Hard Exclusive Reactions Measured with HERMES

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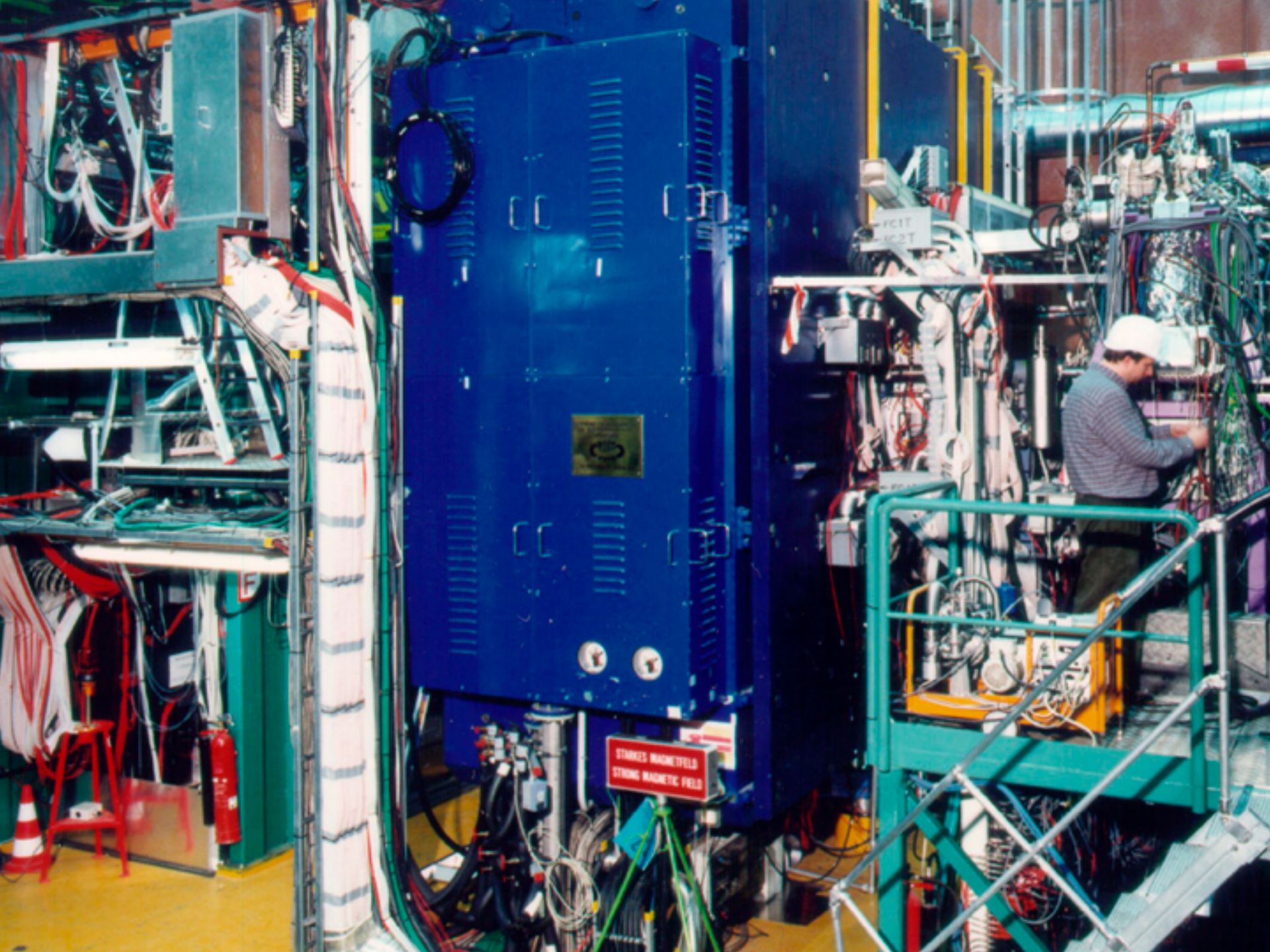
STARKES MAGNETFELD
STRONG MAGNETIC FIELD

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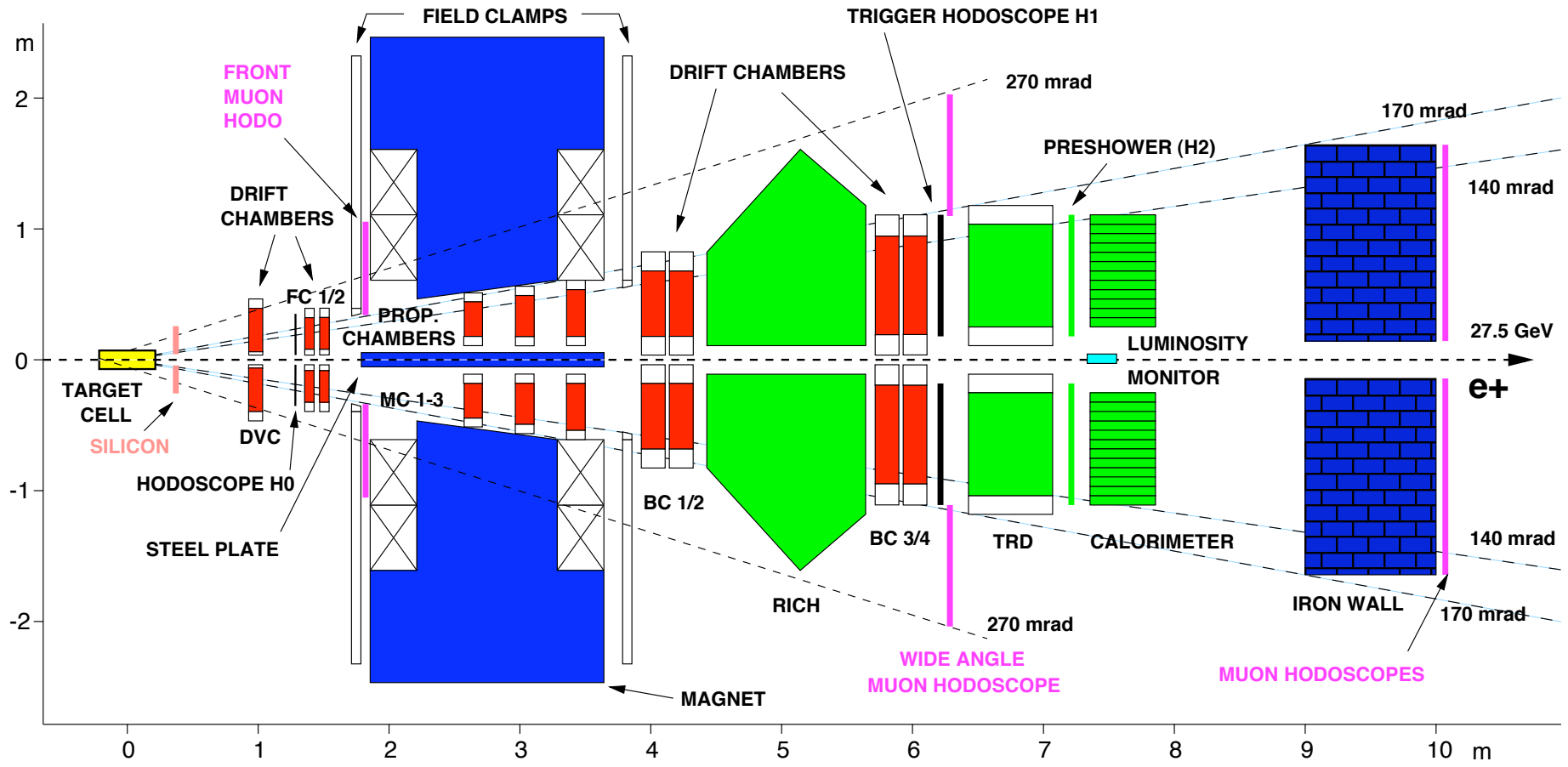
The HERMES Spectrometer



- polarised $e^{\pm}$ beam ($\leftrightharpoons$)
- polarised H, D targets ($\leftrightharpoons, \perp$)
- open geometry
- excellent particle ID

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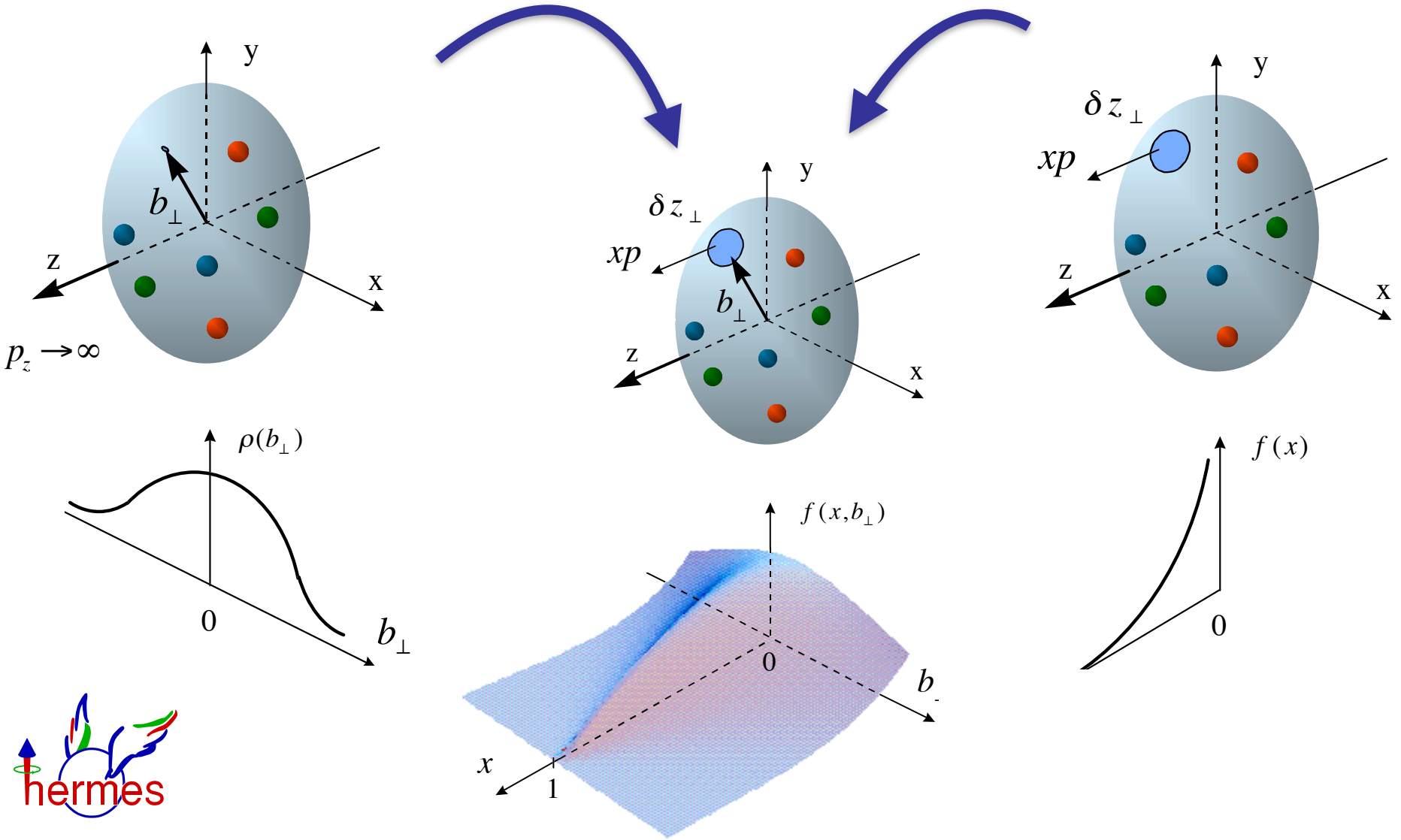
Generalised Parton Distributions



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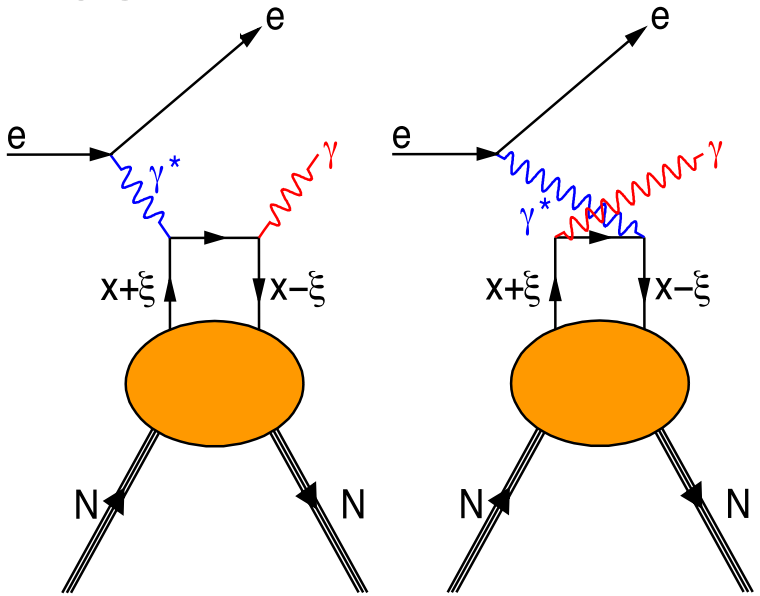
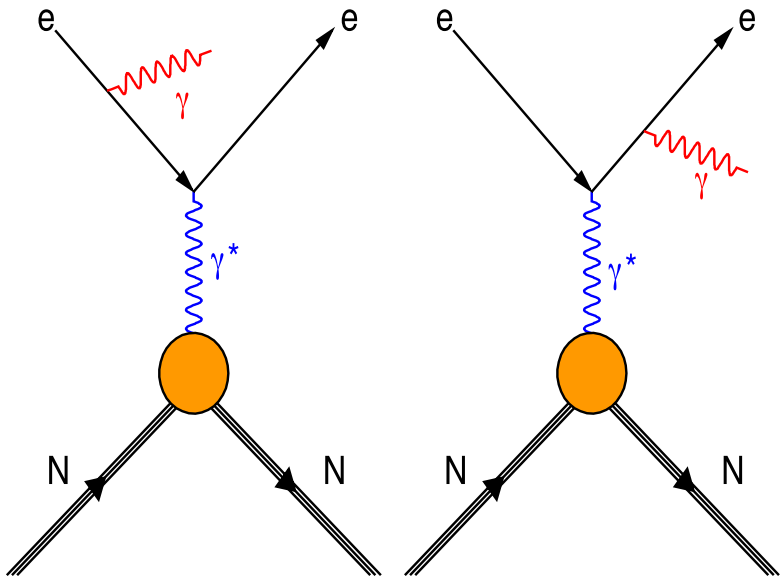
Deeply Virtual Compton Scattering

DVCS



Identical final states
exploit interference



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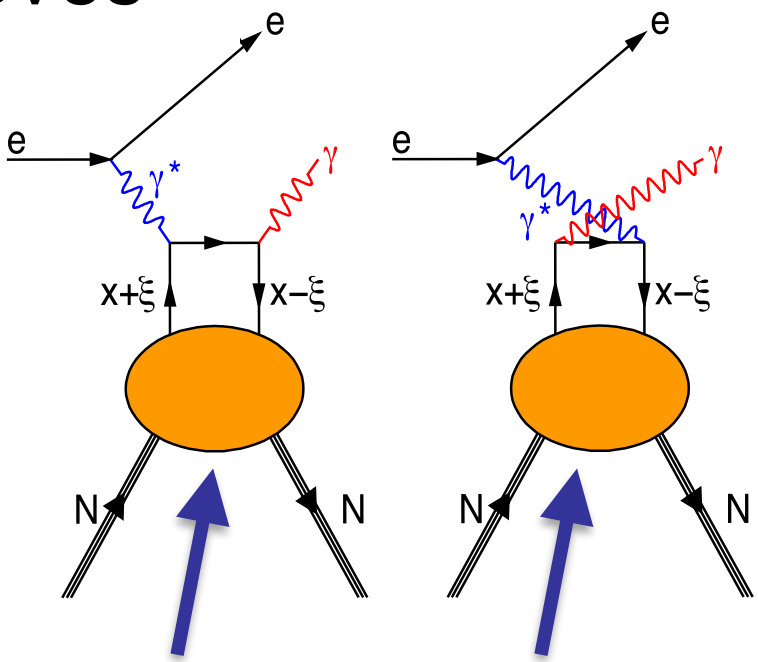
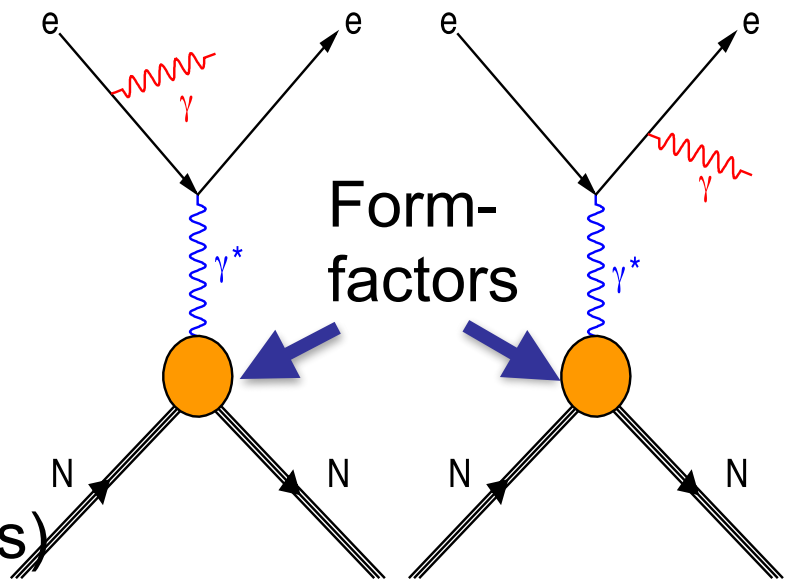
Deeply Virtual Compton Scattering

DVCS



Generalised Parton Distributions (via Compton Formfactors)

Identical final states exploit interference



Form-factors

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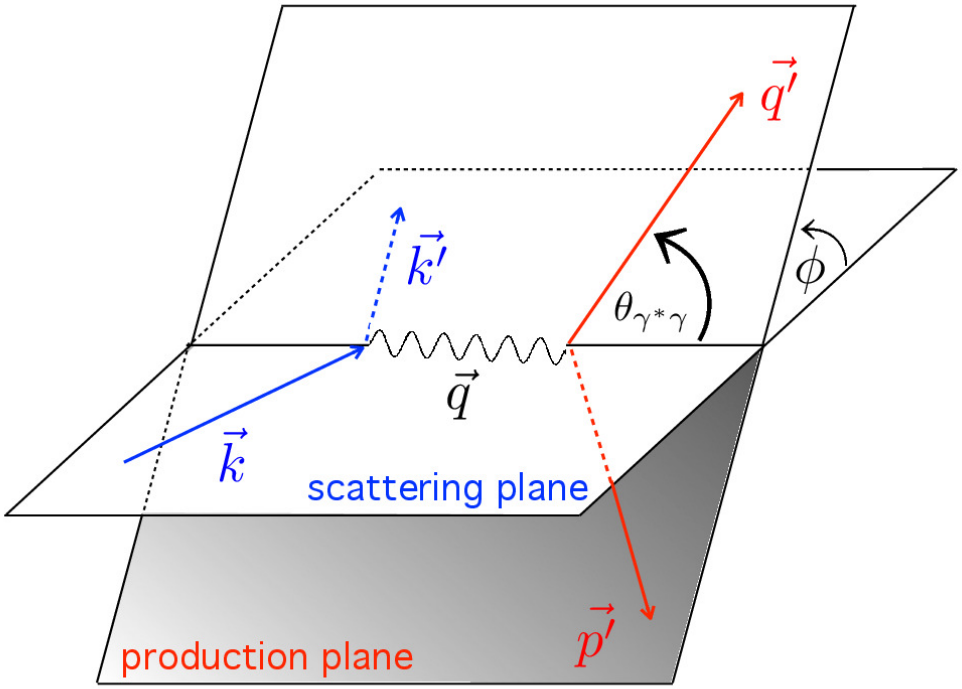
Kinematics and Definitions



$$\nu = E - E'$$

$$Q^2 = 4EE' \sin^2 \frac{\theta}{2}$$

$$x = \frac{Q^2}{2M\nu} \qquad y = \frac{\nu}{E}$$

$$W^2 = M^2 + 2M\nu - Q^2$$

$$z = \frac{E_h}{\nu}$$

$$p_T^h = p^h \sin \theta^h$$

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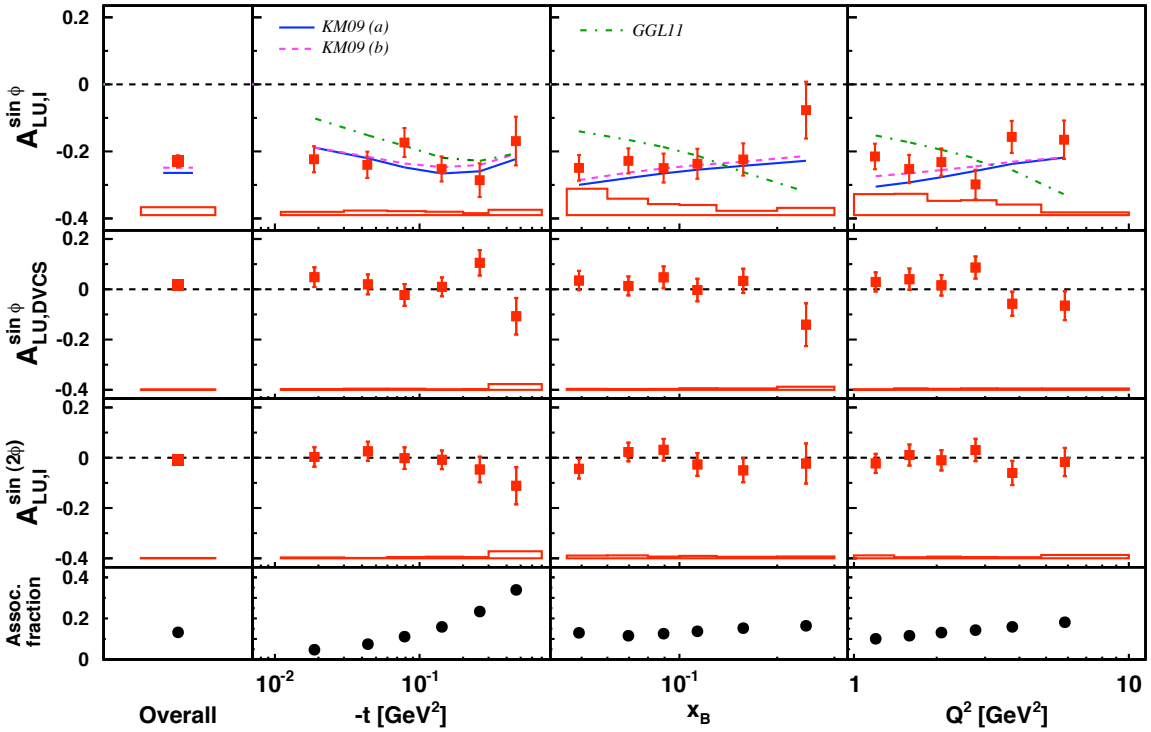
DVCS at HERMES - an Overview



Beam Spin Asymmetry: access to the imaginary part of CFF $\mathcal{H}$

JHEP 1207 (2012) 032

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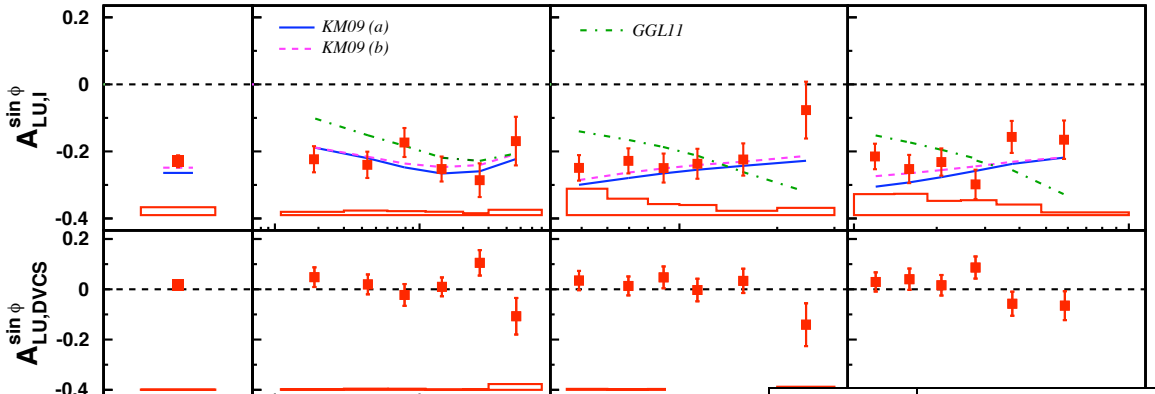
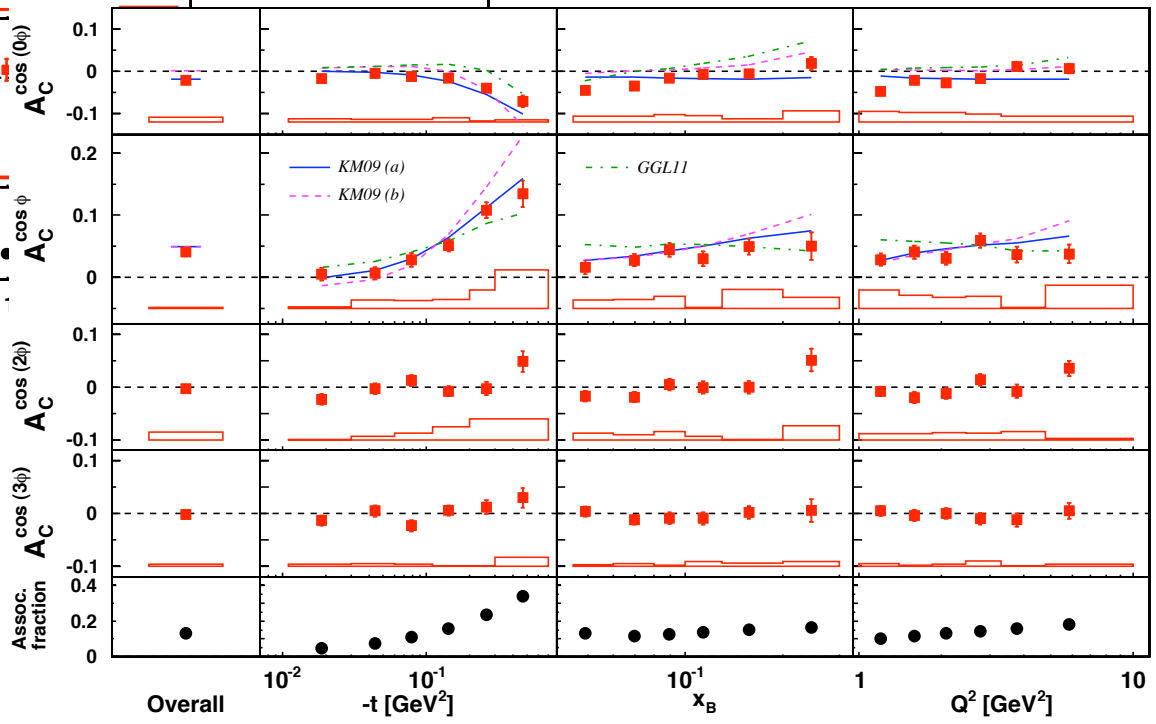
DVCS at HERMES - an Overview

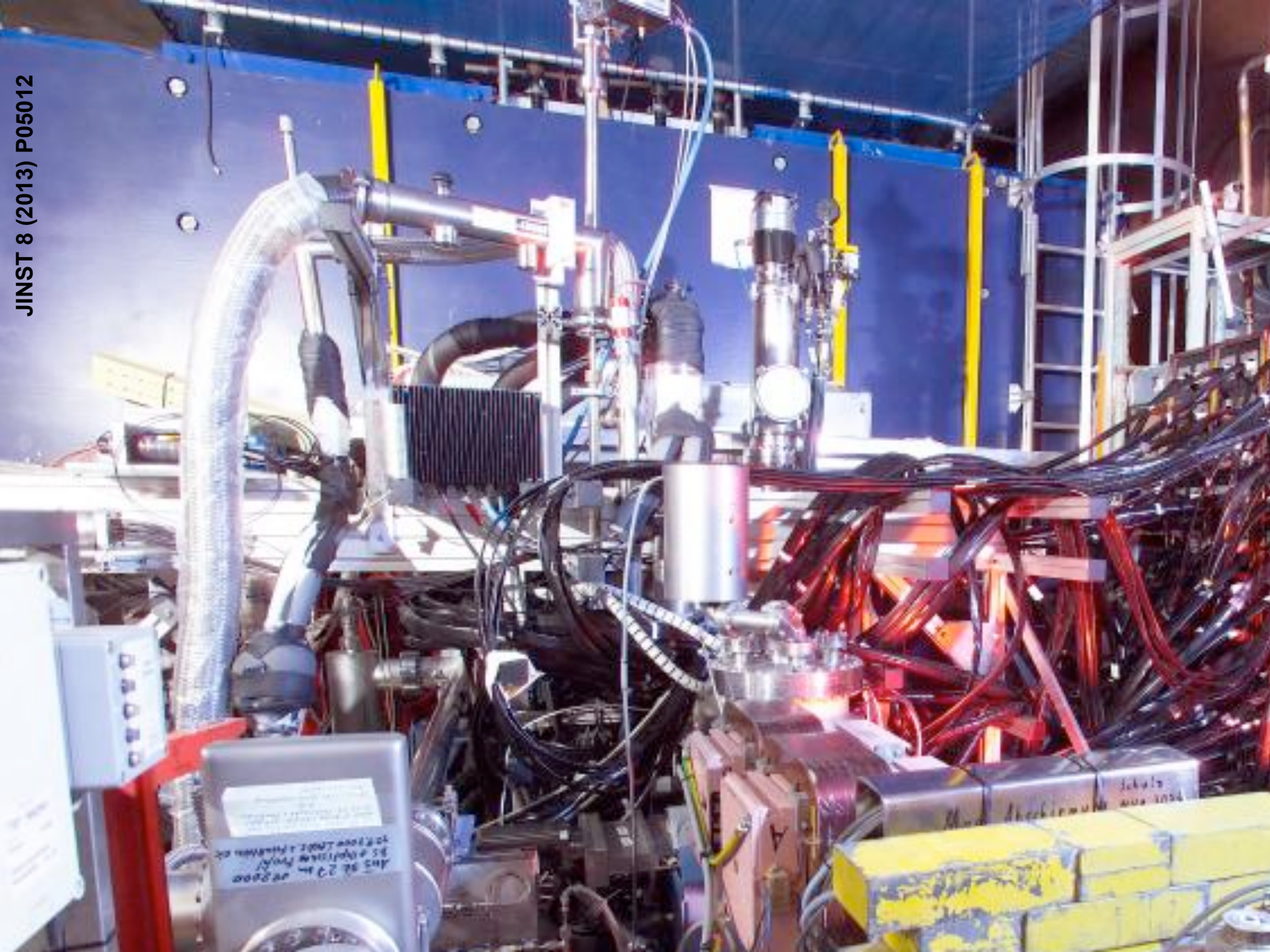


Beam Spin Asymmetry: access to the imaginary part of CFF $\mathcal{H}$

JHEP 1207 (2012) 032



Beam Charge Asymmetry: access to the real part of CFF $\mathcal{H}$



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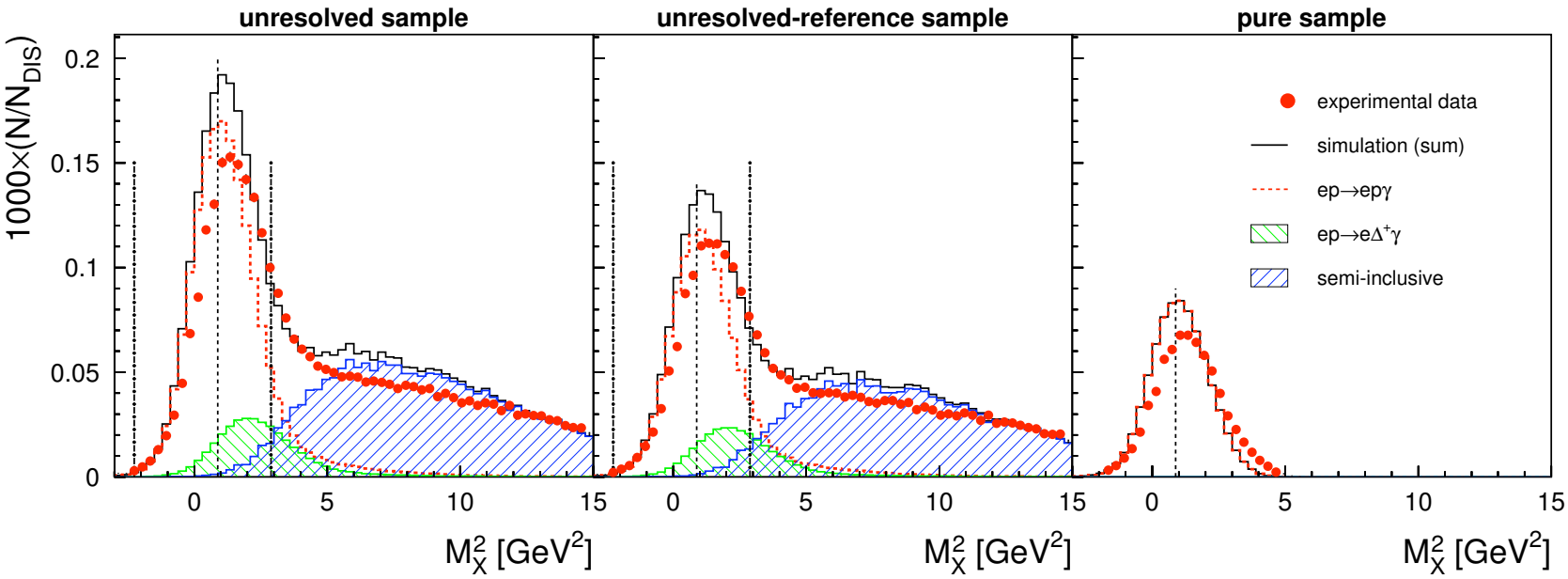
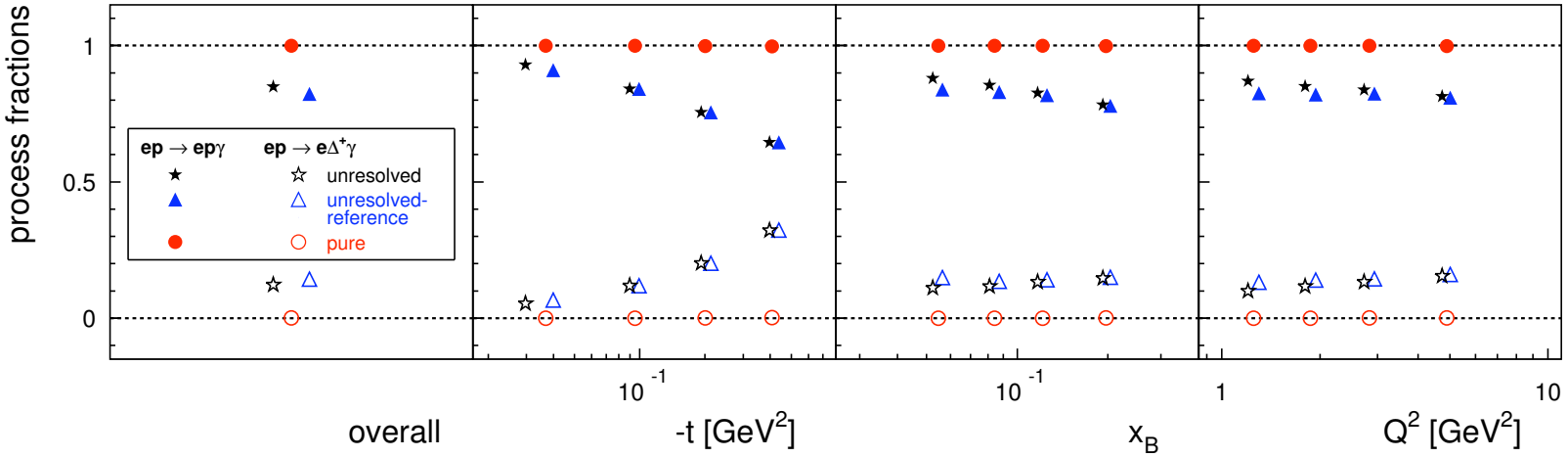
Recoil Event Reconstruction





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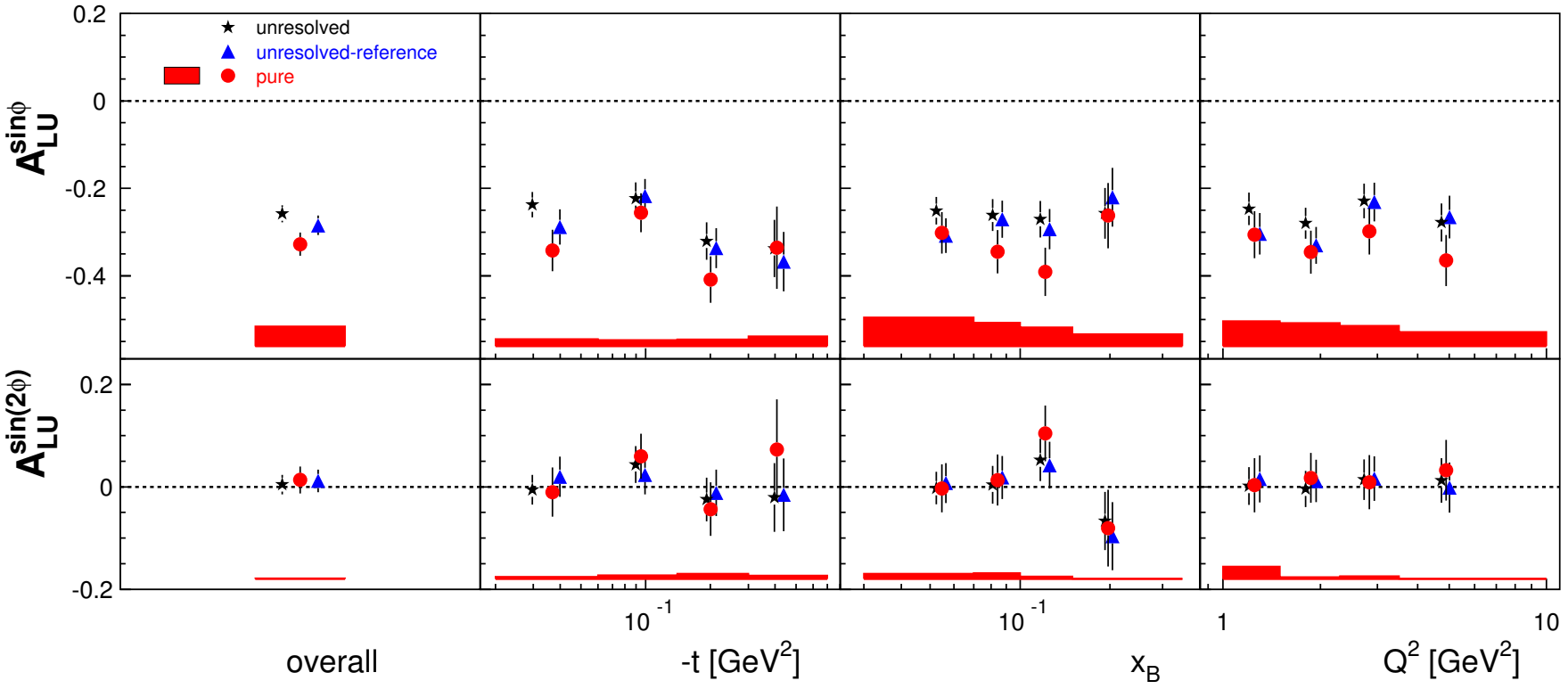
Kinematically Pure Results



cf JHEP 1210 (2012) 042

- only sin Φ contributes (parity conservations)
- constrains GPD H
- pure data show increased amplitude

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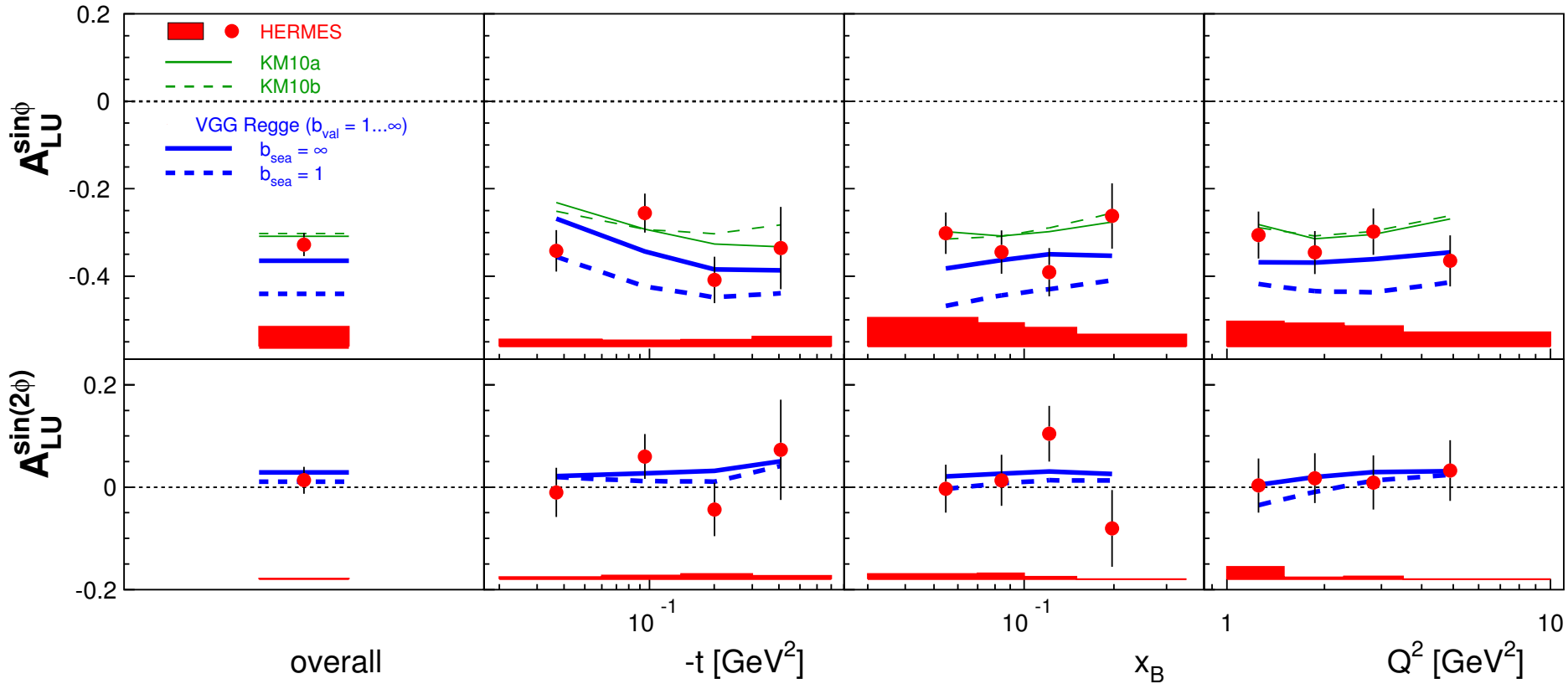
Comparison with Theory



- constrains GPD H
- trend in kinematic dependence reproduced by VGG
- maximal skewness (- - - - -) disfavoured

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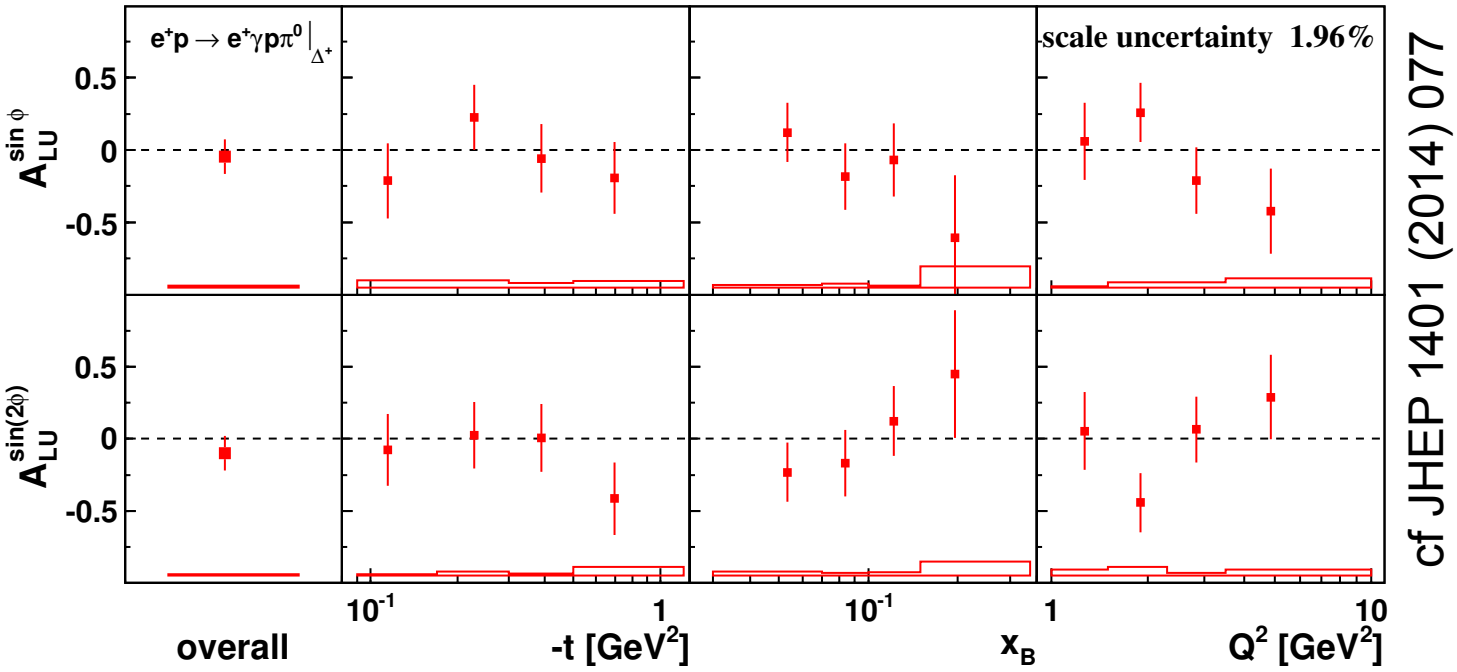
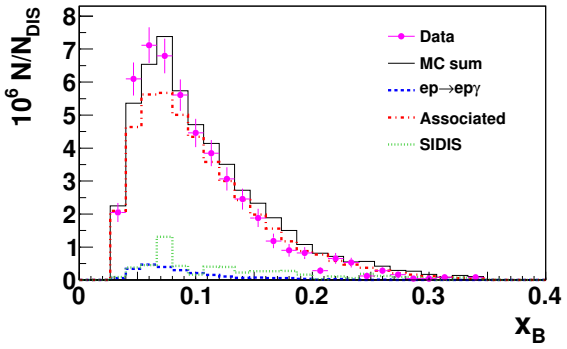
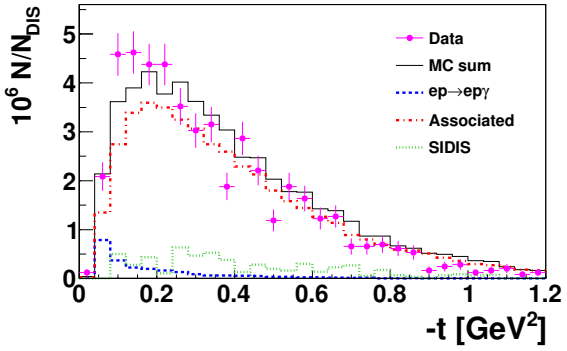
$ep \rightarrow e\gamma\pi^\circ p$

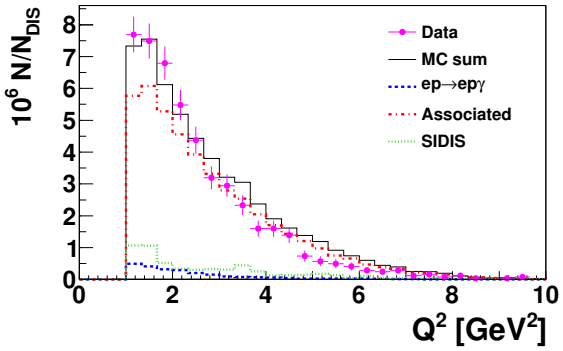


cf JHEP 1401 (2014) 077

Detecting **p** in recoil detector in addition







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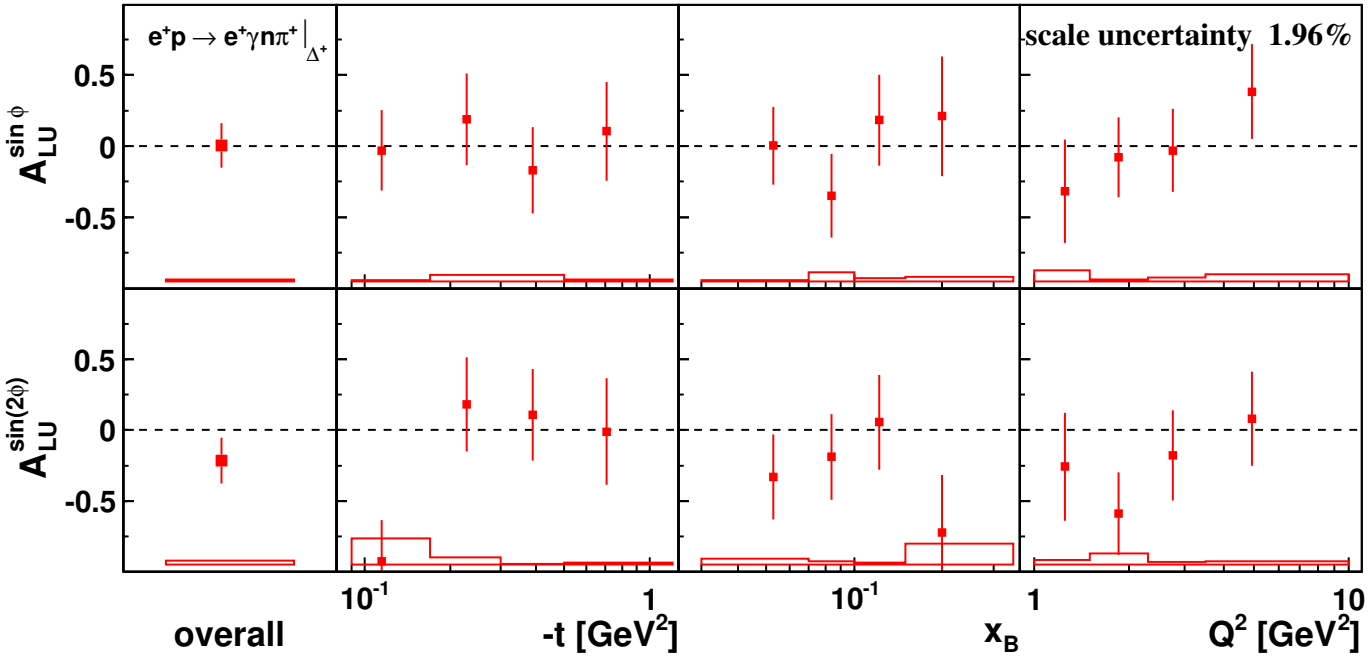
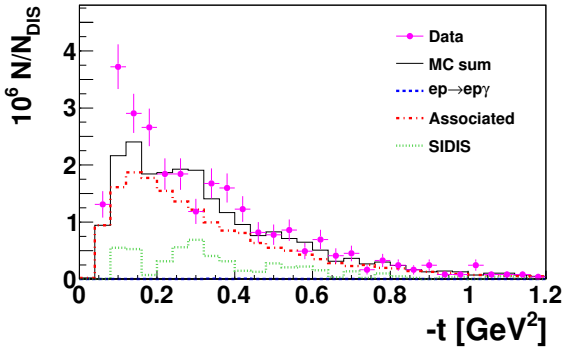
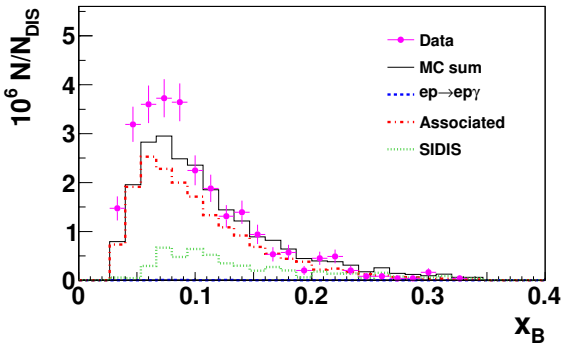
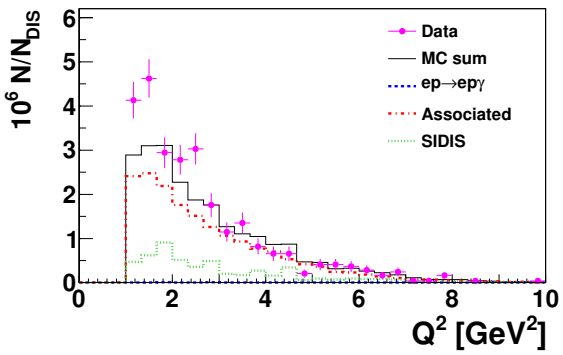
$ep \rightarrow e\gamma\pi^+n$



Detecting π^+ in recoil detector in addition







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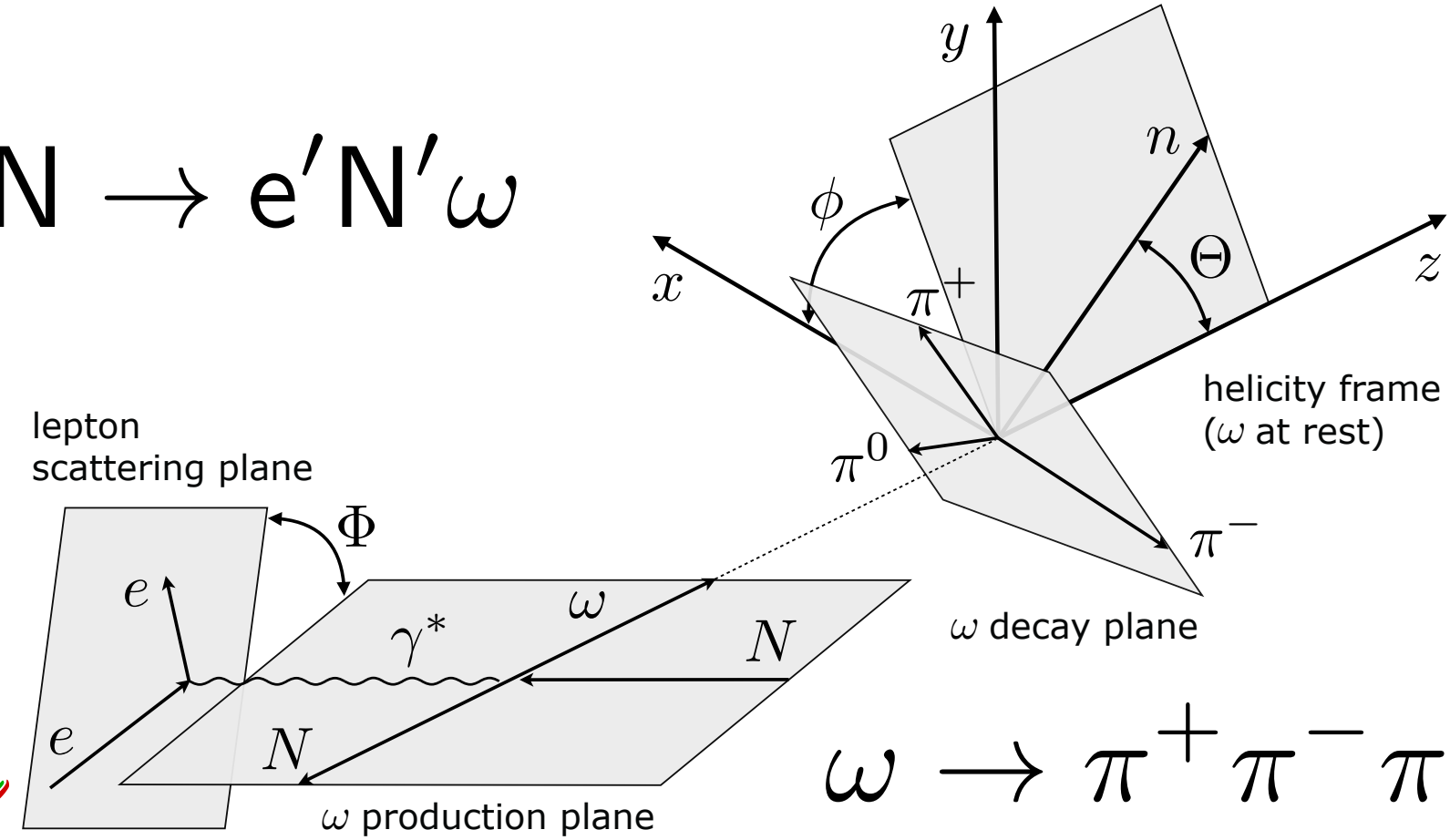
Vector Meson Kinematics

$$eN \rightarrow e'N'\omega$$



$$\omega \rightarrow \pi^+\pi^-\pi^\circ$$

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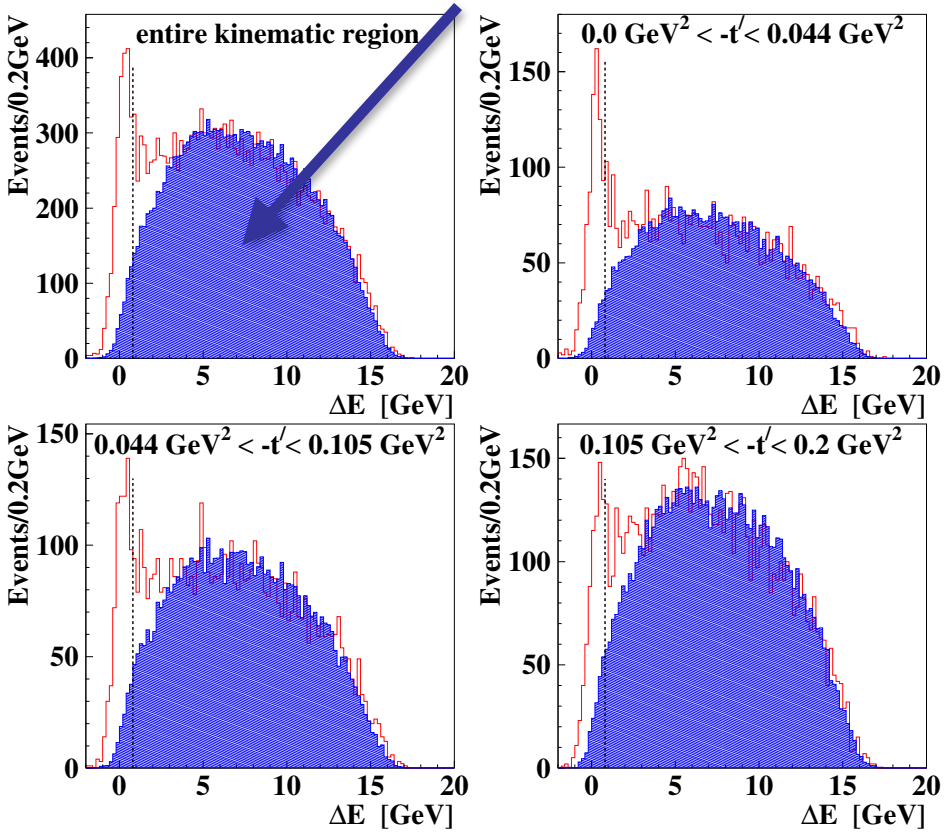
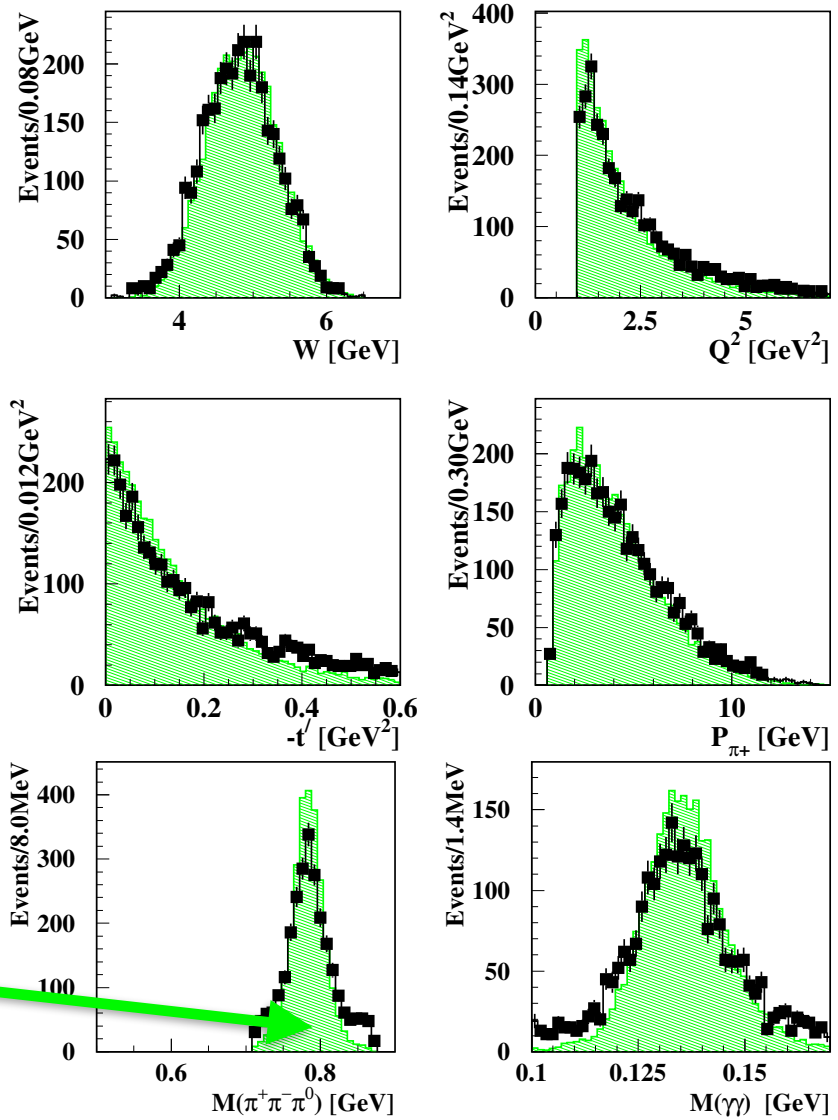
ω Event Selection

PYTHIA SIDIS



exclusive PYTHIA simulation



Spin Density Matrix Elements

$$r^1_{1-1} + \mathrm{Im}(r^2_{1-1}) = 0$$

= -0.004 ± 0.038 ± 0.015

= -0.033 ± 0.049 ± 0.004

$$\mathrm{Re}(r^5_{10}) + \mathrm{Im}(r^6_{10}) = 0$$

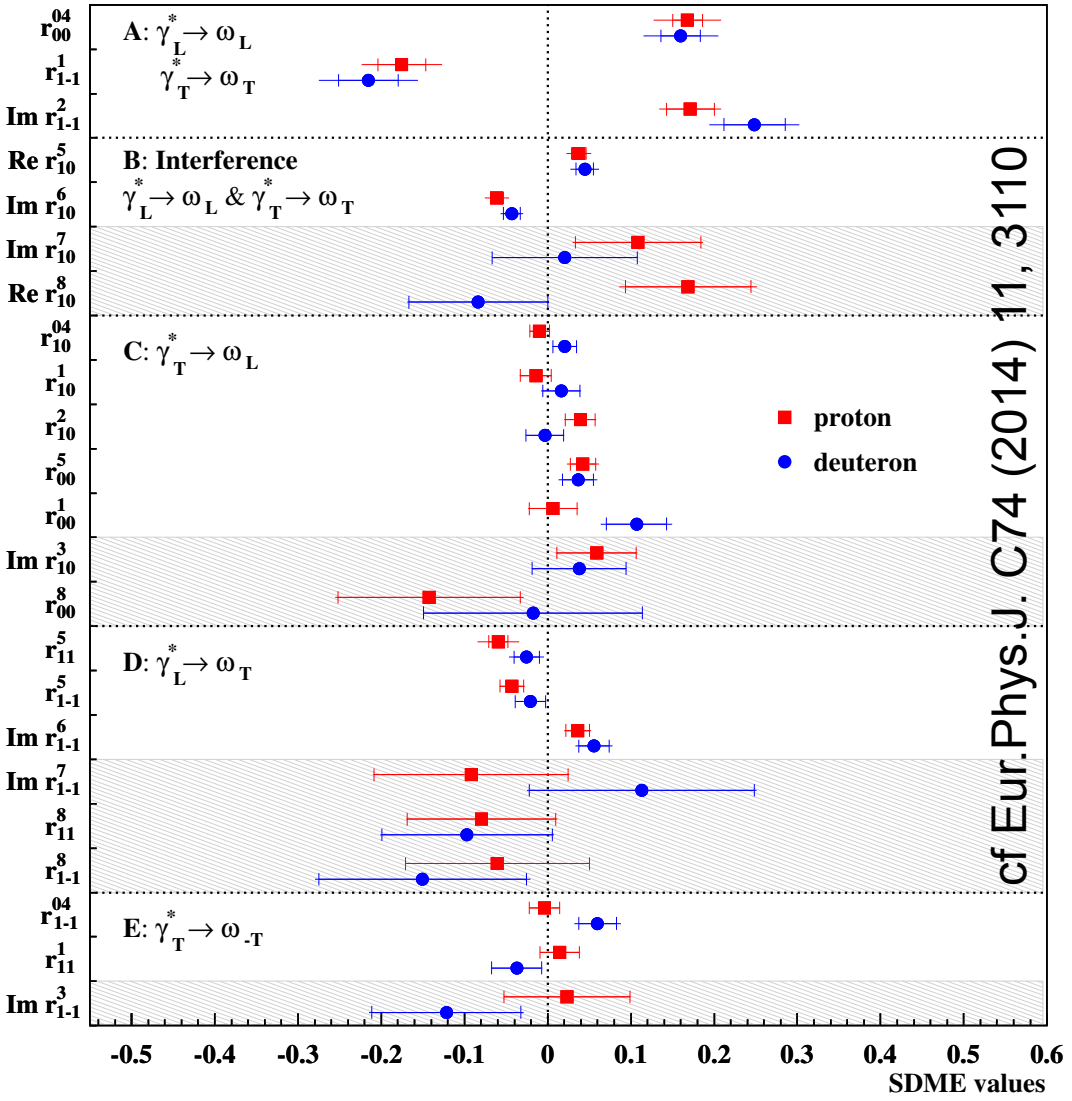
= -0.024 ± 0.013 ± 0.004

= -0.001 ± 0.016 ± 0.005

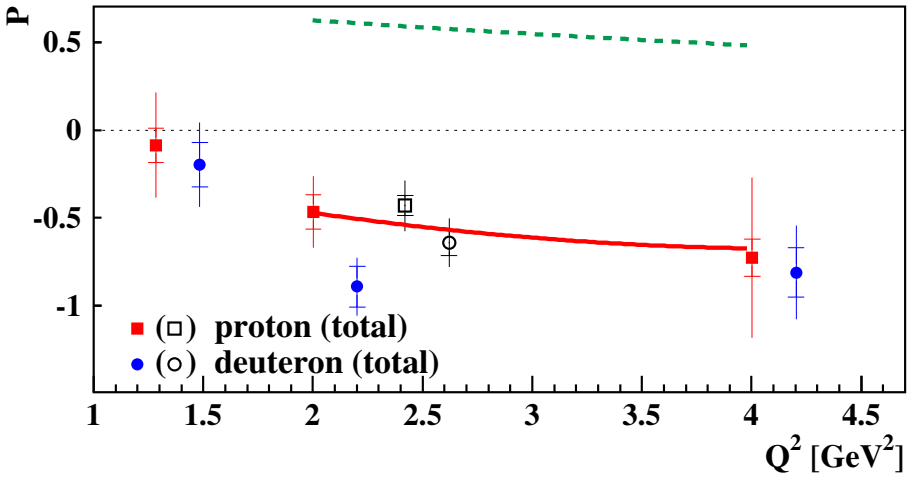
$$\mathrm{Im}(r^7_{10}) - \mathrm{Re}(r^8_{10}) = 0$$

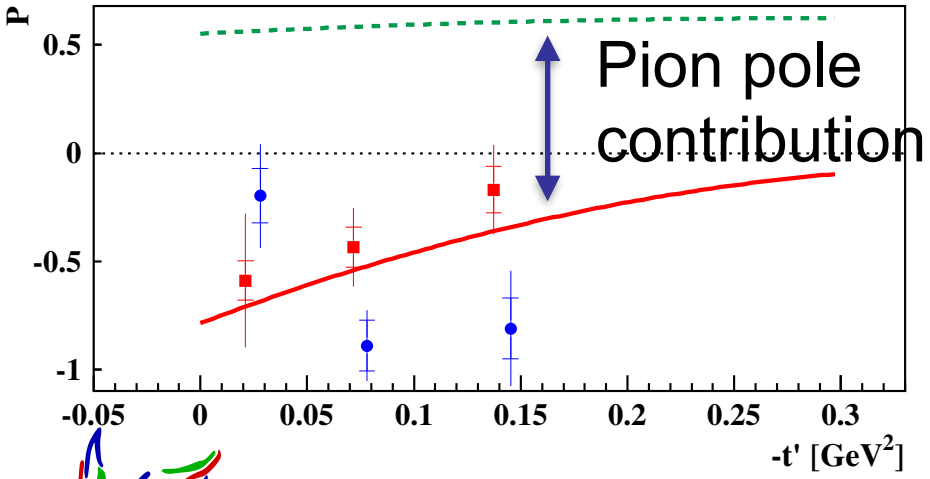
= -0.060 ± 0.100 ± 0.018

= -0.104 ± 0.110 ± 0.023



Natural vs Un-natural Parity Exchange





Regge Phenomenology

Natural Parity Exchange:	Un-natural Parity Exchange:
$J^P = 0^+, 1^-, \ldots$	$J^P = 0^-, 1^+, \ldots$

$$P = \frac{d\sigma_T^N - d\sigma_T^U}{d\sigma_T^N + d\sigma_T^U}$$

$$\approx \frac{2r_{1-1}^1 - r_{00}^1}{1 - r_{00}^{04}}$$

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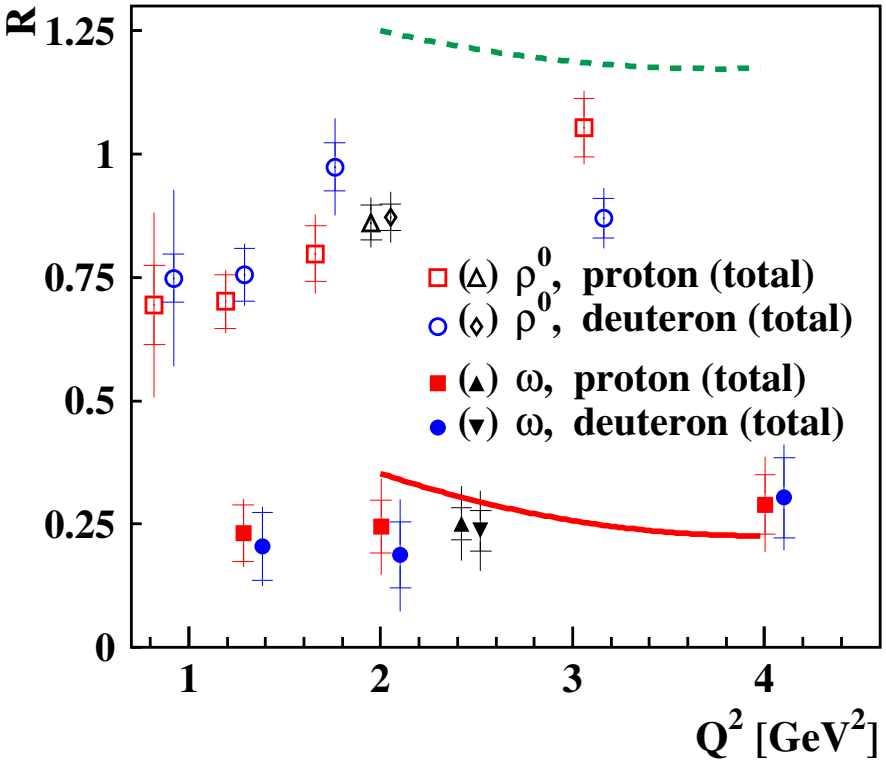
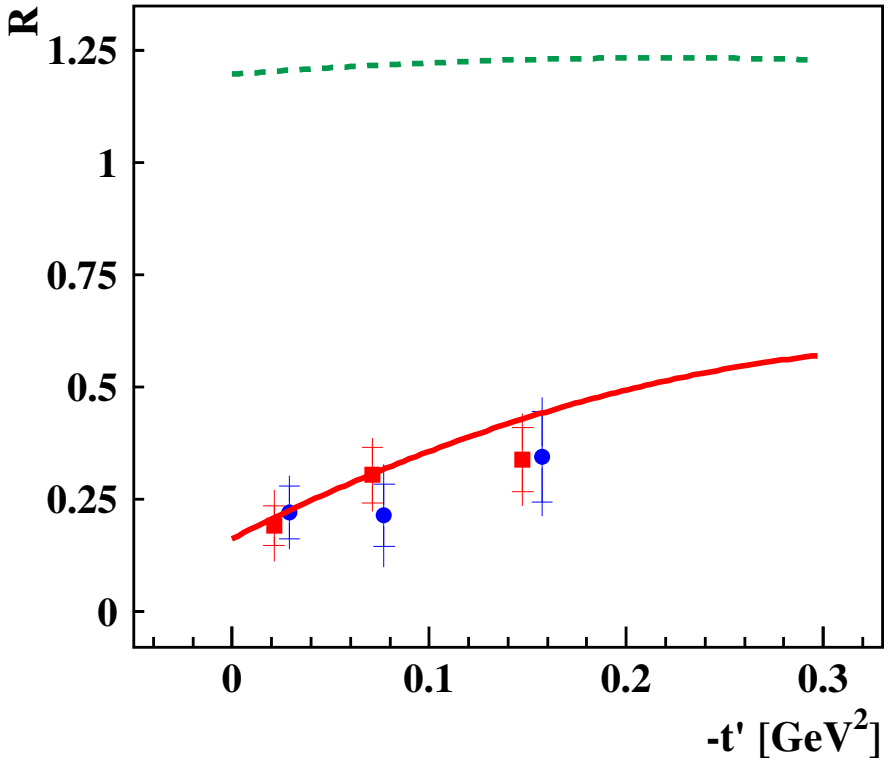
Longitudinal to Transverse Cross Section Ratio





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$$R = \frac{d\sigma_L(\gamma_L \to V)}{d\sigma_T(\gamma_T \to V)} \approx \frac{1}{\epsilon}\frac{r_{04}^{00}}{1 - r_{04}^{00}}$$

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Summary and Conclusion

- Hard exclusive reactions provide unique access to the quark and gluon dynamics inside nucleons
- Many reactions pioneered at HERMES using the unique combination of polarised $e^{\pm}$ and (un)polarised H,D targets
- Event sample purified with addition of HERMES recoil detector
- pure DVCS events show increased amplitude in A_{LU}
- A_{LU} in Δ-DVCS measured, constraining transition GPDs
- Extraction of SDME for ω in exclusive electro-production allows test of SCHC, parity exchanges and longitudinal to transverse cross section ratios

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