Beam Charge Asymmetry associated with DVCS at HERMES

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for the HERMES-Collaboration

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- HERMES
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THE SPIN STRUCTURE OF THE NUCLEON

longitudinally polarized nucleon

$$\frac{1}{2} = \underbrace{\frac{1}{2}\Delta\Sigma + L_q}_{J_q} + \underbrace{\Delta G + L_g}_{J_g}$$

STATUS:

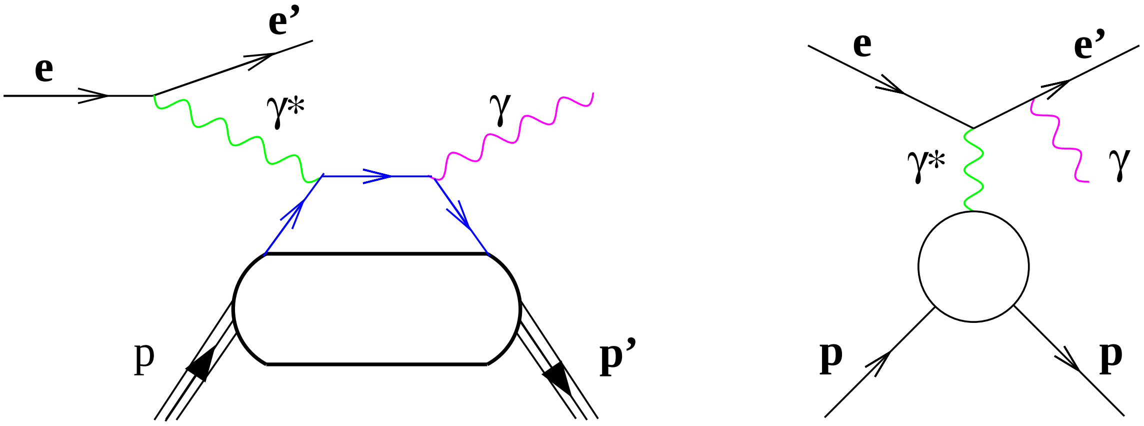
- VALENCE- AND SEAQUARK CONTRIBUTION ($\Delta\Sigma$) APPROXIMATELY 30 %
- GLUON CONTRIBUTION (ΔG) POSITIVE ($\rightarrow$ HERMES)

X.JI, 1997: THE SECOND MOMENT OF THE UNPOLARIZED GPD'S IS RELATED TO J_q.

$$J_q = \frac{1}{2}\int_{-1}^{1} dx x[H^q(x,\xi,\Delta^2=0) + E^q(x,\xi,\Delta^2=0)]$$

DVCS

DVCS-final-state $e + p \rightarrow e' + p' + \gamma$ is indistinguishable from the Bethe-Heitler Process



$\rightarrow$ Amplitudes add up coherently

Bethe-Heitler Process calculable in QED with the knowledge of the Proton Form Factors

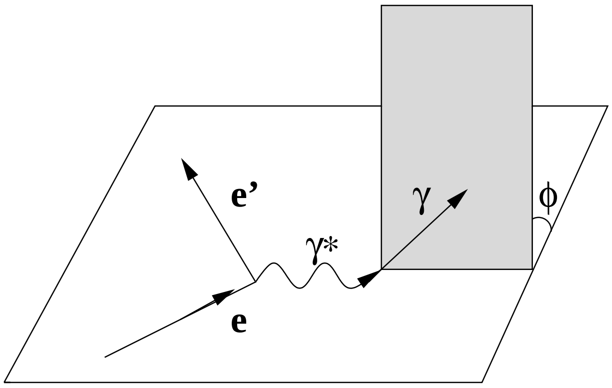
Photon-Production cross section:

$$d\sigma \propto |\tau_{\mathrm{DVCS}} + \tau_{\mathrm{BH}}|^2$$
$$= |\tau_{\mathrm{DVCS}}|^2 + |\tau_{\mathrm{BH}}|^2 + (\tau^*_{\mathrm{DVCS}}\tau_{\mathrm{BH}} + \tau^*_{\mathrm{BH}}\tau_{\mathrm{DVCS}})$$

Real and Imaginary parts of the DVCS-Amplitudes can be expressed in terms of the GPDs H, H̃, E, Ẽ.

Charge and Helicity Asymmetry

$$I \propto \pm(c_0^I + \sum_n [c_n^I \cos(n\phi) + \lambda s_n^I \sin(n\phi)])$$



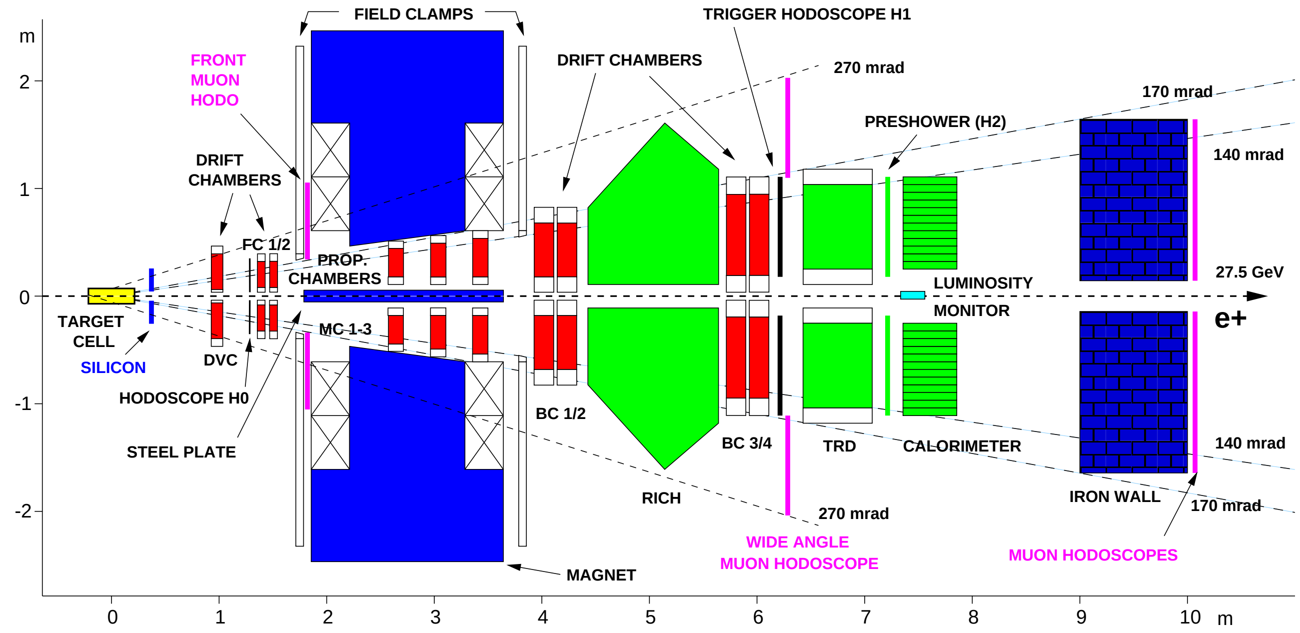
Imaginary Part of the Interference-Term can be accessed via Beam Helicity Asymmetry using polarized beam and unpolarized target::

$$\frac{d\sigma(\overrightarrow{e^+}p) - d\sigma(\overleftarrow{e^+}p)}{d\sigma(\overrightarrow{e^+}p) + d\sigma(\overleftarrow{e^+}p)} \sim \sin(\phi_\gamma) \times \mathrm{Im}\,(\tau_{\mathrm{DVCS}}\tau_{\mathrm{BH}})$$

Real Part of the Interference-Term can be accessed via Lepton Charge Asymmetry using unpolarized beam and target:

$$\frac{d\sigma(e^+p) - d\sigma(e^-p)}{d\sigma(e^+p) + d\sigma(e^-p)} \sim \cos(\phi_\gamma) \times \mathrm{Re}\,(\tau_{\mathrm{DVCS}}\tau_{\mathrm{BH}})$$

The HERMES-Spectrometer



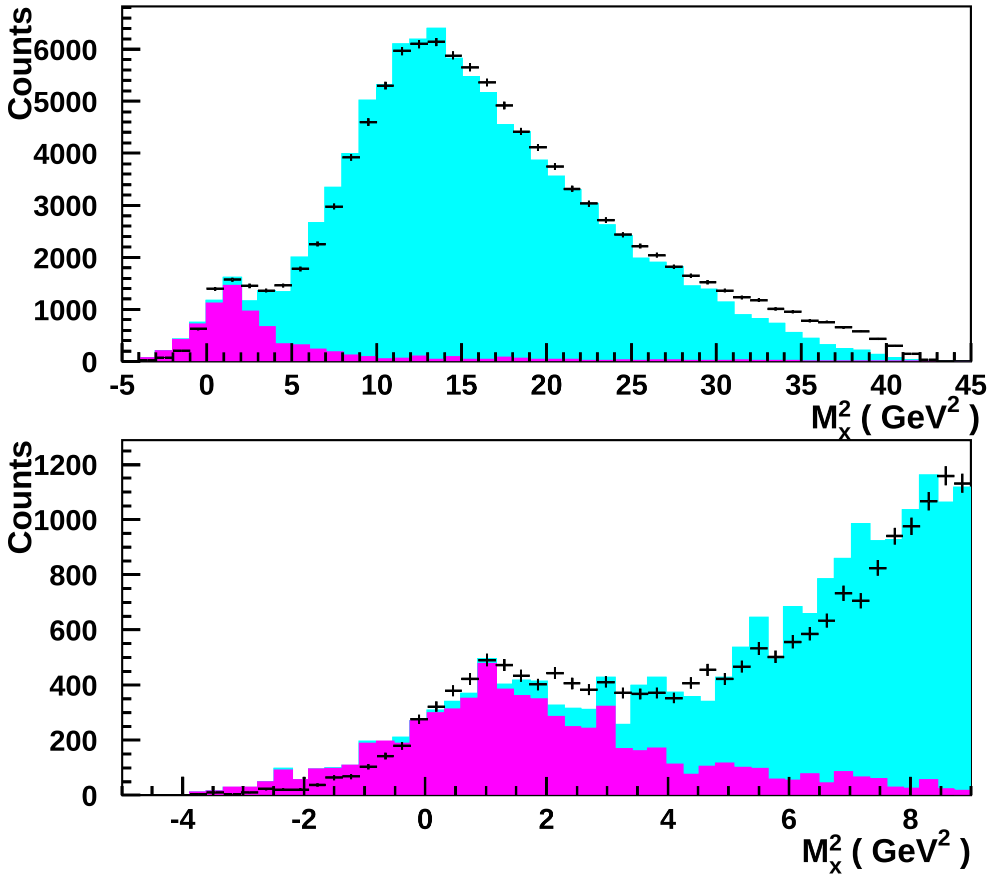
- Electron/Positron Identification via TRD, Preshower, Calorimeter $\Rightarrow$ Hadron contamination of the Lepton-Sample $\leq 1\%$

- momentum reconstruction via tracking chambers $\Rightarrow$ resolution $\approx 1.5\%$

- Identify Photon via Preshower and track-less cluster in Calorimeter

- energy reconstruction via Calorimeter $\Rightarrow$ about 5% for DVCS-Photons

Exclusive Reaction?



Exclusive Reaction:

$$M_x^2 = (q + p - p_\gamma)^2 = M_p^2$$

Missing Mass (M_x) resolution $\approx$ 0.9 GeV ($\rightarrow$ Calorimeter)

$\Rightarrow$ no separation between exclusive and associated DVCS

$\Rightarrow$ "Exclusive" bin (-1.5 $< M_x <$ 1.7 GeV)

BCA-Data

- Hydrogen 2000 (e^+) and Hydrogen 1998 (e^-)
- After Standard Data-Quality and DIS Cuts
  - * $Q^2 > 1$ GeV^2
  - * $W^2 > 4$ GeV^2
  - * $\nu < 23$ GeV
  - * ...

  $\Rightarrow$ 530k/40k events with DIS-positron/DIS-electron and one trackless cluster in the calorimeter (2000/1998)

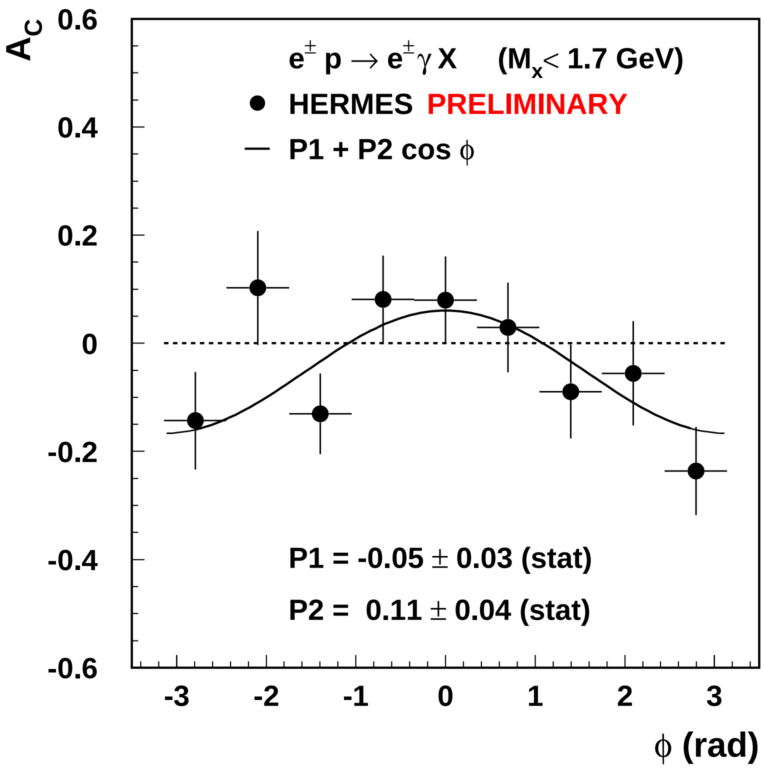
- Photon Selection:
  - * $15 < \theta_{\gamma^*\gamma} < 70$ mrad
  - * Signal in Preshower
  - * ...

  $\Rightarrow$ Few thousand/hundred events in the "exclusive" bin.

Beam Charge Asymmetry

$$I \propto \pm(c_0^I + \sum_n [c_n^I \cos(n\phi) + \lambda s_n^I \sin(n\phi)])$$

$\Rightarrow$ Use "Helicity cancelled" sample to get rid of $\sin(\phi)$–dependence in the numerator.



Beam Charge Asymmetry $A_C(\phi)$:

$$A_C(\phi) = \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

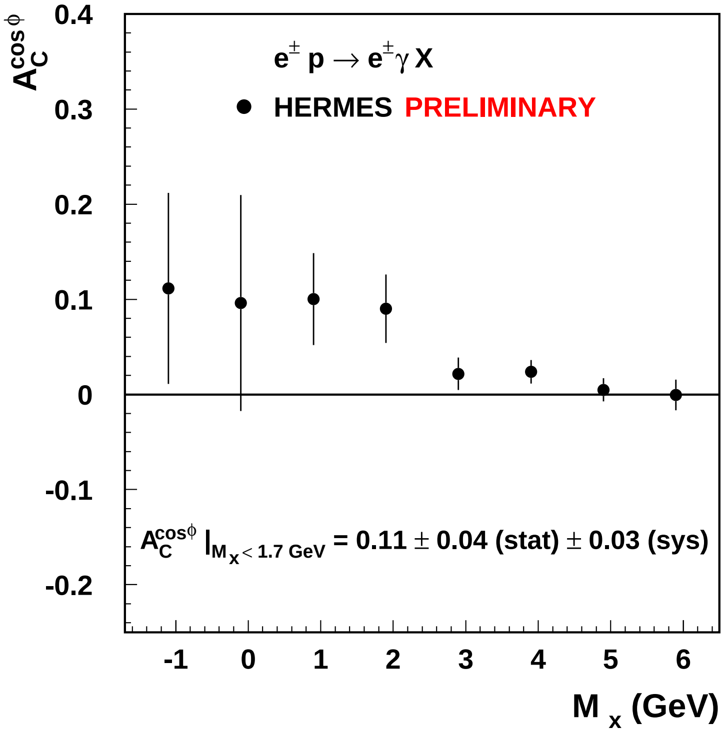
In the "exclusive" bin A_C exhibits the expected $\cos(\phi)$–dependence.

$\cos(\phi)$–Moment

No $\cos(\phi)$–dependence in higher missing mass bins $\Rightarrow$ $\cos(\phi)$–Moment

$$A_{\mathrm{C}}^{\cos\phi} = \frac{\int_0^{2\pi} d\phi \cos\phi \, \frac{d\sigma^+}{d\phi}}{\int_0^{2\pi} d\phi \, \frac{d\sigma^+}{d\phi}} - \frac{\int_0^{2\pi} d\phi \cos\phi \, \frac{d\sigma^-}{d\phi}}{\int_0^{2\pi} d\phi \, \frac{d\sigma^-}{d\phi}}$$

(small contribution from BH in the numerator)



$< Q^2 >= 2.8\ \mathrm{GeV}^2$

$< x >= 0.12$

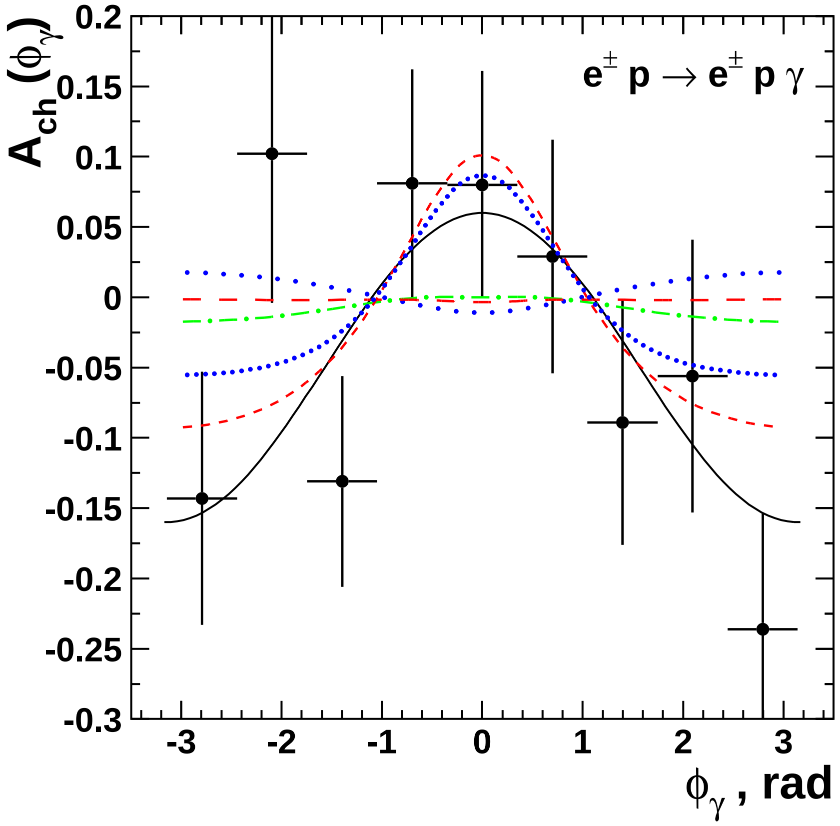
$< -t >= 0.27\ \mathrm{GeV}^2$

$$\Leftrightarrow A_{\mathrm{C}}^{\cos\phi} = 2 \cdot \frac{\int_0^{2\pi} d\phi \cos\phi \, \frac{d\sigma^+}{d\phi} - \int_0^{2\pi} d\phi \cos\phi \, \frac{d\sigma^-}{d\phi}}{\int_0^{2\pi} d\phi \, \frac{d\sigma^+}{d\phi} + \int_0^{2\pi} d\phi \, \frac{d\sigma^-}{d\phi}}$$

The "D-Term"

t-independent part can be parametrized by:

$$H^q(x,\xi) = H^q_{DD}(x,\xi) + \text{D-Term}$$
$$E^q(x,\xi) = E^q_{DD}(x,\xi) - \text{D-Term}$$



GPD-model calculation without the "D-Term" lead to negative or at most basically zero asymmetry

⇒ Data seem to favour parametrization with additional D-Term.

Summary

- Real and Imaginary Part of the DVCS-Amplitudes can be accessed through DVCS-BH interference

- Measurement of the Helicity Asymmetry at HERMES ($\rightarrow$ Phys. Rev. Lett. **87**, 182001 (2001)) confirmed with 2000 data, first preliminary result on kinematical dependencies

- First Measurement of the Beam Charge Asymmetry, preliminary value in the "exclusive" bin: $0.11 \pm 0.04(\mathrm{stat}) \pm 0.03(\mathrm{sys})$

- First experimental hint towards the existence of the D-Term.

Outlook

- short term:
  - Target Spin Asymmetry on Hydrogen
  - Beam Spin, Beam Charge, and Target Spin Asymmetries on Deuterium
  - Kinematical dependencies of the Beam Charge Asymmetry
  - Reproduction of Data-Sets:
    $\Rightarrow$ gain 70–90% events
  + Beam Charge Asymmetry on Hydrogen
  + Helicity Asymmetry and kinematical dependencies on Hydrogen

- long term upgrade:
  - Large-Acceptance Recoil Detector planned for HERMES to ensure the exclusivity of measured events