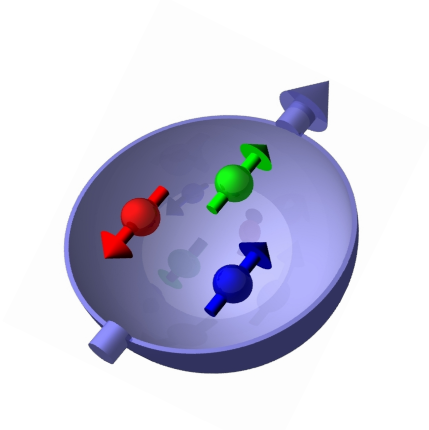


Deeply Virtual Compton Scattering off polarised and unpolarised protons at HERMES

Michael Düren

Universität Gießen

— Int. Spin Physics Symposium SPIN2010, FZ Jülich, Sept. 27, 2010 —

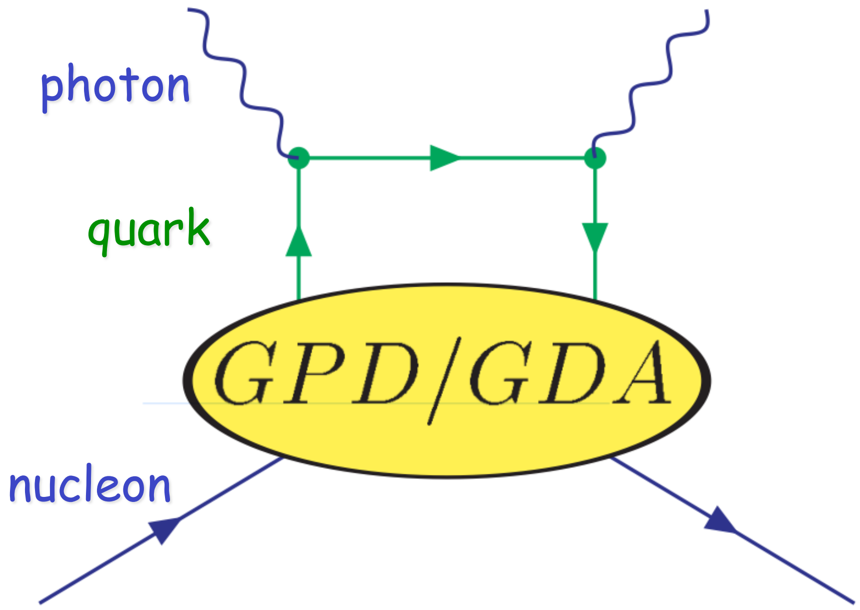
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Generalized Parton Distributions

Quantum phase-space „tomography“
of the nucleon

Generalized Parton Distributions
and Generalized Distribution Amplitudes

GPDs and GDAs describe quarks and gluons in the nucleon

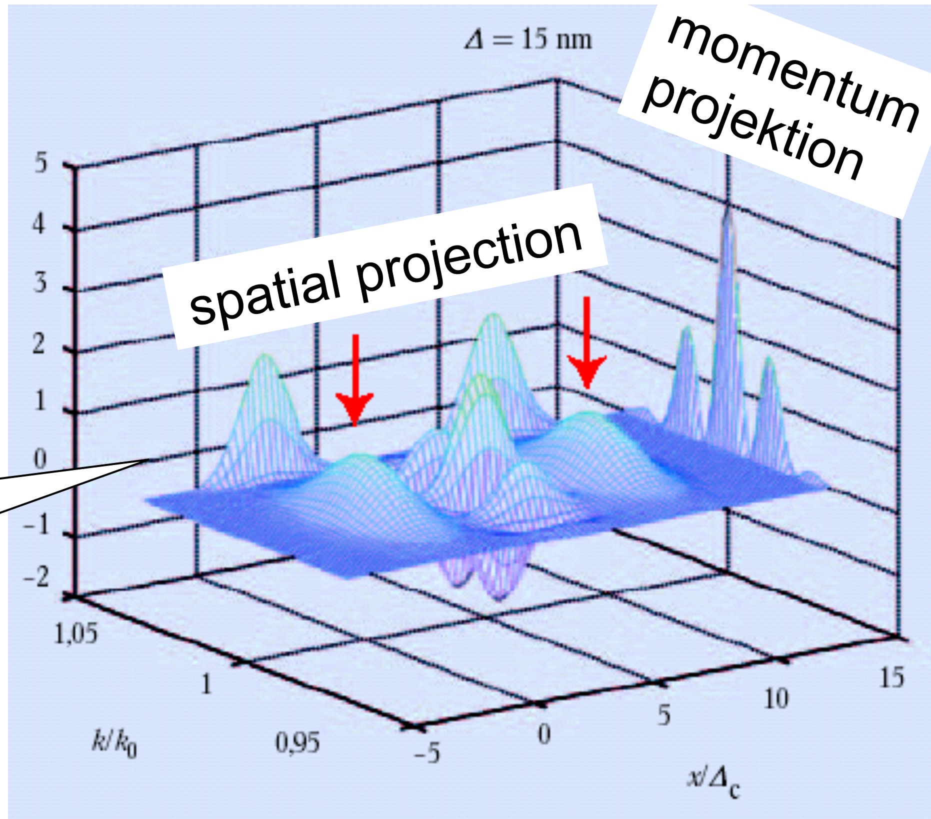


- spatial distributions (Form Factors)
- momentum distributions (Structure Functions)
- correlations in phase space (Wigner Distribution)
- spin and orbital angular momentum (Ji Sum Rule)

Wigner distribution in QM phase-space

- Wigner introduced the first well-defined phase-space distribution in quantum mechanics (1932)
  (despite of the uncertainty principle)
- Wigner function: $W(x,p) = \int \psi^*(x-\eta/2)\psi(x+\eta/2)e^{ip\eta}\,d\eta$

The Wigner function contains the *most complete (one-body) info* about a quantum system.



Example of a Wigner function
(a particle passing an interferometer)

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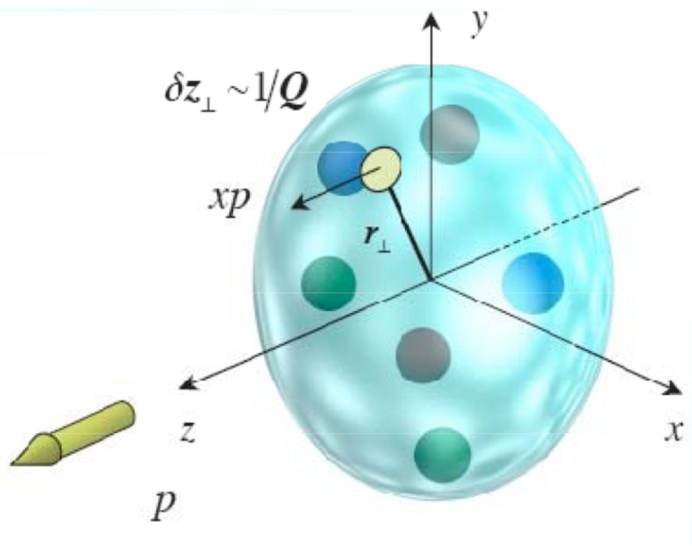
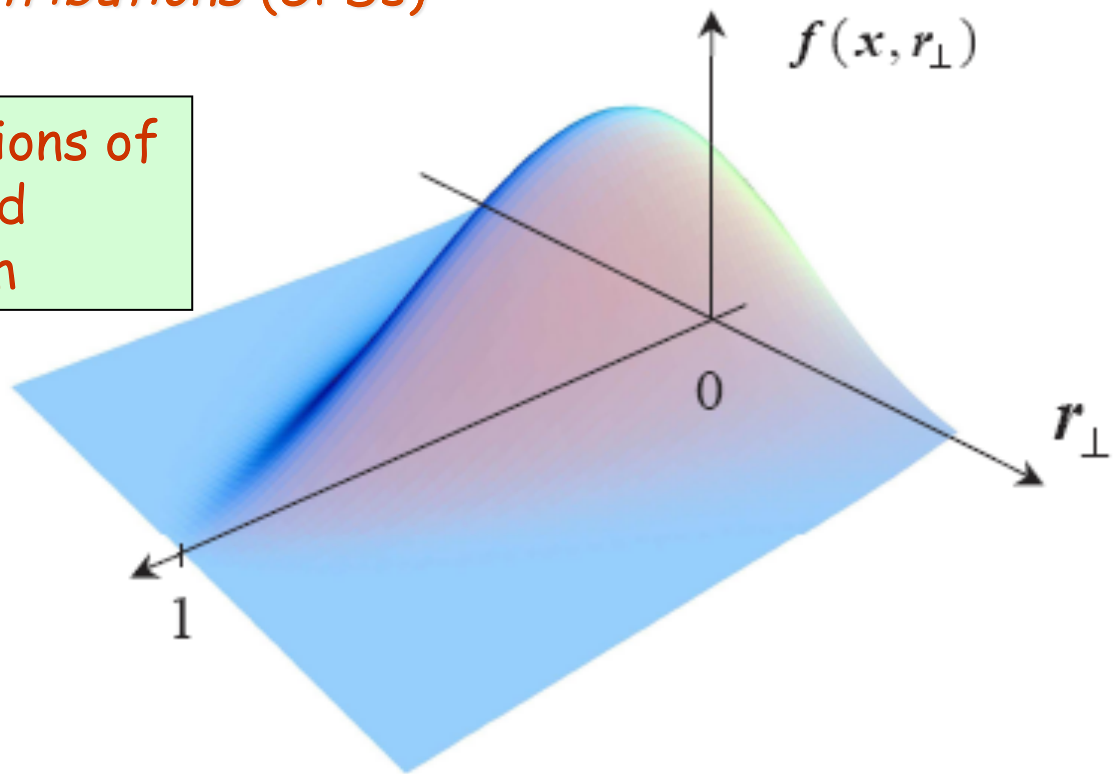
Generalized Parton Distribution

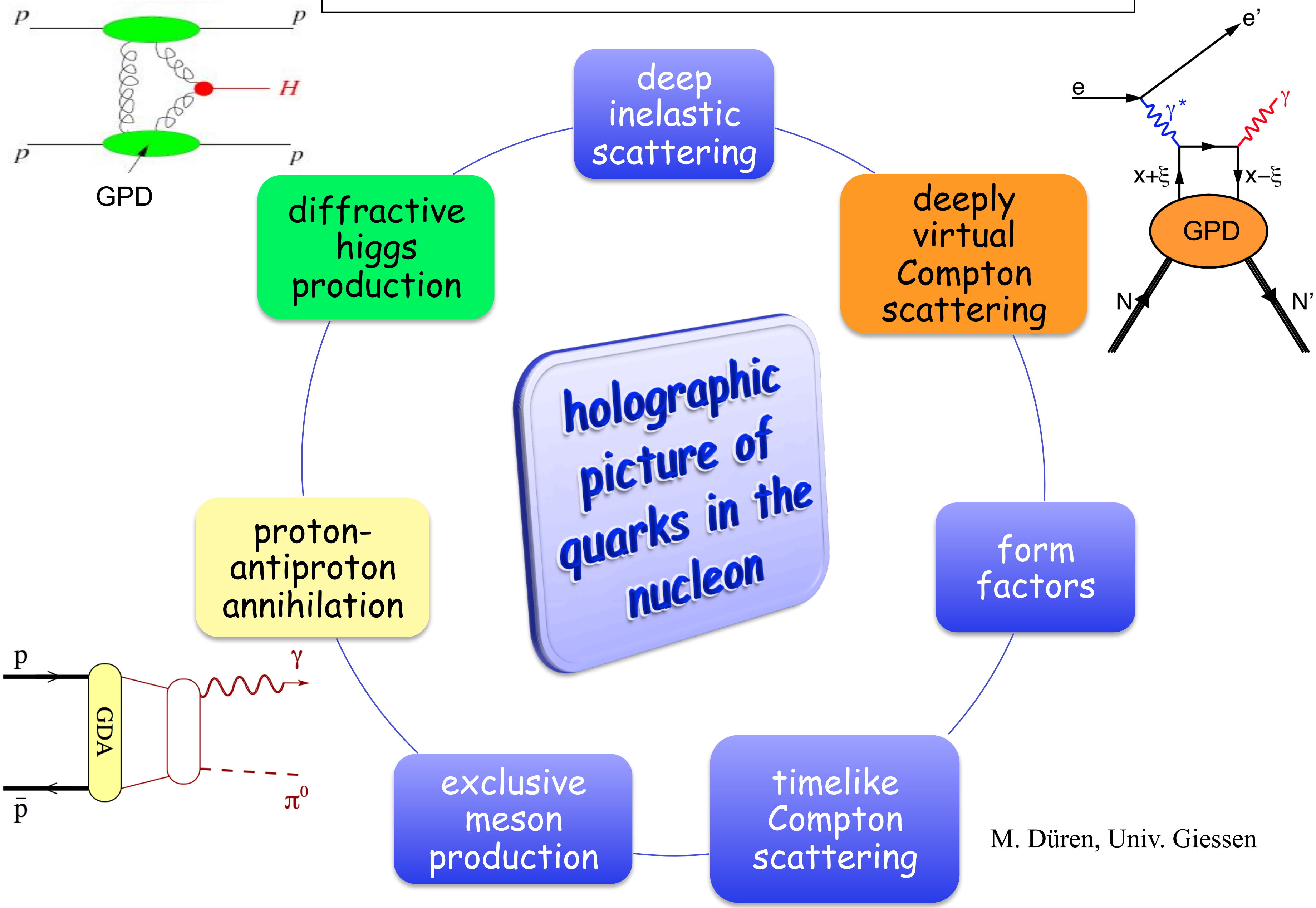
- A Wigner operator can be defined that describes quarks and gluons in the nucleon
- The reduced Wigner distribution is related to *Generalized Parton distributions* (GPDs)

GPDs describe e.g. correlations of transverse position and longitudinal momentum





Are GPDs/GDAs universal?



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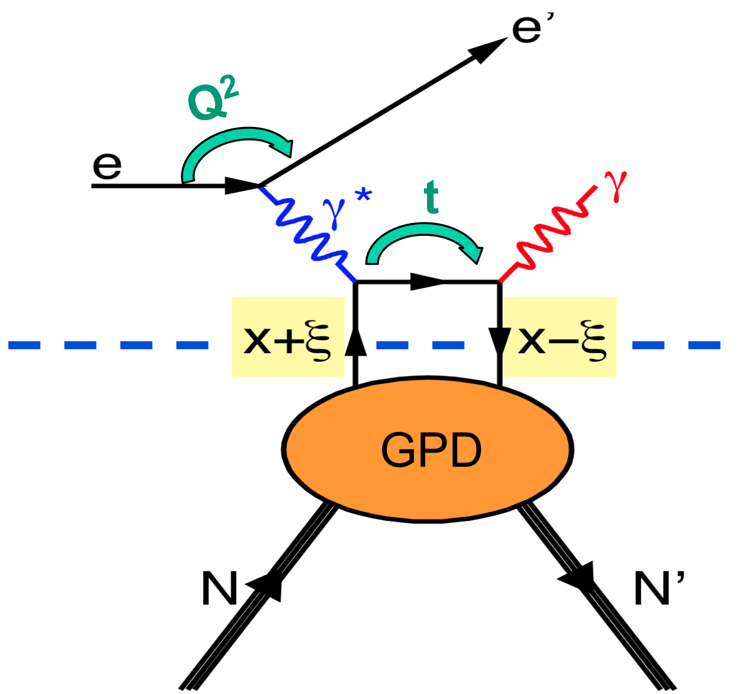
Deeply Virtual Compton Scattering (DVCS)

DVCS is the cleanest way to access GPDs

Factorization theorem is proven!



Handbag diagram separates

- hard scattering process (QED & QCD) (NLO) and
- non-pertubative structure of the nucleon: GPD(x,ξ,t,Q^2)

GPDs = probability amplitude for a nucleon to emit a parton with $x+\xi$ and to absorb it with momentum fraction $x-\xi$

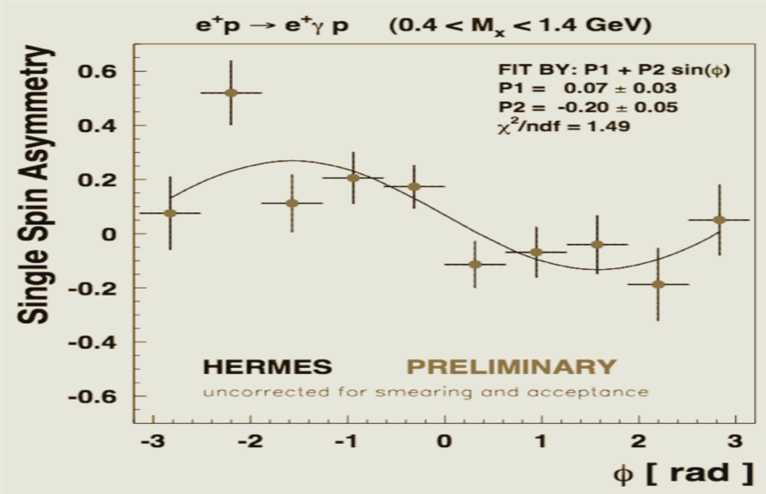
$$\xi \approx \frac{x_{Bj}}{2 - x_{Bj}}$$

HERMES: a pioneering experiment

… from Ellis-Jaffe to Ji et al. …

The HERMES Experiment

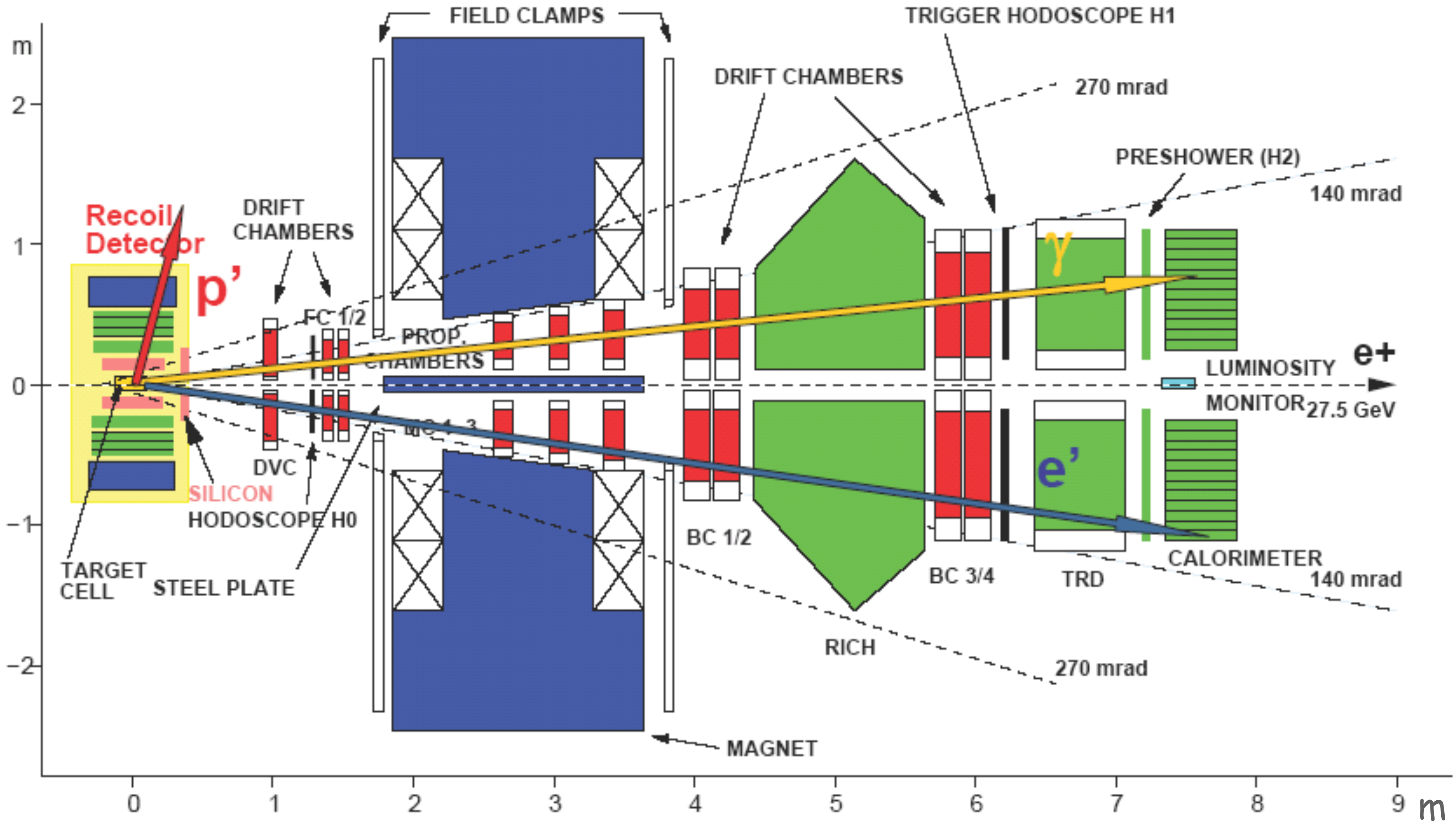
- Designed at times of the spin crisis
  - Ellis-Jaffe & Bjorken sum rule
  - strange quark polarization
- 12 years data taking 1995-2007
- Pioneering results of DVCS



First non-zero DVCS SSA (2000)

- Today: most complete experimental access:
  - charge reversal (e^+ and e^- beams)
  - beam spin reversal (both beam helicities)
  - target spin reversal (parallel, transverse, unpolarized)
  - target mass variation (H, D, He, N, Ne, Kr, Xe)
  - recoil and spectator proton detection
  - ...

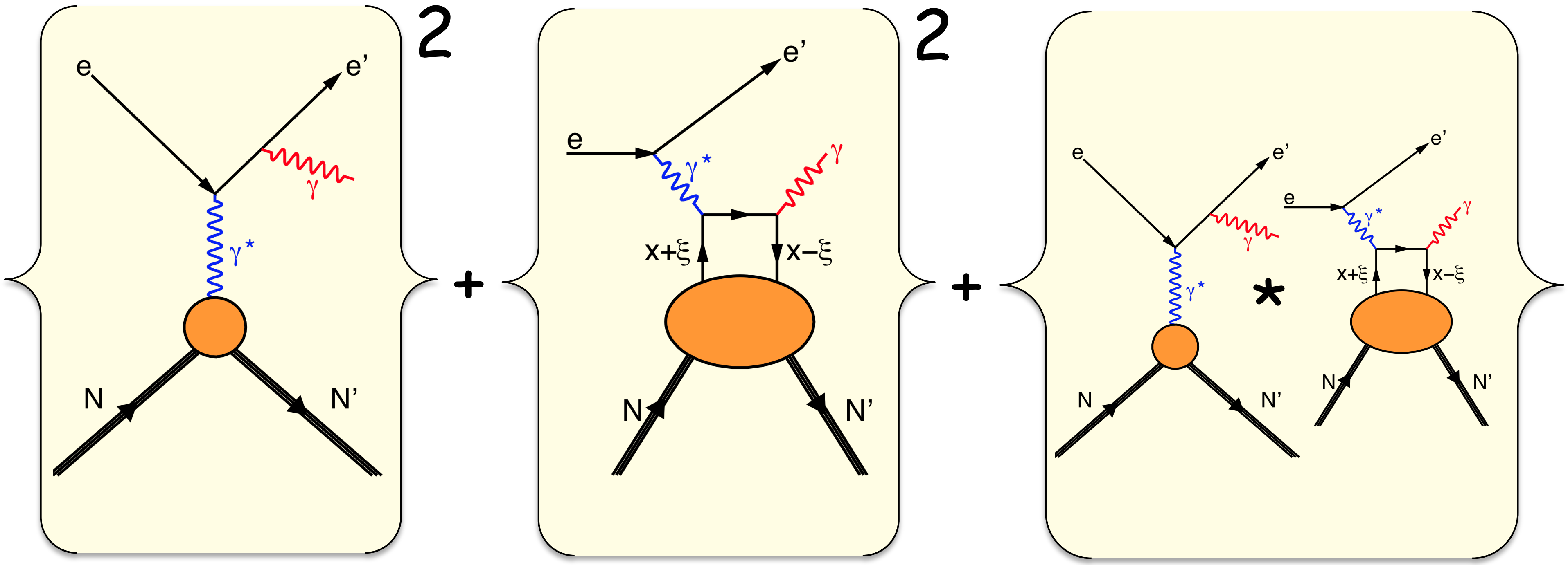
HERMES with recoil detection



HERMES talks at SPIN2010

- **DVCS - Michael Düren (Universität Giessen) Mo 14:00**
- Recoil detection – Sergey Yaschenko (DESY) Mo 15:00
- g_2 – Markus Diefenthaler (Univ. of Illinois) Mo 15:2
- Vector mesons - Gliske, Stephen (University of Michigan) Mo 17:00
- Single spin asymmetries - Rith, Klaus (University of Erlangen) Th. 14:00
- Transverse momentum - Diefenthaler, Markus (Univ. of Illinois) Tu 14:30
- Helicity amplitudes - Marianski, Bohdan (Inst. for Nucl. Studies) Th. 14:30
- 2-photon exchange - Rith, Klaus (University of Erlangen) Th. 15:00
- Cosine modulation - Giordano, Francesca (DESY, Hamburg) Tu 17:20
- DVCS on D and nuclei – Riedl, Caroline (DESY) Fr 16:30
- Spin transfer coefficient - Veretennikov, Denis (PNPI) Fr 17:00
- Nuclear Lambda production - Naryshkin, Yury (PNPI) Fr 17:50
- Hard exclusive electroproduction - Avetisyan, Eduard (DESY) Fr 17:50
- **Overview of recent HERMES results – S. Yaschenko (DESY) Fr 12:00**

Exclusive ep → epγ cross section at HERMES



BH: LARGE
+ known

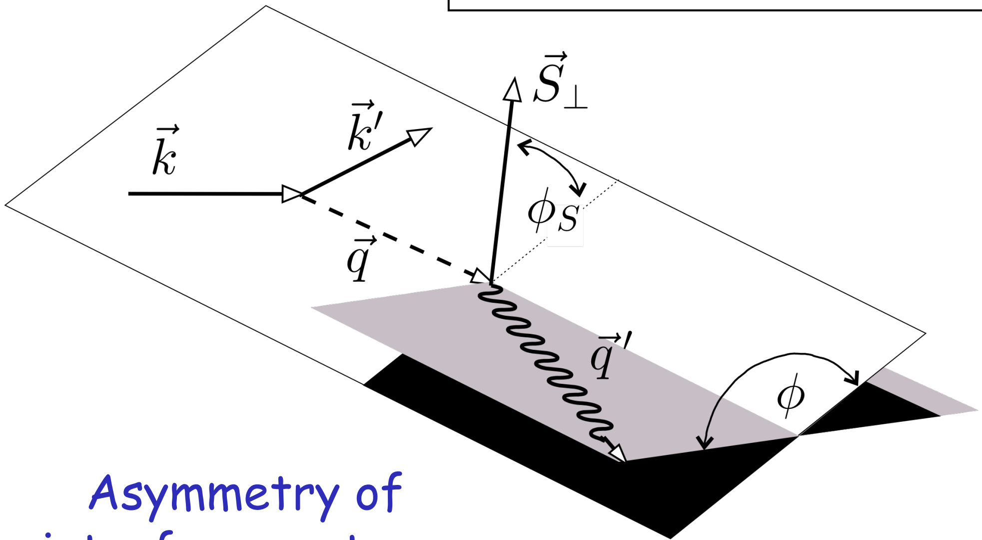
DVCS: small
+ unknown

Interference: medium
+ non-zero azimuthal
asymmetries

$$\frac{d\sigma}{dx_B\, dQ^2\, d|t|\, d\phi} = \frac{x_B\, e^6}{32\,(2\pi)^4\, Q^4\, \sqrt{1+\epsilon^2}} \left[|\tau_{BH}|^2 + |\tau_{DVCS}|^2 + \overbrace{\tau_{DVCS}\, \tau_{BH}^* + \tau_{DVCS}^*\, \tau_{BH}}^{I} \right]$$

Direct access to DVCS matrix elements

Separation of amplitudes



- reversal of charge **and** spin

Asymmetry of interference term

$$\mathcal{A}_{\mathrm{LU}}^{\mathrm{I}}(\phi) \equiv \frac{(d\sigma^{+\rightarrow} - d\sigma^{+\leftarrow}) \ominus (d\sigma^{-\rightarrow} - d\sigma^{-\leftarrow})}{(d\sigma^{+\rightarrow} + d\sigma^{+\leftarrow}) + (d\sigma^{-\rightarrow} + d\sigma^{-\leftarrow})}$$

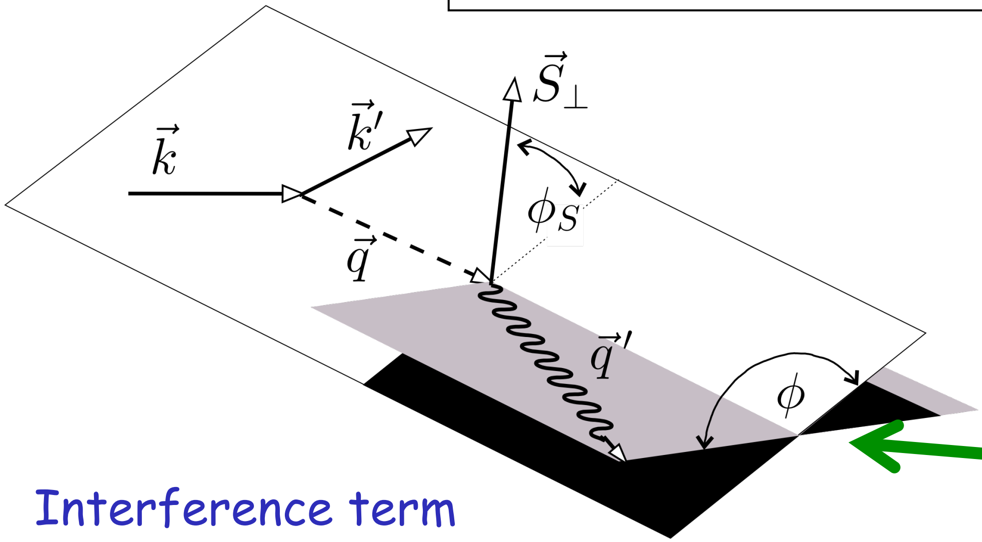
Asymmetry of DVCS

$$\mathcal{A}_{\mathrm{LU}}^{\mathrm{DVCS}}(\phi) \equiv \frac{(d\sigma^{+\rightarrow} - d\sigma^{+\leftarrow}) \oplus (d\sigma^{-\rightarrow} - d\sigma^{-\leftarrow})}{(d\sigma^{+\rightarrow} + d\sigma^{+\leftarrow}) + (d\sigma^{-\rightarrow} + d\sigma^{-\leftarrow})}$$

longitudinal beam spin

unpolarized target spin

Separation of amplitudes



- reversal of charge **and** spin
- Fourier analysis of **azimuthal** modulation

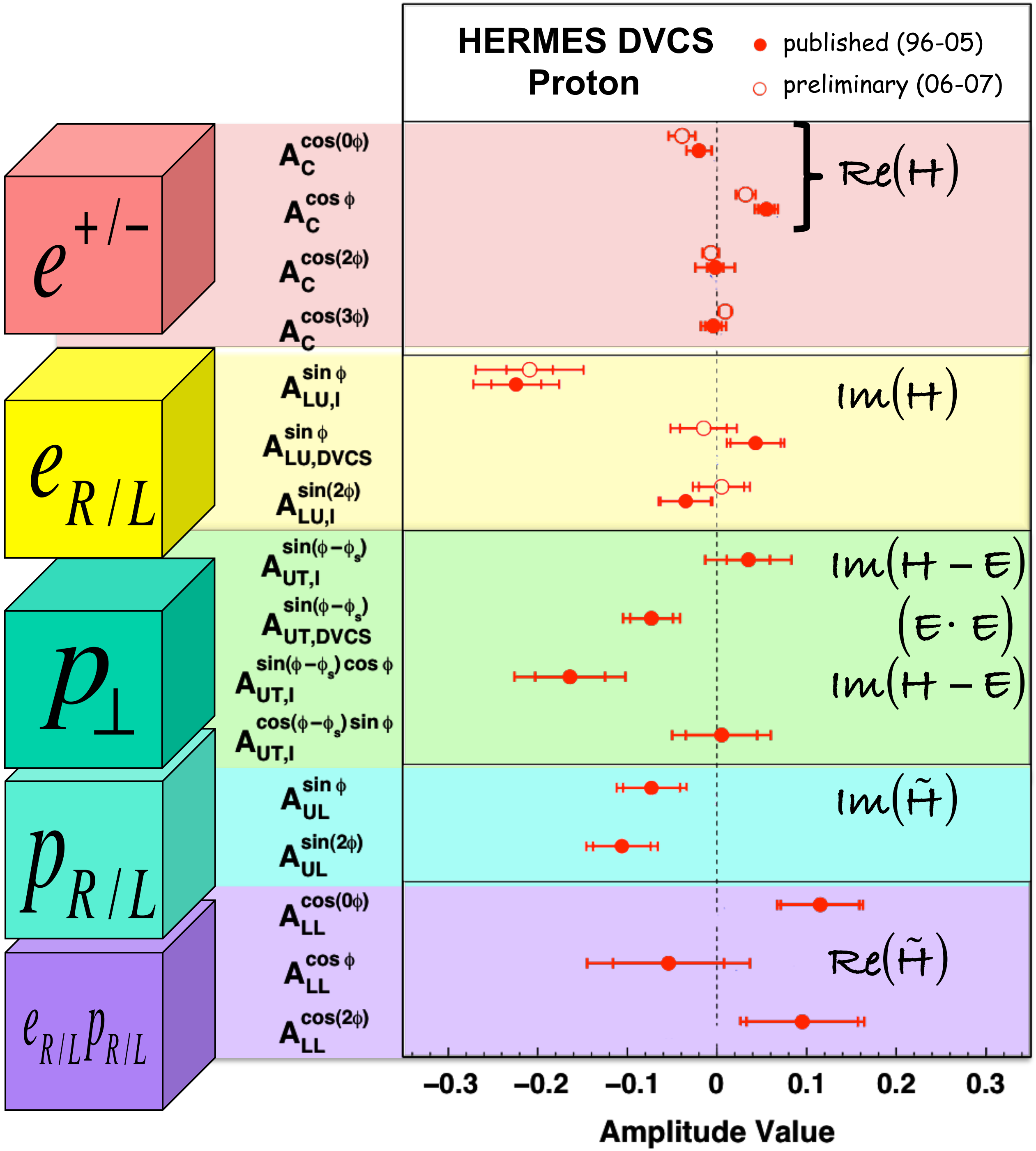
Interference term asymmetrie

Fourier coefficients

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

$$= \frac{-\frac{K_{\mathrm{I}}}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left[\sum_{n=1}^{2} s_n^{\mathrm{I}} \sin(n\phi)\right]}{\frac{K_{\mathrm{BH}}}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\sum_{n=0}^{2} c_n^{\mathrm{BH}}\cos(n\phi) + \frac{1}{Q^2}\sum_{n=0}^{2} c_n^{\mathrm{DVCS}}\cos(n\phi)}$$

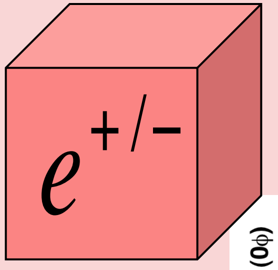
Access to GPD H, H̃, E



JHEP 11 (2009) 083

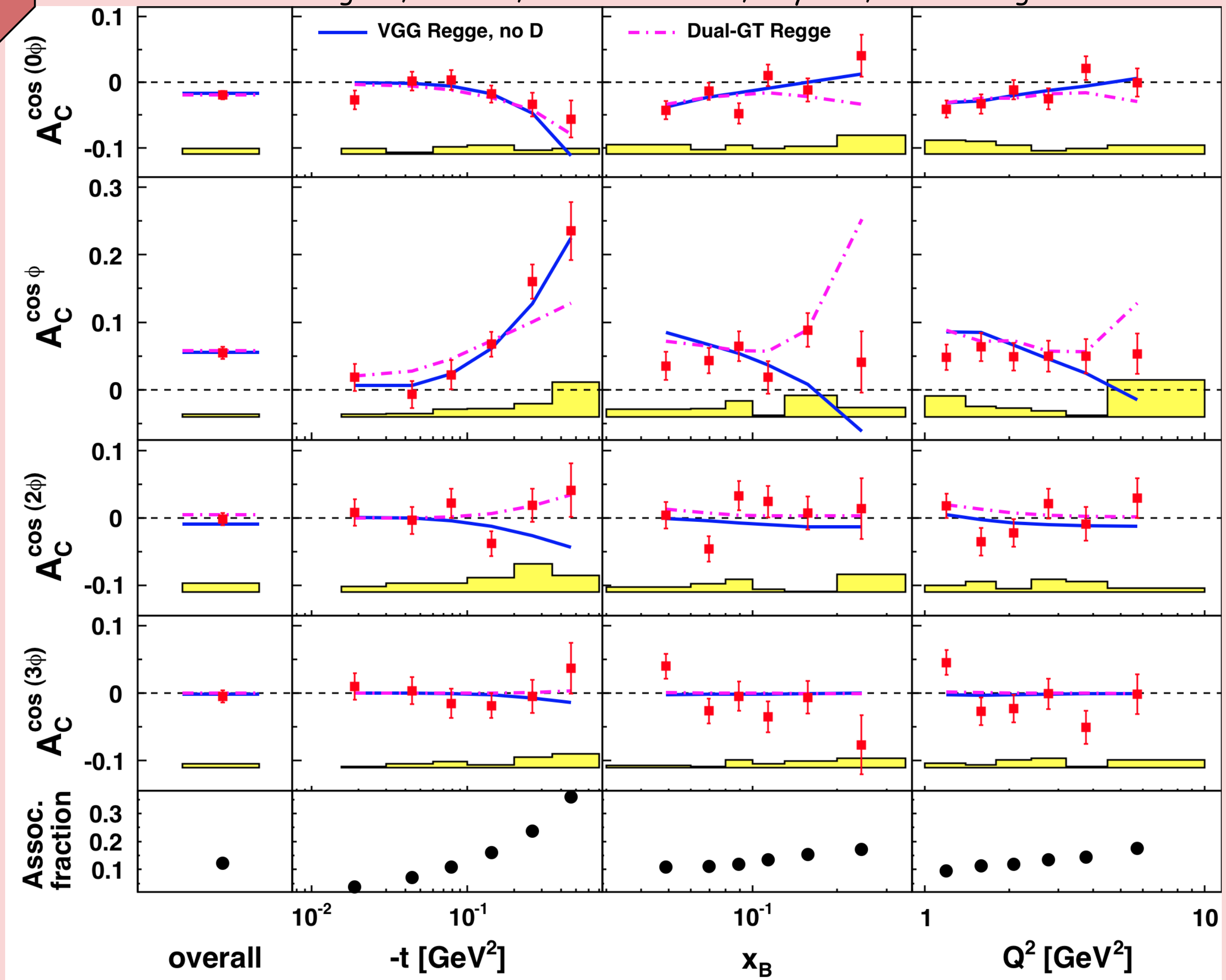
JHEP 06 (2008) 066

JHEP 06 (2010) 019



Beam charge asymmetry (published)

Vanderhaeghen, Guichon, Guidal - Goeke, Polyakov, Vanderhaeghen

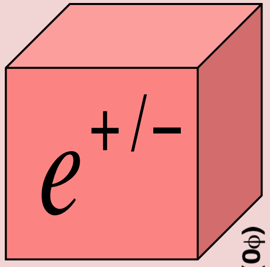


Re(H)

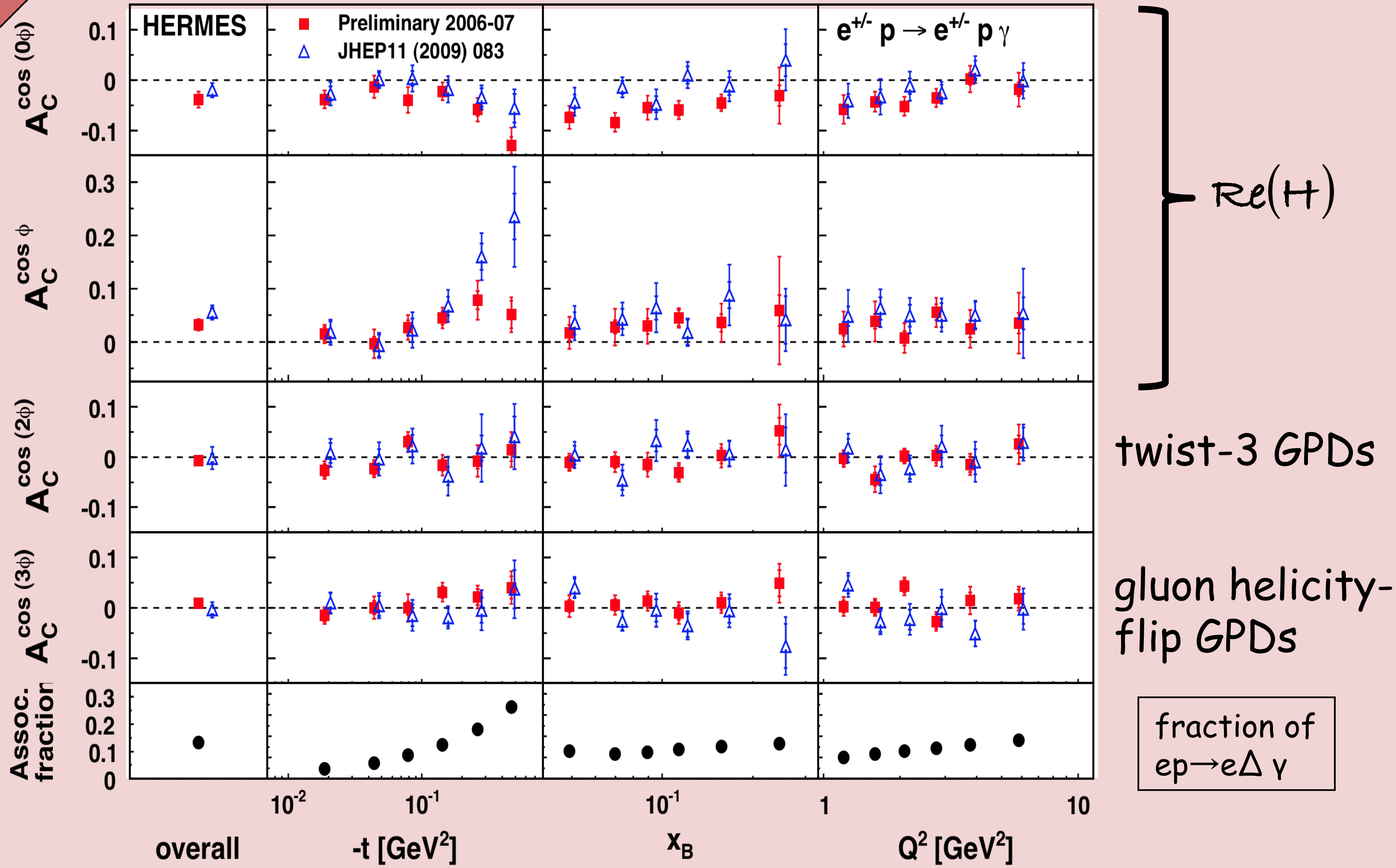
twist-3 GPDs

gluon helicity-flip GPDs

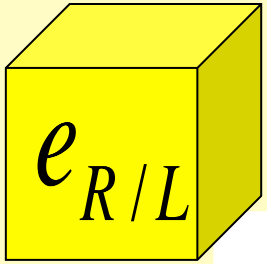
fraction of ep→eΔ γ

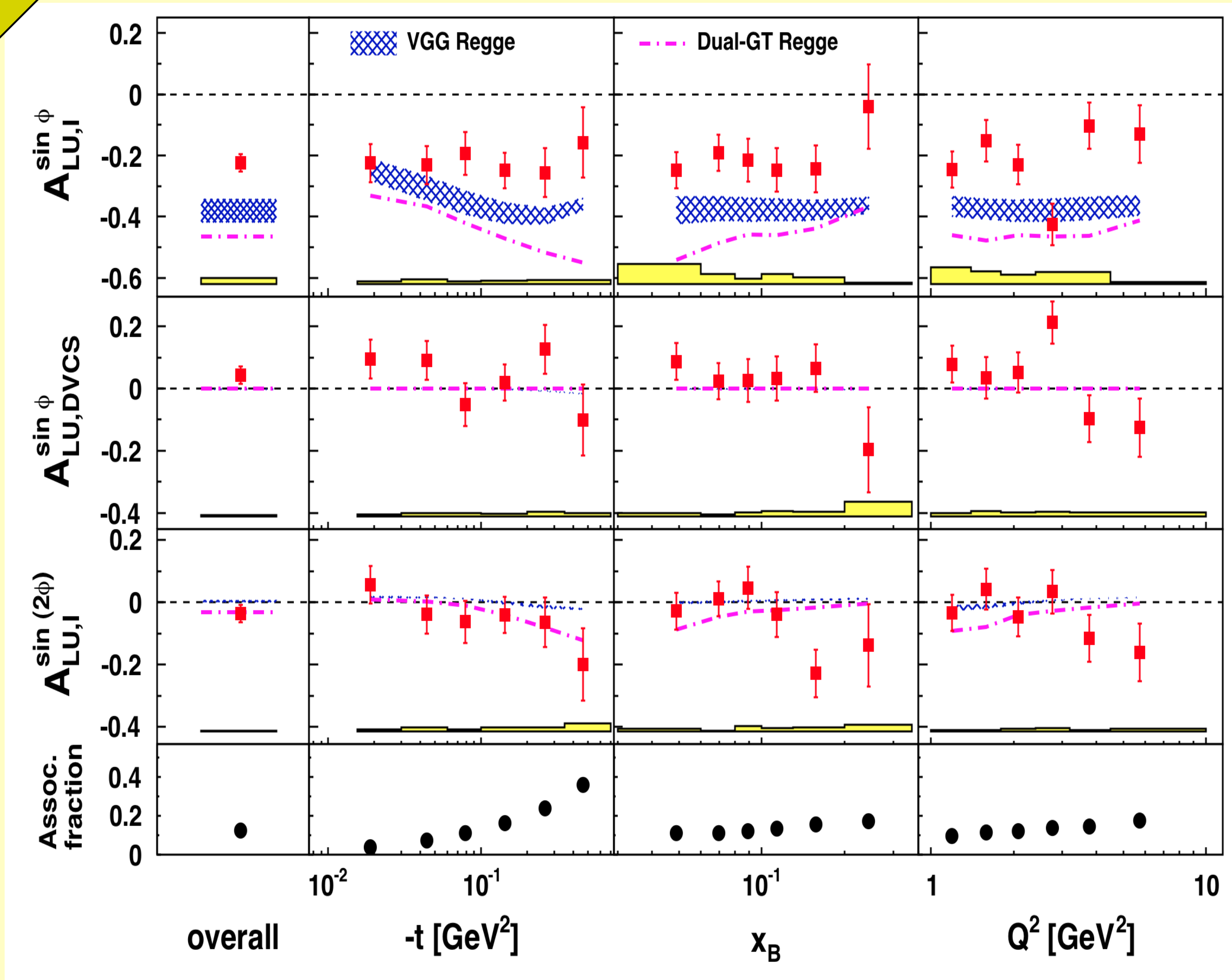


Beam charge asymmetry (new data)



Beam helicity asymmetry



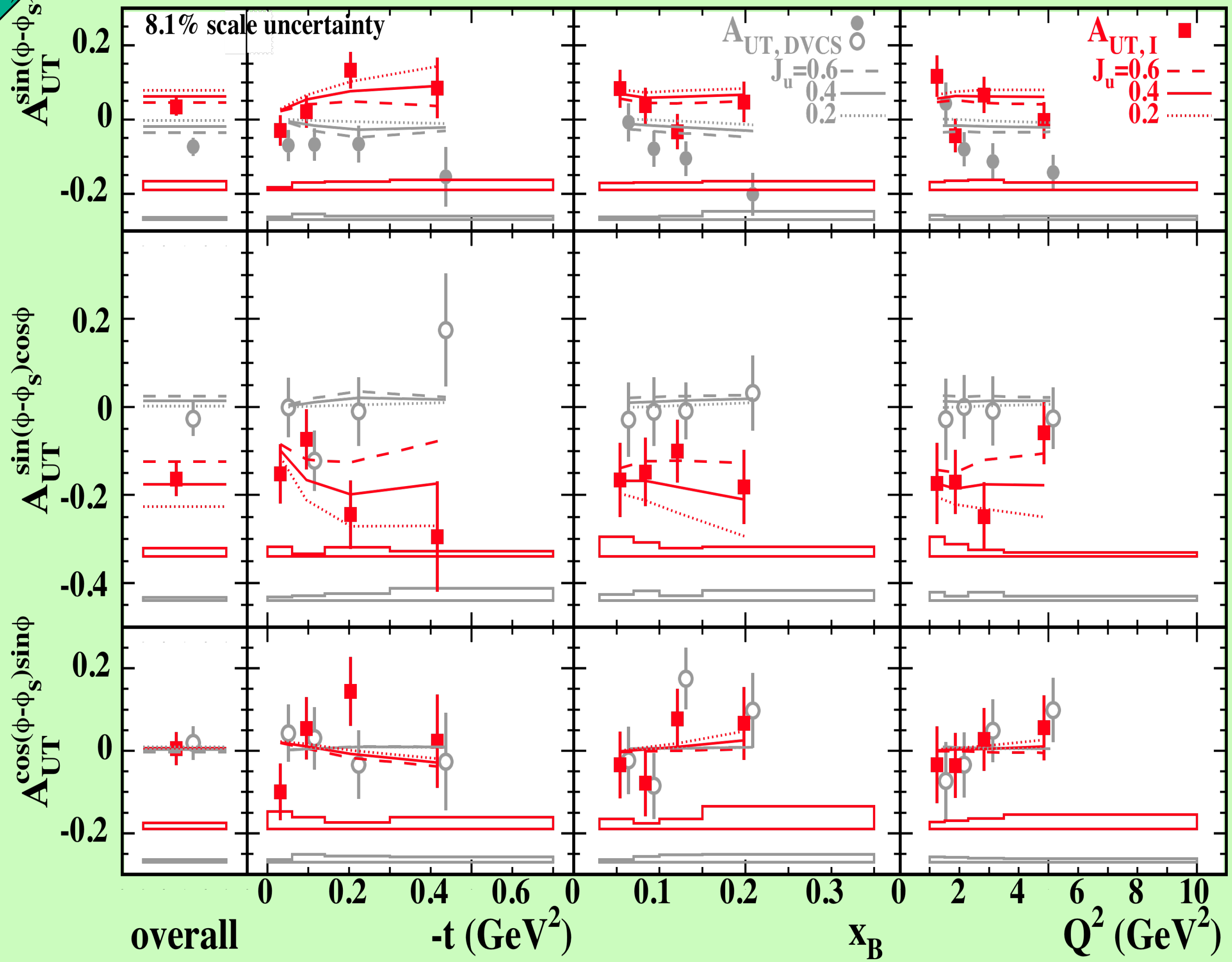


Im(H)

twist-3 GPDs

fraction of ep→eΔ γ

Transverse target spin asymmetry

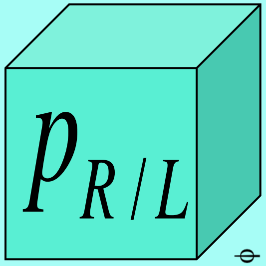


sensitive to J_u

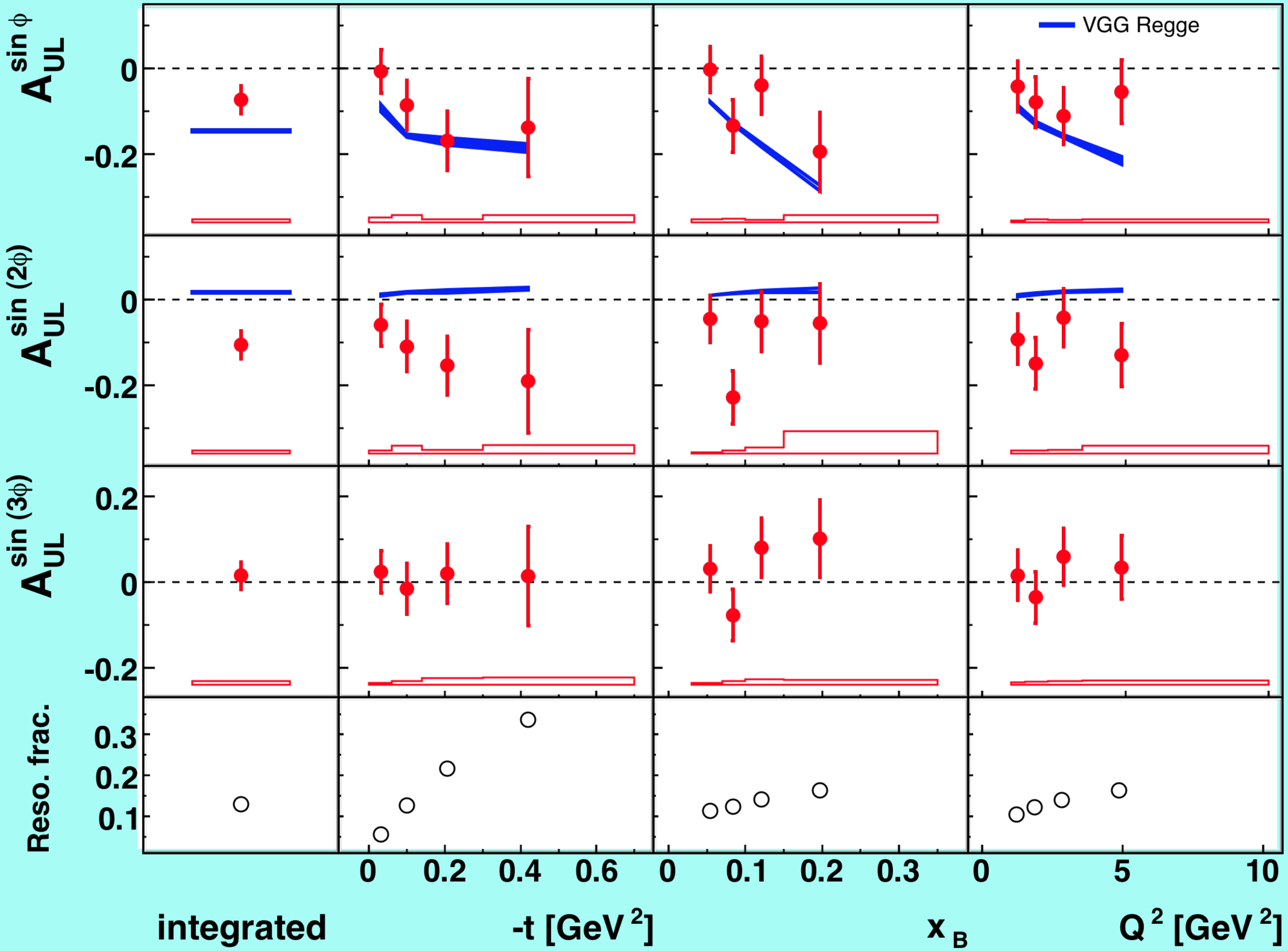
$Im(H - E)$

$(E \cdot E)$

$Im(\tilde{H} - \tilde{E})$

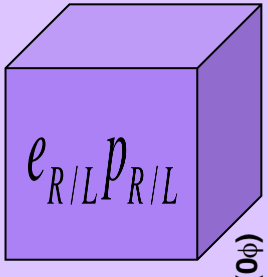


Target helicity asymmetry

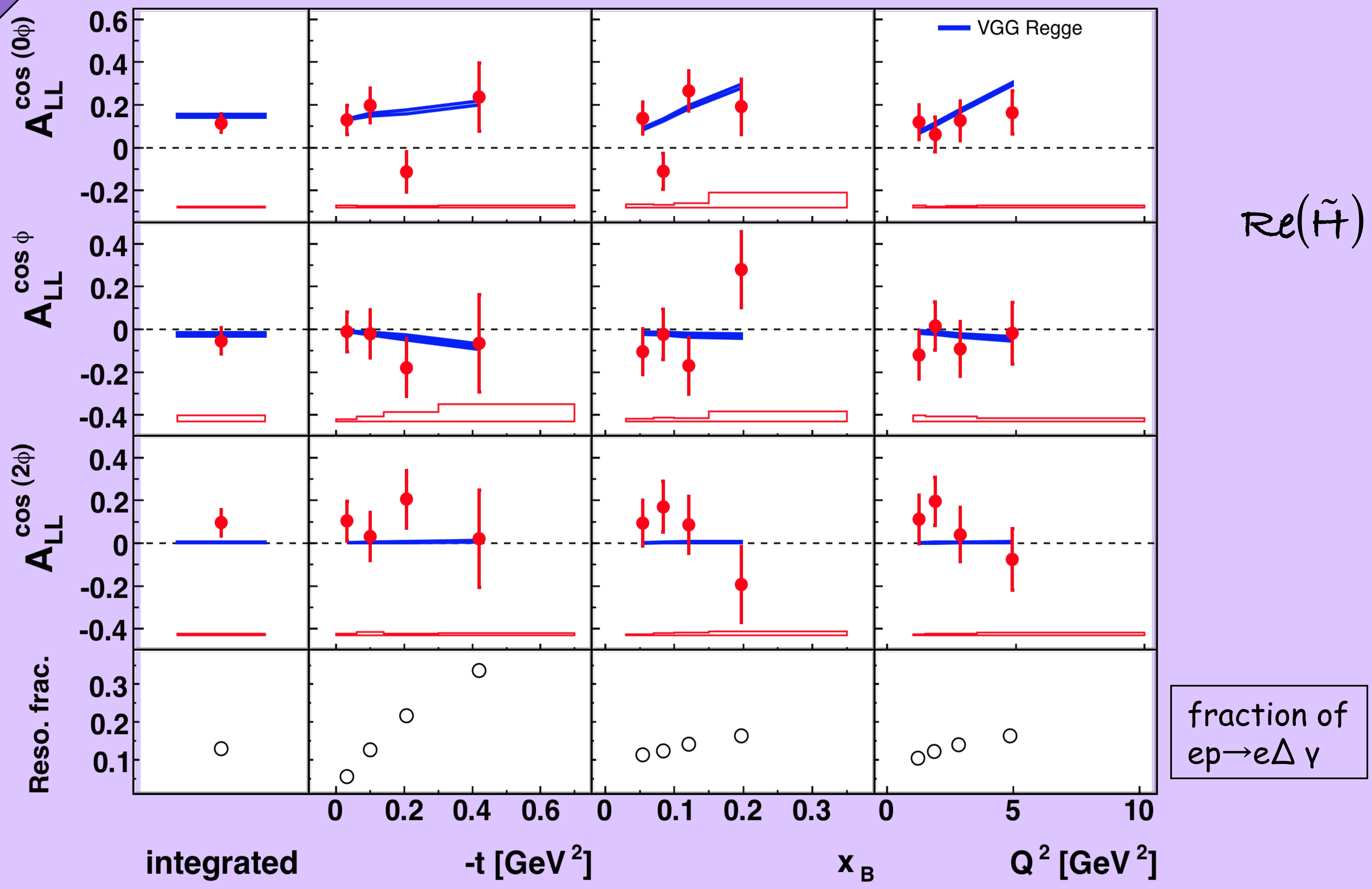


$Im(\tilde{H})$

fraction of $ep \to e\Delta\gamma$



Double spin asymmetry



Conclusion and Outlook

- GDPs are THE access to the nucleon structure
- HERMES is a pioneering experiment of DVCS
- Many more results from HERMES:
  - deuterium and nuclear DVCS (see talk by Caro Riedl)
  - exclusive meson production
  - recoil detection
  - …

GOTO SERGEY @ 15:00 (Session D)

END