DVCS with the HERMES Recoil Detector

Jennifer Bowles, Caroline Riedl and Sergey Yaschenko

on behalf of the hermes collaboration

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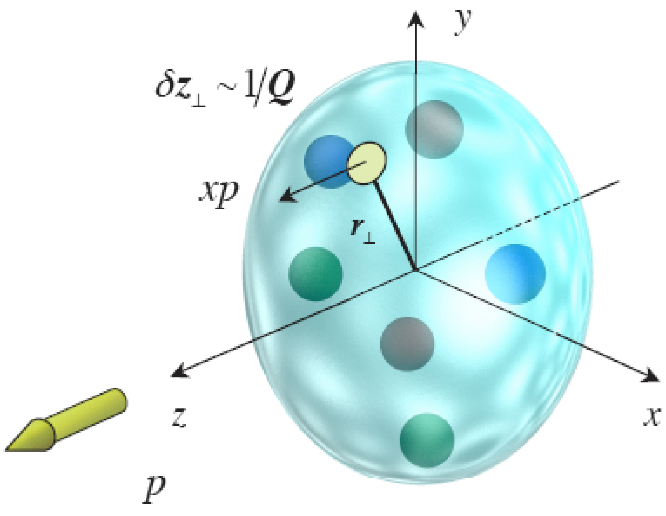
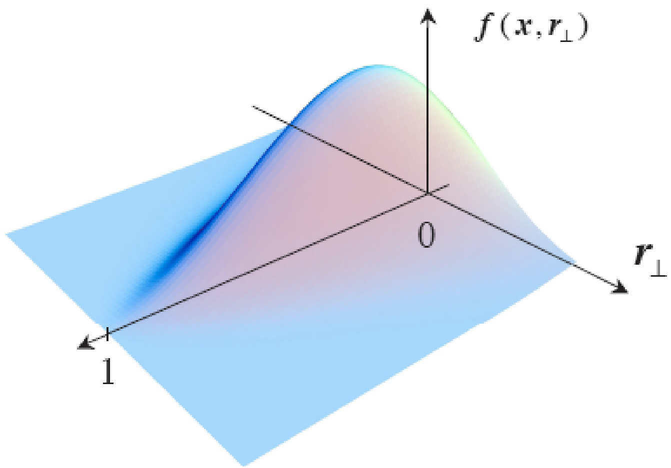
HELMHOLTZ | ASSOCIATION

DESY

Generalized Parton Distributions (GPDs)



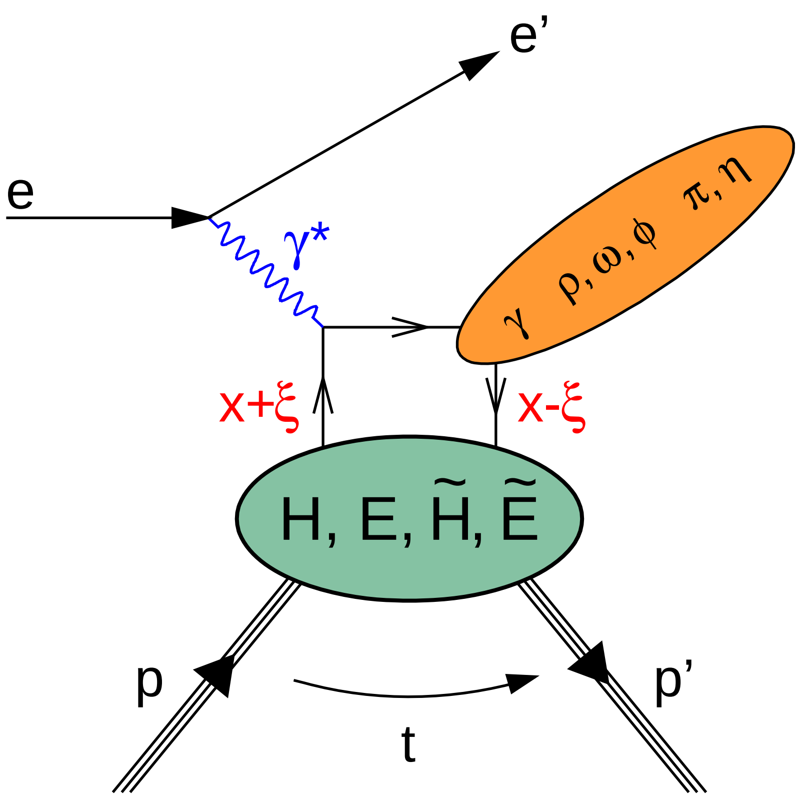


- Include Form Factors and Parton Distribution Functions as moments and forward limits, respectively
- Multidimensional description of nucleon structure (longitudinal momentum vs. transverse position)
- Access to the quark total angular momentum via Ji relation

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

X. Ji, Phys. Rev. Lett. 78 (1997) 610

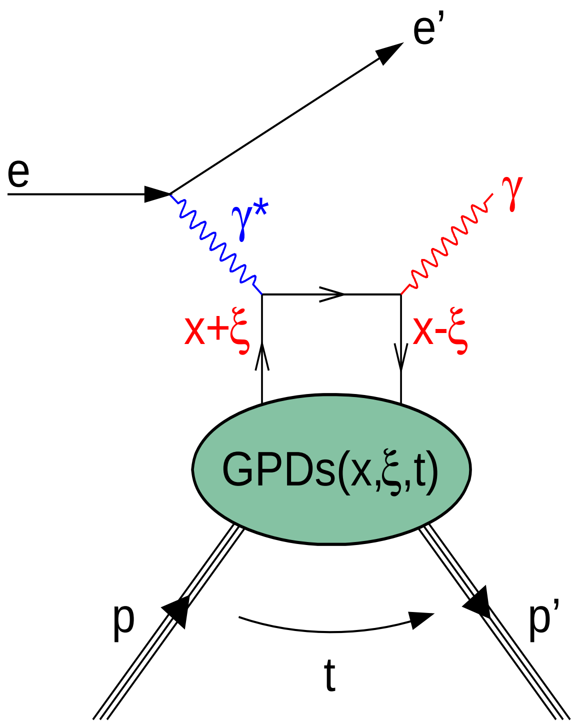
Access to GPDs via Exclusive Processes



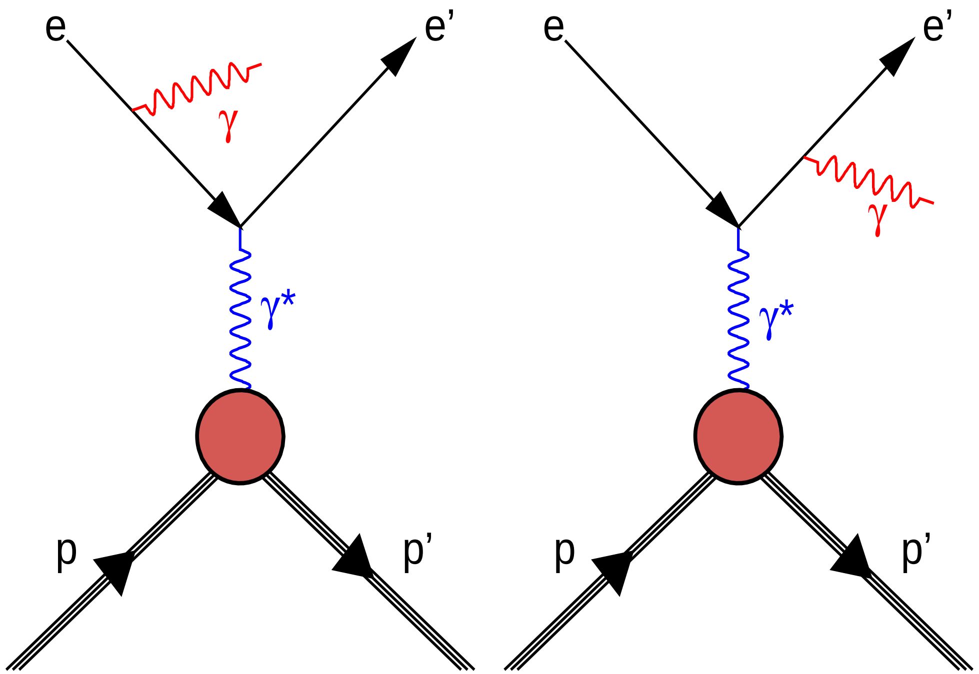
- Sensitivity of different final states to different GPDs
- For spin-1/2 target 4 chiral-even leading-twist quark GPDs: $H, E, \tilde{H}, \tilde{E}$
- $H, \tilde{H}$ conserve nucleon helicity, $E, \tilde{E}$ involve nucleon helicity flip
- DVCS (γ) → $H, E, \tilde{H}, \tilde{E}$
- Vector mesons (ρ, ω, ϕ) → H, E
- Pseudoscalar mesons (π, η) → $\tilde{H}, \tilde{E}$

Deeply Virtual Compton Scattering (DVCS)

DVCS



Bethe-Heitler



- DVCS and Bethe-Heitler: same initial and final state → interference
- Bethe-Heitler dominates at HERMES kinematics
- GPDs accessible through azimuthal asymmetries

Unique DVCS Measurements at HERMES

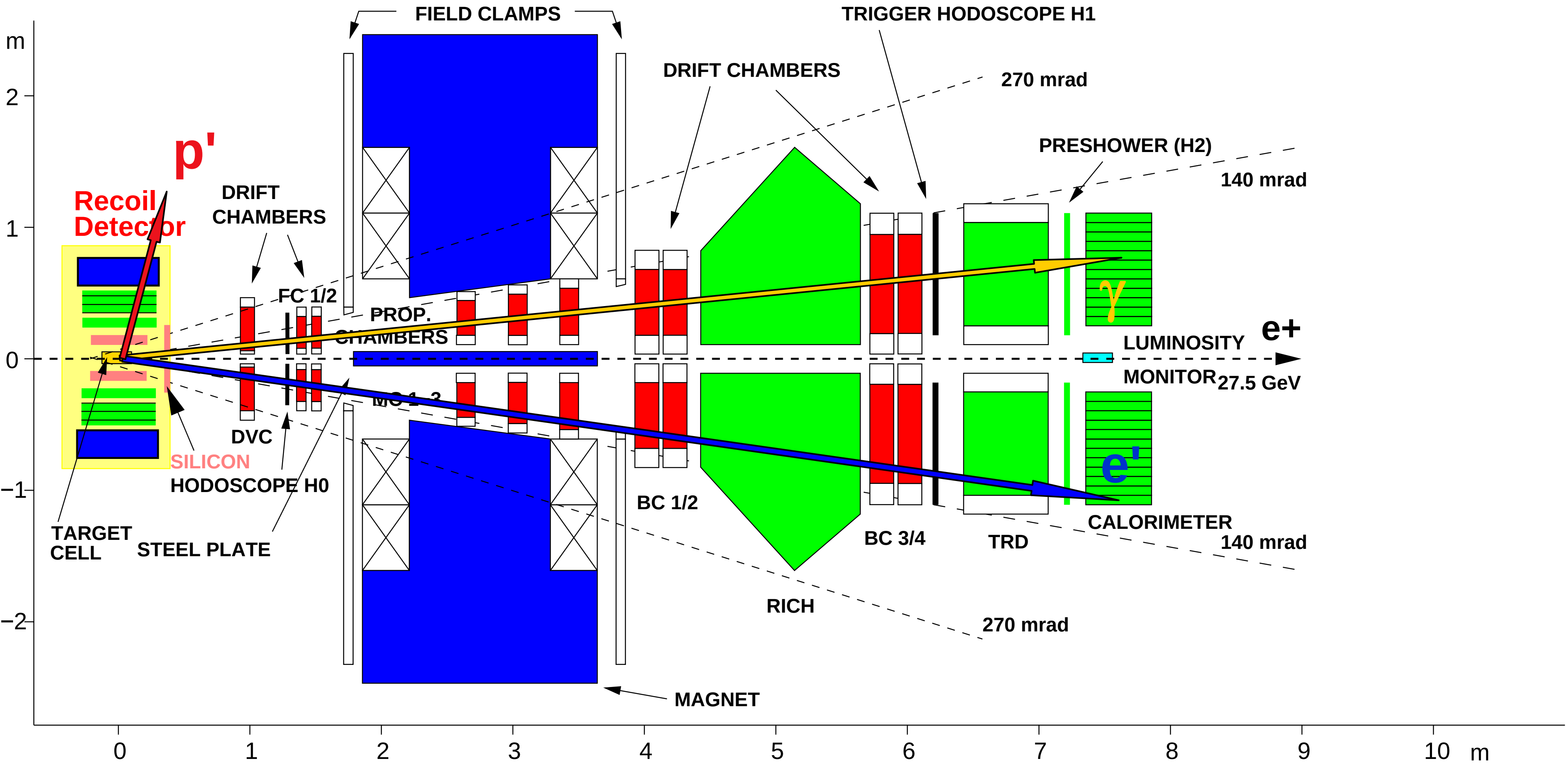
- Both beam charges
- Longitudinal beam polarization (both helicities)
- Longitudinally polarized H and D targets
- Transversely polarized H target

⇓

Access to large number of asymmetry amplitudes

- Unpolarized H, D and nuclear targets
- Recoil Detector

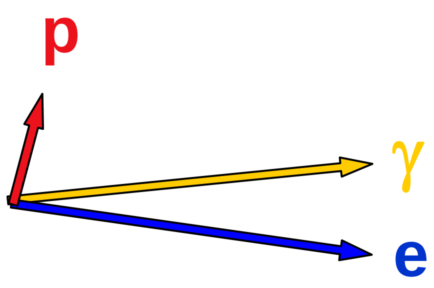
HERMES with the Recoil Detector (2006-2007)



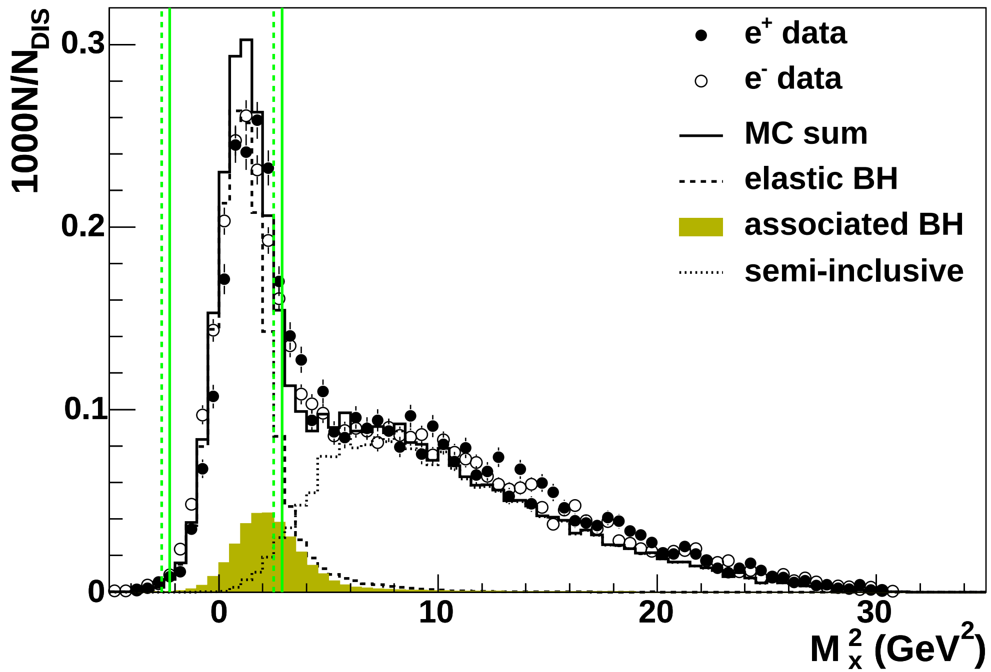
- Two beam helicities, 27.57 GeV electron and positron beams
- Unpolarized hydrogen and deuterium targets

DVCS Measurements without and with Recoil Detector

$ep \rightarrow ep\gamma$



$M_X^2 = (p_e+p_\gamma-p_b-p_t)^2$



- Pre-Recoil data
  - Scattered lepton and photon were detected in the forward spectrometer
  - Recoil proton was not detected
  - Exclusivity achieved via missing mass technique
  - Associated processes (e.g. $ep \rightarrow e\Delta\gamma$) were not resolved (12% contribution)
- Recoil data
  - Detection of recoil proton
  - Suppression of the background to <1% level

Azimuthal Asymmetries in DVCS

- Cross section

$$\sigma_{LU}(\phi;P_B,C_B)=\sigma_{UU}[1+\boxed{P_B}A_{LU}^{DVCS}+\boxed{C_BP_B}A_{LU}^{I}+\boxed{C_B}A_C]$$

- Beam-charge asymmetry

$$A_C(\phi)=\frac{(\sigma^{+\rightarrow}+\sigma^{+\leftarrow})-(\sigma^{-\leftarrow}+\sigma^{-\rightarrow})}{(\sigma^{+\rightarrow}+\sigma^{+\leftarrow})+(\sigma^{-\leftarrow}+\sigma^{-\rightarrow})}=-\frac{1}{D(\phi)}\frac{x_B}{y}\sum_{n=0}^{3}\boxed{c_n^I}\cos(n\phi)$$

- Charge-difference beam-helicity asymmetry

$$A_{LU}^{I}(\phi)=\frac{(\sigma^{+\rightarrow}-\sigma^{+\leftarrow})-(\sigma^{-\rightarrow}-\sigma^{-\leftarrow})}{(\sigma^{+\rightarrow}+\sigma^{+\leftarrow})+(\sigma^{-\rightarrow}+\sigma^{-\leftarrow})}=-\frac{1}{D(\phi)}\frac{x_B}{y}\sum_{n=1}^{2}\boxed{s_n^I}\sin(n\phi)$$

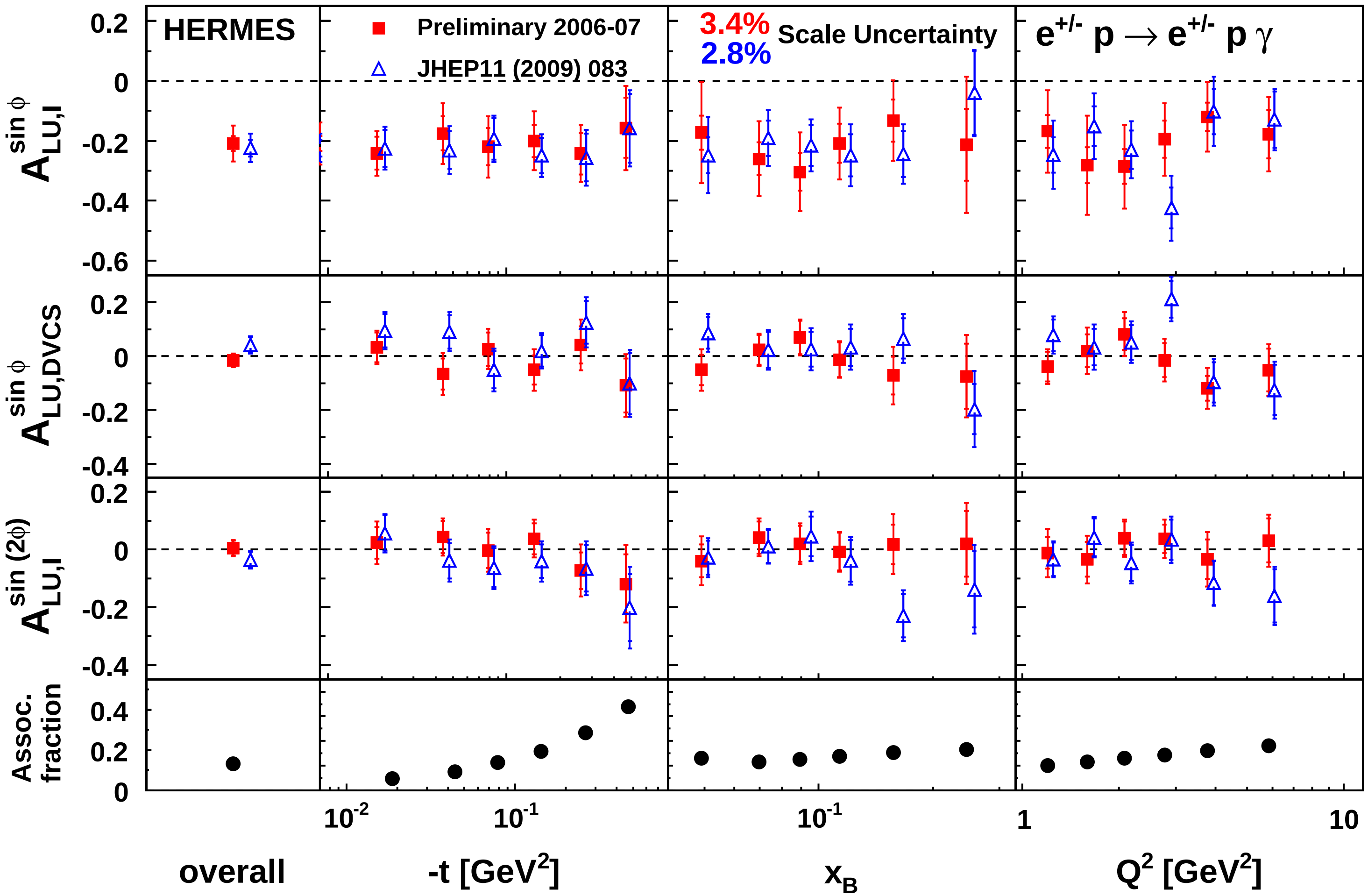
- Charge-averaged beam-helicity asymmetry

$$A_{LU}^{DVCS}(\phi)=\frac{(\sigma^{+\rightarrow}-\sigma^{+\leftarrow})+(\sigma^{-\rightarrow}-\sigma^{-\leftarrow})}{(\sigma^{+\rightarrow}+\sigma^{+\leftarrow})+(\sigma^{-\leftarrow}+\sigma^{-\rightarrow})}=\frac{1}{D(\phi)}\cdot\frac{x_B^2 t\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}{Q^2}\boxed{s_1^{DVCS}}\sin(\phi)$$

- Separation of contributions from DVCS and interference term
- Impossible in case of single-charge beam-helicity asymmetry

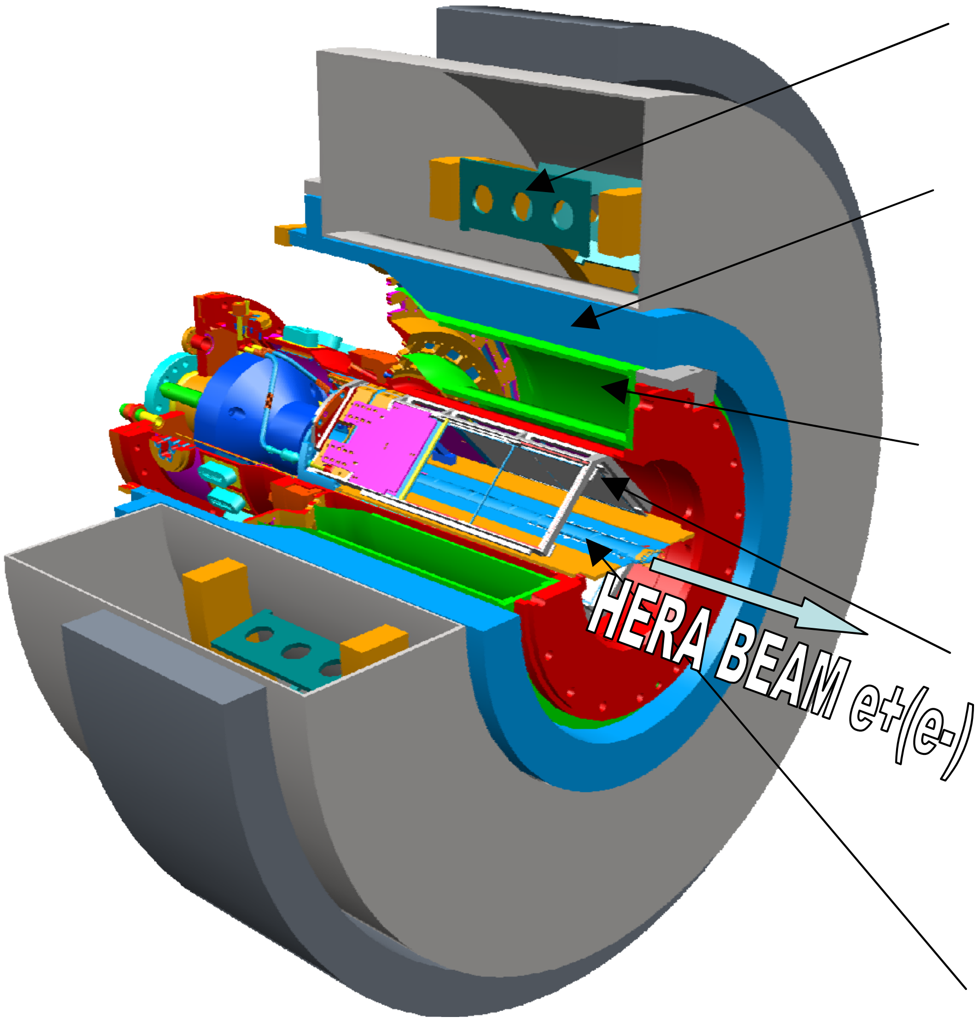
$$A_{LU}(\phi)=\frac{\sigma^{\rightarrow}-\sigma^{\leftarrow}}{\sigma^{\rightarrow}+\sigma^{\leftarrow}}$$

Beam-Helicity Asymmetry without Recoil Detector (2006-07 data)



- Data from 2006-2007 analyzed without the Recoil Detector are in agreement with previously published data from 1996-2005
- Associated processes are part of signal

HERMES Recoil Detector



1 Tesla superconducting solenoid

Photon Detector (PD)
- detect gammas
- p/π PID for momentum > 600 MeV/c

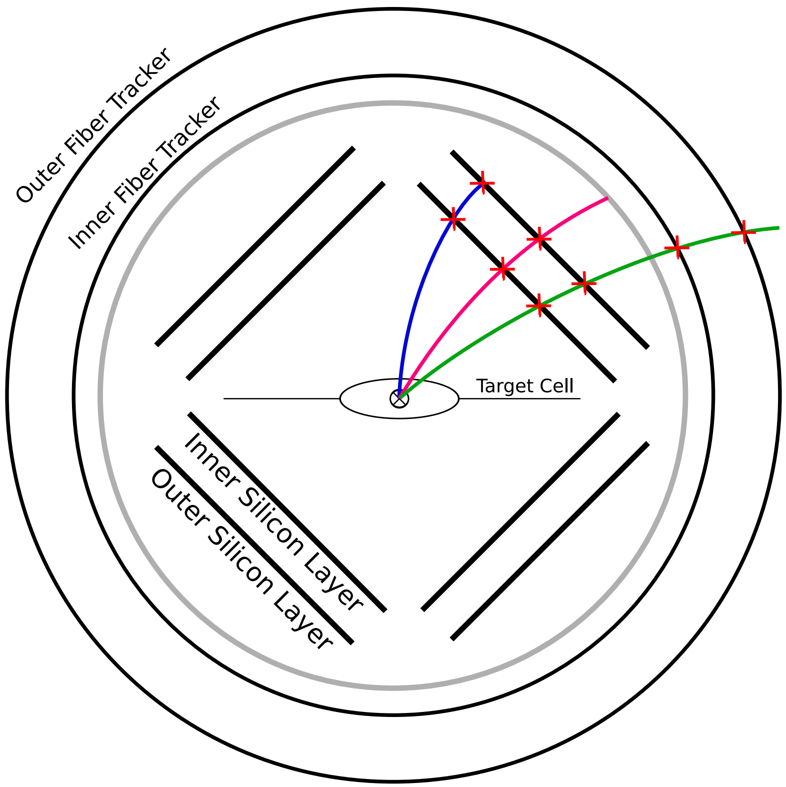
Scintillating Fiber Tracker (SFT)

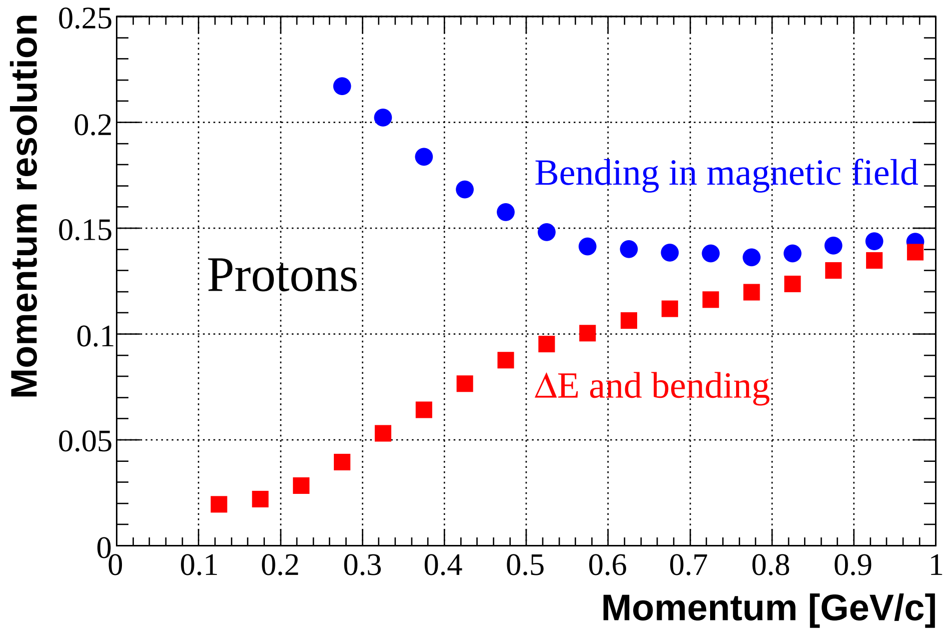
Momentum reconstruction by bending in magnetic field

Silicon Strip Detector (SSD)
- Inside the HERA vacuum
- 5 cm close to the beam
- Momentum reconstruction by energy deposit for protons and deuterons

Target cell
- Unpolarized hydrogen and deuterium targets

Momentum Reconstruction in the Recoil Detector





- Momentum reconstruction by bending in the magnetic field
- Improved momentum reconstruction for protons using bending in the magnetic field and energy deposits in both silicon layers

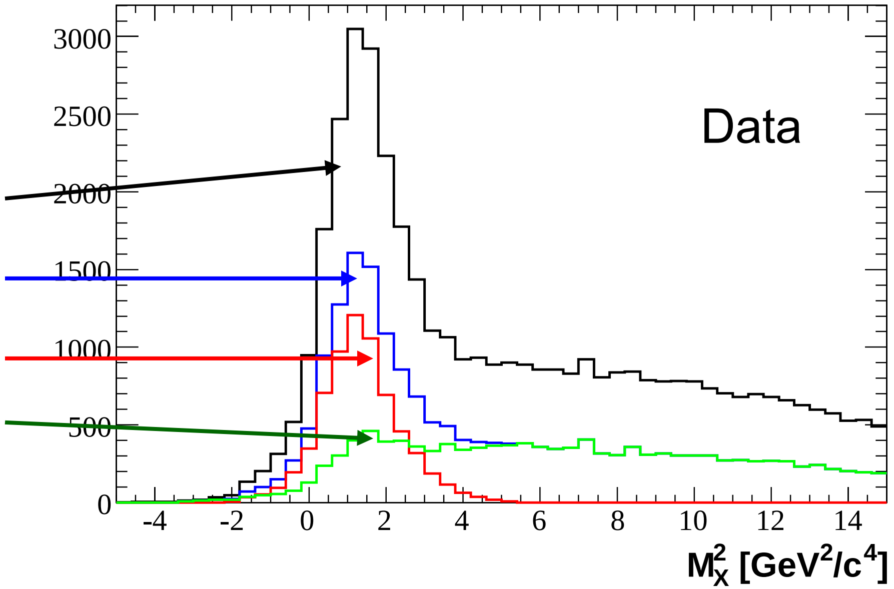
DVCS Analysis with the Recoil Detector

- Analysis of 2006-2007 data with fully operational Recoil Detector with positron beam
- Extraction of single-charge beam-helicity asymmetry
- The same selection criteria for scattered electron and photon as in the analysis without the Recoil Detector
- No requirements for the missing mass
- Use kinematic event fitting
- Background-free event sample

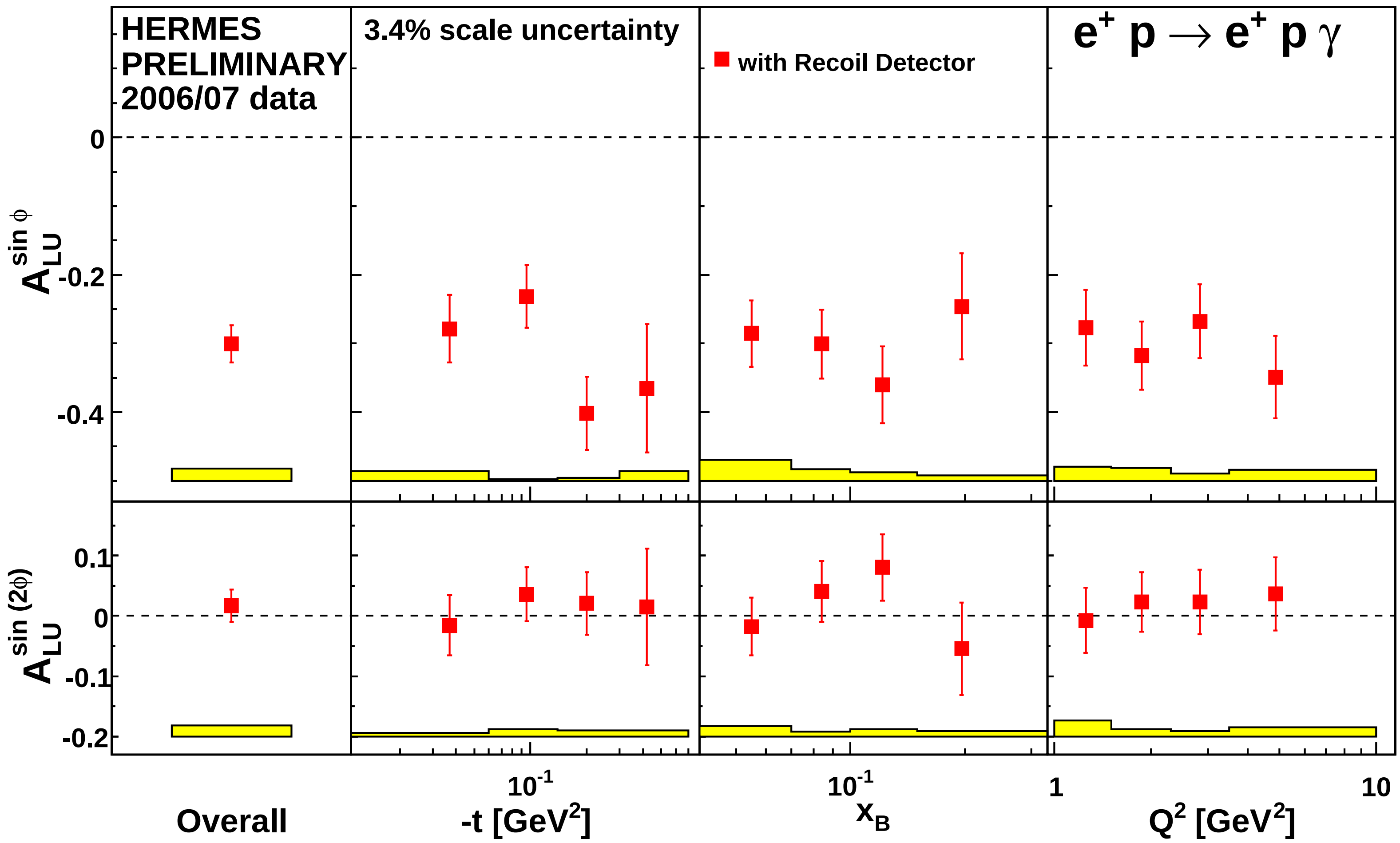
DVCS Event Selection with the Recoil Detector

- Kinematic event fitting technique
  - All 3 particles in final state detected → 4 constraints from energy-momentum conservation
  - Selection of elastic DVCS with high efficiency (~84%)
  - Allows to suppress background from associated and semi-inclusive processes to a negligible level (~0.1%)

- Missing mass distribution
  - No requirement for Recoil
  - Positively charged Recoil track
  - Kinematic fit probability > 1%
  - Kinematic fit probability < 1%



Beam-Helicity Asymmetry with the Recoil Detector



- Asymmetry amplitudes for elastic data sample (background < 0.1%)

DVCS Event Samples

- Comparison with results obtained without Recoil Detector
  - Different kinematic phase space (most essential at low –t)

- Select a data sample in similar kinematic phase space to separate the effect from associated background from difference in kinematics

- Create an event sample with 'hypothetical proton' expected in Recoil Detector acceptance
  - Do not use any Recoil Detector information
  - Calculate kinematics of expected proton using measured kinematics of electron and photon assuming the proton mass (1C kinematic fitting)
  - Apply requirements of Recoil Detector acceptance

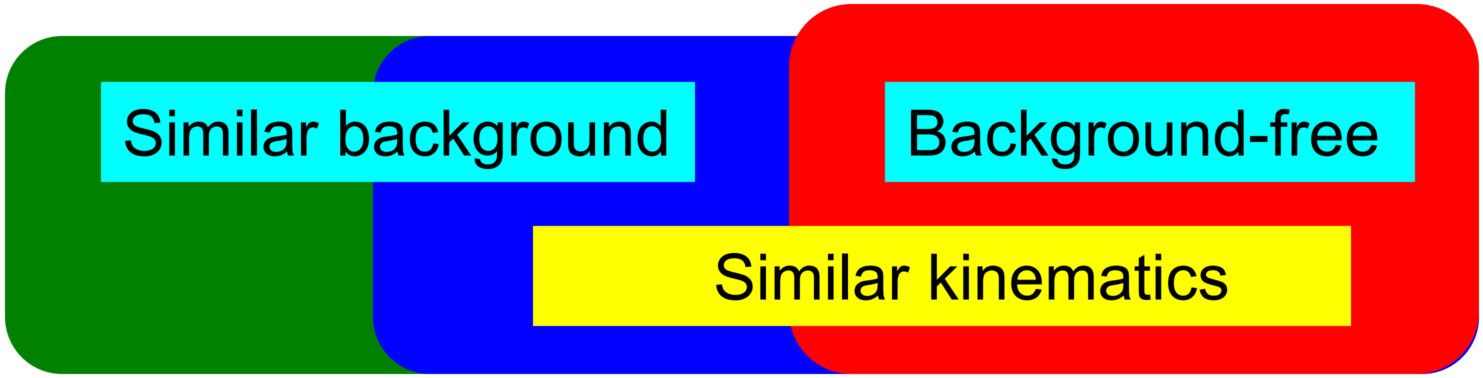
- Compare 3 data samples: with Recoil Detector, in Recoil Detector acceptance and without Recoil Detector

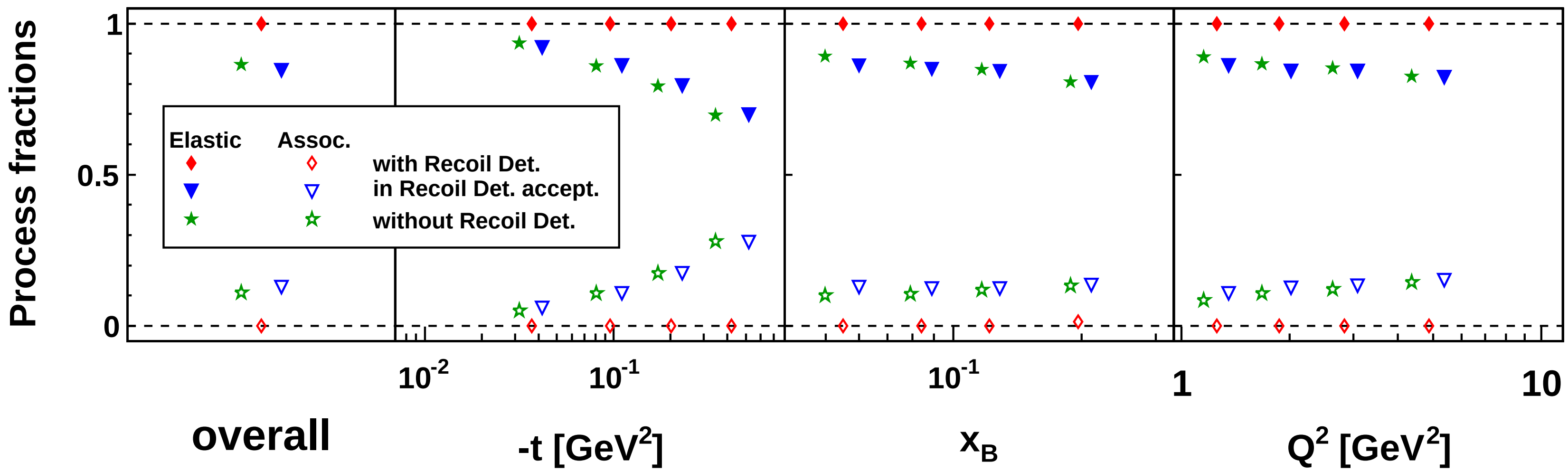
DVCS Event Samples

Without Recoil Detector

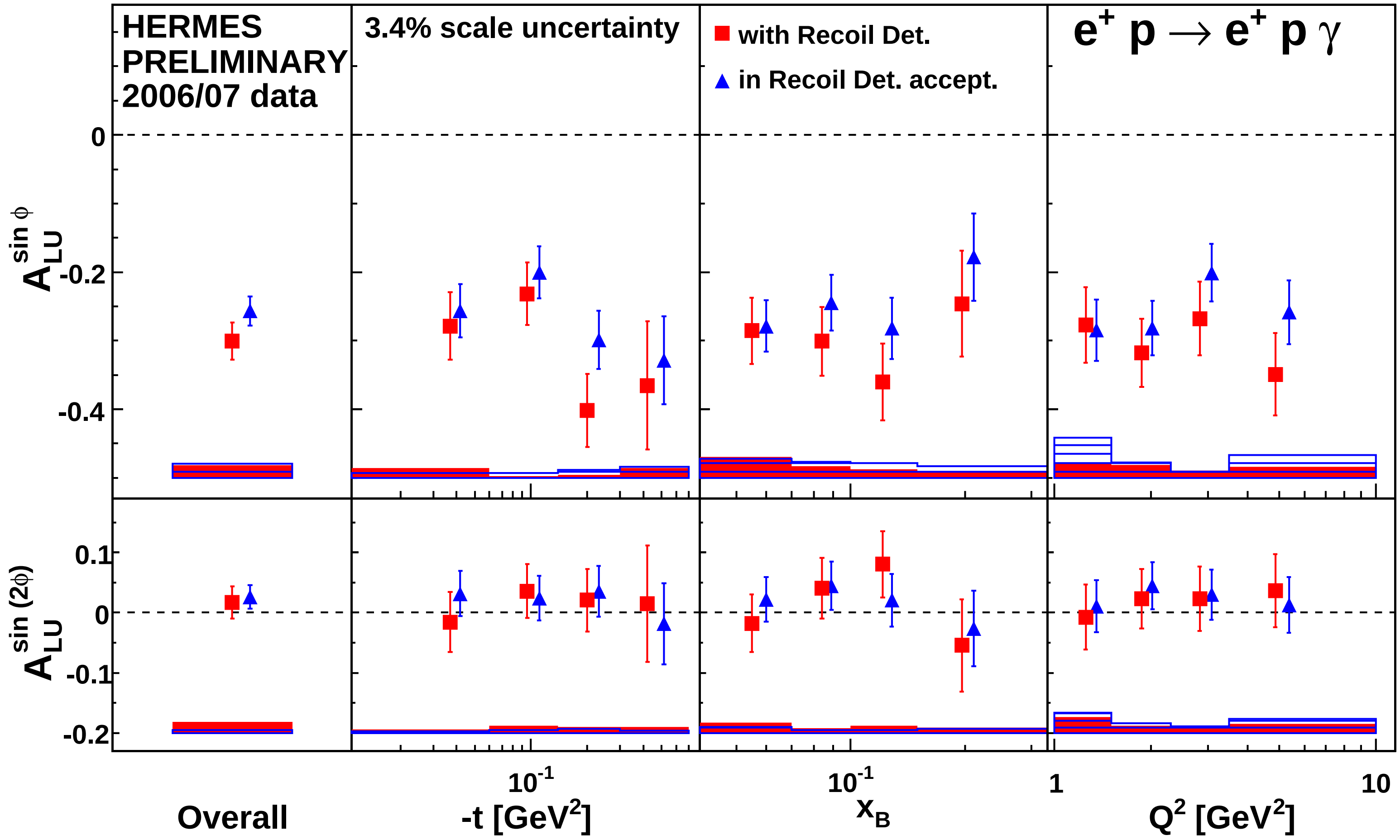
In Recoil Detector acceptance

With Recoil Detector



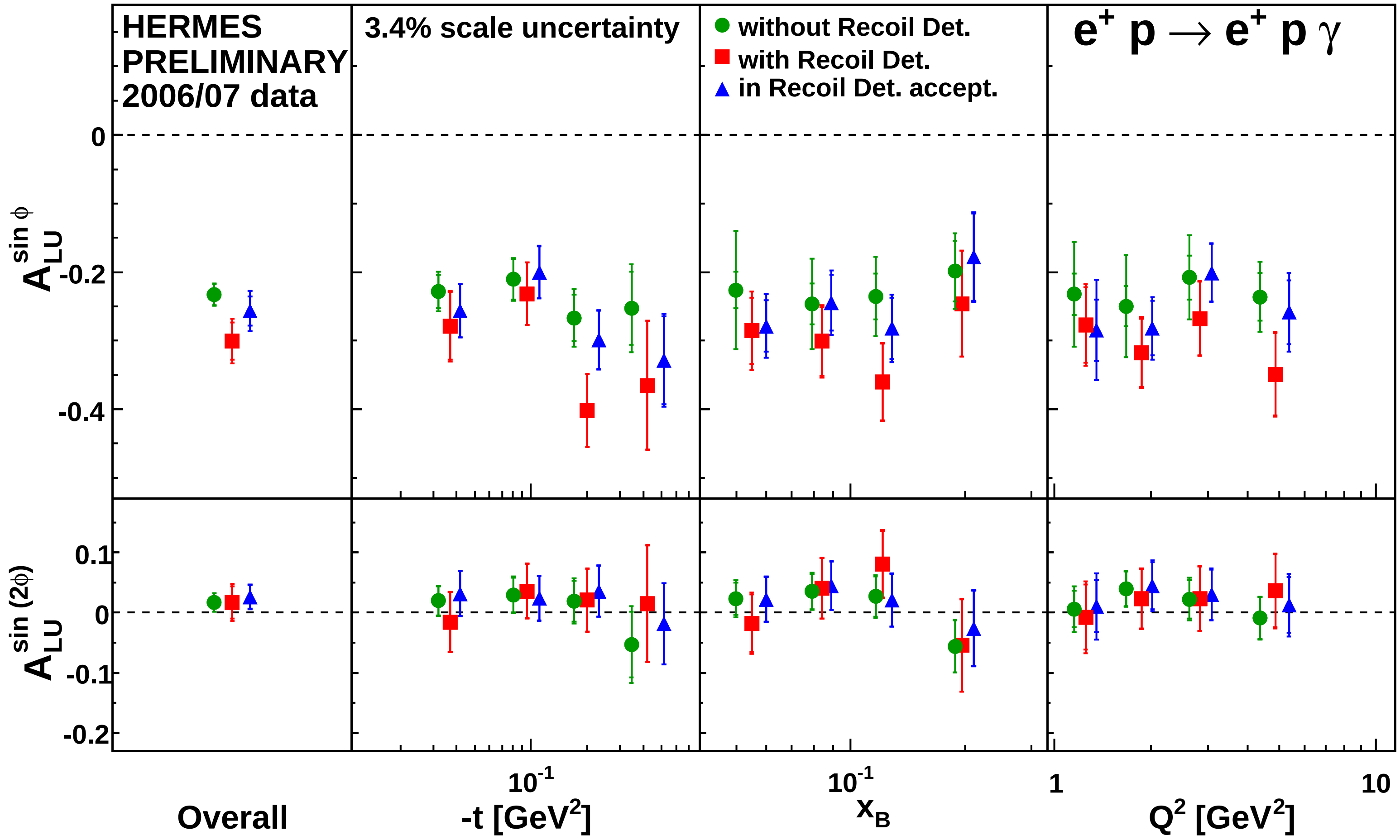


Comparison with Results in Recoil Detector Acceptance



- Indication that the leading amplitude for elastic process (background < 0.1%) is slightly larger in magnitude than the one in Recoil Detector acceptance

Comparison of All DVCS Data Samples



- Extraction of asymmetry amplitudes for associated processes is a subject of ongoing dedicated analysis

Summary

- Background-free measurement of beam-helicity asymmetry in DVCS - first physics results from the HERMES Recoil Detector