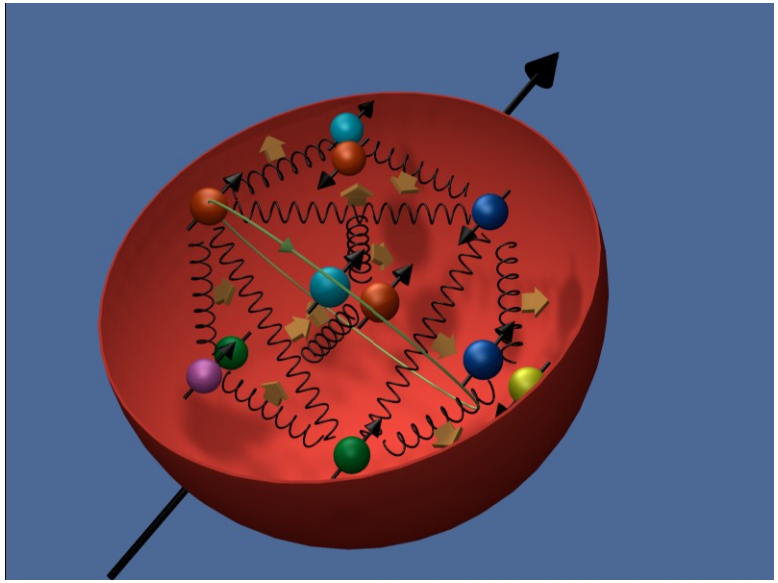
Report from HERMES



Sergey Yaschenko

74. DESY PRC meeting
Zeuthen, 8.11.2012

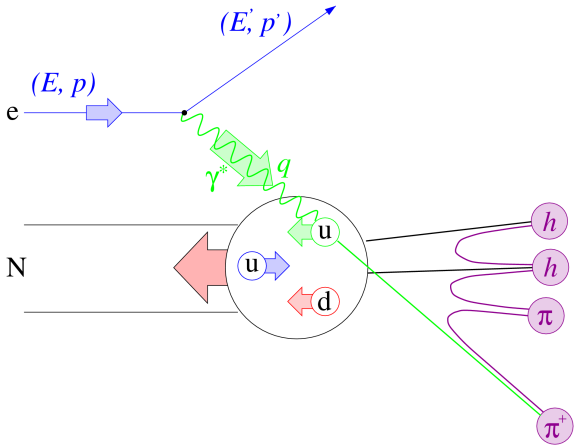
HELMHOLTZ ASSOCIATION

DESY

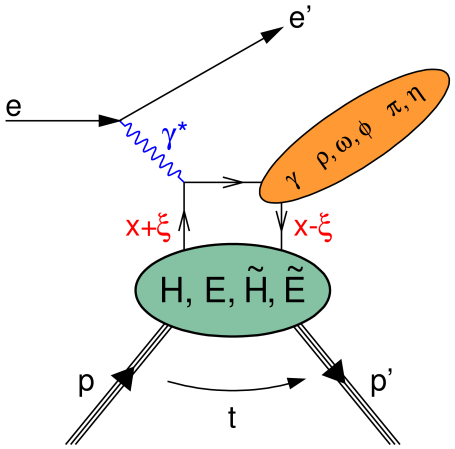
HERMES recent highlights

- Hadronization/fragmentation
  → Semi-inclusive measurements
- Transverse Momentum Dependent PDFs (TMDs)
  → Semi-inclusive measurements
- Generalized Parton Distributions (GPDs)
  → Exclusive measurements

Semi-inclusive DIS



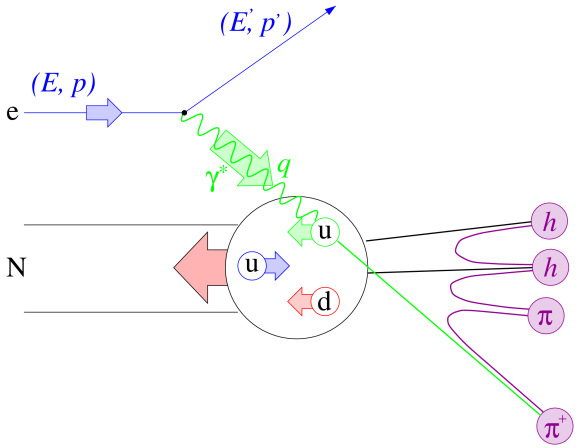
Exclusive production of real photon and mesons



HERMES recent highlights

- Hadronization/fragmentation
  - → Semi-inclusive measurements
- Transverse Momentum Dependent PDFs (TMDs)
  - → Semi-inclusive measurements
- Generalized Parton Distributions (GPDs)
  - → Exclusive measurements

Semi-inclusive DIS



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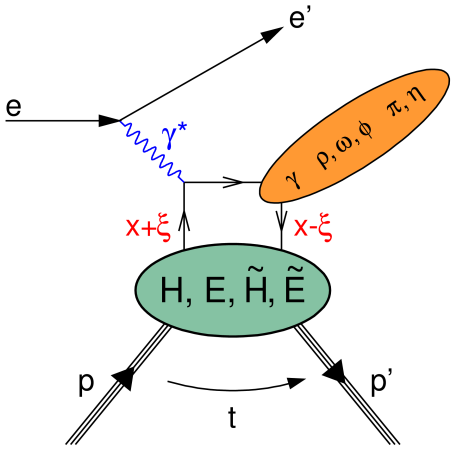


Hadronization/fragmentation

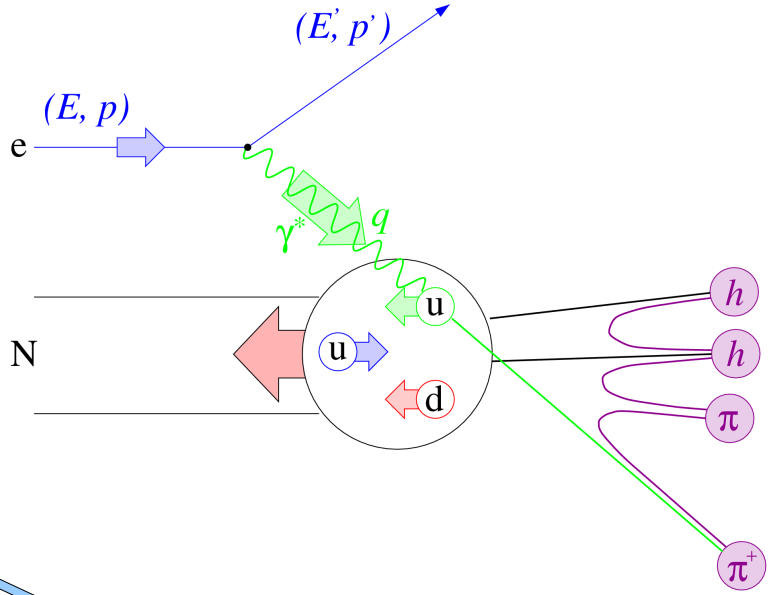
- Charge-separated hadron multiplicities

$$\sigma_{UU} \propto f_1 \otimes D_1$$

$$M^h(x_B, Q^2, z, P_{h\perp}, \phi) = \frac{N^h(x_B, Q^2, z, P_{h\perp}, \phi_h)}{N^{DIS}(x_B, Q^2)}$$

- Sensitive to individual (anti)quark flavors in the fragmentation process → step forward from inclusive measurements

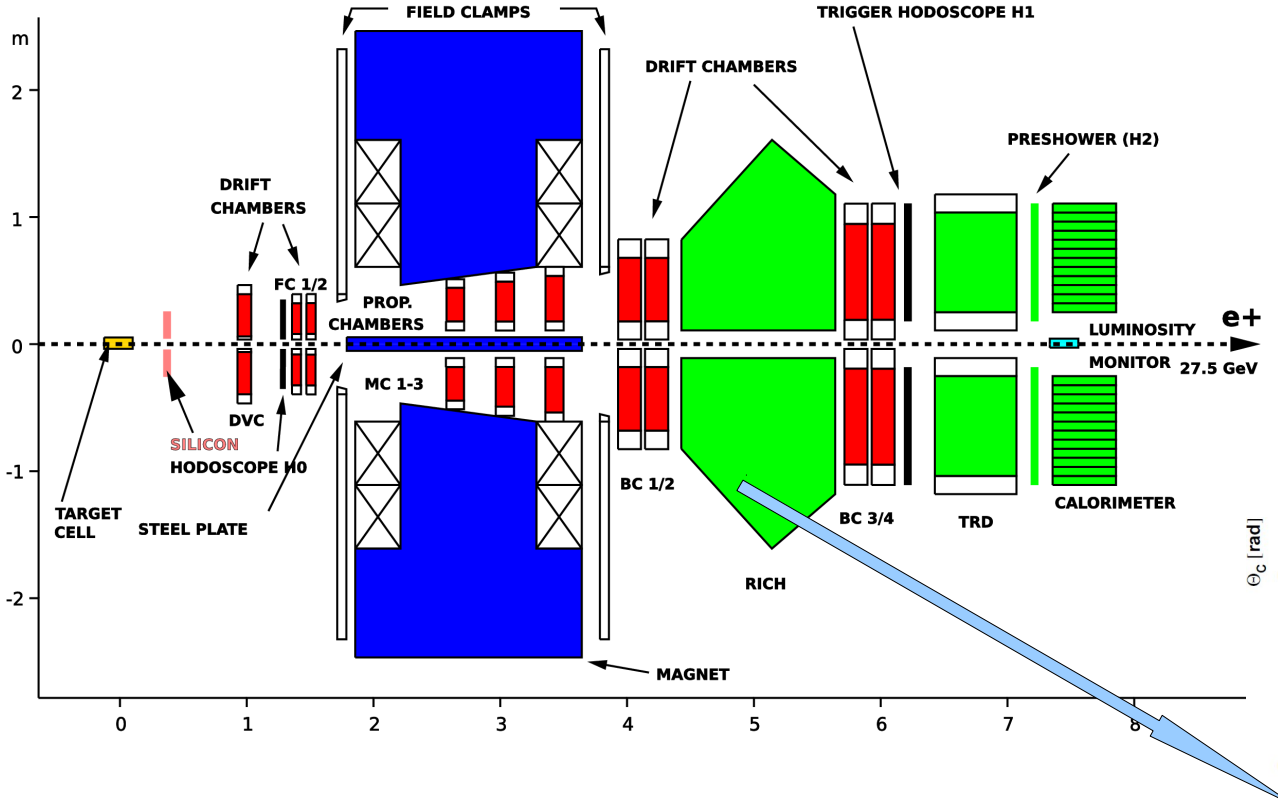
- Leading order interpretation of multiplicity results in the framework of collinear factorization

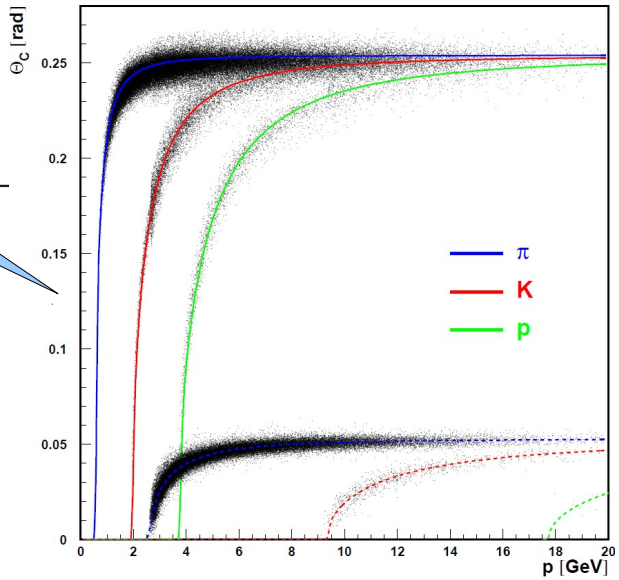


$$M^h \propto \frac{\sum_q e_q^2 \int dx f_{1q}(x, Q^2) D_{1q}^h(z, Q^2)}{\sum_q e_q^2 \int dx f_{1q}(x, Q^2)}$$

PDF, FF

HERMES spectrometer

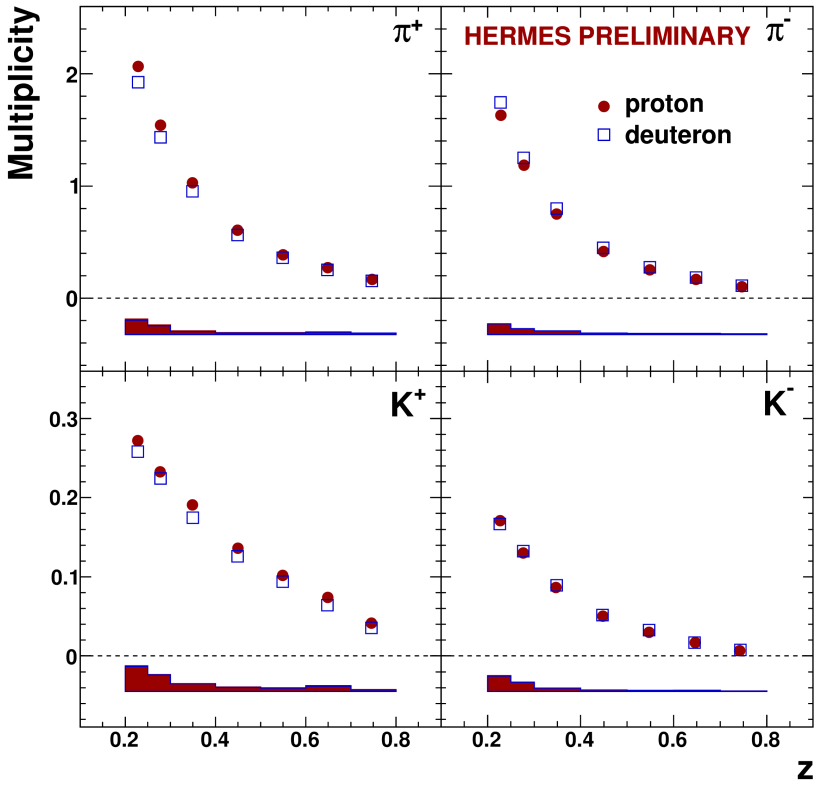


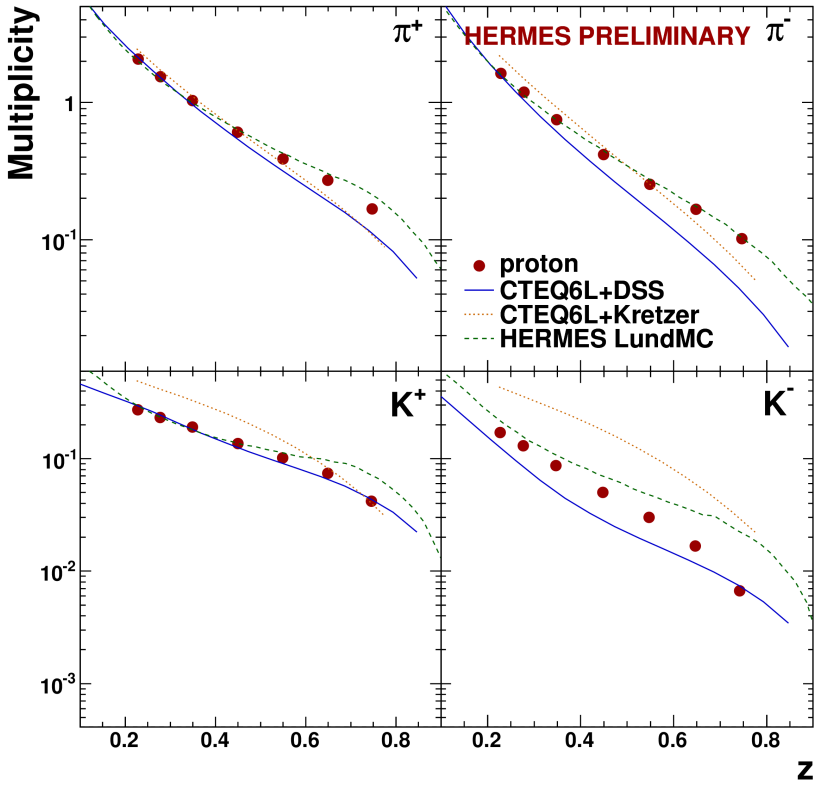


- Electron and positron beams 27.6 GeV
- Hydrogen and Deuterium targets
- Good momentum resolution (<2%)
- Excellent particle identification

Results on pion and kaon multiplicities

Near submission (DESY 12-157)

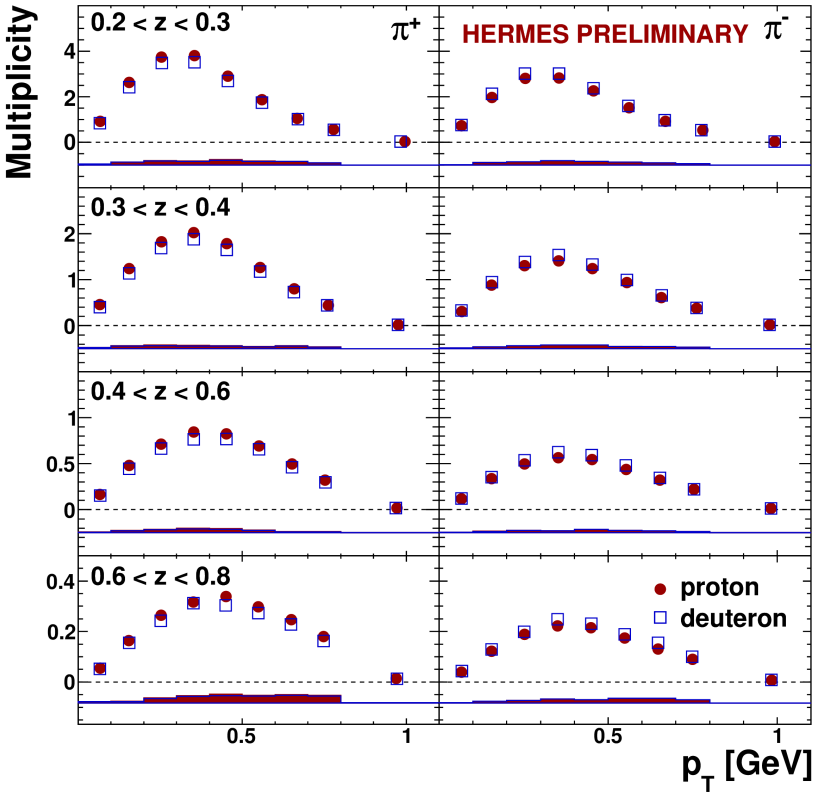


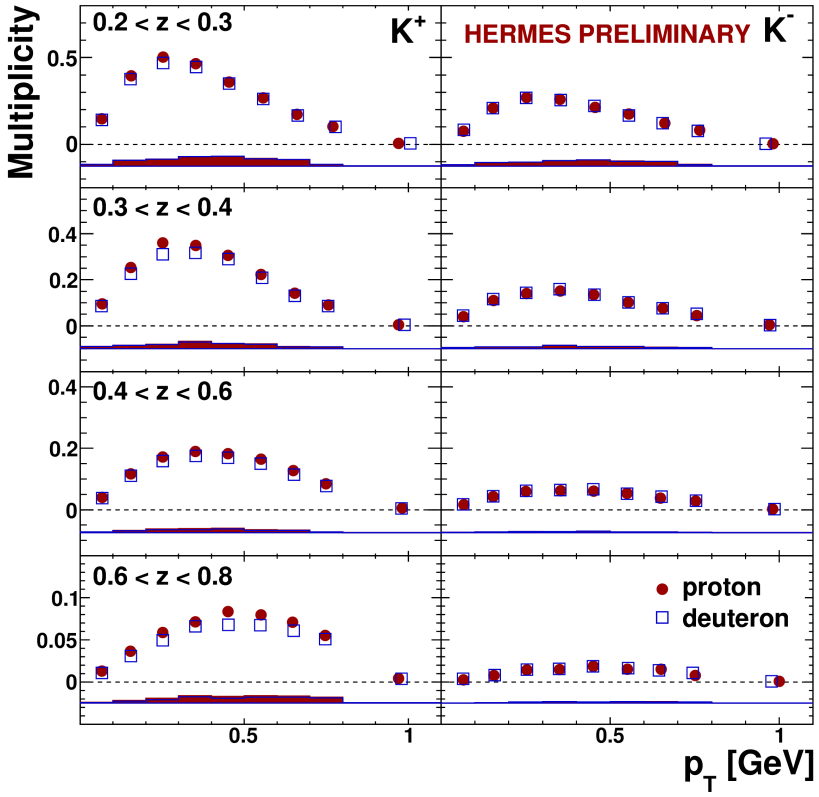


- DSS and Kretzer FF fits together with CTEQ6L PDFs:
  - Fair agreement for positively charged hadrons
  - Data on negatively charged hadrons provide clear impact on further improvements of FF models

Multidimensional kinematic dependences

Near submission (DESY 12-157)





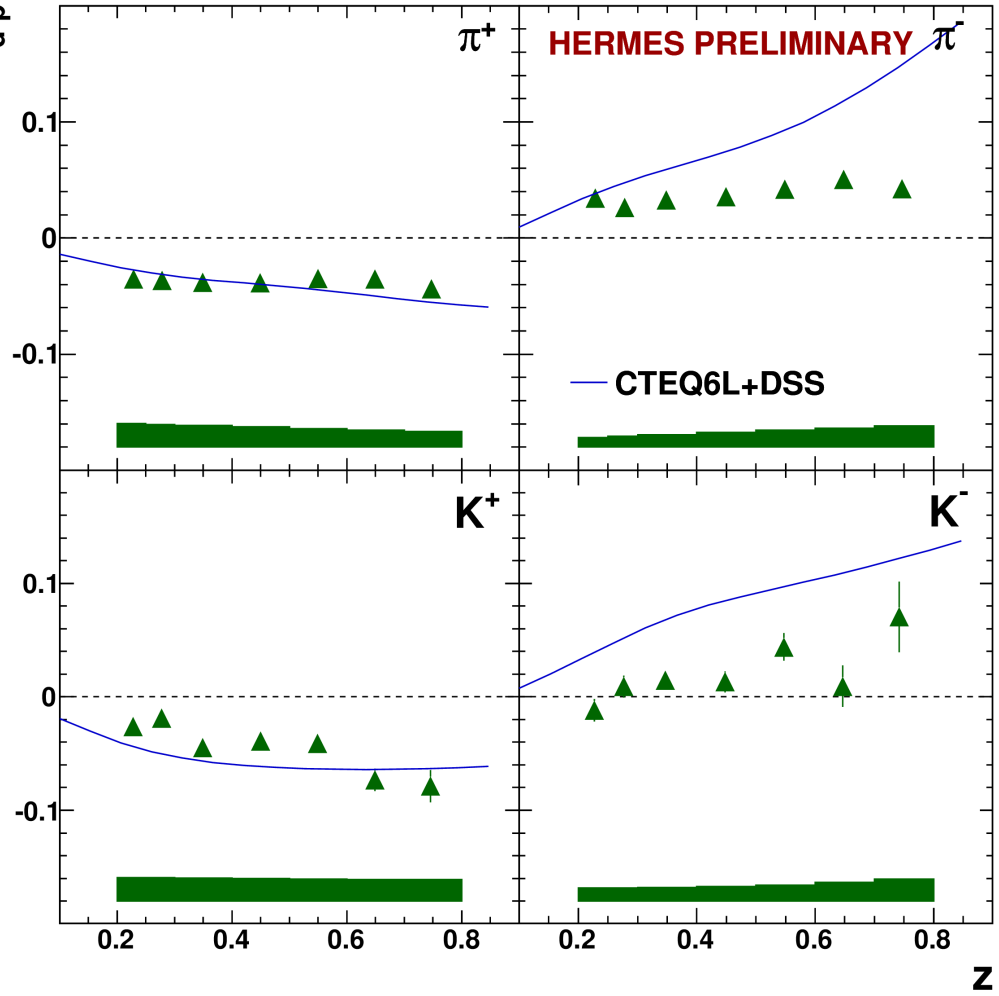
- Disentangle *z* and $P_{h\perp}$ dependences → access to intrinsic transverse momentum of struck quarks
- Provide constraints on models of the motion of quarks inside the nucleon and on the models of the fragmentation process

D-H asymmetry of hadron production

- Asymmetry between the hadron production on proton and deuteron

$$A_{d-p}^{h} = \frac{M_{deuteron}^{h} - M_{proton}^{h}}{M_{deuteron}^{h} + M_{proton}^{h}}$$

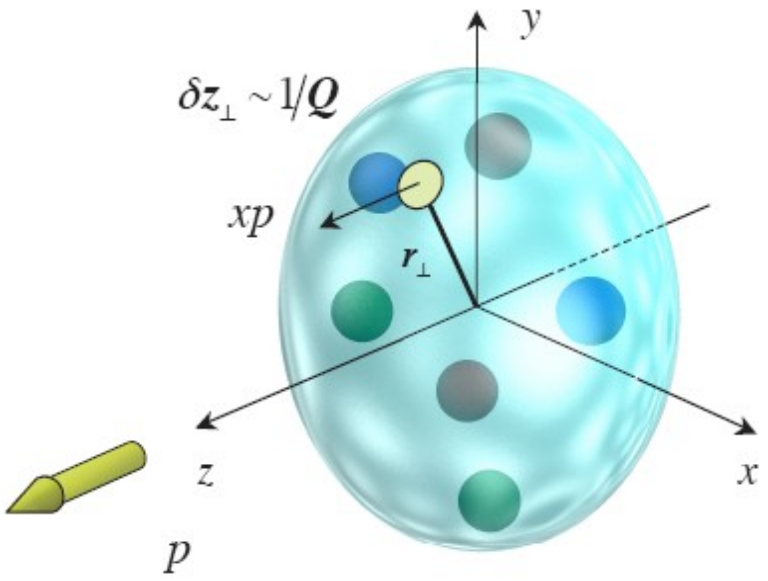
- Reflects different flavor content of the target
- Correlated systematics cancels
- Results on π^- and K^- provide important constraints on the fragmentation models

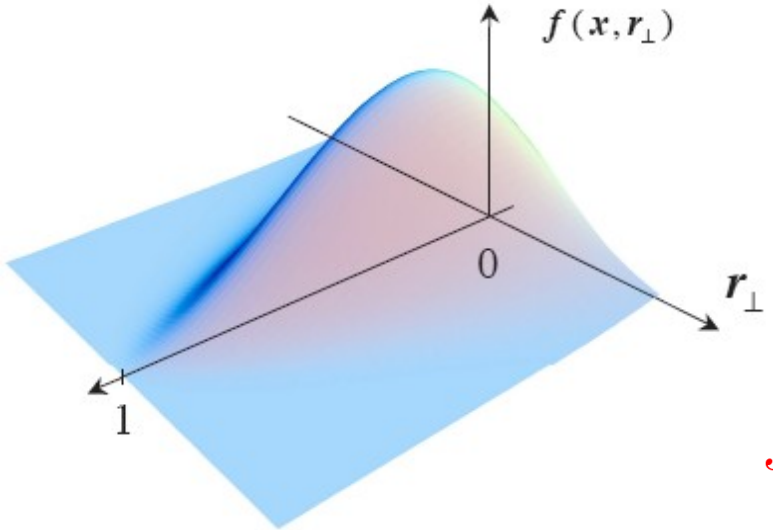


Summary of results on hadron multiplicities

- High-statistics data set for π^+, π^- and K^+, K^- multiplicities on Hydrogen and Deuterium targets
- Fragmentation is favored for the hadrons containing the struck quark as a valence quark
- Data will allow more reliable extraction of unfavored fragmentation function
- Multiplicity dependences on $P_{h\perp}$ will provide constraints
  - for models of the motion of quarks in the nucleon in the transverse plane of momentum space
  - for models of the fragmentation process

Generalized parton distributions (GPDs)

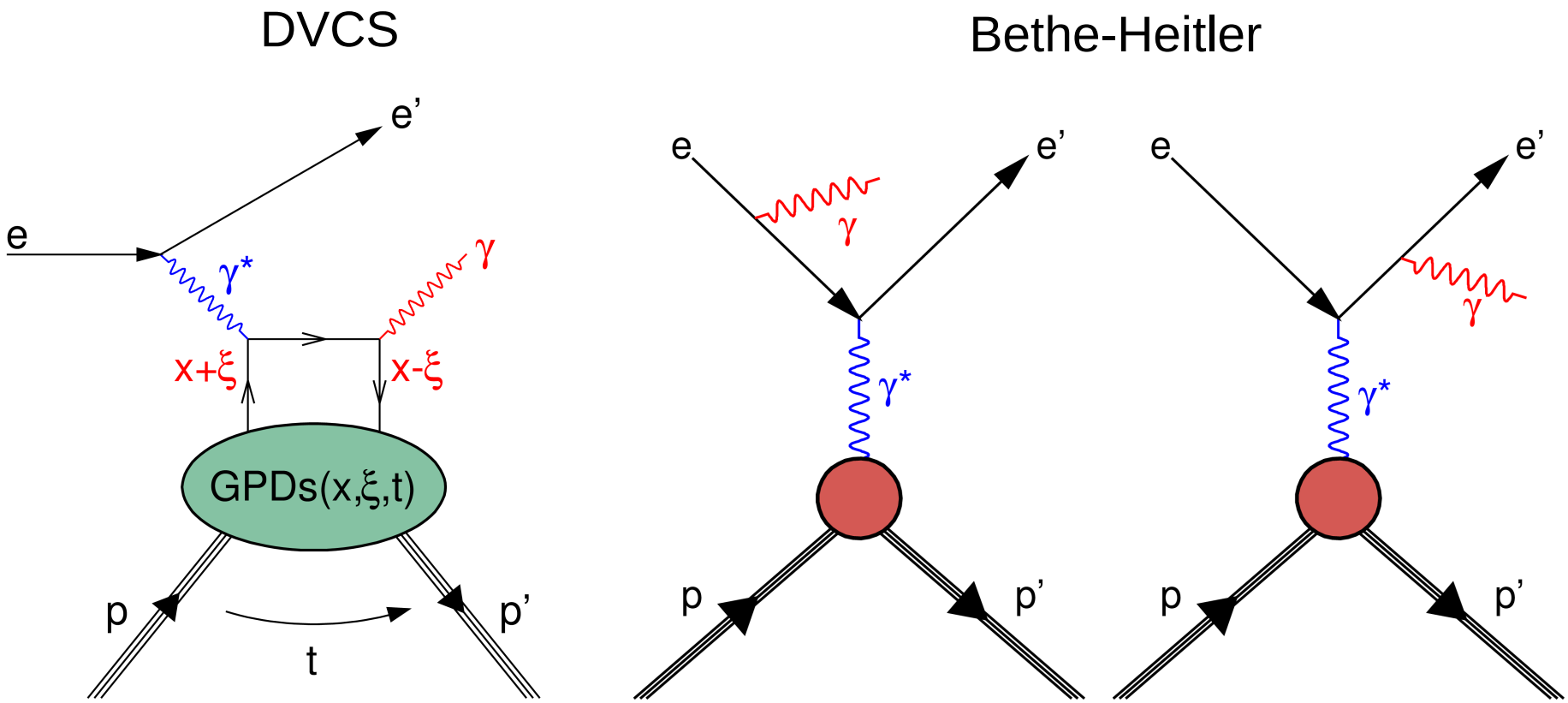




- Multidimensional description of nucleon structure (longitudinal momentum vs transverse position)
- Include parton distribution functions and form factors as forward limits and moments, respectively
- Can provide access to the total (and hence orbital) angular momentum of quarks in the nucleon via Ji relation:

$$J_q = \lim_{t\to 0} \int_{-1}^{1} dx\ x[H_q(x,\xi,t) + E_q(x,\xi,t)]$$

Deeply virtual Compton scattering (DVCS)



- The same initial and final state → interference
- Bethe-Heitler dominates at HERMES kinematics
- Access to GPDs through azimuthal asymmetries

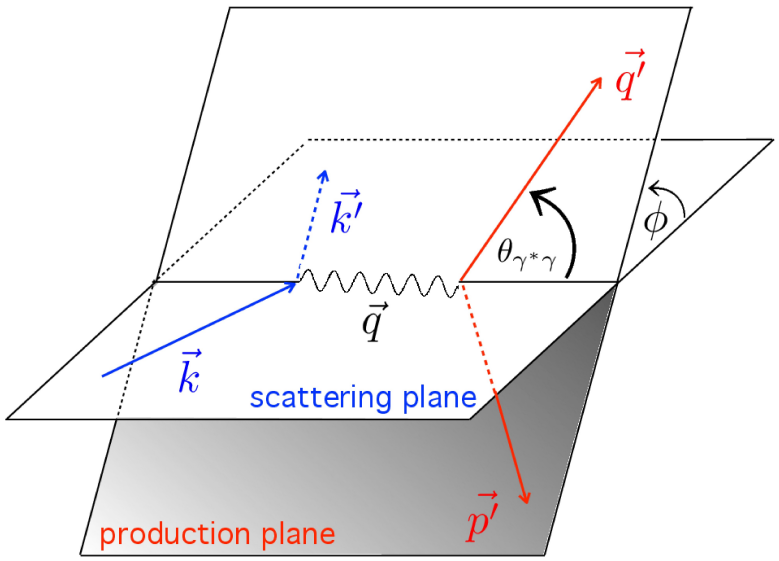
Beam-helicity asymmetry in DVCS

- In the case of single beam charge and unpolarized target, cross section

$$\sigma_{LU}(\phi, P_B) = \sigma_{UU}[1 + P_B A_{LU}]$$

- Beam-helicity asymmetry

$$A_{LU}(\phi) = \frac{\sigma^{\rightarrow} - \sigma^{\leftarrow}}{\sigma^{\rightarrow} + \sigma^{\leftarrow}}$$

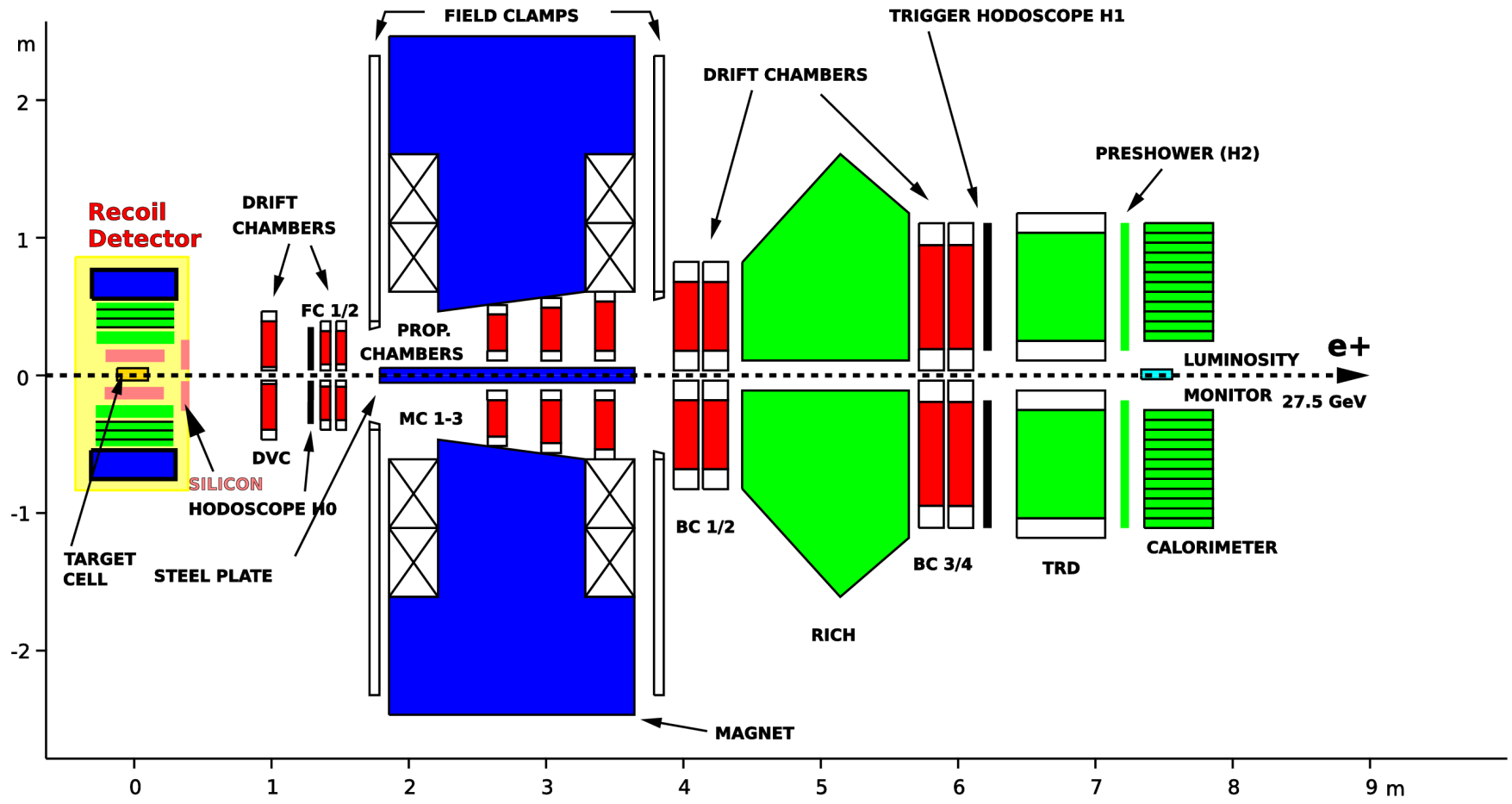


- Expansion of the asymmetry

$$A_{LU}(\phi) = \sum_{n=1}^{2} A_{LU}^{\sin(n\phi)} \sin(n\phi)$$

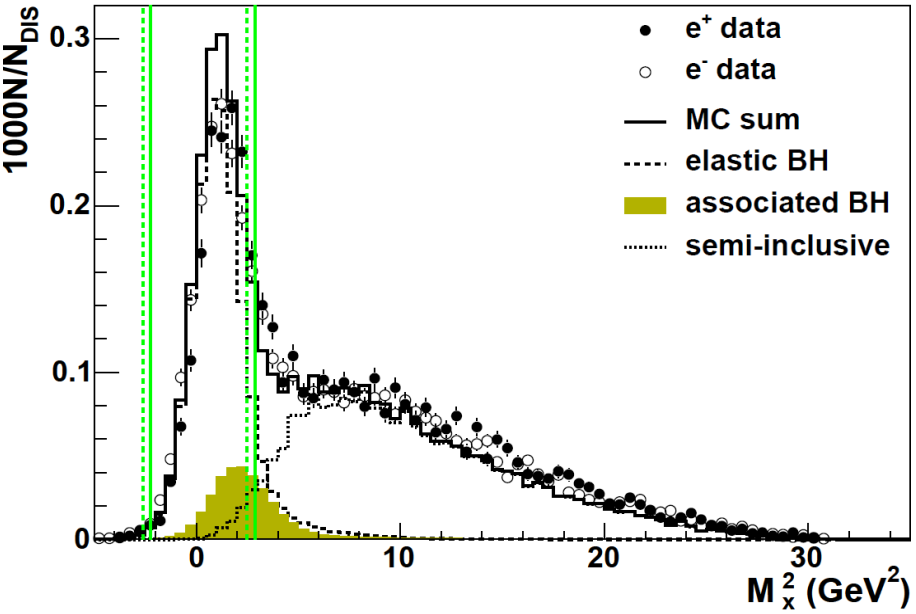
- Extraction of asymmetry amplitudes using Maximum Likelihood Method

HERMES spectrometer with the Recoil Detector



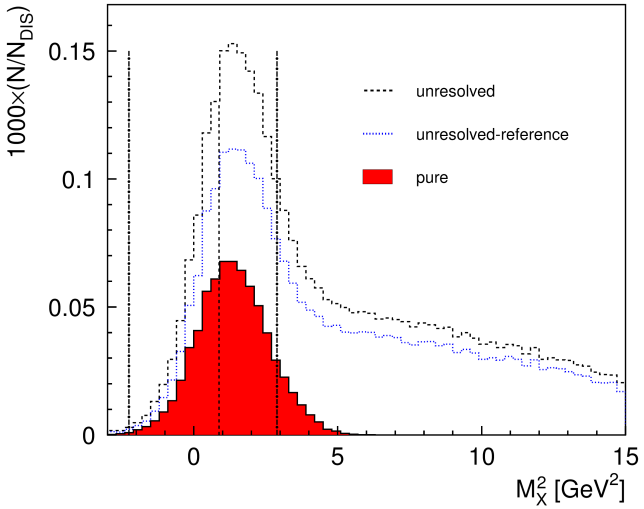
- High-statistics data set with unpolarized Hydrogen and Deuterium targets

Selection of DVCS events



- Pre-Recoil data:
  - Selection of *ep → eyp* events using missing-mass method
  - Corrections for SIDIS background (3%)
  - Background from associated process (12%) is part of the signal

- Recoil data:
  - All particles in the final state detected
  - Kinematic fitting: 4 constraints from energy-momentum conservation
  - Selection of pure DVCS/BH events with negligible (<0.2%) background

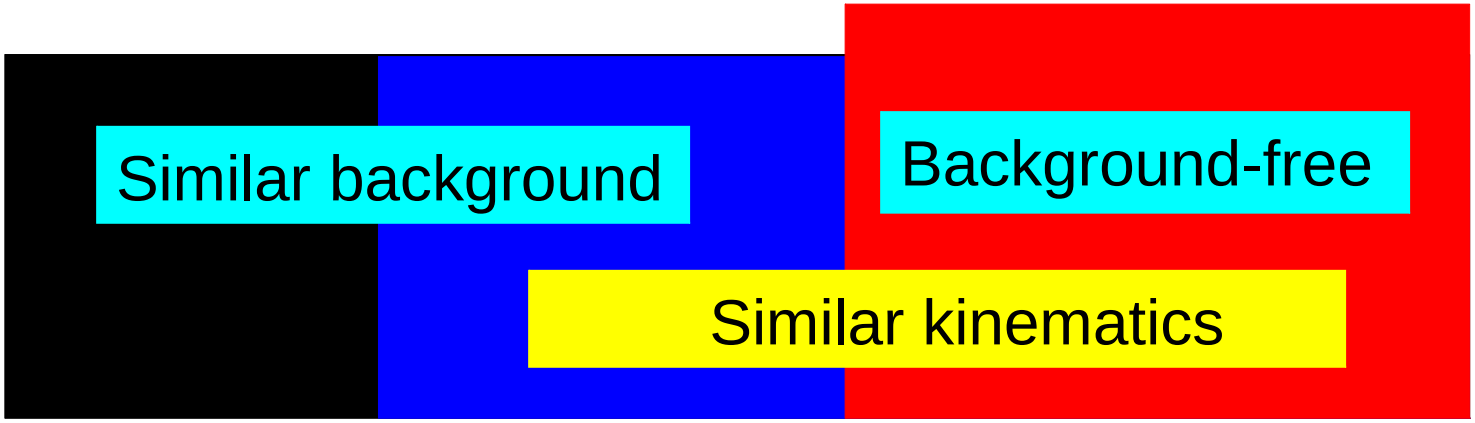


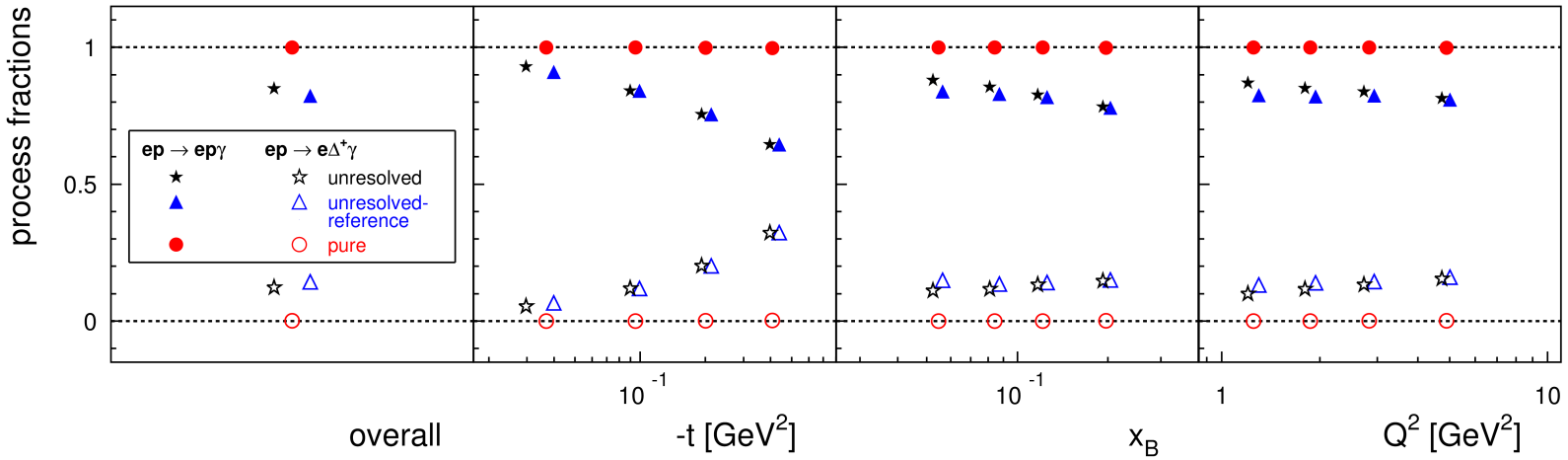
Event selection with the Recoil Detector

Unresolved (without Recoil Detector)

Unresoved-reference (in RD acceptance)

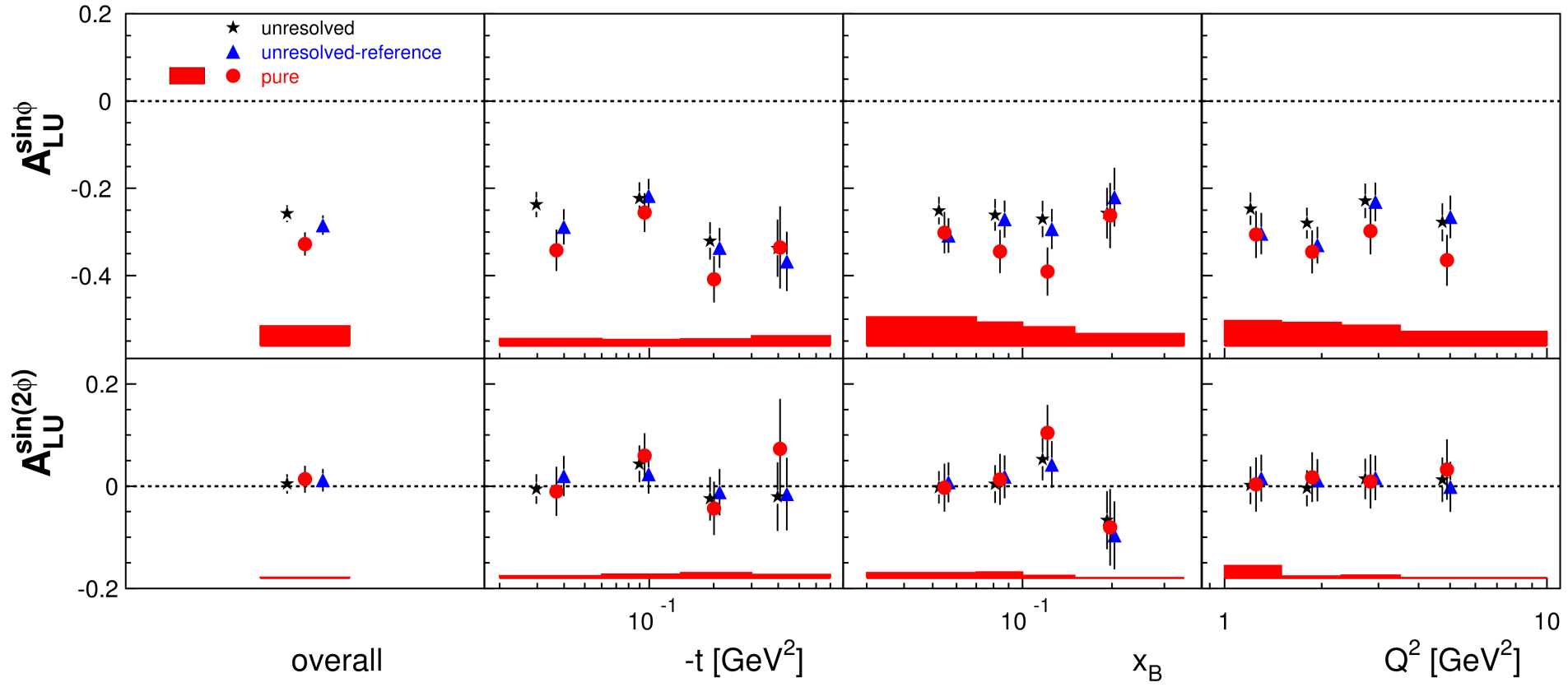
Pure (with RD)





Results for all DVCS data samples

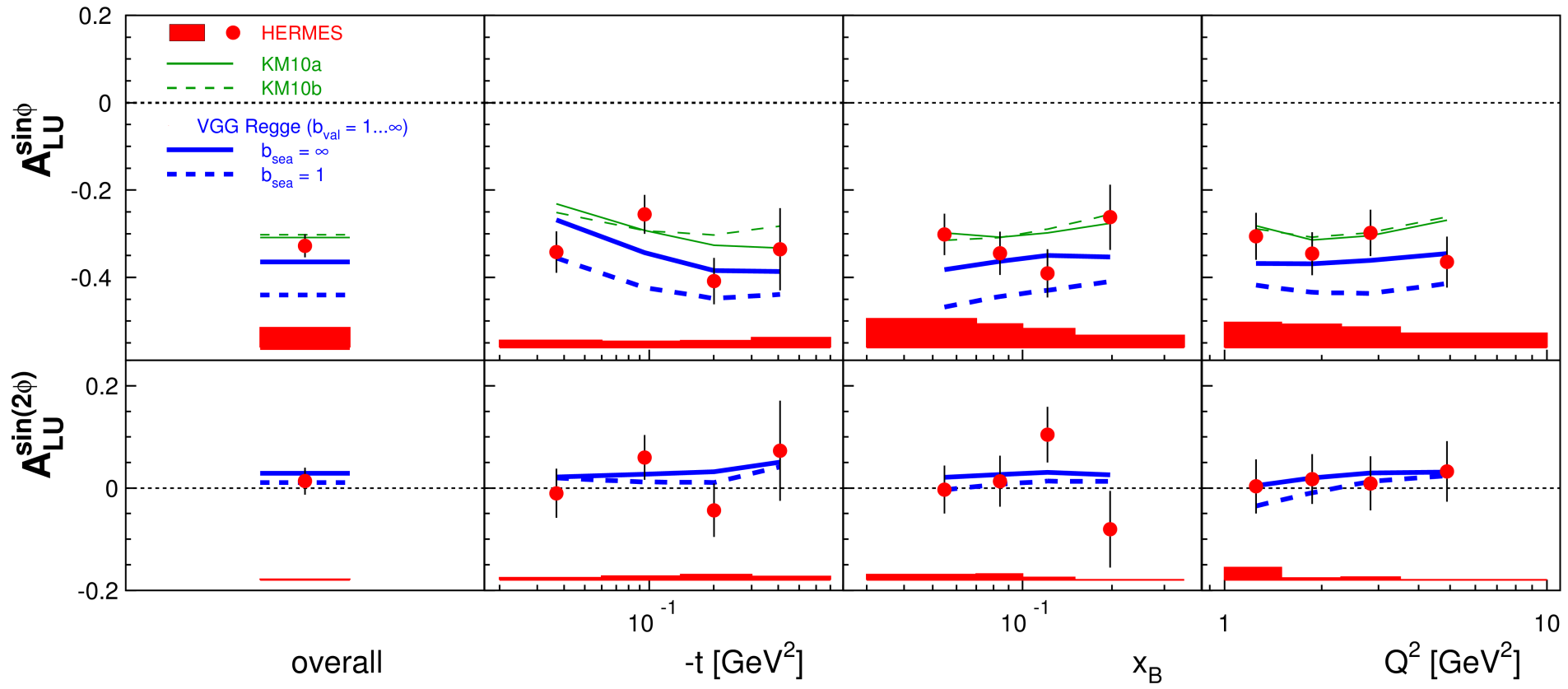
Published: JHEP 10 (2012) 042



- Leading amplitude for pure DVCS/BH is slightly larger in magnitude than the one in the Recoil Detector acceptance

Comparison with theoretical calculations

Published: JHEP 10 (2012) 042

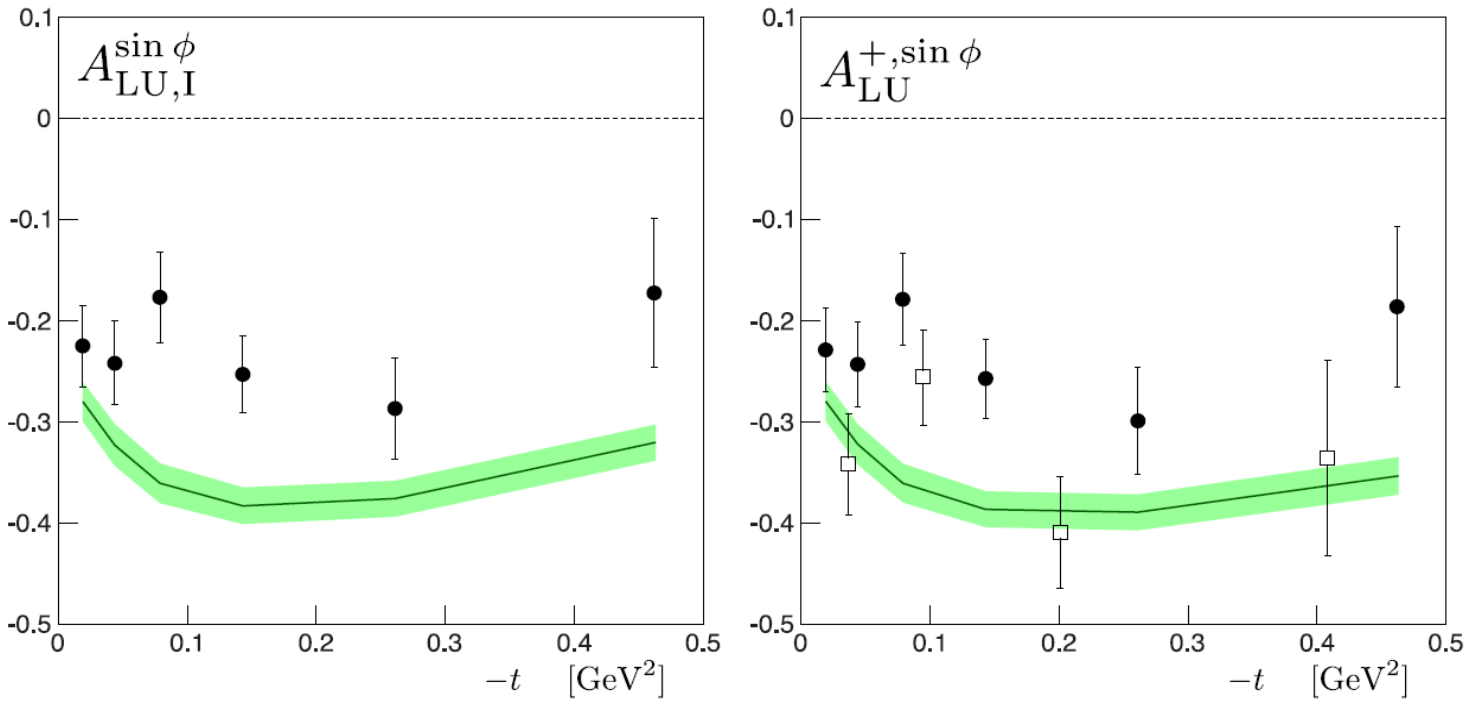


- GPD models and fits reasonably describe data

M. Vanderhaeghen, P.A.M. Guichon, and M. Guidal, Phys. Rev. D 60 (1999) 094017

K. Kumerički and D. Müller, Nucl. Phys. B 841 (2010) 1

Comparison with theoretical calculations



- GPD parameterization constrained by exclusive meson production data

  P. Kroll, H. Moutarde, F. Sabatié, From hard exclusive meson electroproduction to deeply virtual Compton scattering, arXiv:1210.6975

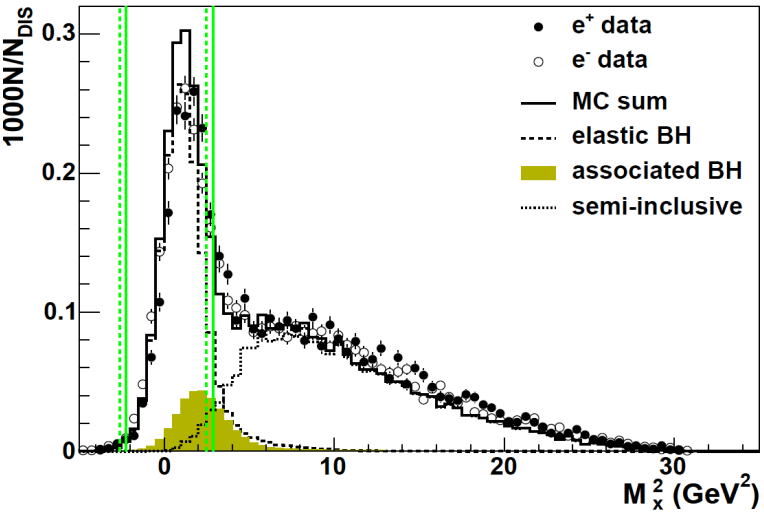
  Comparison with HERMES DVCS data

  Full points – DVCS pre-Recoil data, *JHEP 07 (2012) 032*

  Open points – DVCS Recoil data, *JHEP 10 (2012) 042*

Associated production $ep \to e\gamma N\pi$ in the Δ-resonance region

- Delta resonance region → possible access to transition GPDs

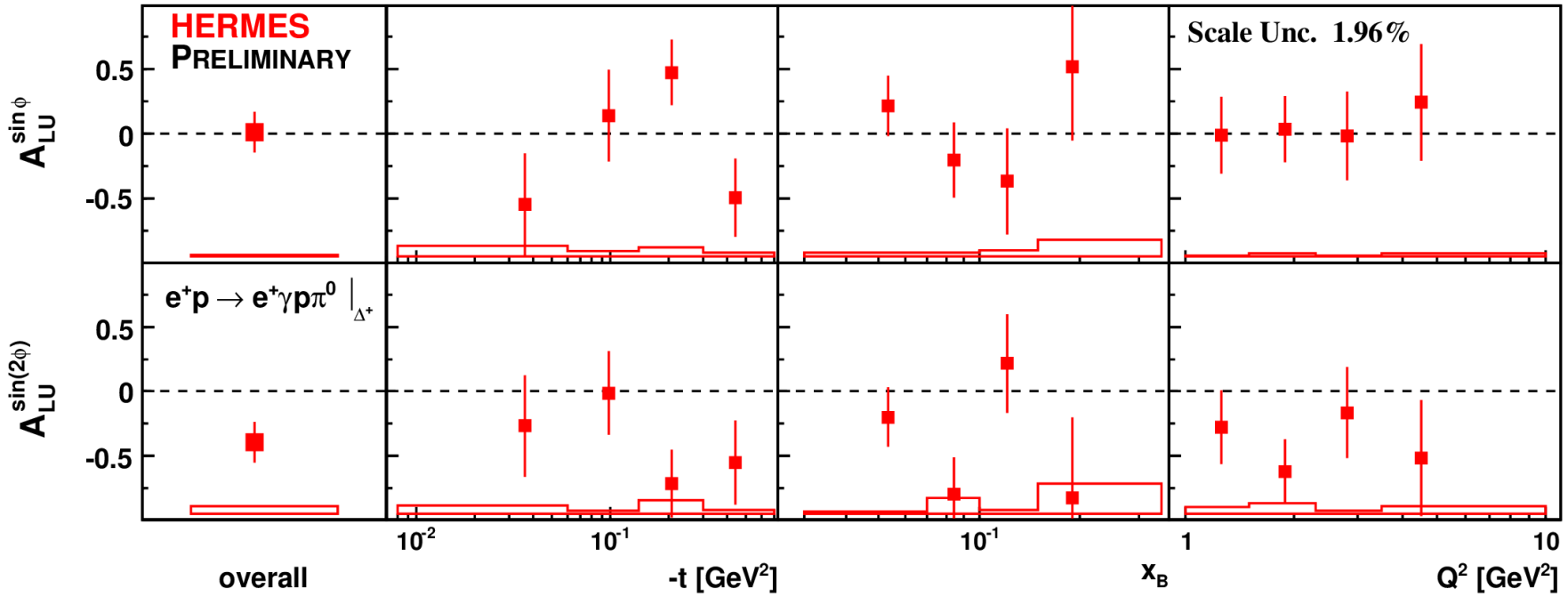


- Selection of associated events $ep \to e\gamma p\pi^0$ and $ep \to e\gamma n\pi^+$:
  - The yield is much smaller than that of $ep \to e\gamma p$
  - The SIDIS yield is not negligible
  - One particle is undetected

- Kinematic fitting under hypotheses of $ep \to e\gamma N\pi$ and $ep \to e\gamma p$
  - To select associated processes $ep \to e\gamma p\pi^0$ and $ep \to e\gamma n\pi^+$
  - To reject background from $ep \to e\gamma p$ (to the level below 1%)
- Particle identification in the Recoil Detector
- Results are corrected for SIDIS background
  - 13% in case of $ep \to e\gamma p\pi^0$, 24% in case of $ep \to e\gamma n\pi^+$

Results on beam-helicity asymmetry for $ep \to eyp\pi^0$

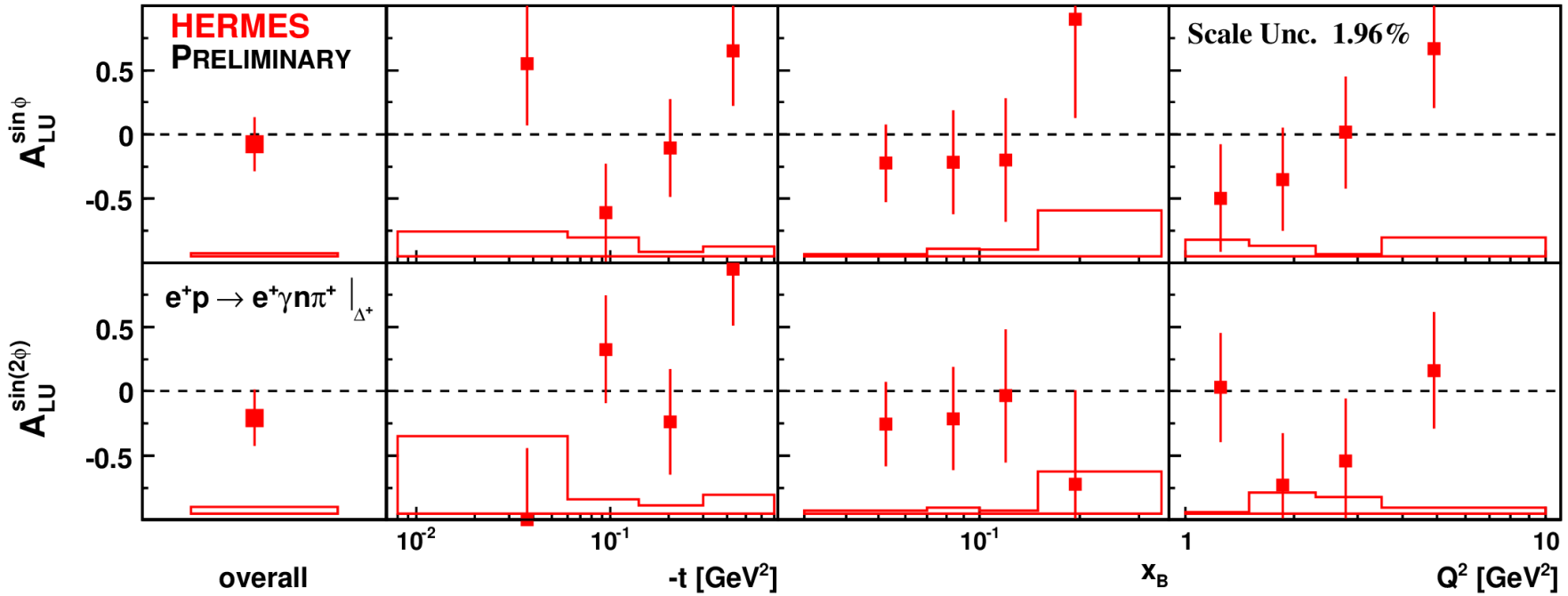
New



- Leading asymmetry amplitude consistent with zero
- Contributes as a dilution in DVCS/BH asymmetry

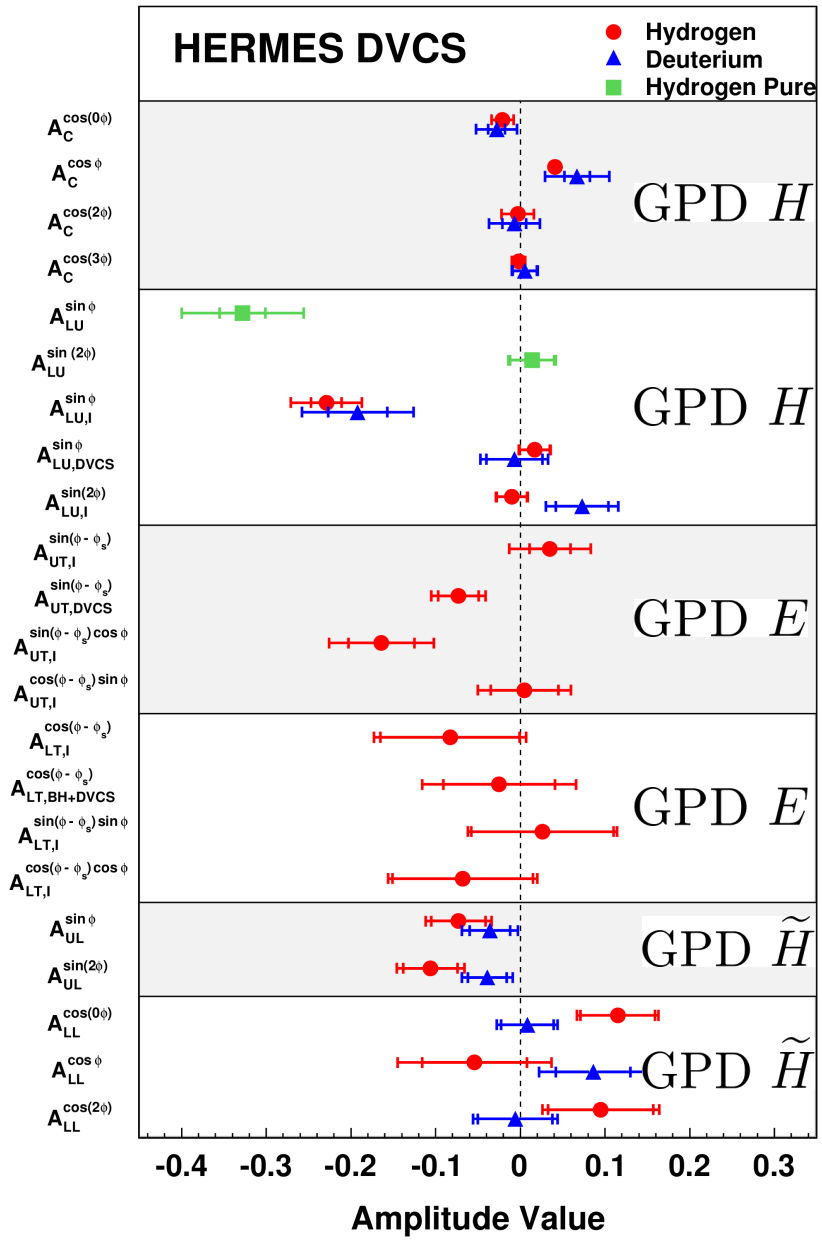
Results on beam-helicity asymmetry for $ep \to eyn\pi^+$

New



- All asymmetry amplitudes consistent with zero
- Contributes as a dilution in DVCS/BH asymmetry

Overview of published HERMES DVCS results



- Beam-charge and beam-spin asymmetry
  - *PRL 87 (2001) 182001*
  - *PRD 75 (2007) 011103*
  - *JHEP 11 (2009) 083*
  - *JHEP 07 (2012) 032*, *JHEP 10 (2012) 042*
  - *Nucl. Phys. B 829 (2010) 1*
- Transverse target-spin asymmetry
  - *JHEP 06 (2008) 066*
- Transverse double-spin asymmetry
  - *Phys. Lett. B 704 (2011) 15*
- Longitudinal target spin asymmetry
  - *JHEP 06 (2010) 019*
- Longitudinal target & double spin asymmetry
  - *Nucl. Phys. B 842 (2011) 265*

Publications and results since the last PRC meeting

- Published:

  Beam-helicity and beam-charge asymmetries associated with deeply virtual Compton scattering on the unpolarised proton, *JHEP 07 (2012) 032*

  Beam-helicity asymmetry arising from deeply virtual Compton scattering measured with kinematically complete event reconstruction, *JHEP 10 (2012) 042*
  → First physics paper using the HERMES Recoil Detector!

- Submitted and near submission:

  Azimuthal distributions of charged hadrons, pions, and kaons produced in deep-inelastic scattering off unpolarized protons and deuterons, submitted to Phys. Rev. D, *arXiv:1204.4161* and *DESY-12-060*

  Multiplicities of charged pions and kaons from semi-inclusive deep-inelastic scattering by the proton and the deuteron, *DESY 12-157*
  → Unique high-statistics data set

- New preliminary result with Recoil Detector:

  Beam-helicity asymmetry in associated electroproduction of real photons $ep \rightarrow e\gamma p\pi^0$ and $ep \rightarrow e\gamma n\pi^+$ in the Δ-resonance region

Data preservation

- Move of analysis to new analysis platform (BIRD)
  - Almost finished
  - Still some testing and adaptation needed
- All data productions concluded
- Intensive use of GRID for current and future MC productions
- User and HERMES data
  - Transferred to new platform
  - Only few items left on old hardware
- Documentation
  - Non-digital documentation stored in the library
  - Transition to INSPIRE
  - Transition of web service ongoing

Summary

- HERMES continues to produce and publish physics results
  - Since the last PRC meeting
    - → 2 papers published
    - → 2 papers submitted or near submission
    - → New preliminary results with Recoil Detector
  - 10 papers in circulation or drafting stage

- Active in conference contributions
  - 25 talks since the last PRC including several plenary and overview talks (8 talks at SPIN2012)

- Essential progress in data preservation