Deeply Virtual Compton Scattering at HERMES

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hermes Collaboration

Joint APS & JPS Meeting

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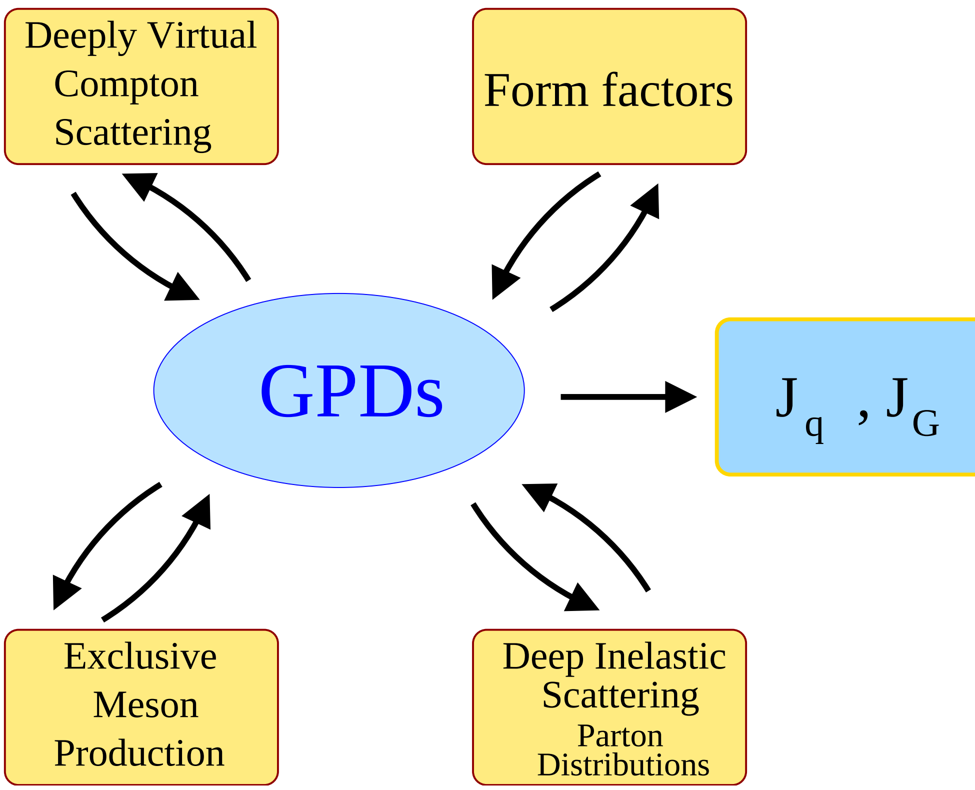
- Introduction
- Single Spin Asymmetries in DVCS
- Summary
- Outlook

Generalized Parton Distributions and DVCS

Generalized (Skewed, or Off-forward)
Parton
Distributions:

Unified Theoretical Description of
Inclusive and (hard) Exclusive Processes

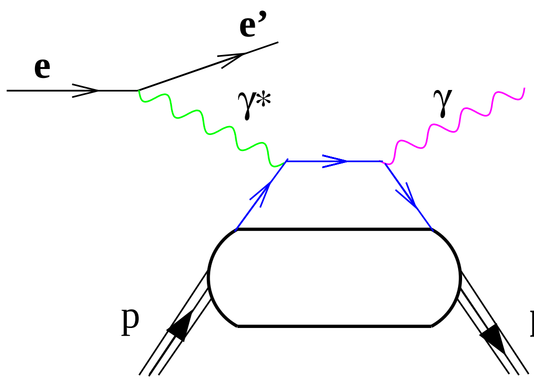


Simplest Hard Exclusive Process: $ep \rightarrow ep\gamma$
$(\gamma^* p \rightarrow \gamma p)$

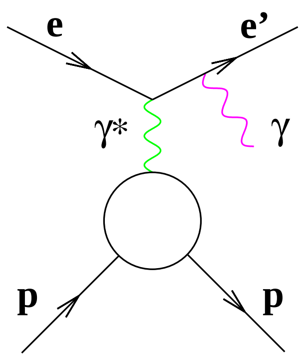
Deeply Virtual Compton Scattering

Deeply Virtual Compton Scattering (DVCS)

- DVCS process factorizes at high Q^2 and low t
  $\rightarrow$ 'hand-bag' diagram
  $\Downarrow$



DVCS



Bethe-Heitler

- Central Issue:

  Photons from DVCS and BH indistinguishable

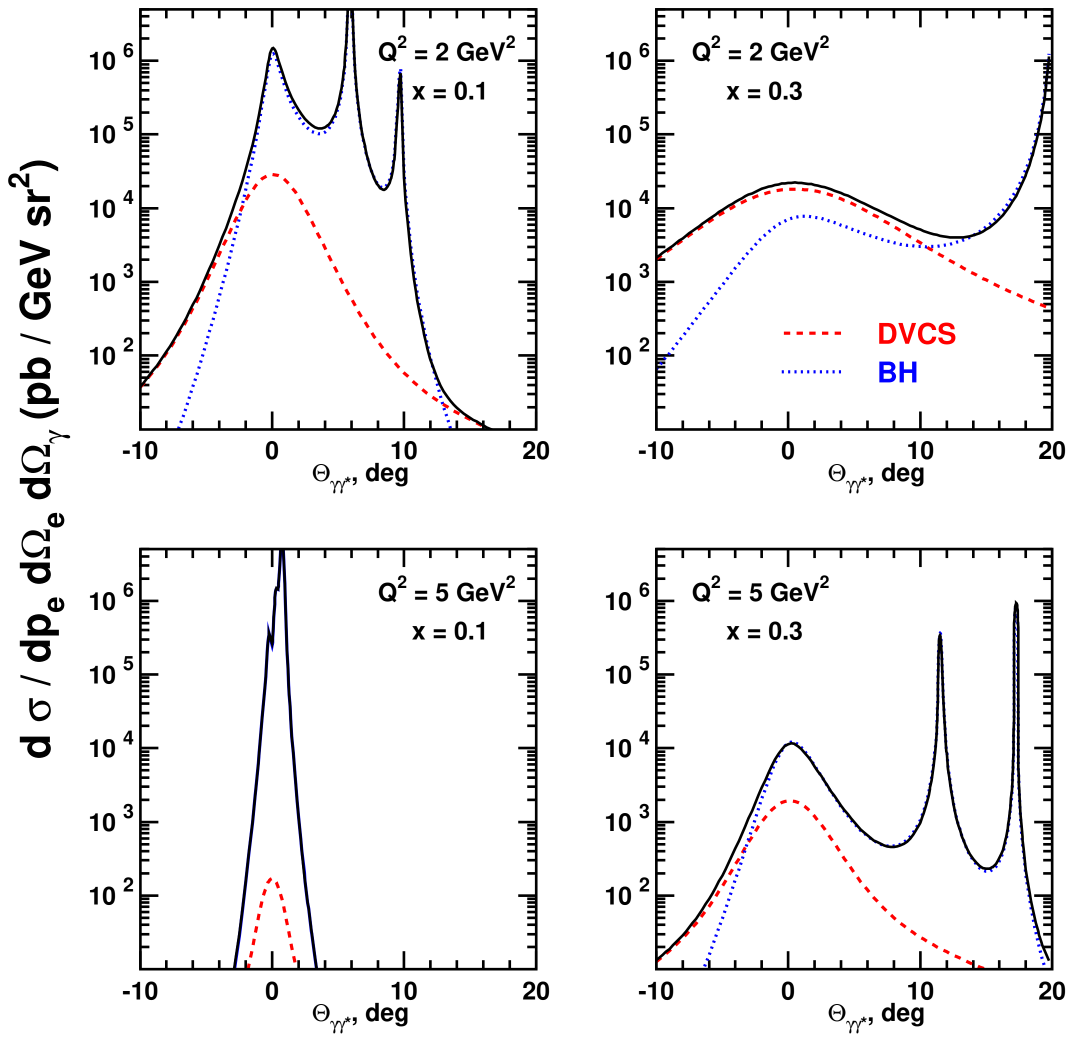
- Background from BH calculable from QED and proton structure functions

- Access to DVCS amplitudes:
  - select kinematical domain where BH suppressed
  - exploit interference between DVCS and BH

DVCS and Bethe-Heitler

- Cross sections at $E = 27.5$ GeV (HERMES):

  'In-plane' cross section: scattering plane = reaction plane



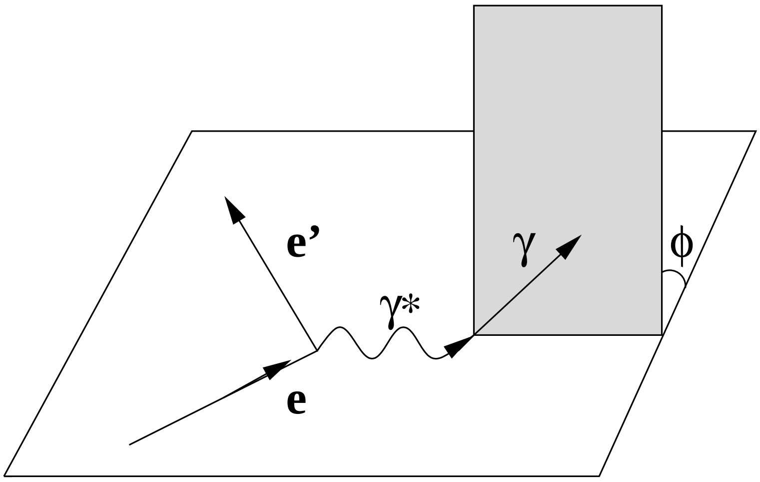
- DVCS dominated by BH in most of kinematical region

- DVCS-BH interference:

  $\Rightarrow$ Use BH as a vehicle to study DVCS

$$d\sigma \propto |\mathcal{T}_{\rm DVCS}|^2 + |\mathcal{T}_{\rm BH}|^2 + (\mathcal{T}^*_{\rm DVCS}\mathcal{T}_{\rm BH} + \mathcal{T}^*_{\rm BH}\mathcal{T}_{\rm DVCS})$$

Azimuthal Asymmetries



Isolate the BH-DVCS interference term ...

- Lepton Helicity Asymmetry (SSA):
  longitudinally polarized beam, unpolarized target (A_{LU})

$$\mathrm{d}\sigma(e^{\rightarrow}p) - \mathrm{d}\sigma(e^{\leftarrow}p) \quad \propto \quad \sin(\phi) \times \mathrm{Im}\,(\mathcal{T}_{\mathrm{DVCS}}\mathcal{T}_{\mathrm{BH}})$$

  $\Rightarrow$ Access to IMAGINARY part of Amplitude

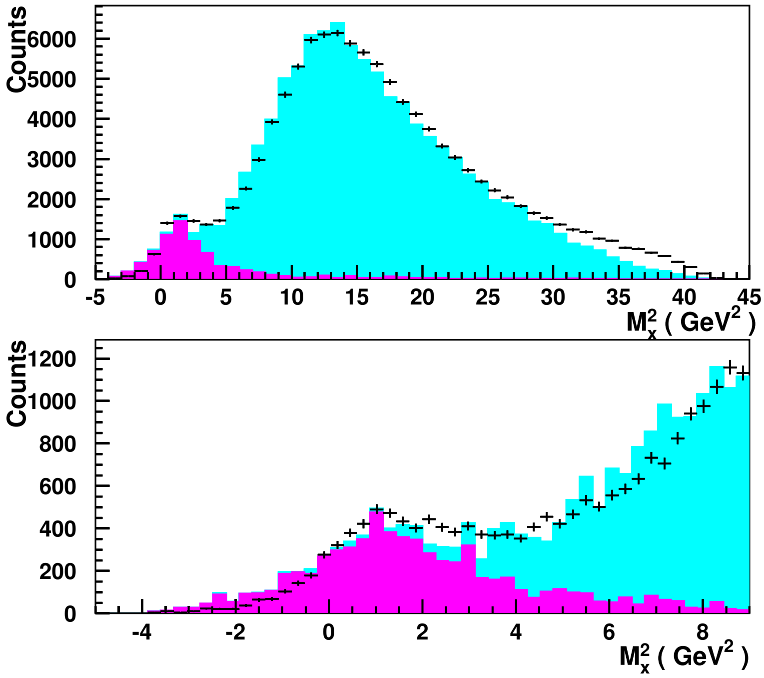
- Lepton Charge Asymmetry:
  unpolarized beam, unpolarized target (A_{ch})

$$\mathrm{d}\sigma(e^{+}p) - \mathrm{d}\sigma(e^{-}p) \quad \propto \quad \cos(\phi) \times \mathrm{Re}\,(\mathcal{T}_{\mathrm{DVCS}}\mathcal{T}_{\mathrm{BH}})$$

  $\Rightarrow$ Access to REAL part of Amplitude

$\rightarrow$ Possibility to study absolute value and complex phase of DVCS amplitude

Exclusivity in DVCS

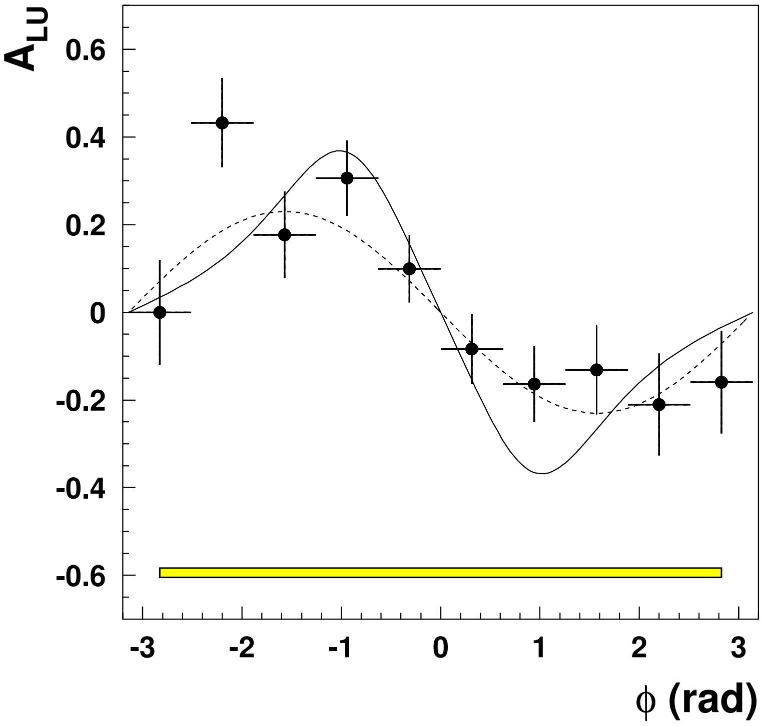


in exclusive DVCS: $M_x^2 = (q + P_p - P_\gamma)^2 = M_p^2$

- due to Calorimeter energy resolution, M_x resolution $\approx$ 0.77 GeV
  $\rightarrow$ no separation of exclusive and associated DVCS
  $\rightarrow$ leakage into negative M_x^2 region
- MC simulation of photons from fragmentation and BH processes compared to data (+)

- 400'000 events with one positron and one untracked cluster
- kinematic requirements:
  $Q^2 > 1$ GeV^2, $W^2 > 4$ GeV^2, $\nu < 24$ GeV
  $15 < \theta_{\gamma^*\gamma} < 70$ mrad to avoid bias on reconstruction of small angles
- background contamination:
  - $\pi^0 \rightarrow 2\gamma$ decay misidentification due to calo granularity $< 5\%$
  - negligible contamination from photons from proton beam line, collimators, radiation in spectrometer

Single Spin Asymmetry -vs- Phi



$$A_{LU}(\phi) = \frac{1}{\langle |P_b| \rangle} \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

using exclusive region of $-1.5 < M_x < 1.7$ GeV
($\rightarrow$ includes associated DVCS)

$$\langle Q^2 \rangle = 2.6 \text{ GeV}^2, \quad \langle W^2 \rangle = 22 \text{ GeV}^2$$
$$\langle x_B \rangle = 0.11$$
$$\langle -t \rangle = 0.27 \text{ GeV}^2$$

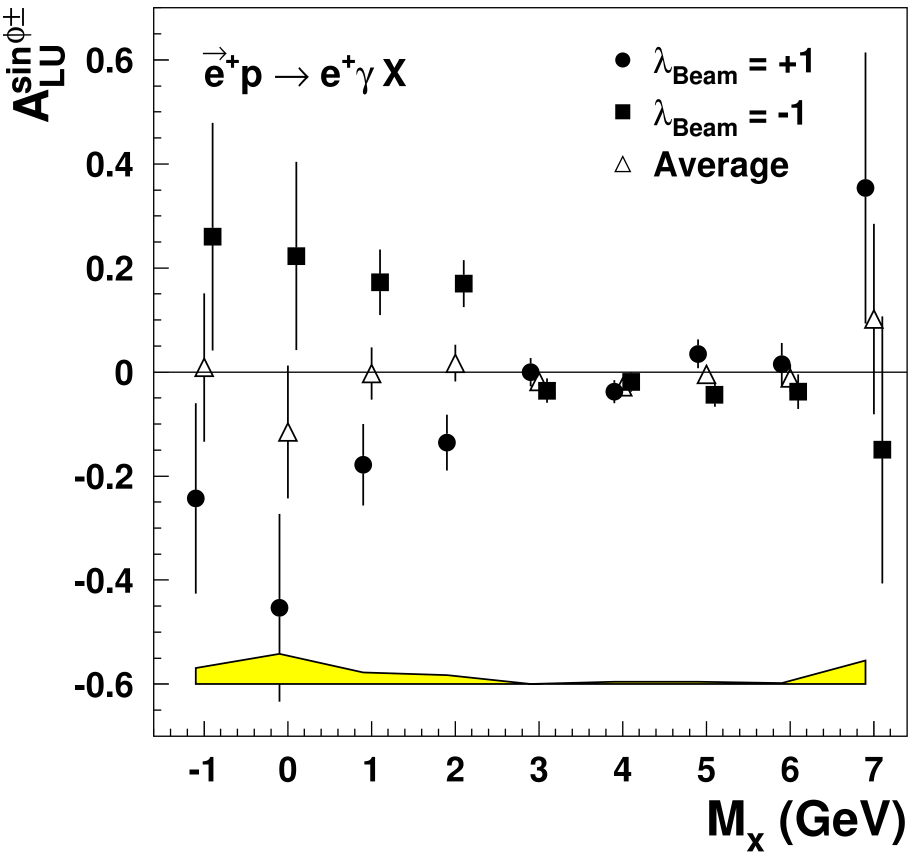
- - $\sin(\phi)$ fit to HERMES data (●)

— GPD calculation by N. Kivel, Polyakov, and Vanderhaeghen

(Phys. Rev. **D63** (2001) 114014)

Single Spin Asymmetry – $\sin(\phi)$ Moment

Separated Beam Helicity:



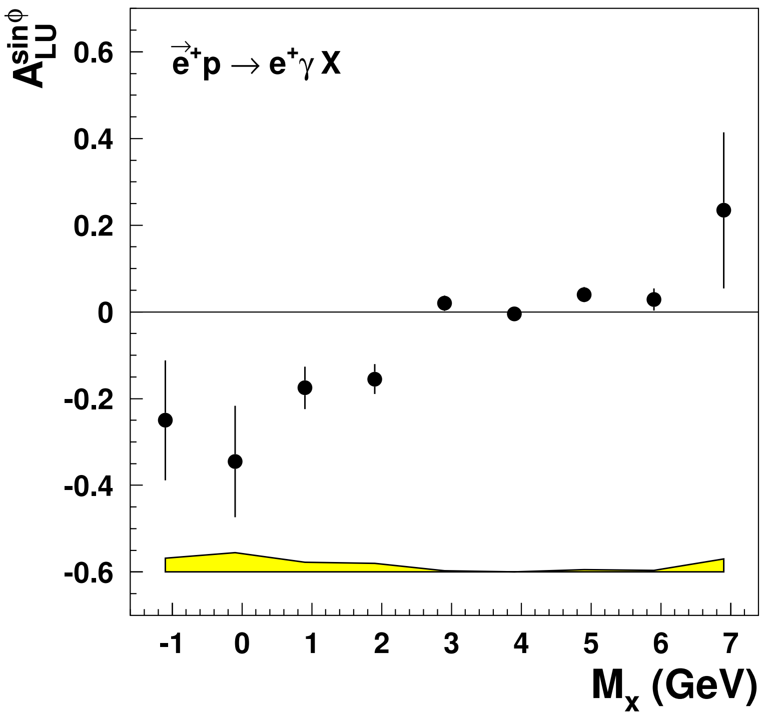
$\sin(\phi)$ Moment of SSA:

$$A_{LU}^{\sin\phi^{\pm}} = \frac{2}{N^{\pm}} \sum_{i=1}^{N^{\pm}} \frac{\sin\phi_i}{|P_b|_i}$$

- use $\sin(\phi)$ moment to extract amplitude
- beam-spin averaged data gives estimate of false asymmetry
  $\rightarrow$ instrumental effects $< 0.03 \pm 0.04$ in exclusive bin
- systematic error band includes beam polarization and smearing

Single Spin Asymmetry -vs- Missing Mass

Combined Data Sets:



Beam-spin analyzing power:

$$A_{LU}^{\sin\phi} = \frac{2}{N} \sum_{i=1}^{N} \frac{\sin\phi_i}{(P_b)_i}$$

- Systematic Uncertainties
  - Smearing effects
    - $\rightarrow$ from fragmentation & Bethe-Heitler MC $< 5\%$
  - Beam polarization and smearing combined error band
  - In exclusive region ($-1.5 < M_x < 1.7$ GeV)
    - false asymmetries due to
      - $\rightarrow$ Bethe-Heitler process $\leq 2.6\%$
      - $\rightarrow$ π^0 contamination 12.5%
    - instrumental false asymmetry: cancels in $A_{LU}^{\sin\phi}$

$$A_{LU}^{\sin\phi} = -0.23 \pm 0.04(\text{stat.}) \pm 0.03(\text{syst.})$$

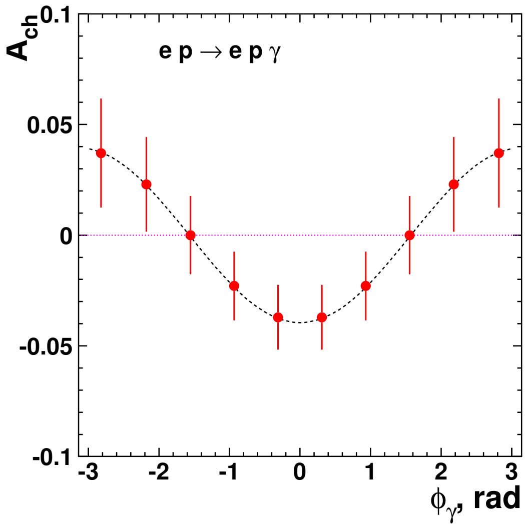
Summary

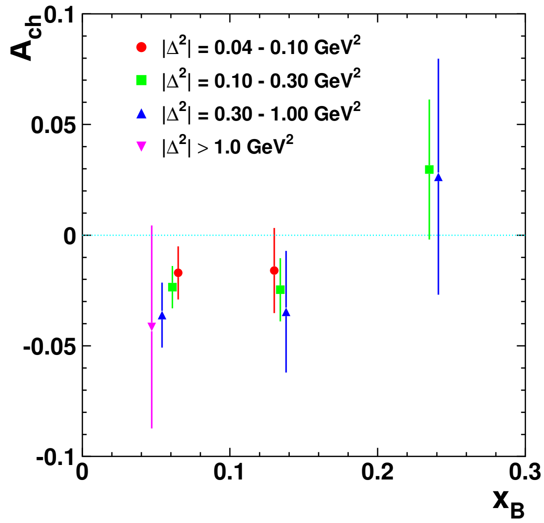
- First measurement of a DVCS SSA performed at HERMES
- DVCS can be accessed through DVCS-BH interference
- data on tape:
  - DVCS SSA asymmetry from 2000 data (high statistics)
  - DVCS charge asymmetry from 1998 data (low statistics)
- HERMES Run II
  - transversely (and longitudinally) polarized targets (low density)
  - electron and positron beams
  - high-density unpolarized targets ($\leq 4 \times 10^{33}$ N/cm^2/s
- Recoil Detector planned to ensure exclusivity of events

HERMES Measurements with a Recoil Detector, Projections[1]

A) Measure lepton charge asymmetry in DVCS:

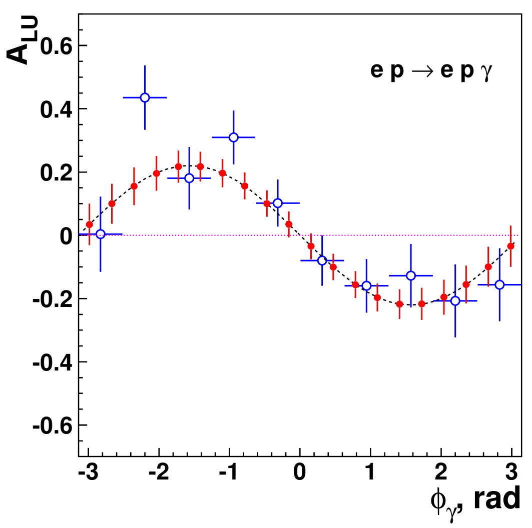
unpolarized beam, unpolarized target

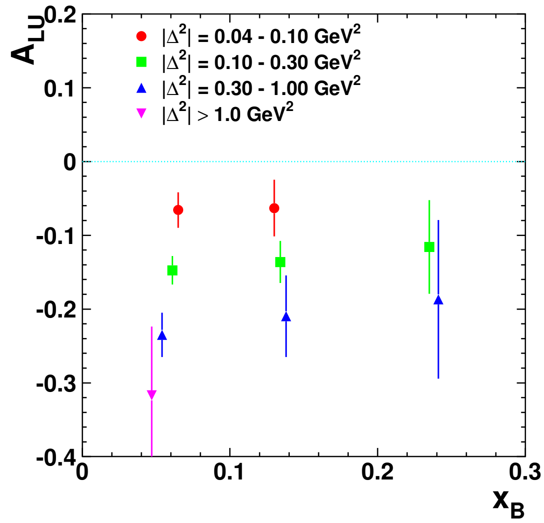




B) Measure lepton helicity asymmetry in DVCS:

polarized beam, unpolarized target

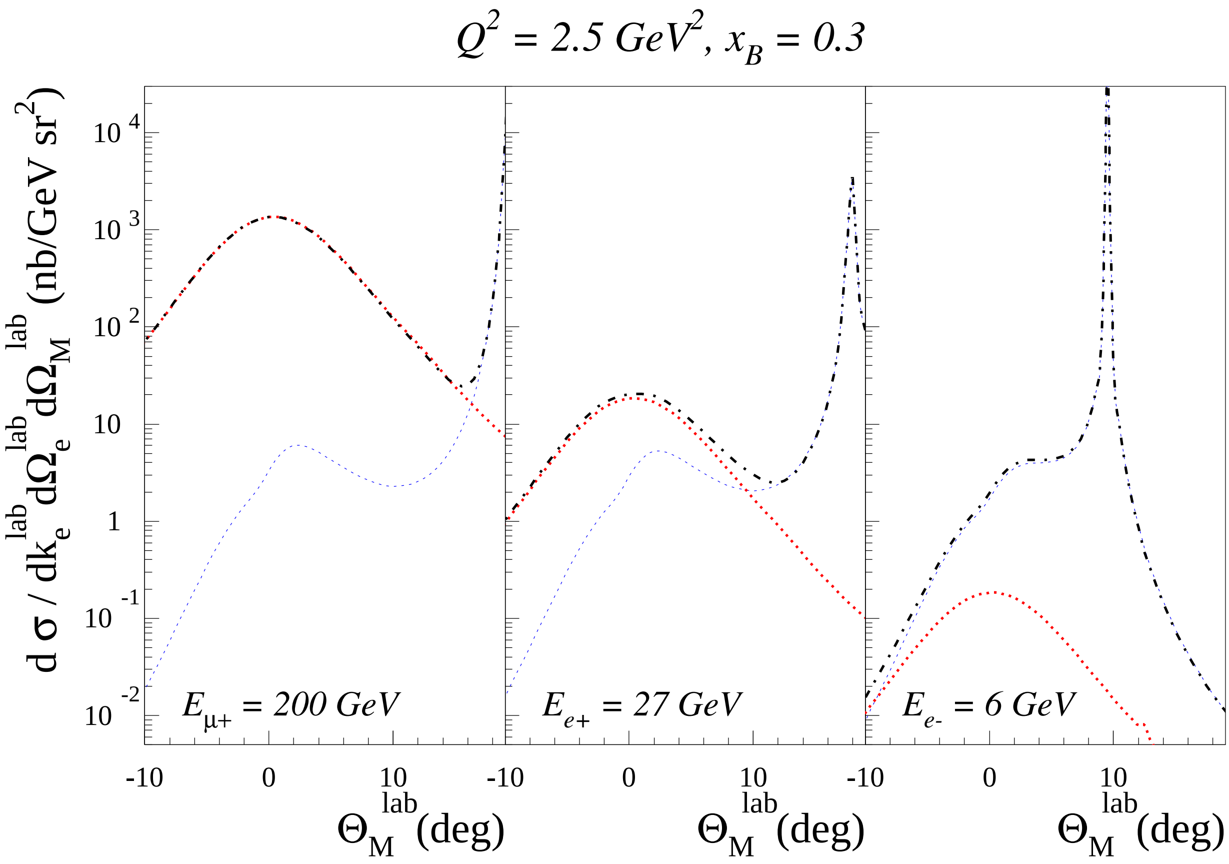




Open circles in left panel: HERMES PRELIMINARY (1996/97 data)

[1] [V. Korotkov, W.-D. Nowak, hep-ph/0108077]

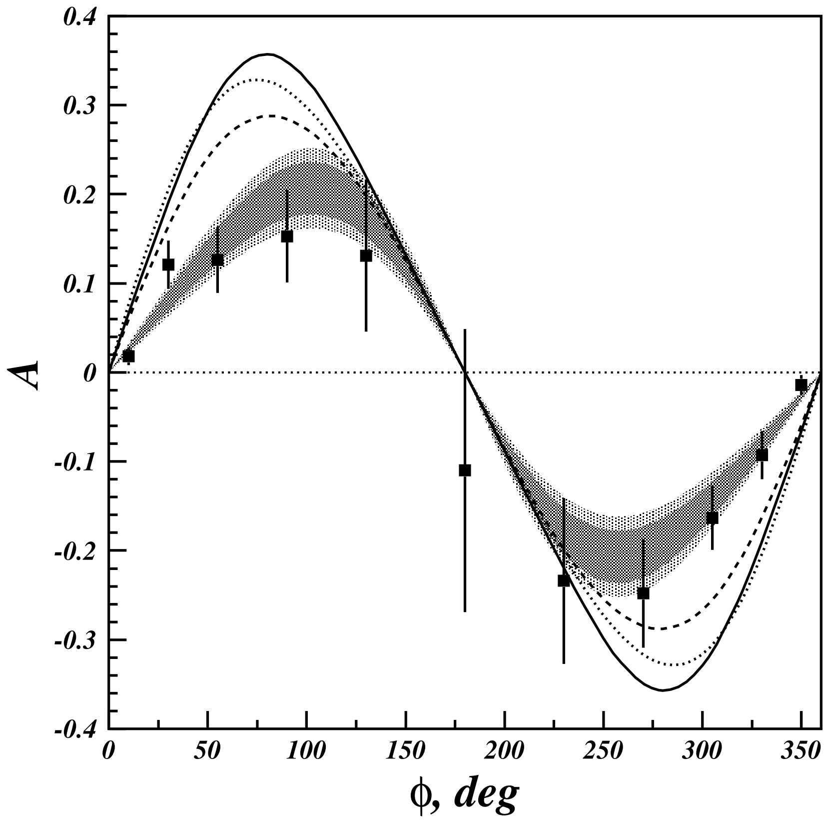
DVCS - Comparison to other Labs



COMPASS HERMES JLab

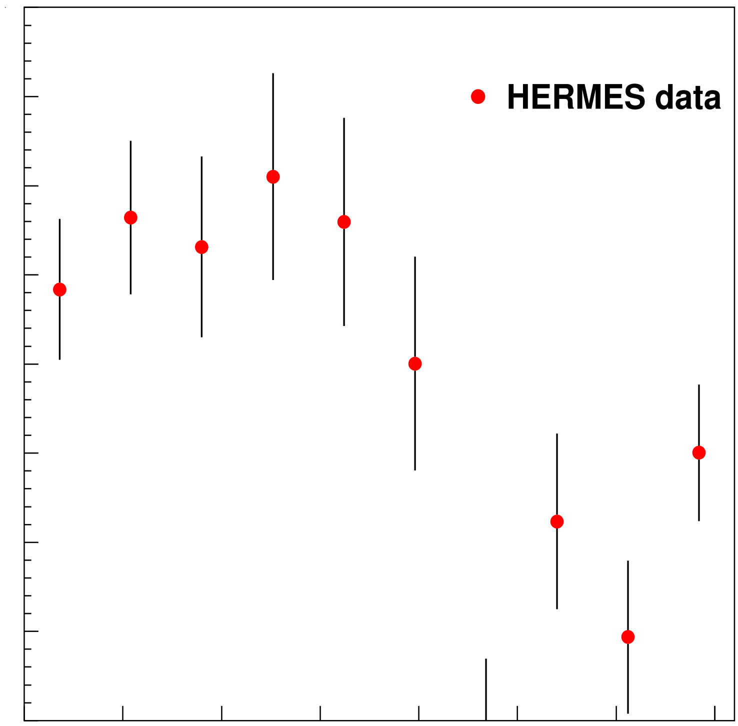
- GPD (LO) calculation by Vanderhaeghen, Guichon, and Guidal (Phys. Rev. **D60** (1999) 094017)
- DVCS and BH have similar magnitudes at HERMES

JLab Observation (hep-ex/0107043)



- ◦ Exclusive measurements from polarized electrons
- ◦ Shaded band indicates best fit, lines are theoretical predictions

$$
\begin{aligned}
\langle Q^2 \rangle &= 1.3\ \mathrm{GeV}^2 \\
\langle W^2 \rangle &= 6.2\ \mathrm{GeV}^2 \\
\langle x_B \rangle &= 0.19 \\
\langle -t \rangle &= 0.19\ \mathrm{GeV}^2
\end{aligned}
$$



$$\langle Q^2 \rangle = 2.6 \text{ GeV}^2$$
$$\langle W^2 \rangle = 22 \text{ GeV}^2$$
$$\langle x_B \rangle = 0.11$$
$$\langle -t \rangle = 0.27 \text{ GeV}^2$$

Experimental Outlook For DVCS

HERMES:

- Results reported for 96/97 data, more statistics soon
- HERMES working on extracting charge asymmetry from 98 electron data set
- Recoil Detector planned to ensure exclusivity of events

Other:

- JLab proposes to measure GPD's as part of 12 GeV upgrade
- COMPASS is looking into exclusive measurements
- Exclusive physics are important part of proposals for ELFE, TESLA-N, and EIC.