An Overview of Recent DVCS Results at HERMES

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on behalf of the hermes collaboration

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HELMHOLTZ | ASSOCIATION

DESY

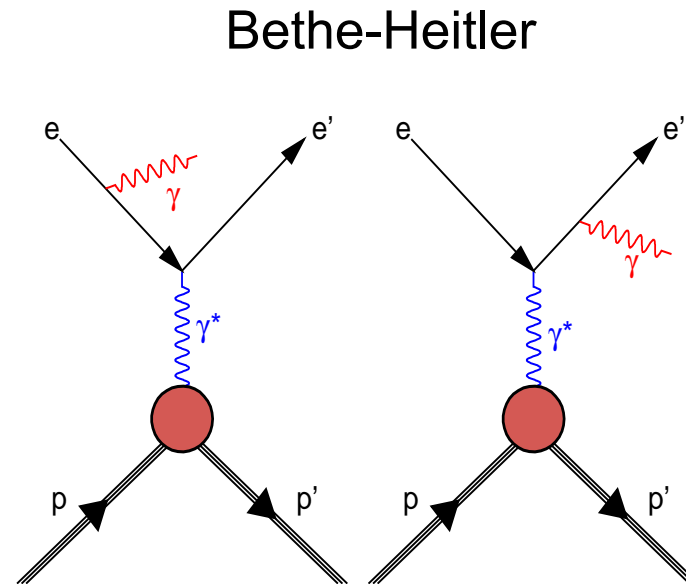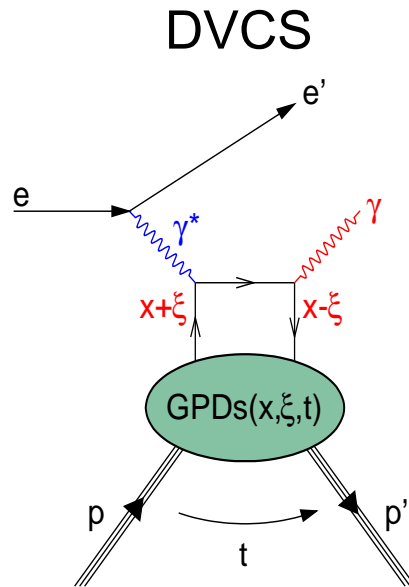# Generalized Parton Distributions (GPDs)

- 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

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

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

Deeply Virtual Compton Scattering (DVCS)

DVCS

Bethe-Heitler
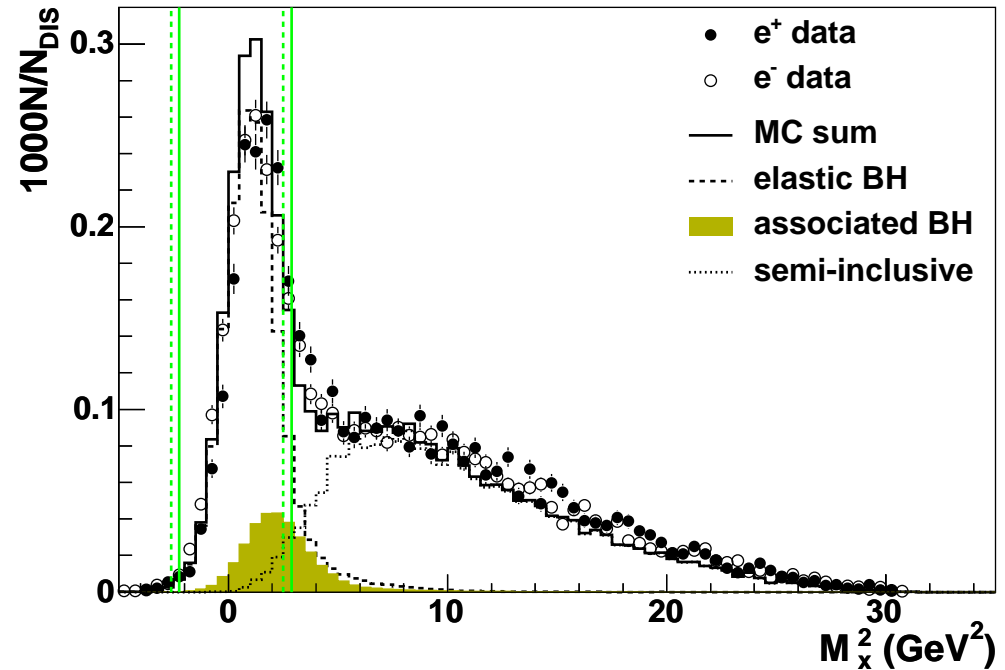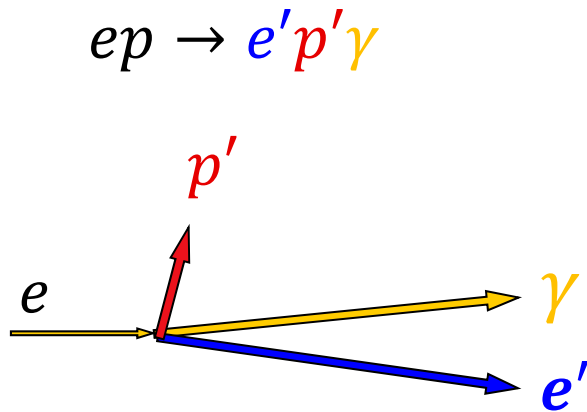

- DVCS and Bethe-Heitler: same initial and final state → interference

$$\frac{d\sigma}{dx_B dQ^2 dt d\phi} \propto |\tau_{BH}|^2 + |\tau_{DVCS}|^2 + I$$

- Bethe-Heitler dominates at HERMES kinematics
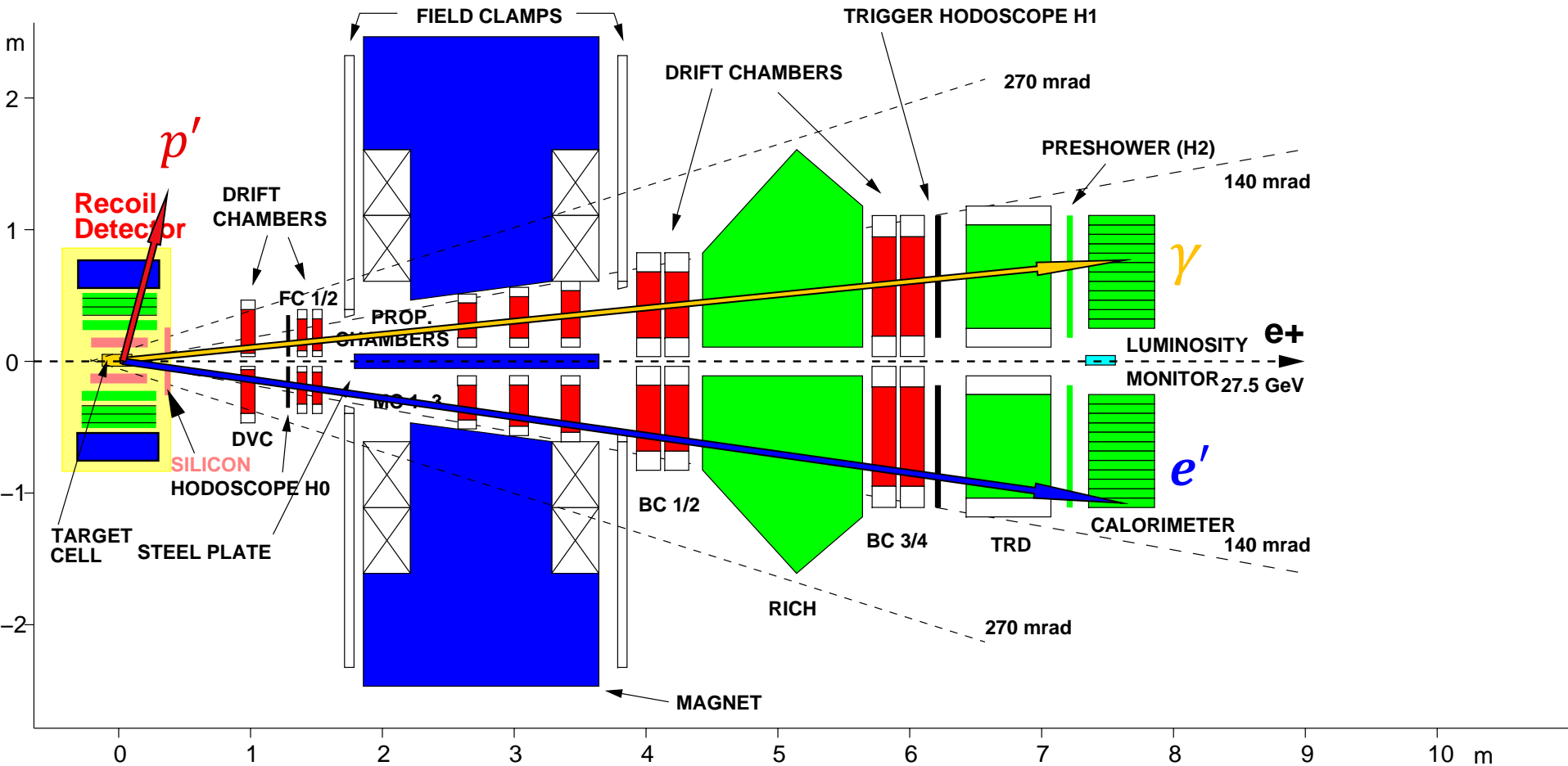- GPDs accessible through azimuthal asymmetries

$$ep \rightarrow e'p'\gamma$$
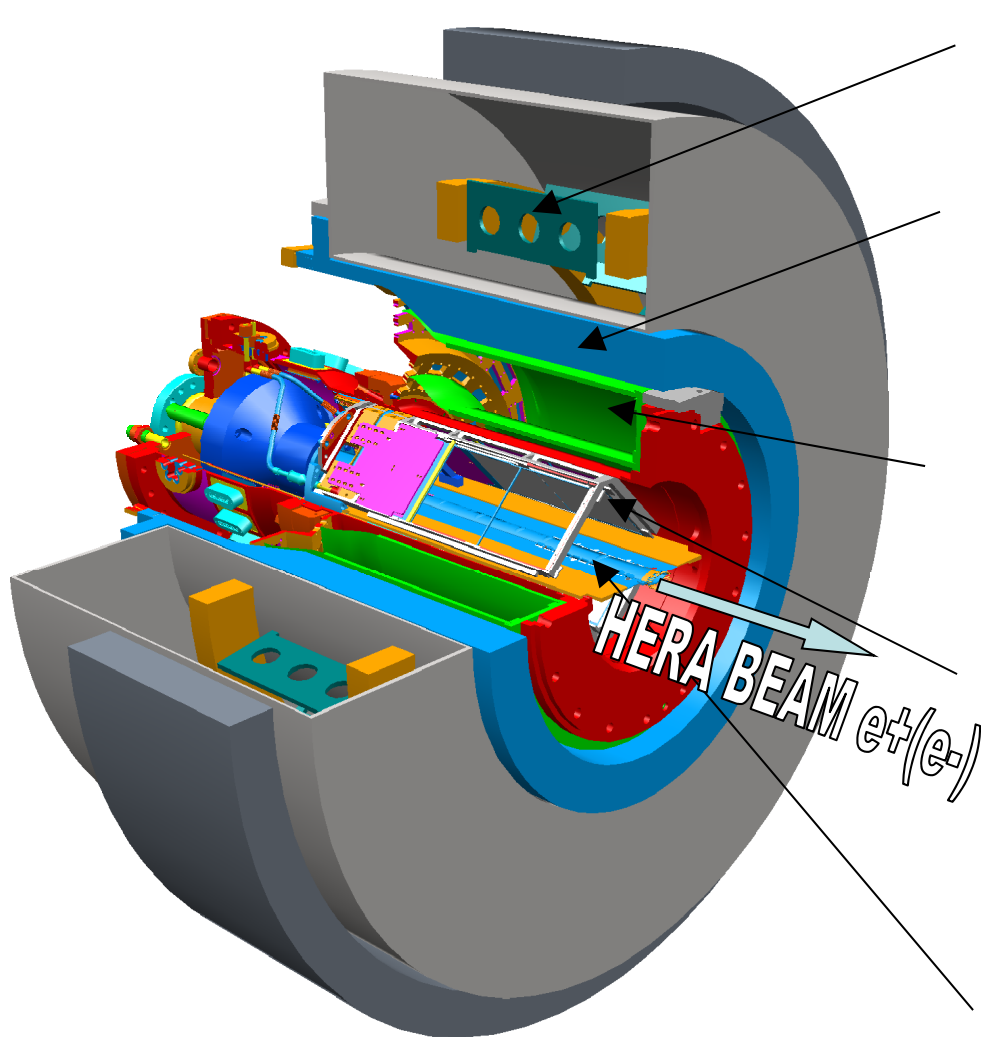

- **Pre-Recoil data**
  - Scattered lepton and photon were detected in the forward spectrometer
  - Recoil proton was not detected
  - Exclusivity achieved via missing mass technique
  - Associated processes (ADVCS, e.g. $ep \rightarrow e\gamma\Delta^+$) were not resolved (12% contribution)

HERMES with the Recoil Detector (2006-2007)

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

S. Yaschenko, An Overview of Recent DVCS Results at HERMES

HERMES Recoil Detector

1 Tesla superconducting solenoid

Photon Detector (PD)
- detect photons
- 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
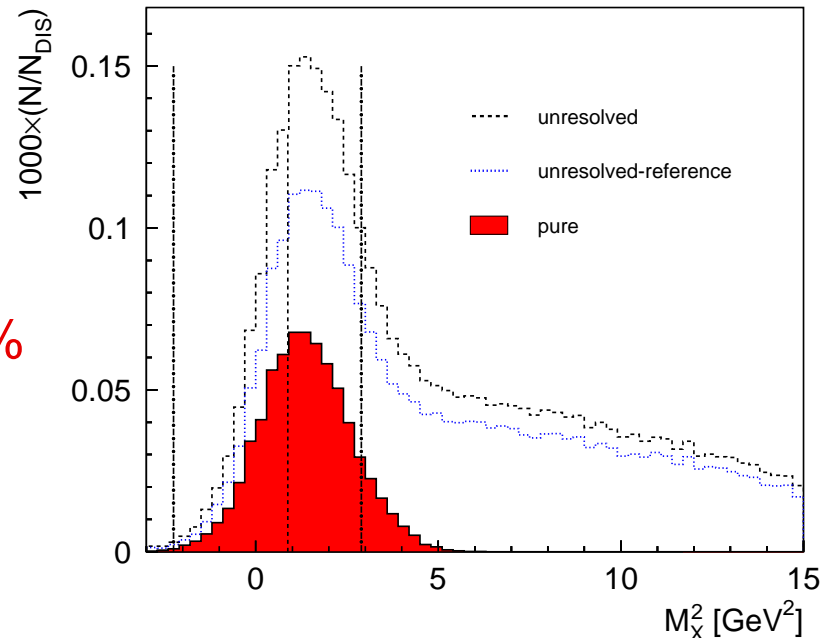- Momentum reconstruction by energy deposit for protons and deuterons

Target cell
- Unpolarized hydrogen and deuterium targets

HERA BEAM e+(e-)

DVCS Event Selection

- Kinematic event fitting technique
  - All 3 particles in the final state detected → 4 constraints from energy-momentum conservation (4C fit)
  - Selection of $ep \rightarrow ep\gamma$ with high efficiency (~84%)
  - Allows to suppress background from associated and semi-inclusive processes to a negligible level

- Missing mass distribution
  - No requirement for Recoil
  - In the Recoil acceptance
  - Kinematic fit probability > 1%
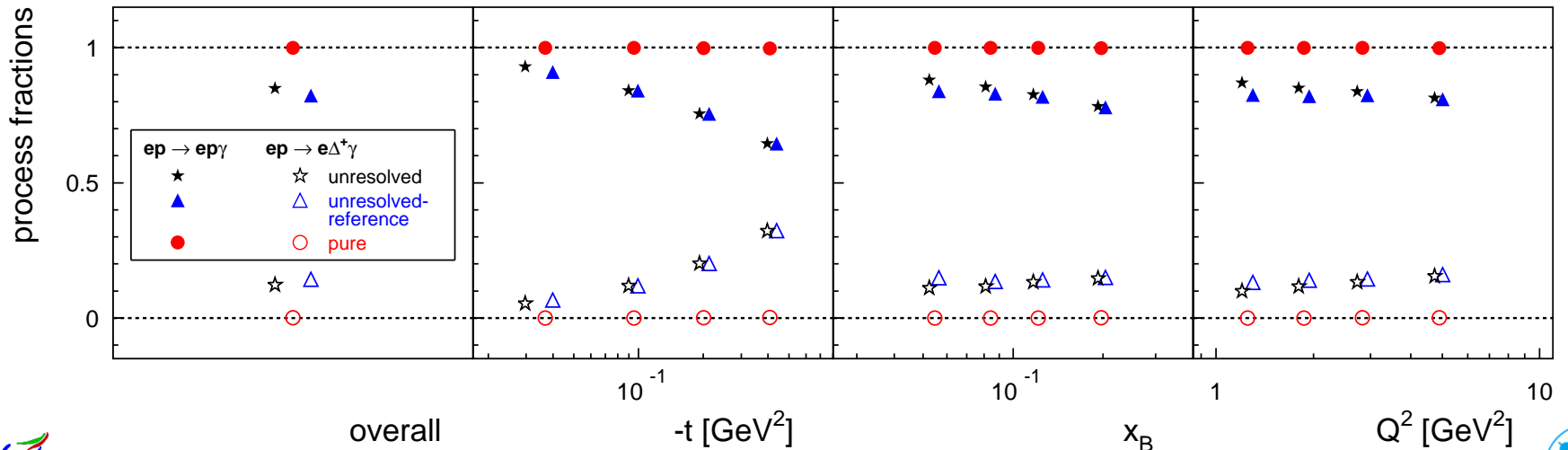
DVCS Event Samples

Without Recoil Detector

In Recoil Detector acceptance

With Recoil Detector

Similar background

Background-free

Similar kinematics

S. Yaschenko, An Overview of Recent DVCS Results at HERMES

Beam-Helicity Asymmetry in DVCS

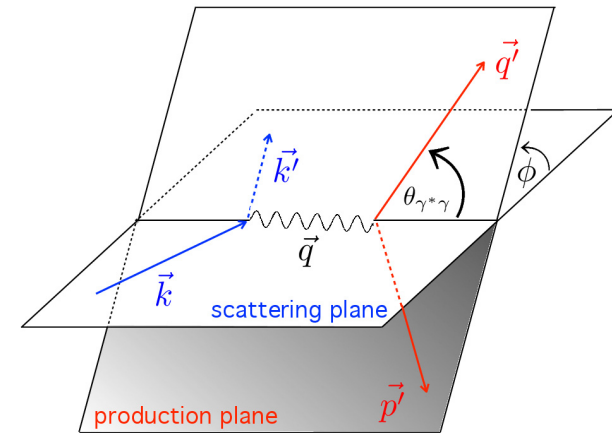- In the case of single charge, cross section

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

- Beam-helicity asymmetry

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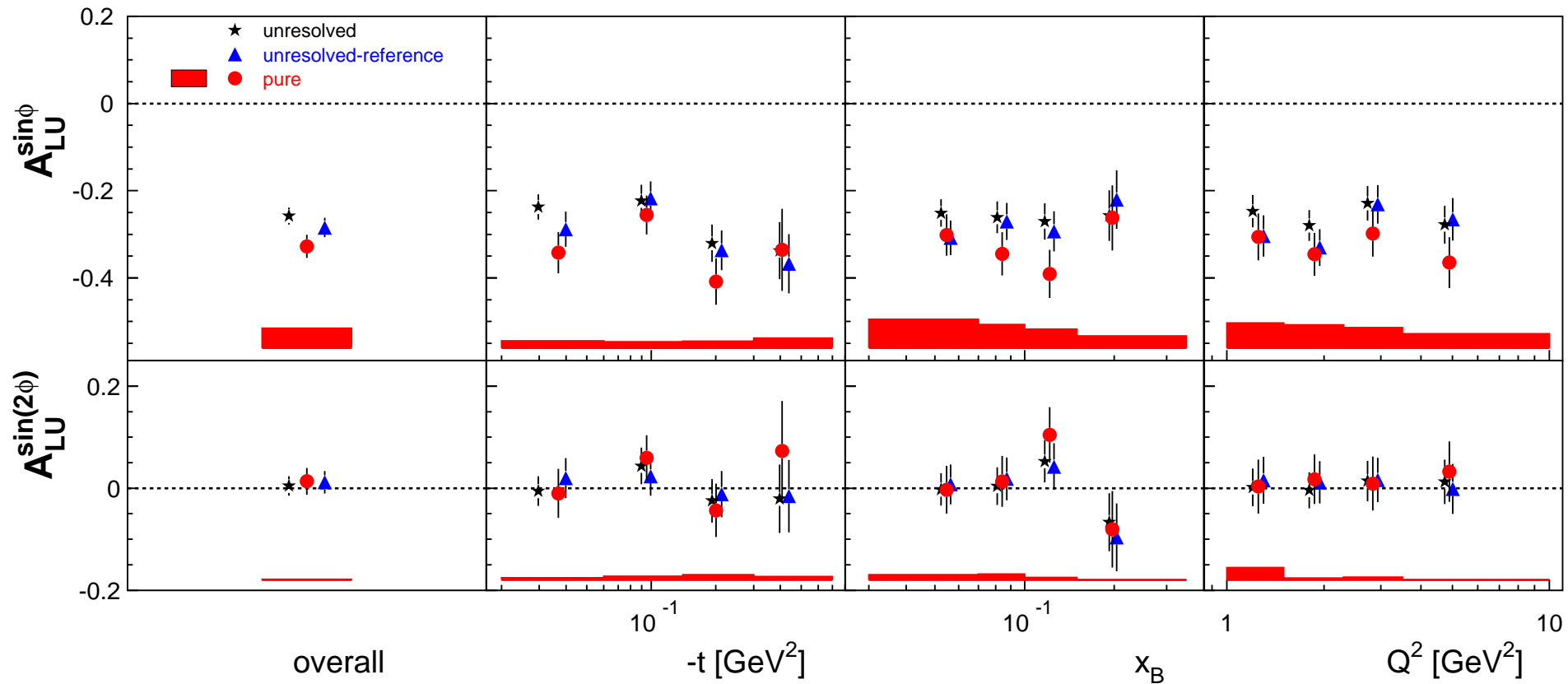

- Expansion of the asymmetry

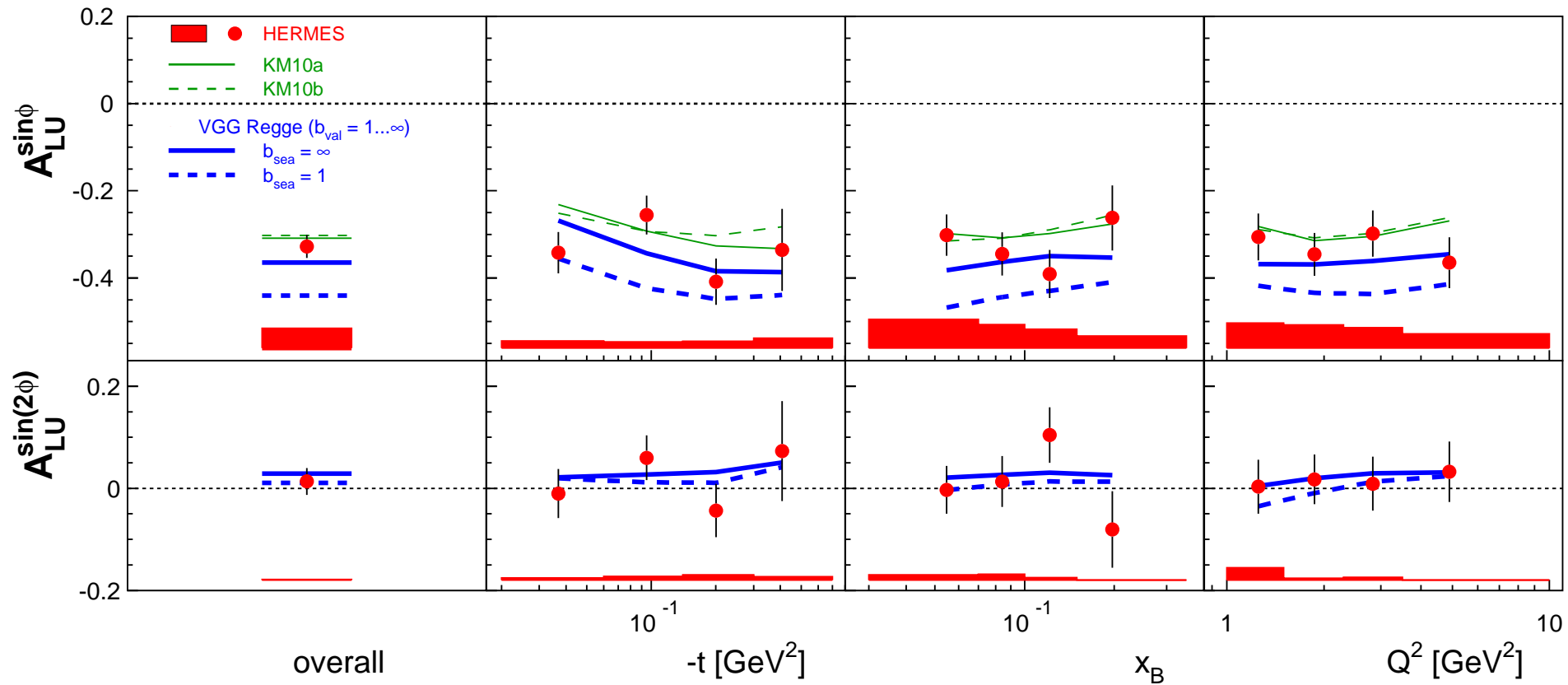$$A_{LU}(\phi) = \sum_{n=1}^{2} A_{LU}^{\sin(n\phi)} \sin(n\phi)$$

- Extraction of asymmetry amplitudes using Maximum Likelihood Method

Leading amplitude for pure BH/DVCS (background < 0.2%) is slightly larger in magnitude than the one in Recoil Detector acceptance

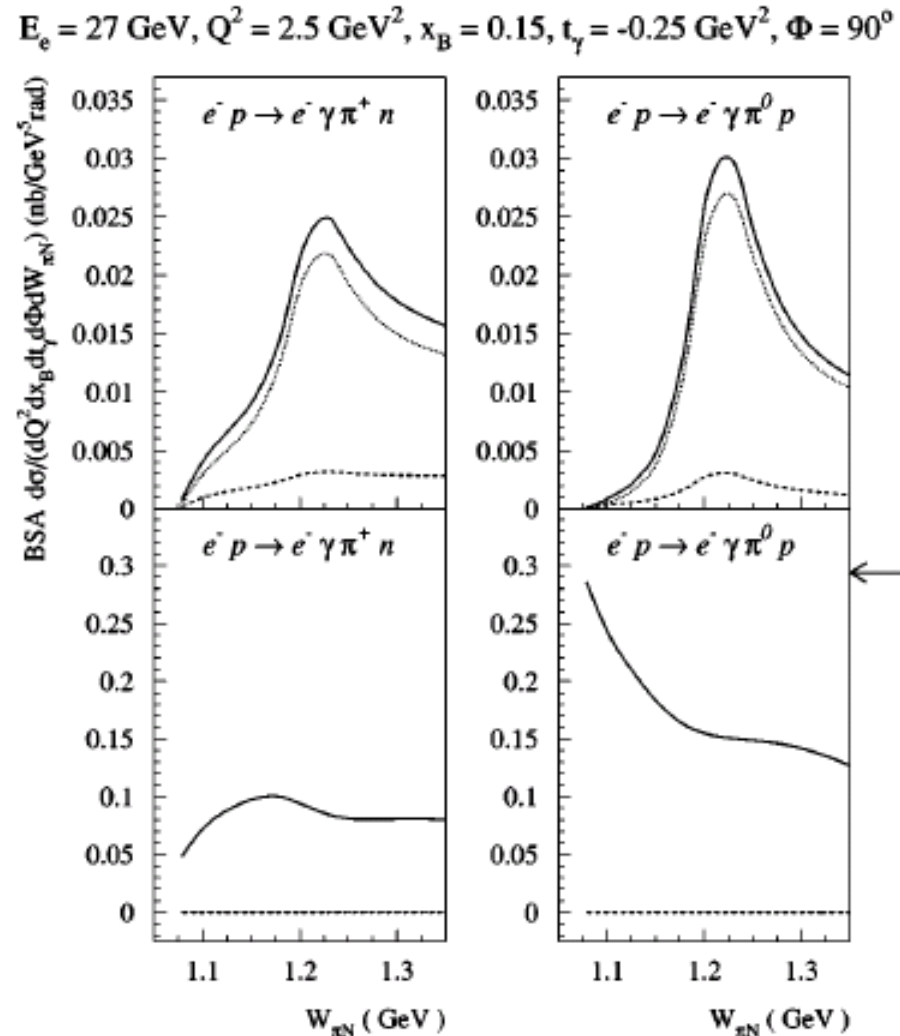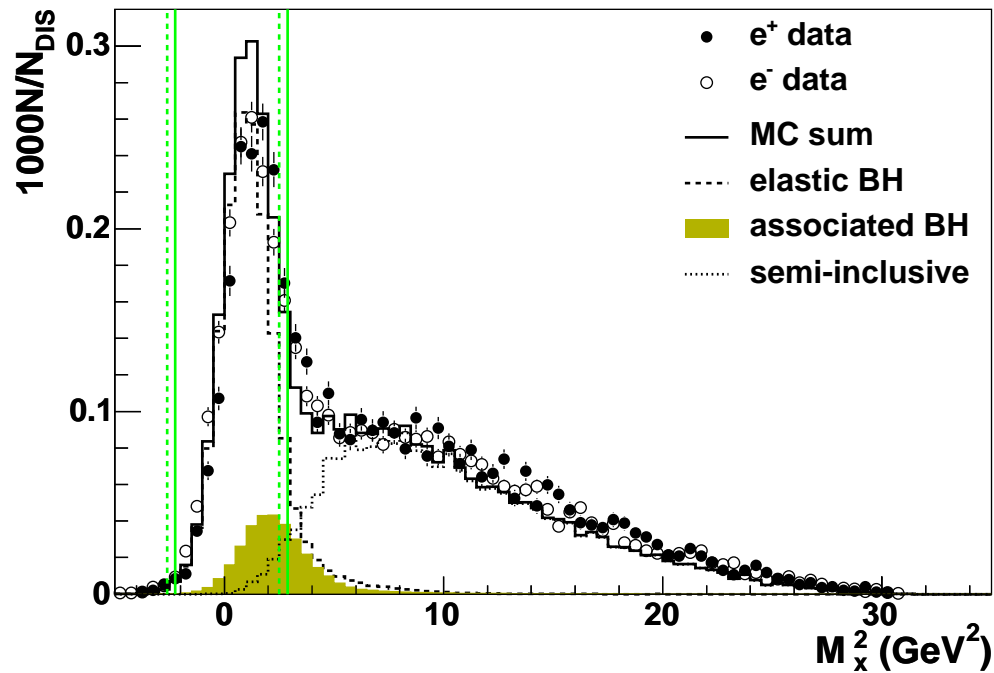GPD models reasonably describe data

Associated Processes

- Associated processes $ep \rightarrow e\gamma p\pi^0$ and $ep \rightarrow e\gamma p\pi^0$ in the Δ resonance region

- Theoretical model *P. Guichon, L. Mosse, M. Vanderhaegen, Phys. Rev. D 68, 034018 (2003)*

- Predictions for HERMES, JLAB and COMPASS

- Different BSA for different decay channels

- Dependence of asymmetry on pion-nucleon invariant mass

$E_e = 27$ GeV, $Q^2 = 2.5$ GeV^2, $x_B = 0.15$, $t_\gamma = -0.25$ GeV^2, $\Phi = 90°$

Selection of Events from Associated Processes

- The yield is much smaller than that of elastic

- The SIDIS yield is not negligible

- One particle always remains undetected

- Perform kinematic fitting
  - To select associated processes
  - To reject contribution of elastic

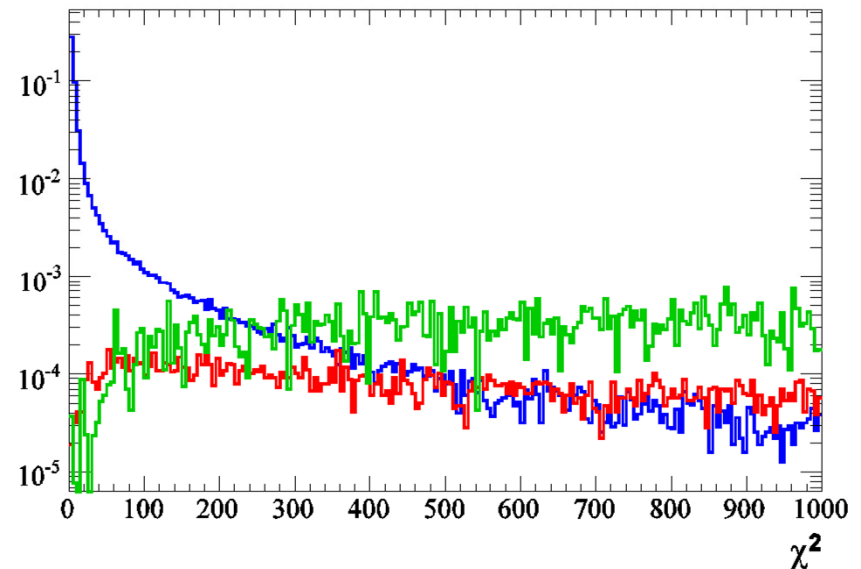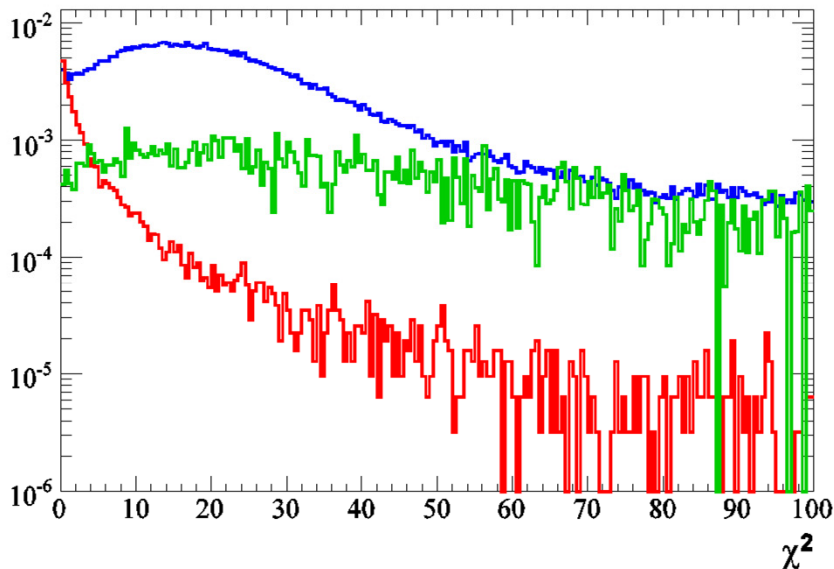- Use particle identification in the Recoil subdetectors

Selection of Associated Processes

- Result of kinematic fitting under hypothesis $ep \to e\gamma p\pi^0$

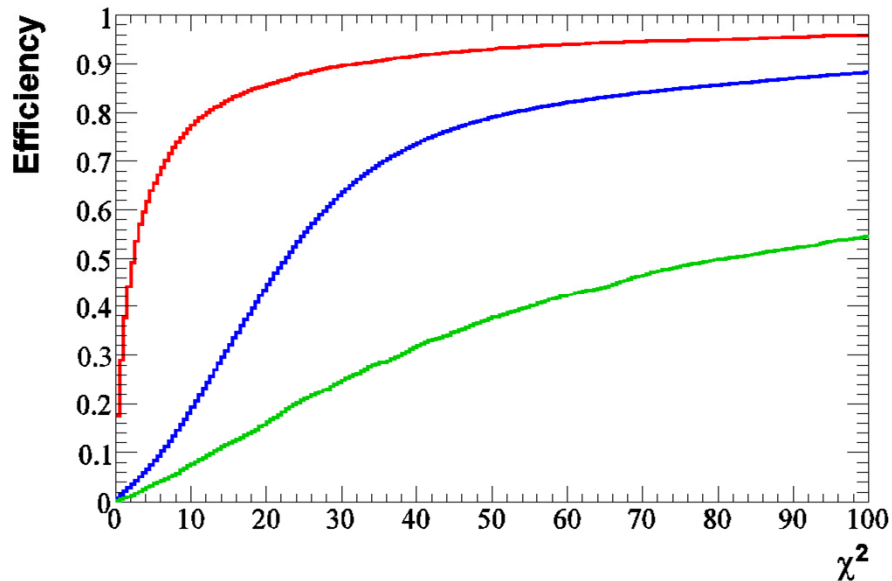- Result of kinematic fitting under hypothesis $ep \to e\gamma p$

- Red - $ep \to e\gamma p\pi^0$
- Blue - $ep \to e\gamma p$
- Green - SIDIS

S. Yaschenko, An Overview of Recent DVCS Results at HERMES

- Efficiency of associated event selection

- Efficiency of associated event selection

$$\chi^2(ep \to e\gamma p\pi^0[n\pi^+]) < \chi^2_{cut}$$
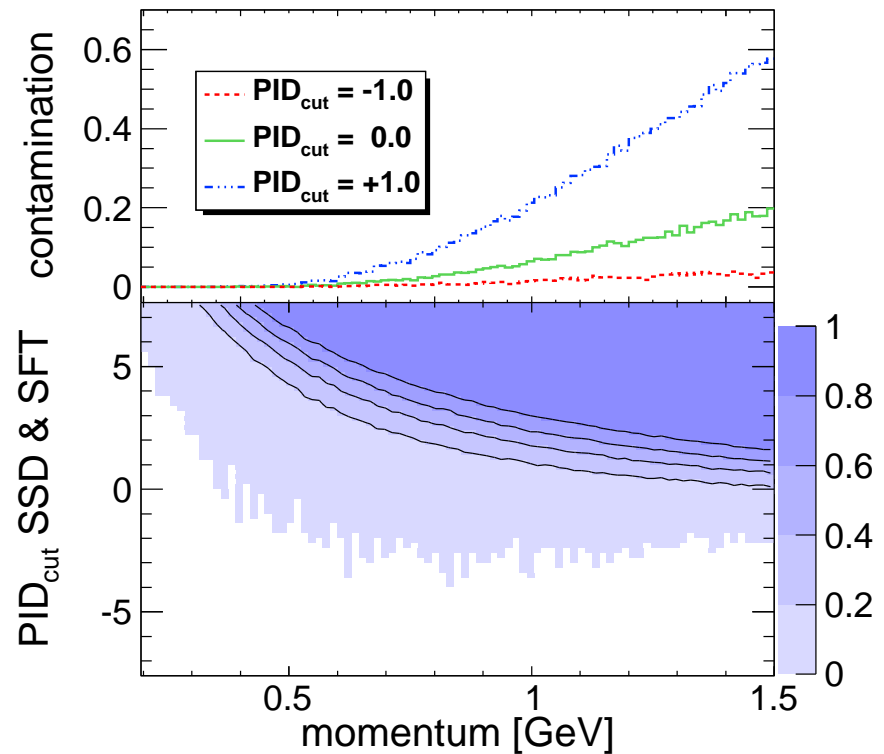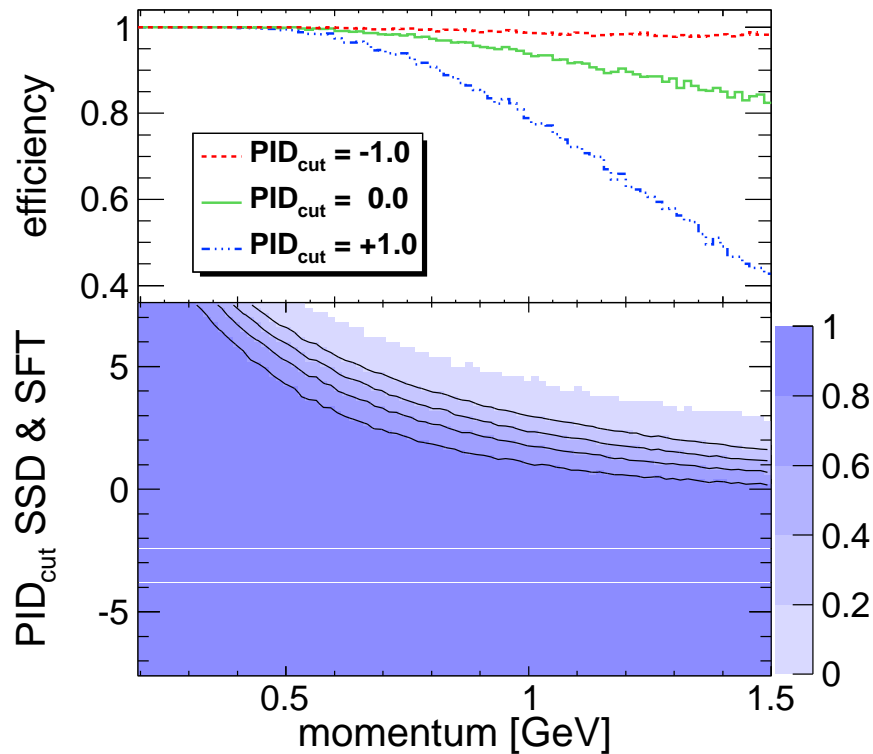
$$\chi^2(ep \to e\gamma p) > \chi^2_{cut}$$

Particle Identification: Selection of Protons
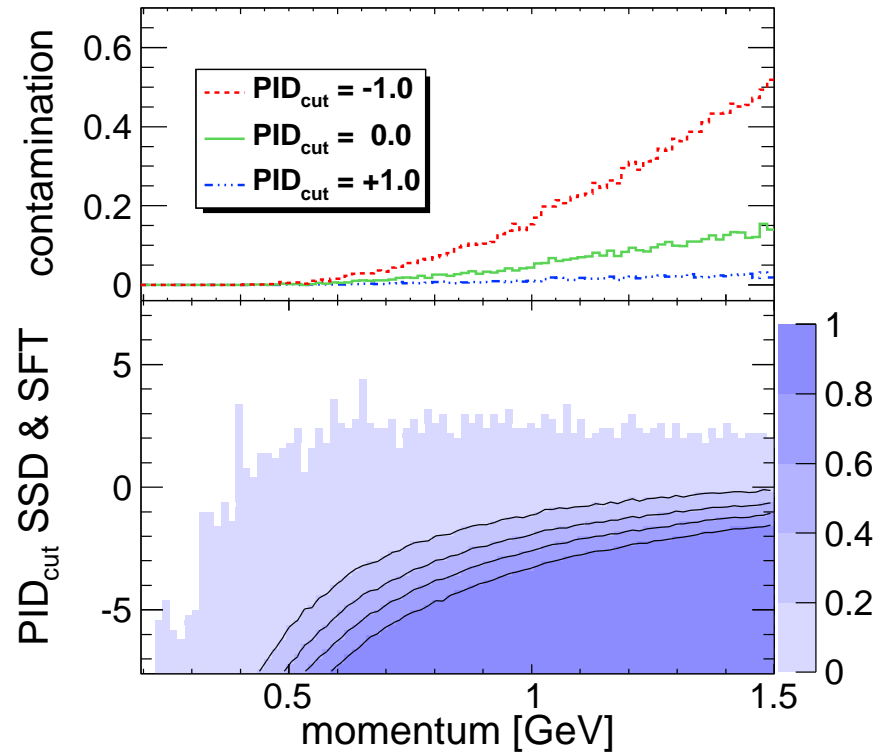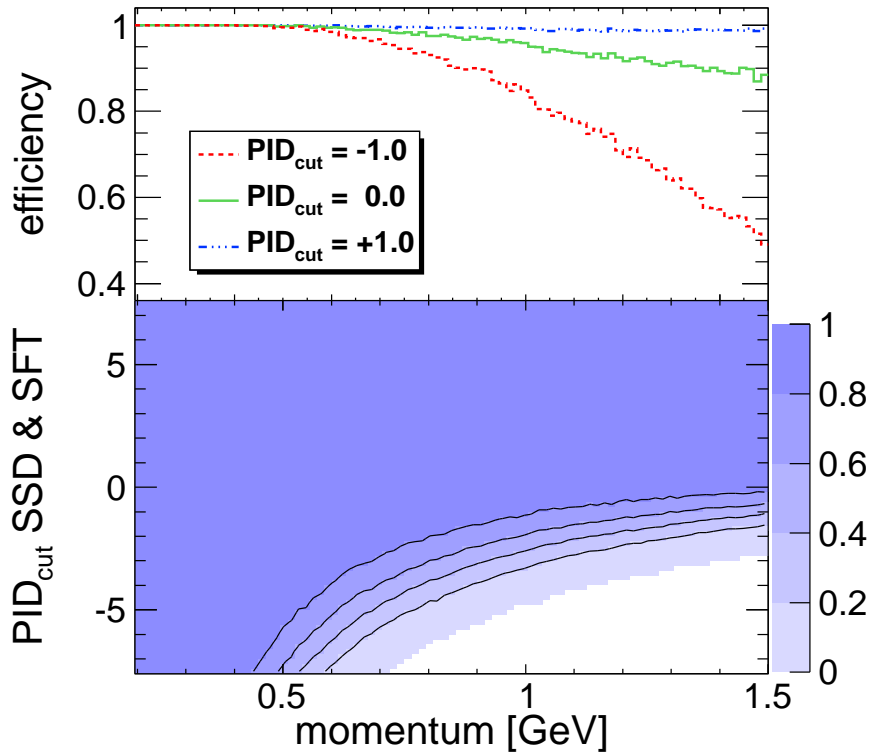
● Define PID values

$$PID(dE; p) = \frac{F\left(dE; \beta\gamma = \frac{p}{m_p}\right)}{F\left(dE; \beta\gamma = \frac{p}{m_\pi}\right)}$$

Particle Identification: Selection of Pions

● Define PID values

$$PID(dE; p) = \frac{F\left(dE; \beta\gamma = \frac{p}{m_p}\right)}{F\left(dE; \beta\gamma = \frac{p}{m_\pi}\right)}$$

- **Selection criteria:**
  - Select associated events using kinematic fitting (2C fit)
  $$\chi^2(ep \rightarrow e\gamma p\pi^0[n\pi^+]) < \chi^2_{cut}$$
  - Reject $ep \rightarrow ep\gamma$ with kinematic fitting (4C fit)
  $$\chi^2(ep \rightarrow e\gamma p) > \chi^2_{cut}$$
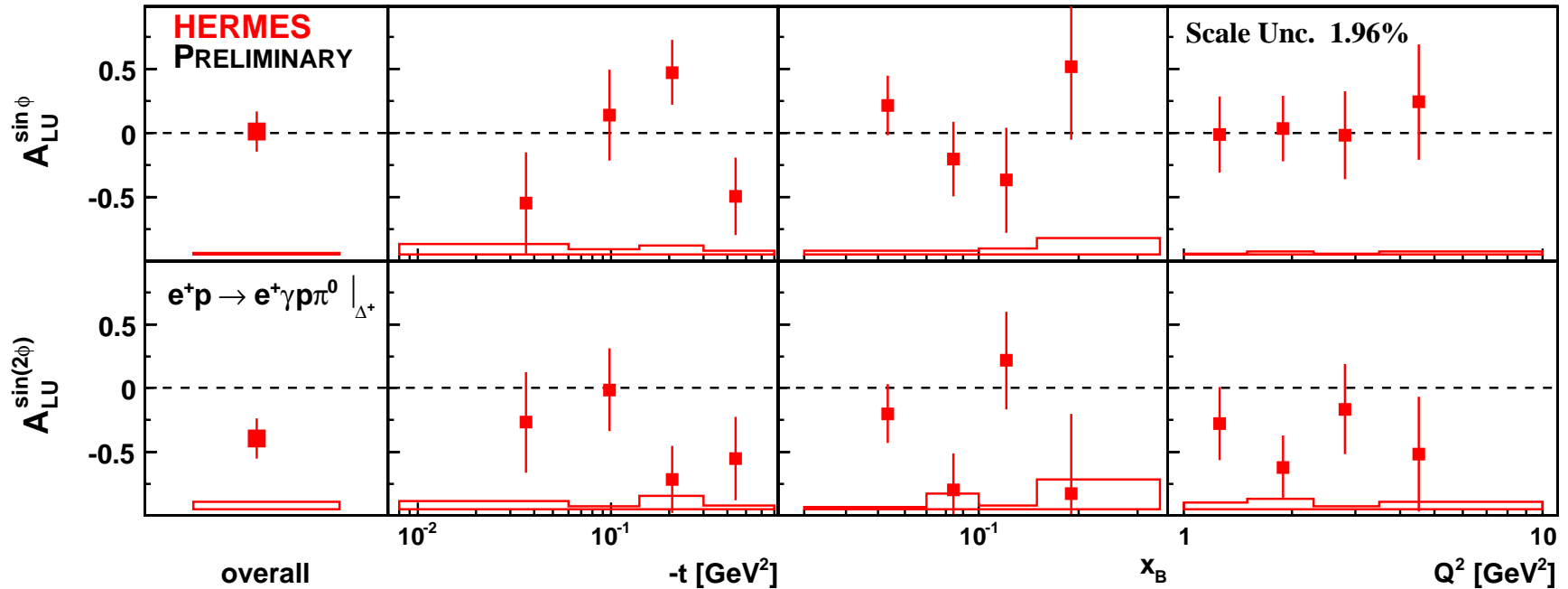 - Identify protons (pions):
  $$PID > [<]PID_{cut}$$

- **Contamination of background processes**
  - <1% from elastic,
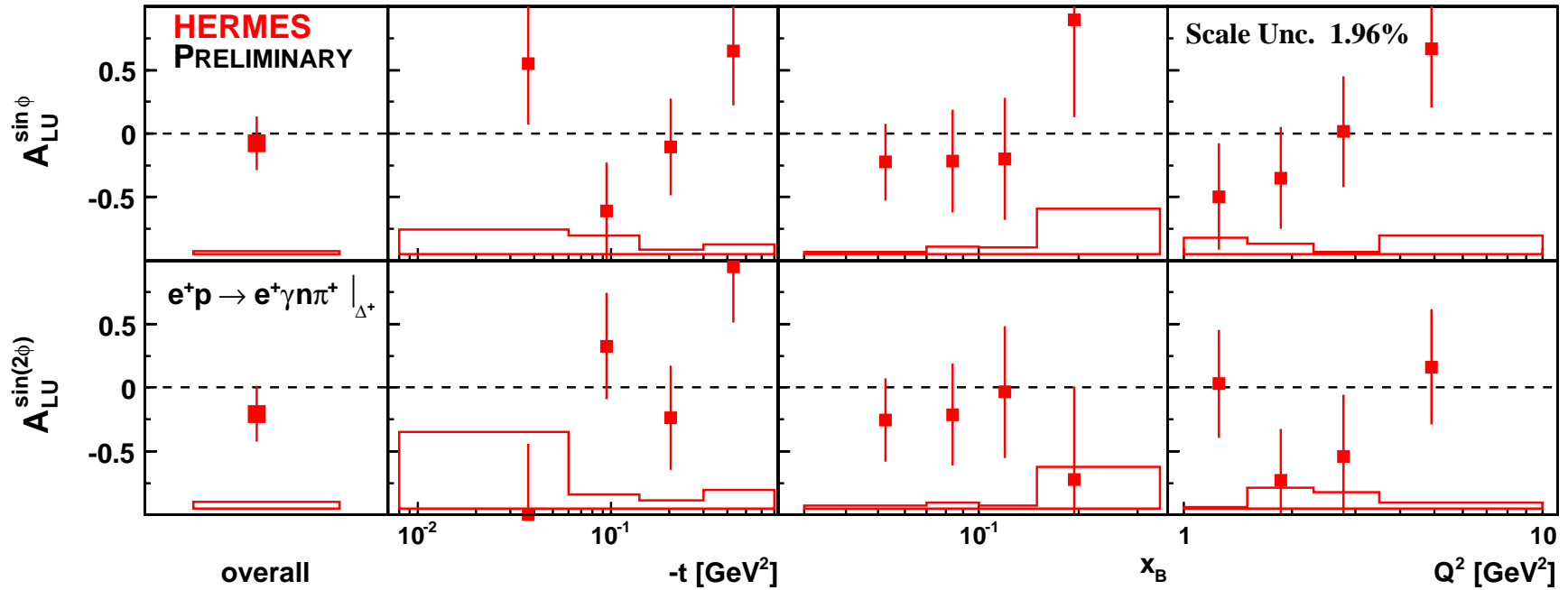 - 13% [24%] from SIDIS

- **Asymmetry results are corrected for the background**

Results on Beam-Helicity Asymmetry for $ep \rightarrow e\gamma p\pi^0$

- Leading amplitude consistent with zero
- Contributes as a dilution to elastic asymmetry

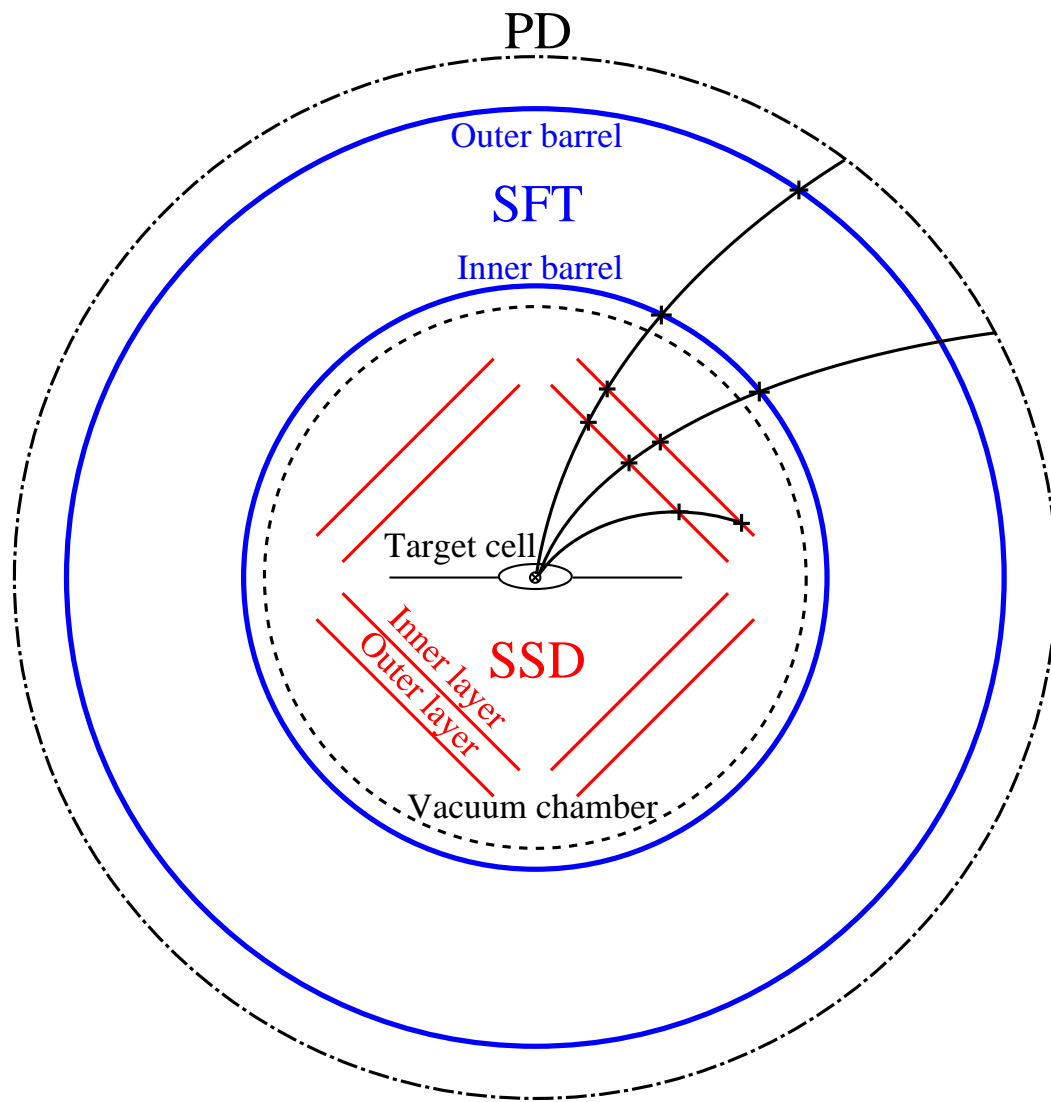# Results on Beam-Helicity Asymmetry for ep→eγnπ⁺
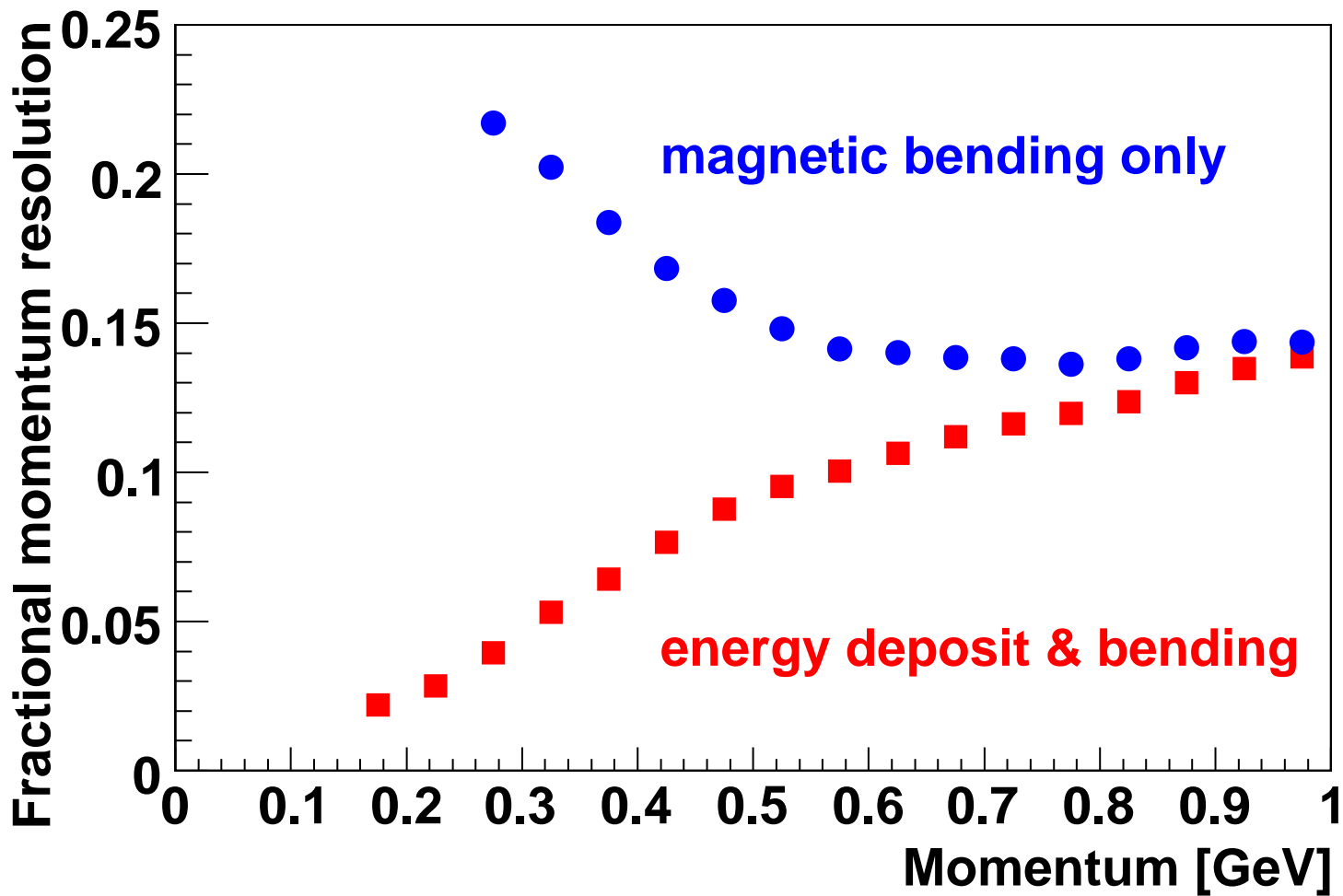

- Amplitudes consistent with zero
- Contributes as a dilution to elastic asymmetry

Summary
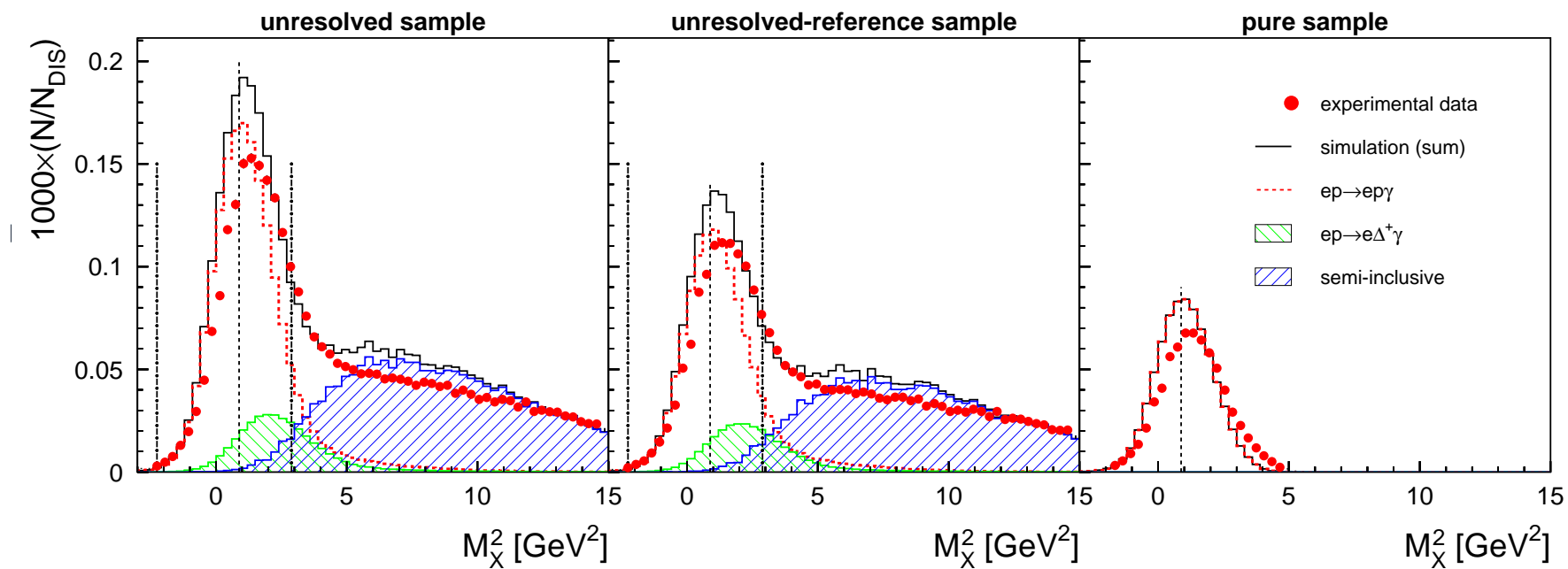
- HERMES produced physics results using the Recoil detector

- DVCS
  – Publication on beam-helicity asymmetry is recently accepted for publication in JHEP

- Associated processes
  – Preliminary results on beam-helicity asymmetry

- Additional HERMES contribution to constrain GPDs

Backup

Backup

PD

Outer barrel

SFT

Inner barrel

Target cell

Inner layer
Outer layer

SSD

Vacuum chamber

hermes

unresolved sample · unresolved-reference sample · pure sample

experimental data
simulation (sum)
$ep \rightarrow ep\gamma$
$ep \rightarrow e\Delta^+\gamma$
semi-inclusive

M_X^2 [GeV^2]

$1000 \times (N/N_{DIS})$

$E_e = 27$ GeV, $Q^2 = 2.5$ GeV^2, $x_B = 0.15$, $t_\gamma = -0.25$ GeV^2, $\Phi = 90°$
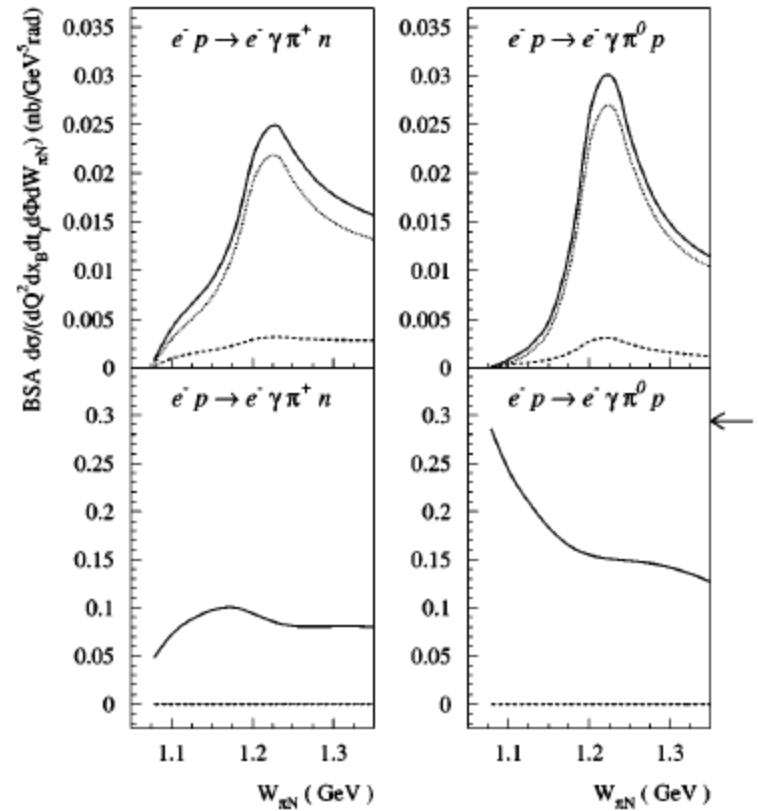

FIG. 14. Fivefold differential cross sections (upper panels) and corresponding beam spin asymmetries (lower panels) for the $e^- p \rightarrow e^- \gamma \pi N$ reactions in HERMES kinematics. Dotted curves, ABH; dashed curves, ADVCS; solid curves, ABH+ADVCS. The arrow gives the elastic value of the BSA for the BH+DVCS process, corresponding to $W_{\pi N} = M = 0.939$ GeV.