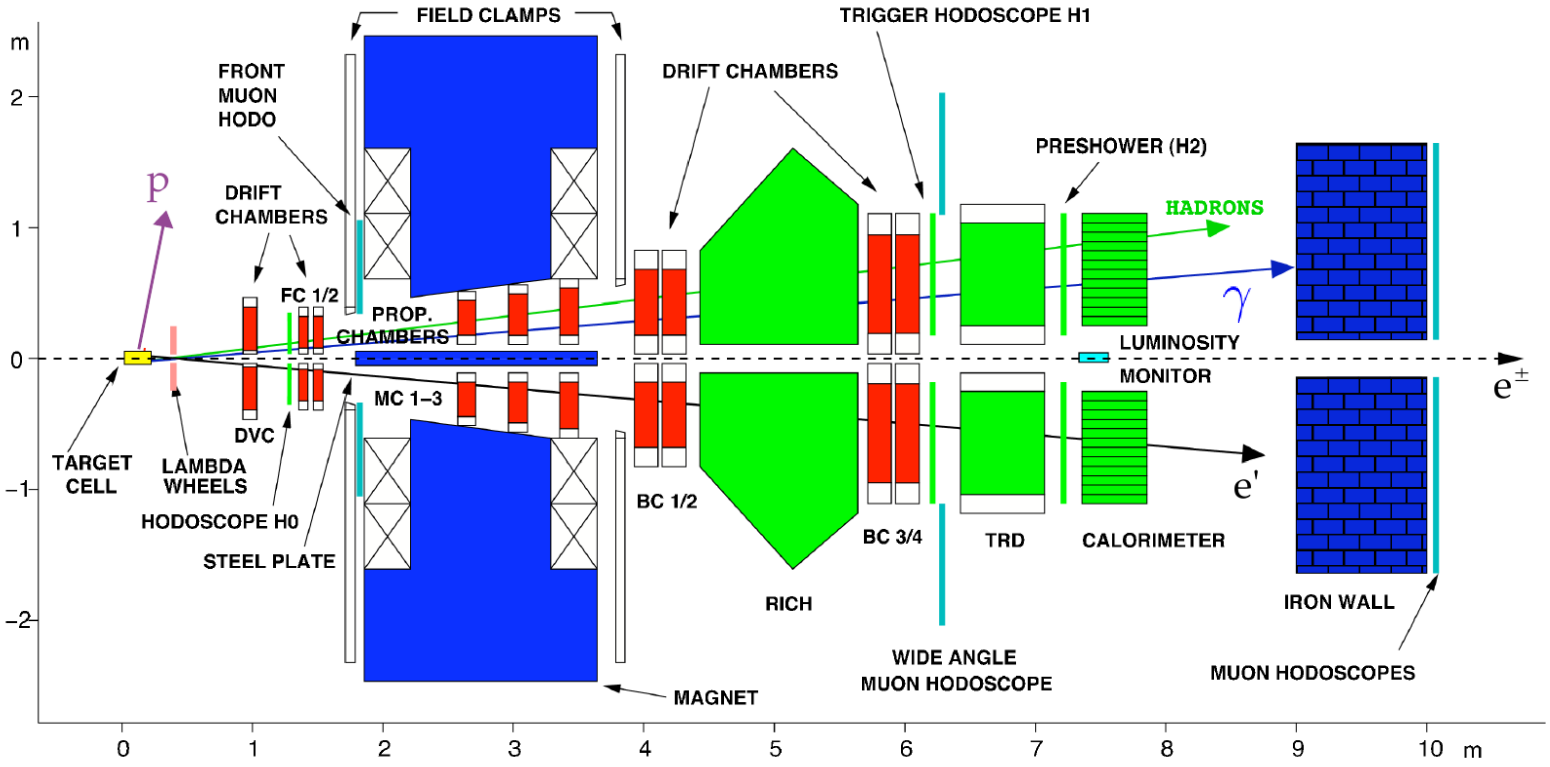
The hermes Experiment




27.6GeV long. polarised (~50%) $e^{\pm}$ beam

- Data taken from 1996-2005 with a variety of (un)polarised gas targets (H, D, He, N, Ne, Ar, Kr and Xe).
- Recoil Detector installation completed in mid-2006. Data (unpolarised H and D) were taken until the HERMES shutdown in mid-2007.

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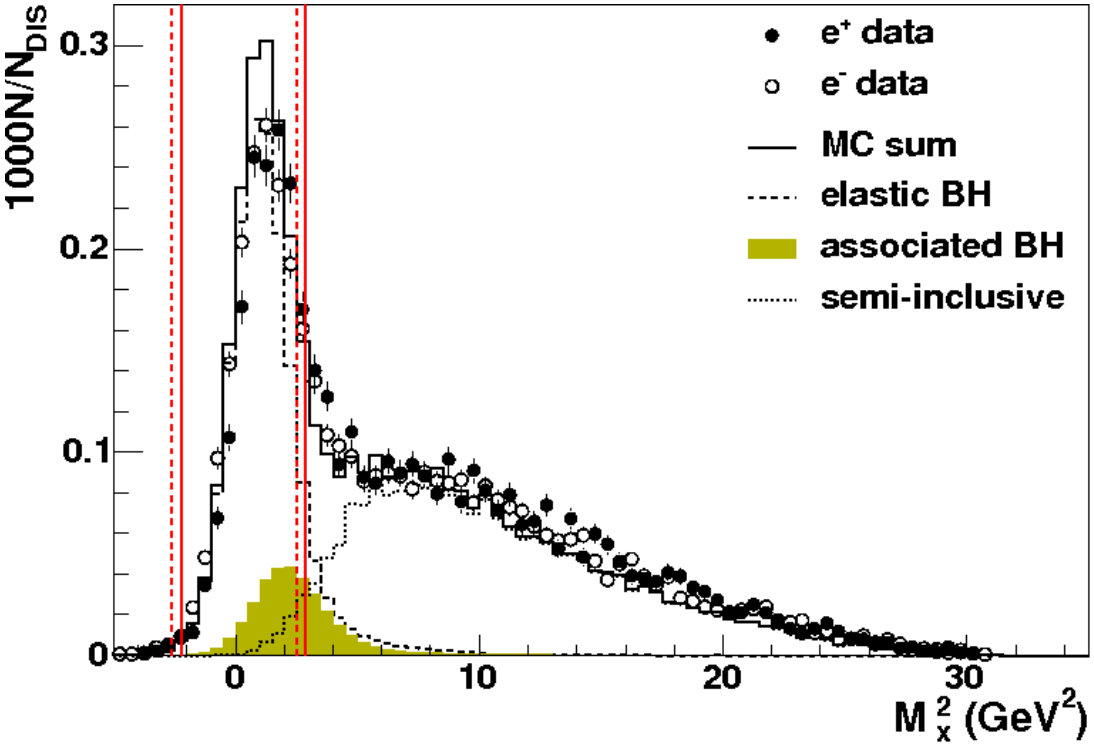
# A Quick Guide to...
# ...HERMES DVCS Event Selection




- One electron and one 'neutral cluster' detected in the calorimeter.
- Fiducial volume and kinematic requirements are imposed:

$$0.03 \le x_B \le 0.35;\ \ 1\text{GeV} \le Q^2 \le 10\text{GeV}$$
$$-t < 0.7\text{GeV};\ \ W > 3\text{GeV}$$

- The reconstructed 'missing-mass' $M_X$ from the $ep \rightarrow e\gamma X$ interaction is required to be close to that of the proton mass (red window).

- The analysed data sample is subject to various forms of background
  - **Associated BH**: Involves the scattering off, or production of, an excited state of the proton
  - **Semi-inclusive neutral meson production**, e.g., the detected $\gamma$ is from a $2\gamma$ decay of a $\pi^0$
  - Exclusive $\pi^0$: Thought to be negligible at HERMES kinematics.

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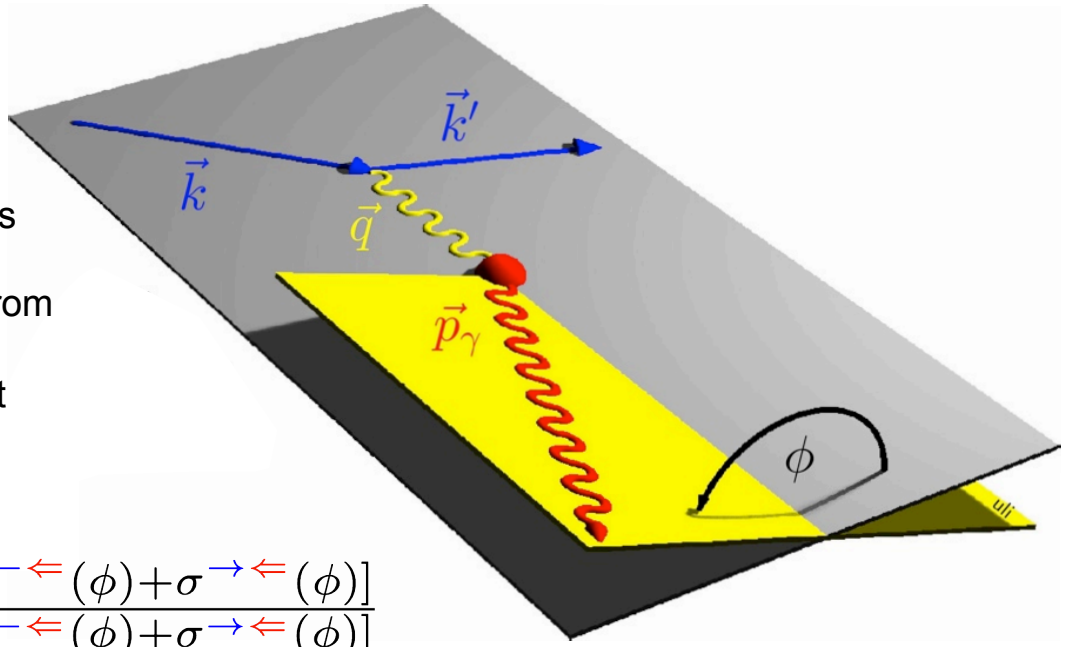
# A Quick Guide to...
# ...HERMES DVCS Asymmetry Extraction

- HERMES has published DVCS asymmetries dependent on beam charge, beam helicity, and target polarisation on a variety of target gases.
- Maximum Likelihood extraction of correlated asymmetries provides a bin-free fit in $\phi$.
- The extracted amplitudes relate to Fourier coefficients* from the expansion of the ep→epγ cross section.
- These in turn relate to various CFFs and hence, GPDs at differing levels (and forms) of suppression




*e.g.*

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

$$= \ldots + \left[K_{\mathrm{DVCS}} s_{1,\mathrm{LP}}^{\mathrm{DVCS}} - \frac{e_\ell K_{\mathrm{I}}}{\mathcal{P}(\phi)} s_{1,\mathrm{LP}}^{\mathrm{I}}\right] \sin\phi + \ldots$$

Beam **U**npol. Target **L**ong. pol.

This Fourier coefficient relates to a bi-linear combination of CFFs but is kinematically suppressed.

This Fourier coefficient relates to the $\Im$m part of CFF $\tilde{\mathrm{H}}$.

* For a full list of Fourier coefficients, see Belitsky, Müller & Kirchner, *Nucl. Phys.* **B629** (2002) 323

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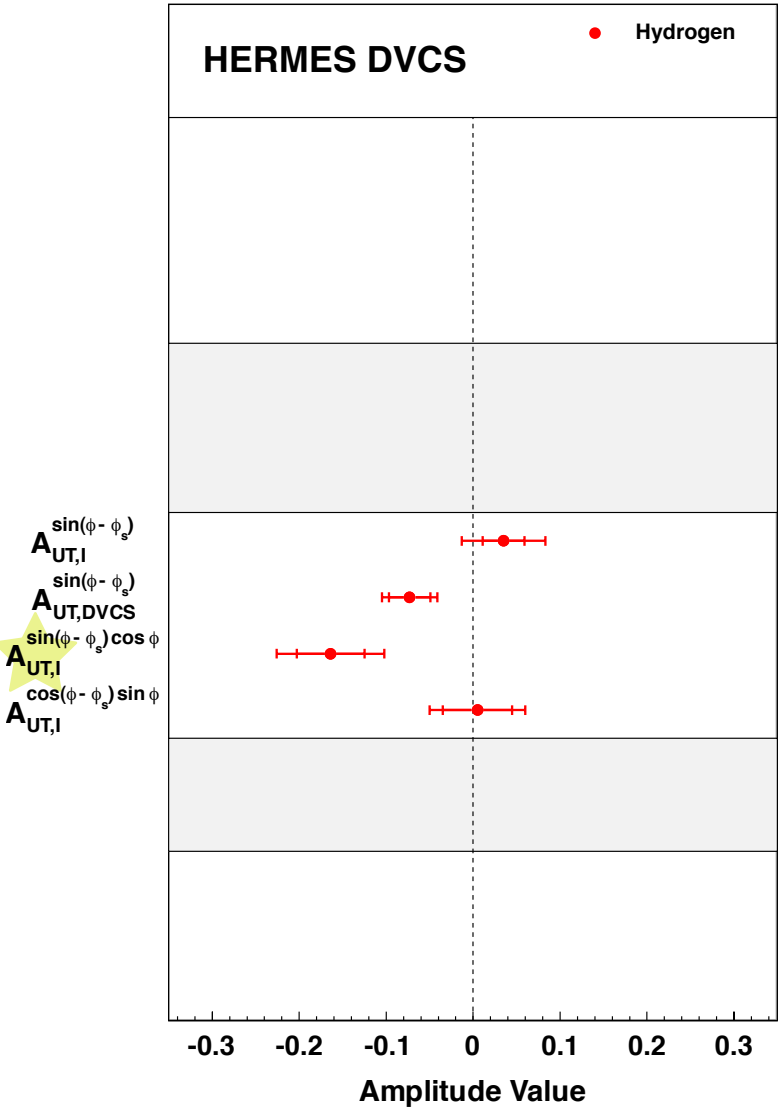
# DVCS Results at HERMES




- Results from transversely-polarised hydrogen *i.e.* *JHEP* **06** (2008) 066, offer the only unsuppressed access to GPD E(ξ, x, t).

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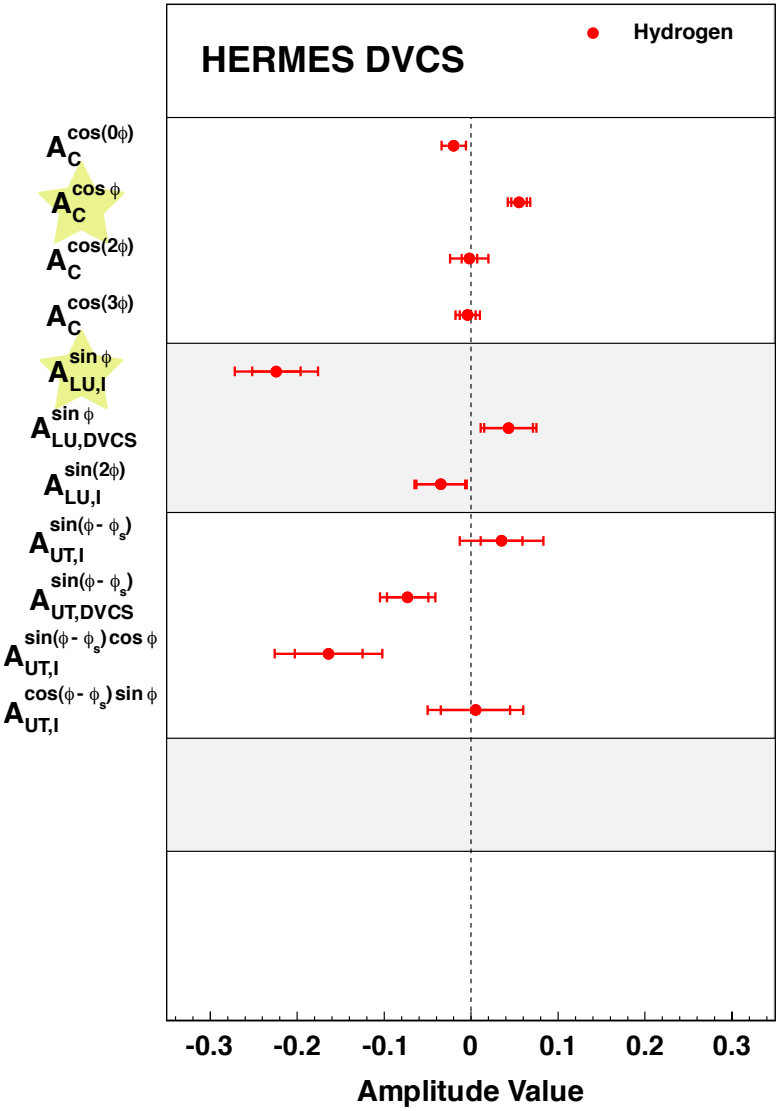


- The beam-charge $A_C$ and beam-helicity $A_{LU}$ asymmetries from pre-Recoil data *i.e.* *JHEP* **11** (2009) 083.
- The cosϕ and sinϕ amplitudes from the interference term can be used to constrain GPD H(ξ, x, t) as they relate to the $\Re$e and $\Im$m parts of CFF H respectively.

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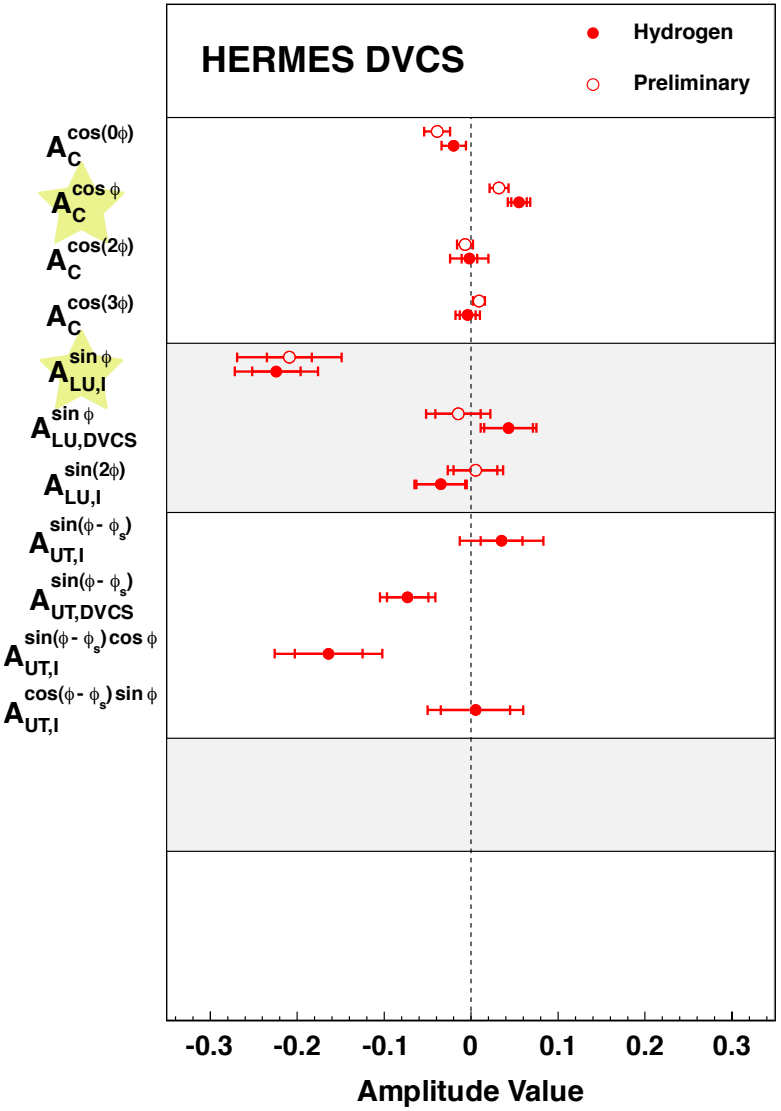


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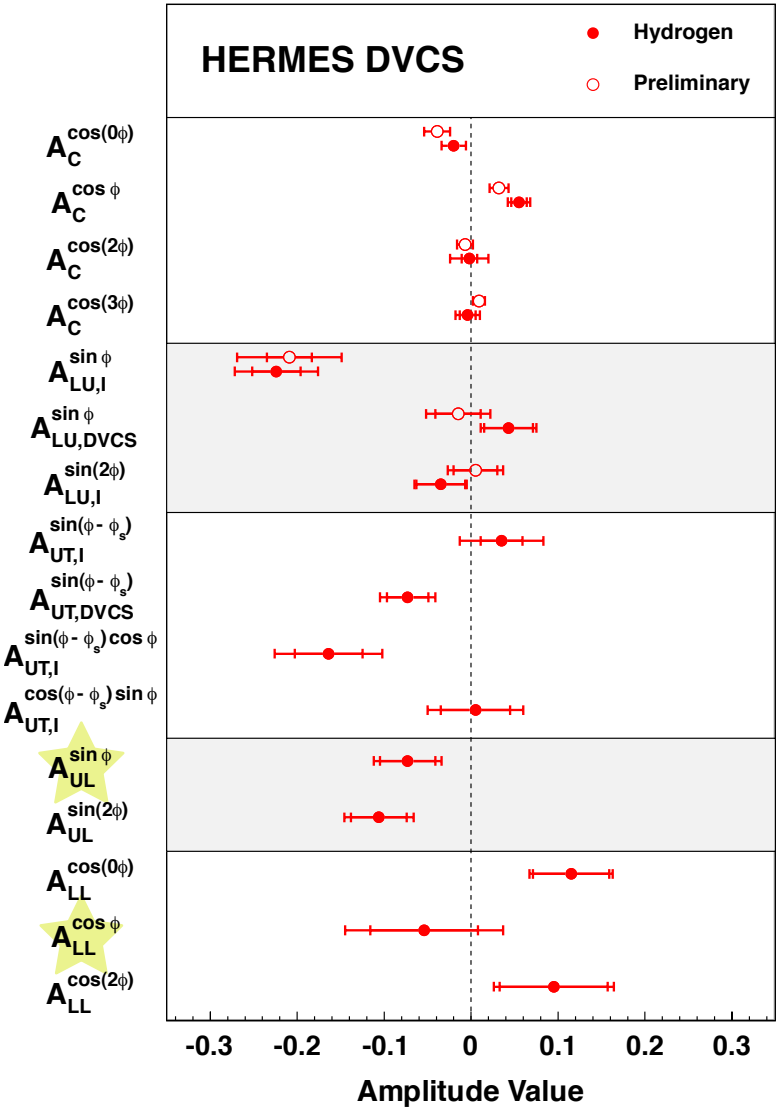


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- Results from transversely-polarised hydrogen *i.e.* *JHEP* **06** (2008) 066, offer the only unsuppressed access to GPD E(ξ, x, t).

- The single-spin $A_{UL}$ and double-spin $A_{LL}$ asymmetries from longitudinally-polarised hydrogen *i.e.* *JHEP* **06** (2010) 019, provide information on GPD $\tilde{H}$(ξ, x, t) as they relate to the $\Re$e and $\Im$m parts of CFF $\tilde{H}$ via the cosϕ and sinϕ amplitudes respectively.
- The sin(2ϕ) amplitude is *unexpectedly* non-zero.

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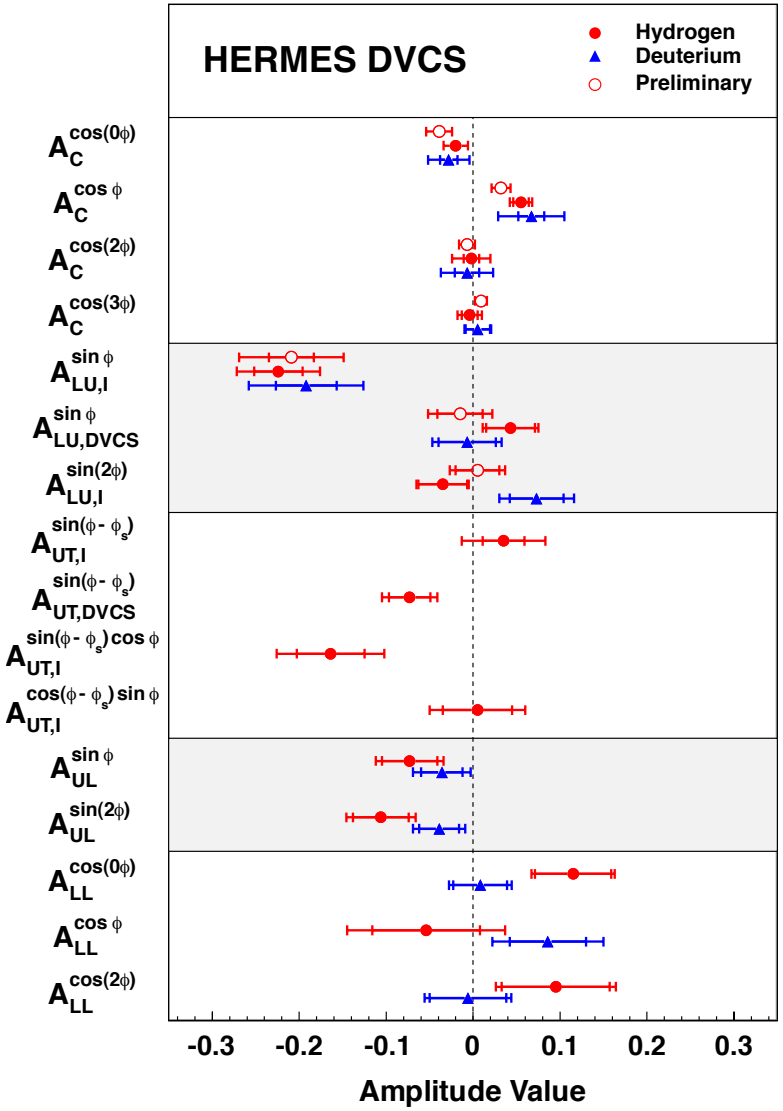
# DVCS Results at HERMES

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- New preliminary results from Recoil data (not using Recoil information) are compatible.
- Deuterium results are compatible *i.e.* *Nucl. Phys.* **B829** (2010) 1.
- Results from transversely-polarised hydrogen *i.e.* *JHEP* **06** (2008) 066, offer the only unsuppressed access to GPD E(ξ, x, t).

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- Deuterium results are compatible *i.e.* *Nucl. Phys.* **B842** (2011) 265

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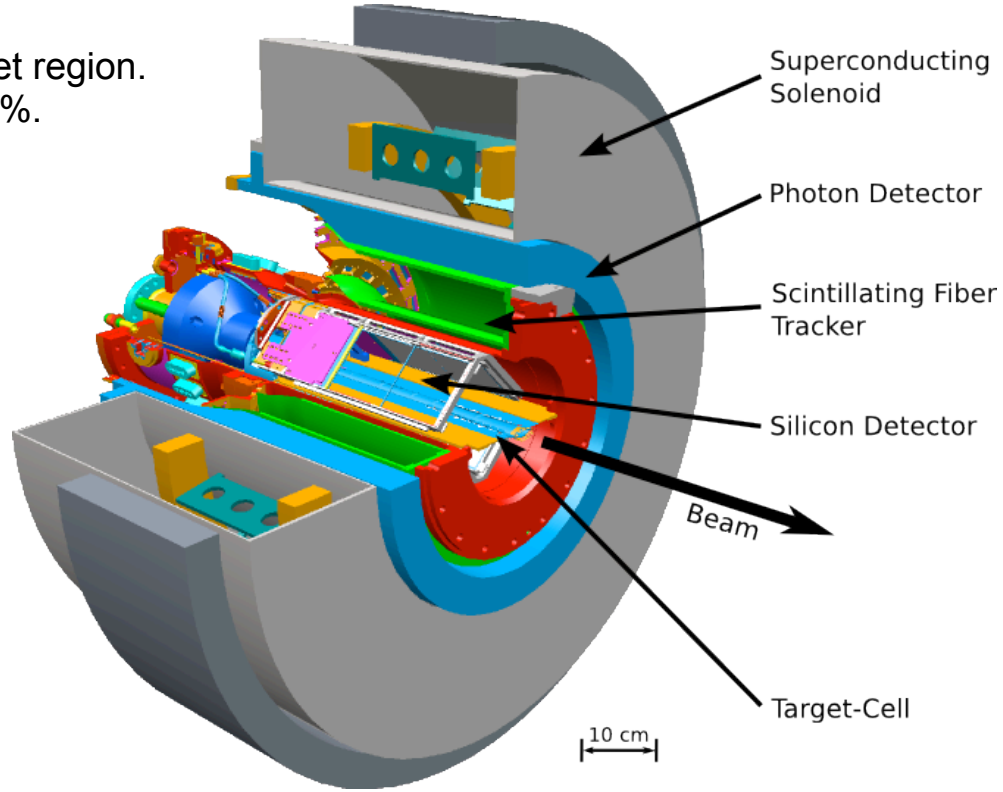
# Future HERMES DVCS Results

- In mid-2006, the Recoil Detector was installed in the target region.
- Semi-inclusive neutral meson background reduced to < 1%.
- $\Delta^+$ resonance production reduced to ~1%.

- An upcoming publication will present the combination of the pre- and post-Recoil unpolarised hydrogen data sets *"...the most statistically-precise DVCS measurement in the HERMES kinematic range".*
- Another publication, presenting world-first $A_{LT}$ results, is expected in the near future.

- Analysis of the 2006/07 unpolarised hydrogen data set with Recoil information is going for release at HERMES **today**!
- Proposed are two new single-charge beam-helicity asymmetry amplitudes.



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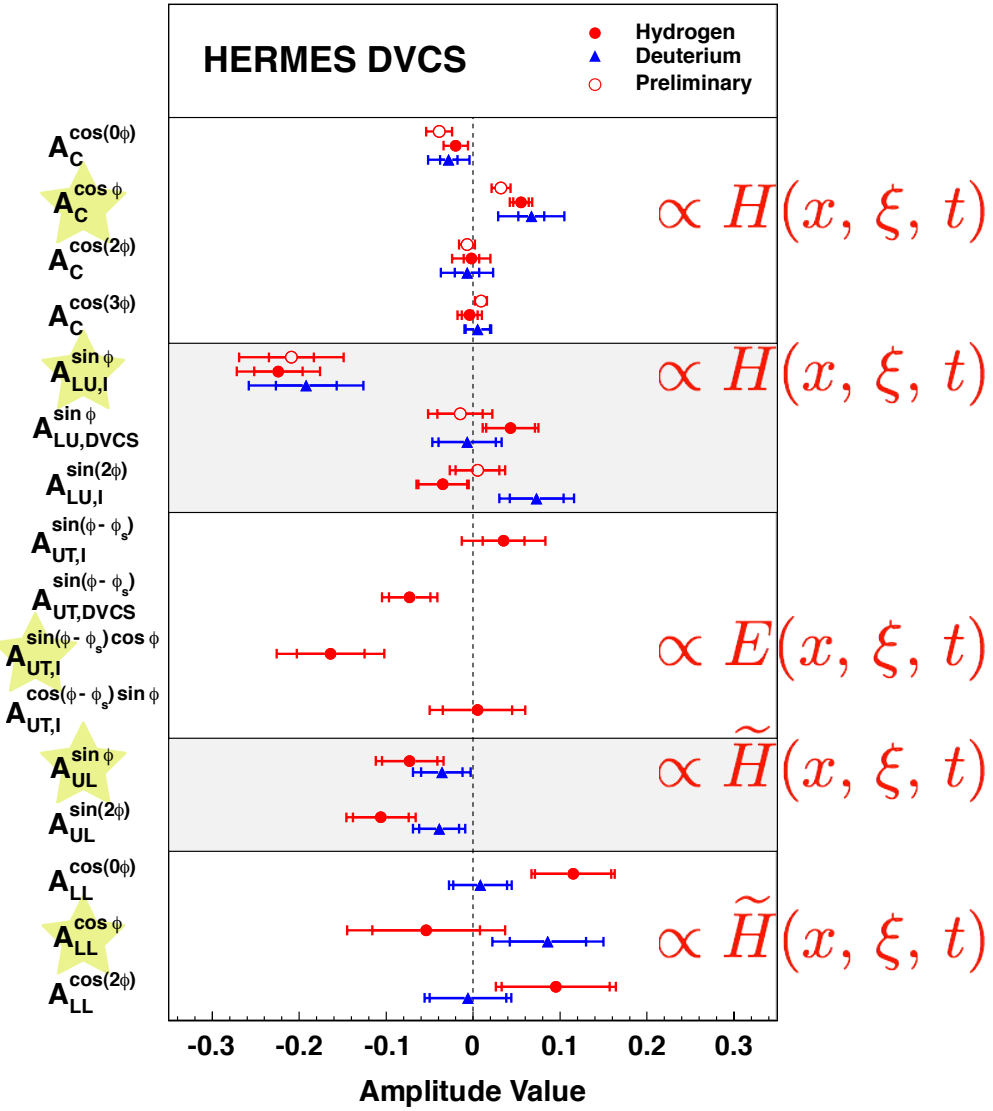
# Summary & Conclusions




- Information on Generalised Parton Distributions can be accessed via the Deeply Virtual Compton Scattering interaction.
- Recent DVCS results from the HERMES experiment have been presented with their links to three of the four spin-½ GPDs.
- Recent from a deuterium target relate to combinations of 9 different spin-1 GPDs.
- These results are used in several global GPD fits being performed *e.g.* Kumerički/Müller, *Nucl. Phys.* **B841** (2010) 1, and Guidal *et al.*, arxiv:1101.2482 (2011)

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# BACKUP SLIDES

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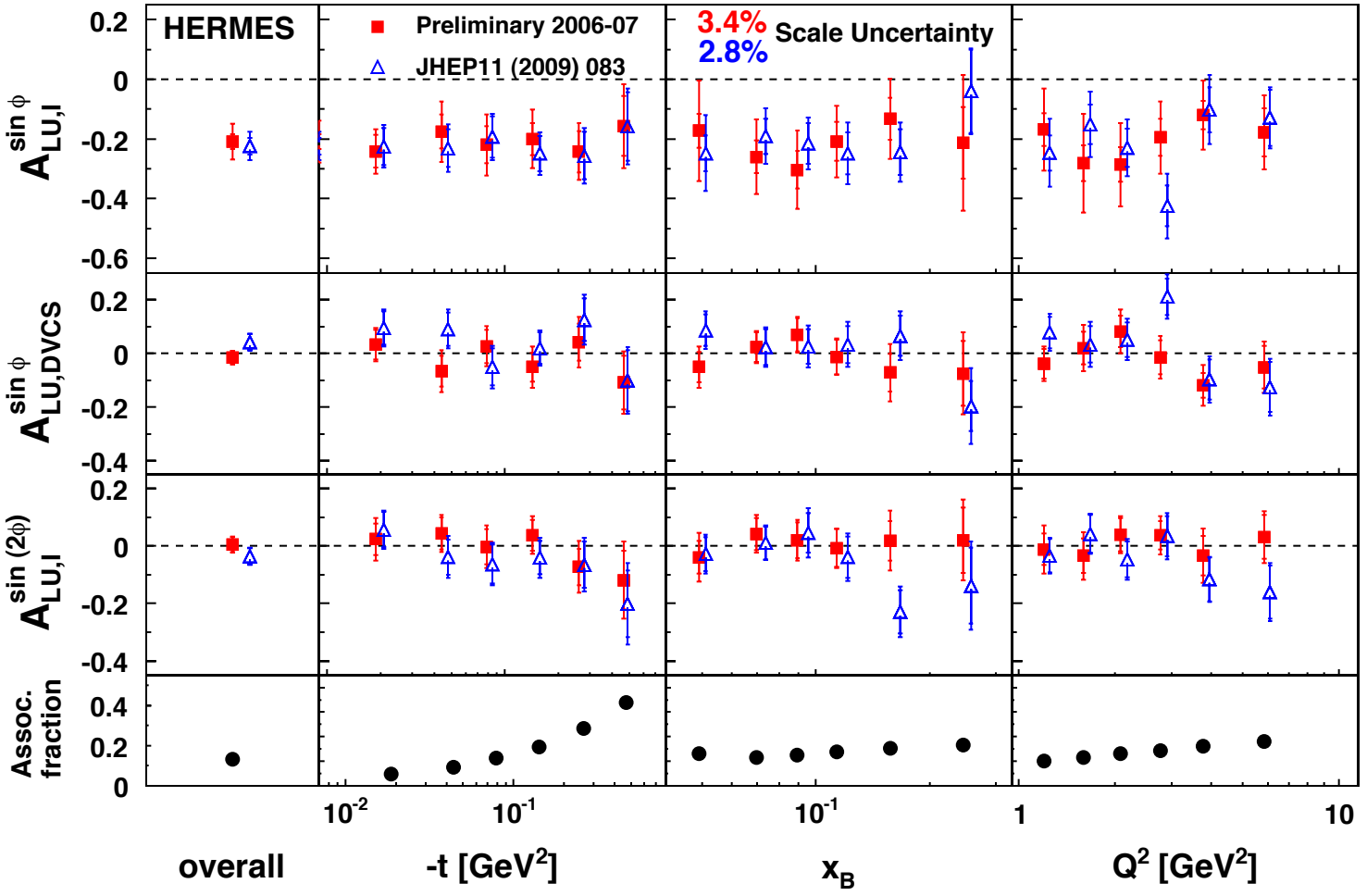
# Beam-Helicity Asymmetries

$$\mathcal{A}_{\mathrm{LU}}^{\mathrm{I|DVCS}} \equiv \frac{[\sigma^{\rightarrow+}(\phi) \pm \sigma^{\leftarrow-}(\phi)] - [\sigma^{\leftarrow+}(\phi) \pm \sigma^{\rightarrow-}(\phi)]}{[\sigma^{\rightarrow+}(\phi) + \sigma^{\leftarrow-}(\phi)] + [\sigma^{\leftarrow+}(\phi) + \sigma^{\rightarrow-}(\phi)]}$$




$H(x, \xi, t)$
twist-2 from Int.

$H(x, \xi, t)$
twist-3 from $T_{DVCS}$

$H(x, \xi, t)$
twist-3 from Int.

Resonance $\Delta^+$ production fraction

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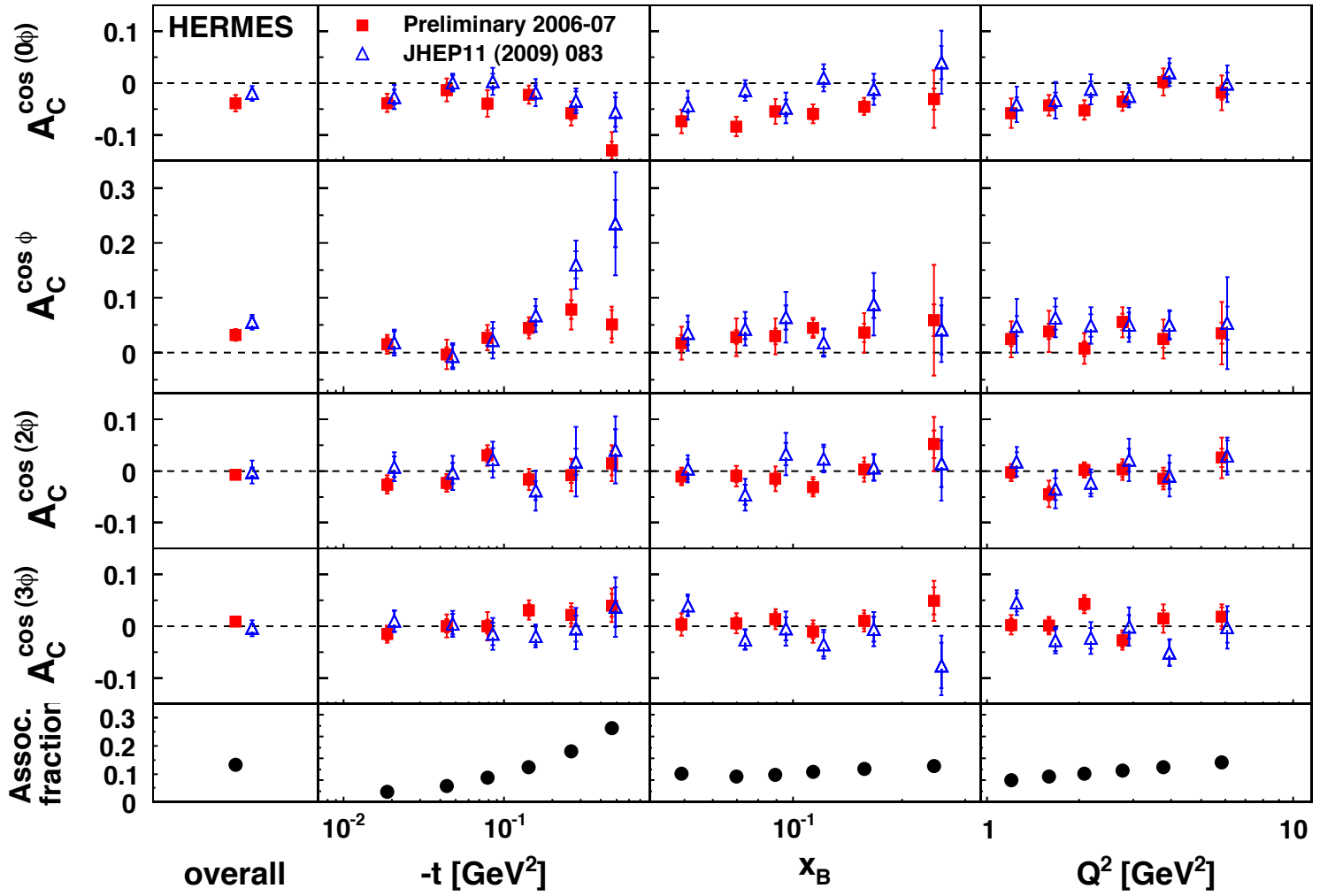
# Beam-Charge Asymmetry

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




$H(x, \xi, t)$
twist-2 from Int.

$H(x, \xi, t)$
twist-2 from Int.

$H(x, \xi, t)$
twist-3 from Int.

Resonance $\Delta^+$ production fraction

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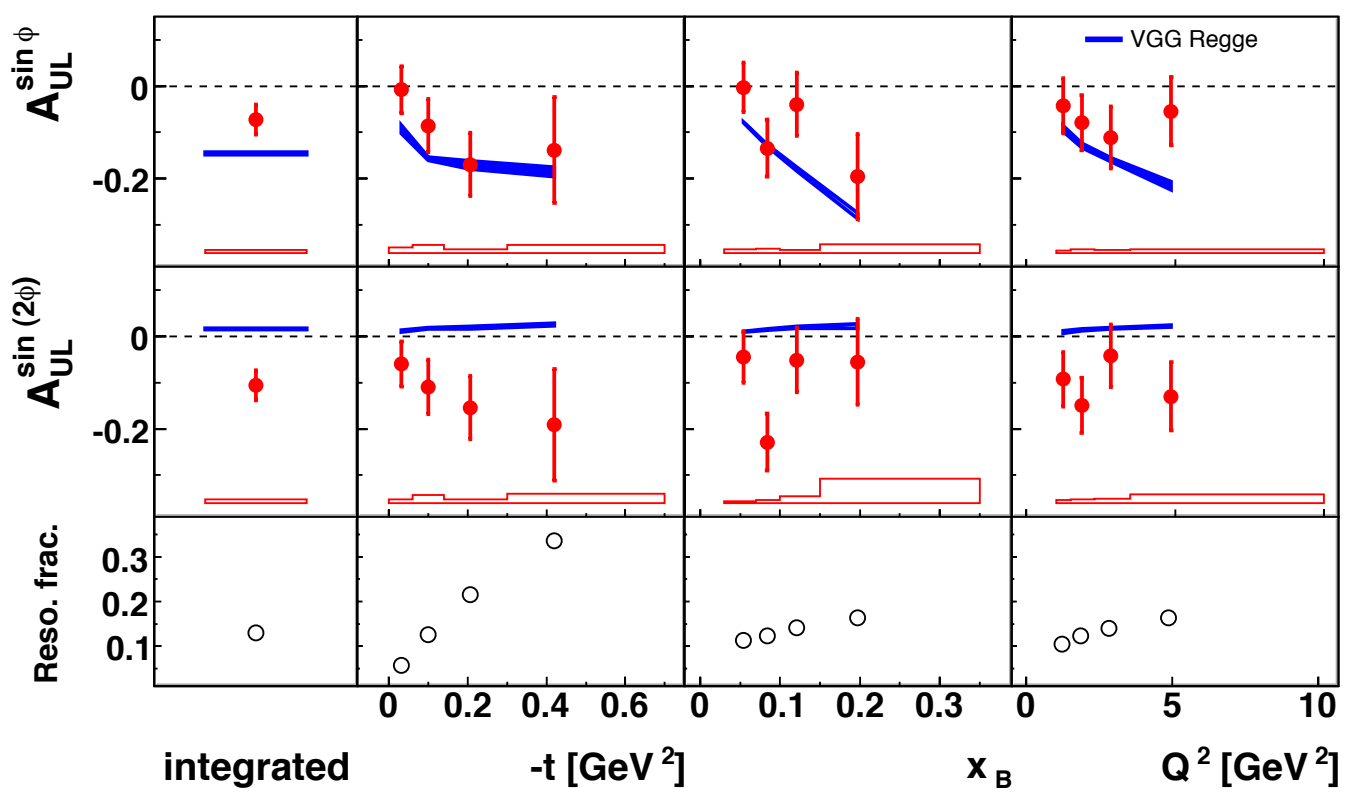
# Longitudinal Target-Spin Asymmetry

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




$\widetilde{H}(x, \xi, t)$
twist-2 from Int.
twist-3 from $T_{DVCS}$

$\widetilde{H}(x, \xi, t)$
twist-3 from Int.
twist-2 from gluon-helicity flip GPDs

Resonance $\Delta^+$ production fraction

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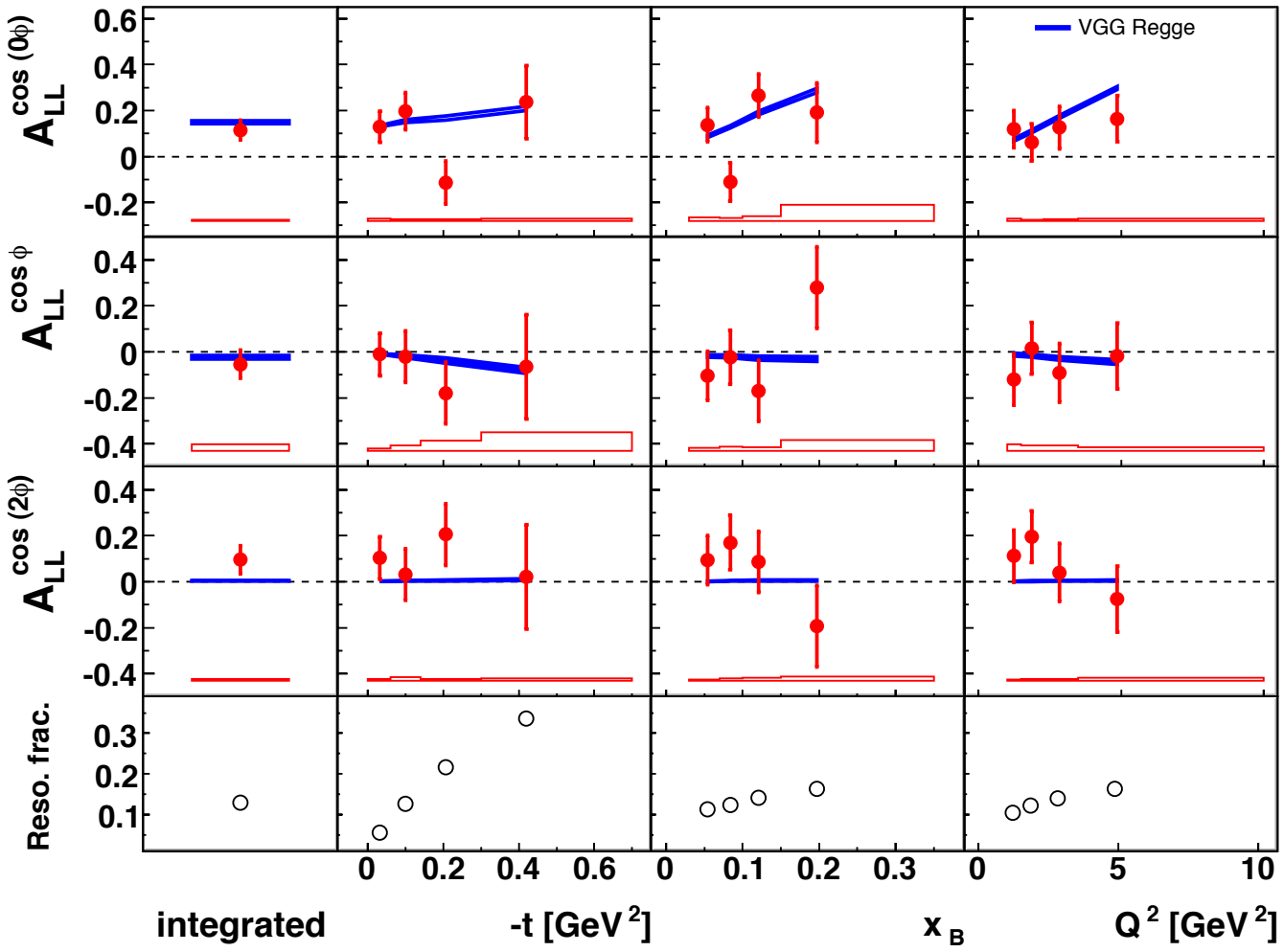
# Double-Spin Asymmetry

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




$\widetilde{H}(x, \xi, t)$
twist-2 from Int.
twist-2 from $T_{DVCS}$
Contrib. from $T_{BH}$

$\widetilde{H}(x, \xi, t)$
twist-2 from Int.
twist-3 from $T_{DVCS}$
Contrib. from $T_{BH}$

$\widetilde{H}(x, \xi, t)$
twist-3 from Int.

Resonance $\Delta^+$
production fraction