Single Spin Asymmetries in Exclusive Electroproduction at HERMES

Björn Seitz

Center for Subatomic Research, Dept. of Physics,
University of Alberta, Edmonton, Canada

on behalf of
the HERMES Collaboration

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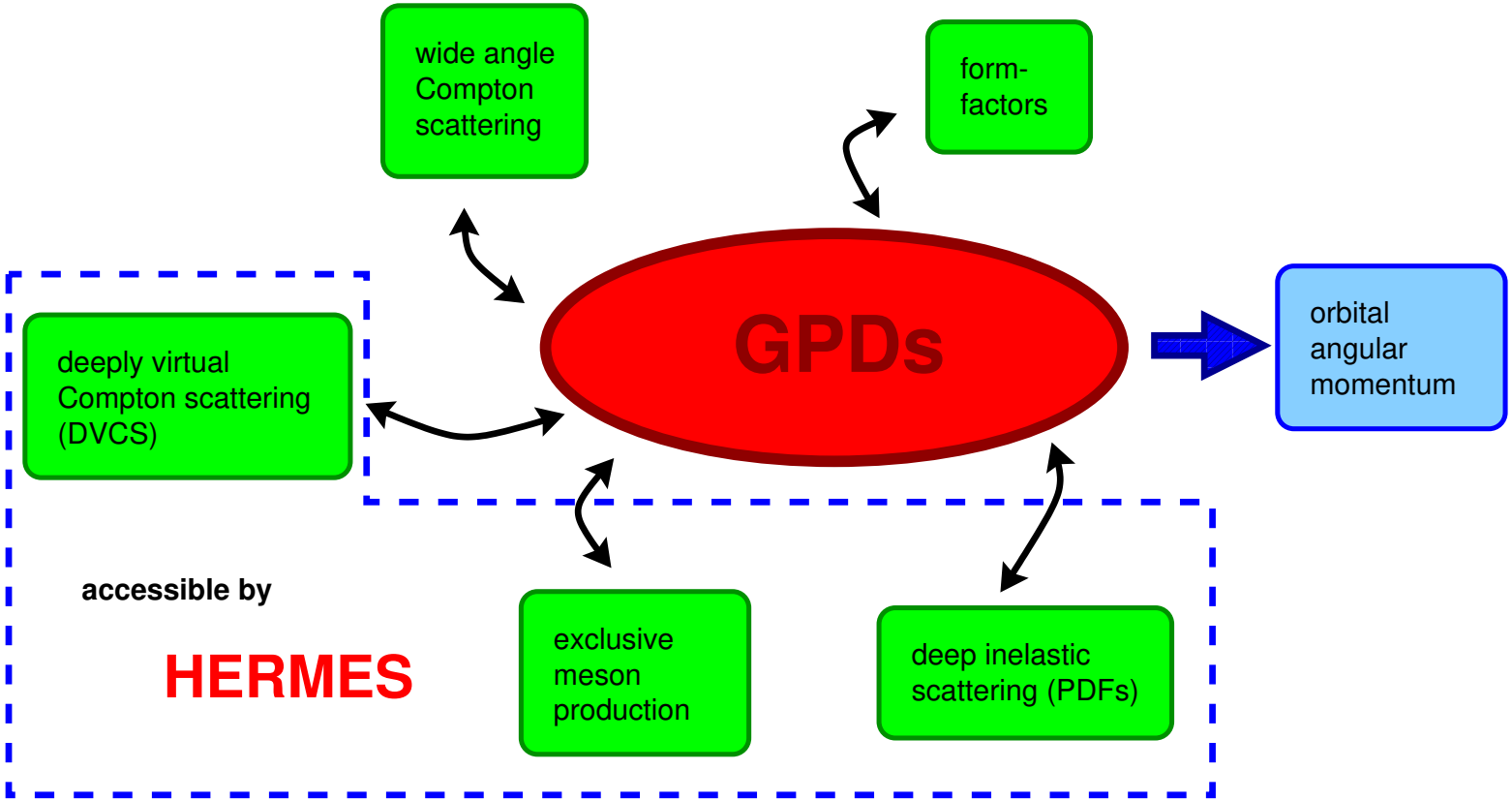
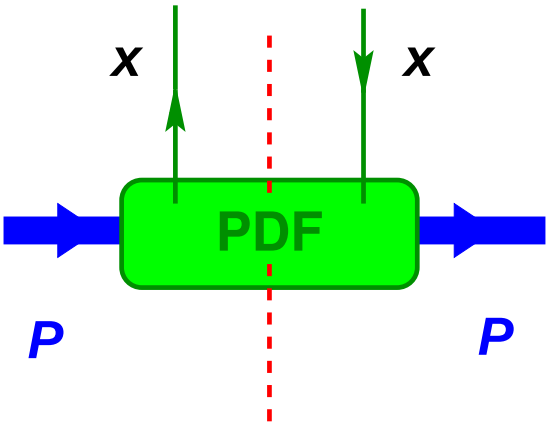
- Motivation
- Experiment and Kinematics
- SSA in DVCS
- SSA in excl. π^+ production
- Conclusion and Outlook

Why measure GPDs . . . ?

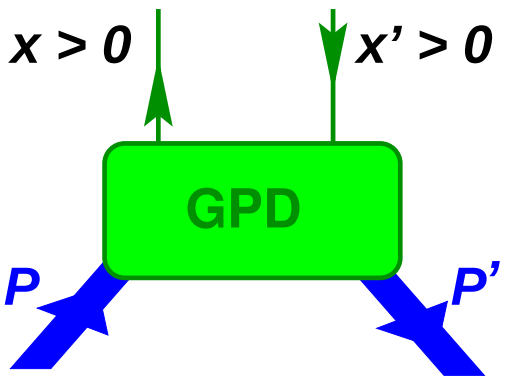


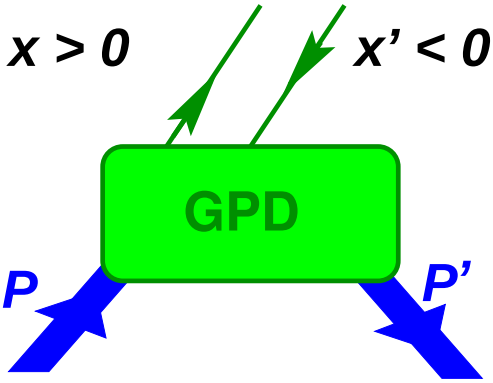
Unified approach to a plenty of processes !

A little more on GPDs



- Prob. to find parton with momentum fraction **x**
- occurs in DIS ($\sigma \propto Im\mathcal{A}$)





- interference of different configurations

$\rightarrow$ take parton with **x** and reinsert with **x**$'$

$\rightarrow$ take parton with **x** and antiparton with **x**$'$

- occurs in e.g. CS amplitude (full $\mathcal{A}$)
- four functions: $\tilde{E}, \tilde{H}, E, H$

Why measure Single Spin Asymmetries ?

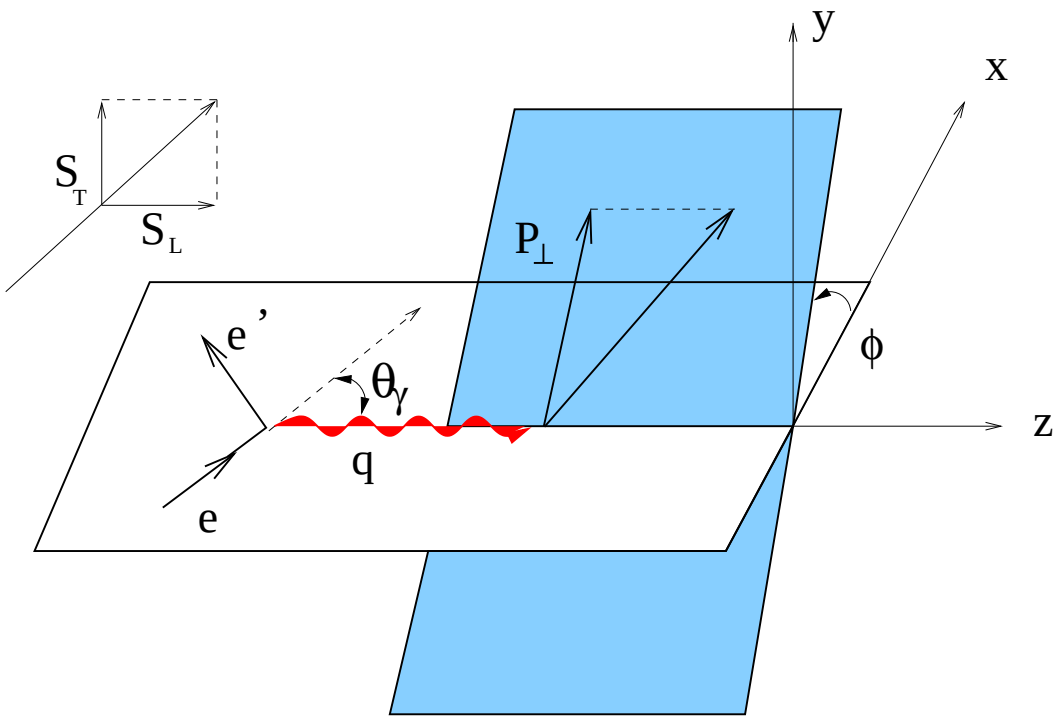
- DVCS: $\rightarrow$ pol. and unpol. GPD $\tilde{E}, \tilde{H}, E, H$
- Vector Mesons: $\rightarrow$ unpol. GPD E, H
- Pseudoscalar Mesons: $\rightarrow$ pol. GPD $\tilde{E}, \tilde{H}$

Only quadratic combinations appear in unpolarized cross sections

$\Rightarrow$ Exploit interference of Bethe–Heitler and DVCS $\rightarrow$ SSA using polarized beam and unpolarized target

$\Rightarrow$ Exploit polarization observables $\rightarrow$ SSA in π^+ using unpolarized beam and polarized target

Kinematics



Detected: e' and π^+ or e' and γ

$$-q^2 \overset{\text{lab}}{=} 4EE'\sin^2(\theta/2) = Q^2$$

$$x_B = \frac{Q^2}{2Pq}$$

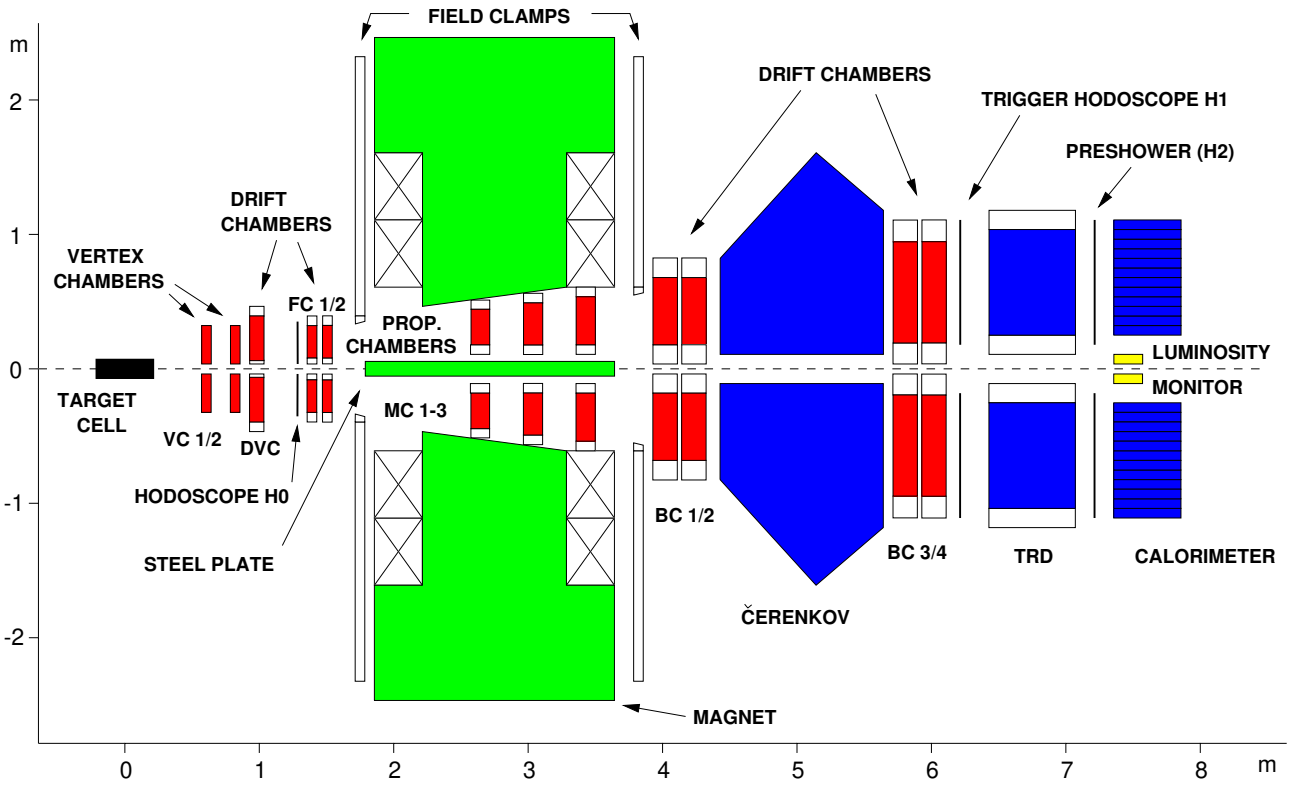
ϕ = Azimuthal angle of reaction product with q

$$M_x^2 = (P+q-p)^2$$

$$t = (q-p)^2 = (P-N)^2$$

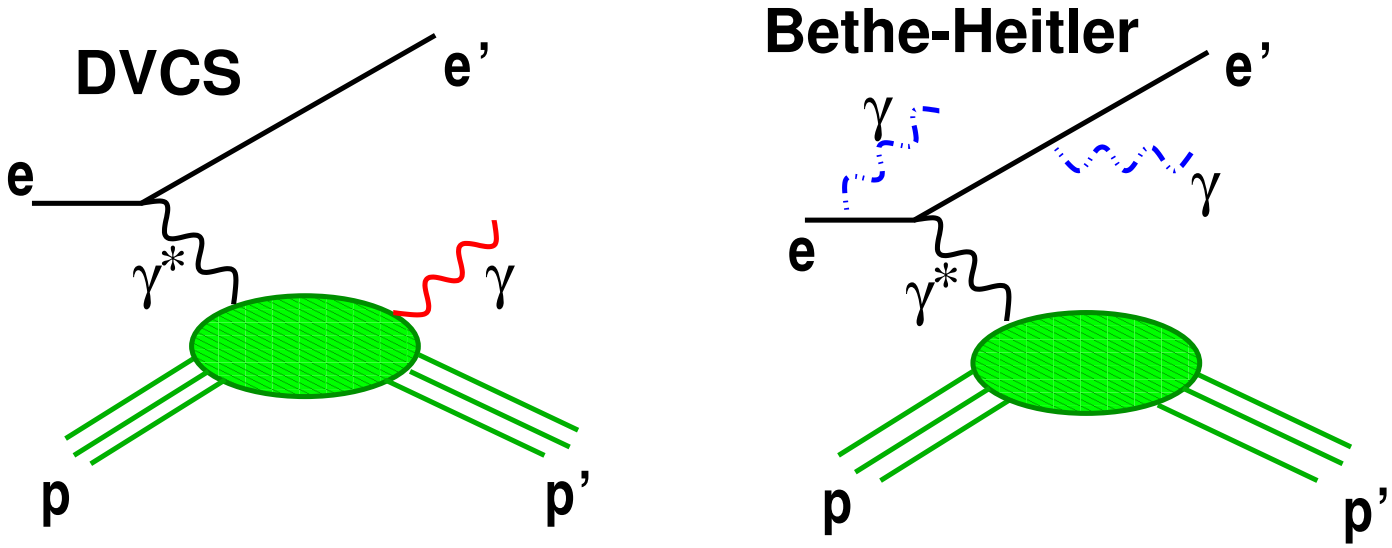
S_T, S_L = target spin projections

The HERMES Detector



- Beam: 27.6 GeV, e^+ or e^-, $\langle P_B \rangle \approx 0.55$
- Target: long. pol. H, $\langle P_T \rangle \approx 0.88$, unpol H_2
- kinematical coverage: $0.02 \leq x_B \leq 0.8$ for $Q^2 > 1$ GeV^2 and $W^2 > 4$ GeV^2
- tracking: 57 tracking planes, $\delta P/P < 1.3\%$
- PID: Calorimeter, Čerenkov, TRD; $\epsilon_e \approx 0.99$

BH - DVCS interference



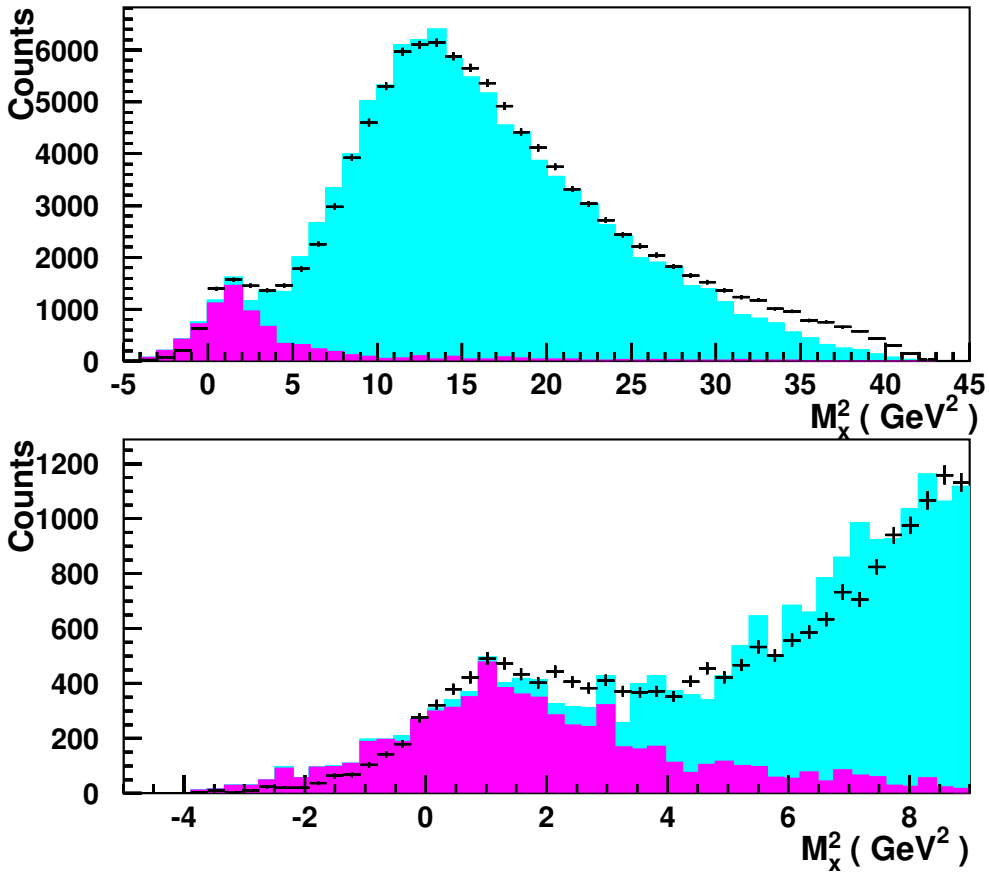
$$\frac{d^4\sigma}{d\phi dt dQ^2 dx_B} = \frac{x_B y^2}{32(2\pi)^4 Q^4} \frac{\left|\tau_{BH} + \tau_{DVCS}\right|^2}{\sqrt{1+4x_B^2 M^2/Q^2}}$$

$$\left(\tau^*_{BH}\tau_{DVCS} + \tau^*_{DVCS}\tau_{BH}\right) = \frac{4\sqrt{2}Me^6}{tQx_B}\frac{1}{\sqrt{1-x_B}} \times \quad eP_B \quad \left[-\sin\phi\sqrt{\frac{1+\epsilon}{\epsilon}} Im\tilde{M}^{1,1}\right]$$

$$Im\tilde{M}^{1,1} \propto GPDs$$

Exploit $\sin\phi$ moment with polarized beam
$\Rightarrow$ direct access to **Imaginary part** of amplitude

Exclusivity in DVCS

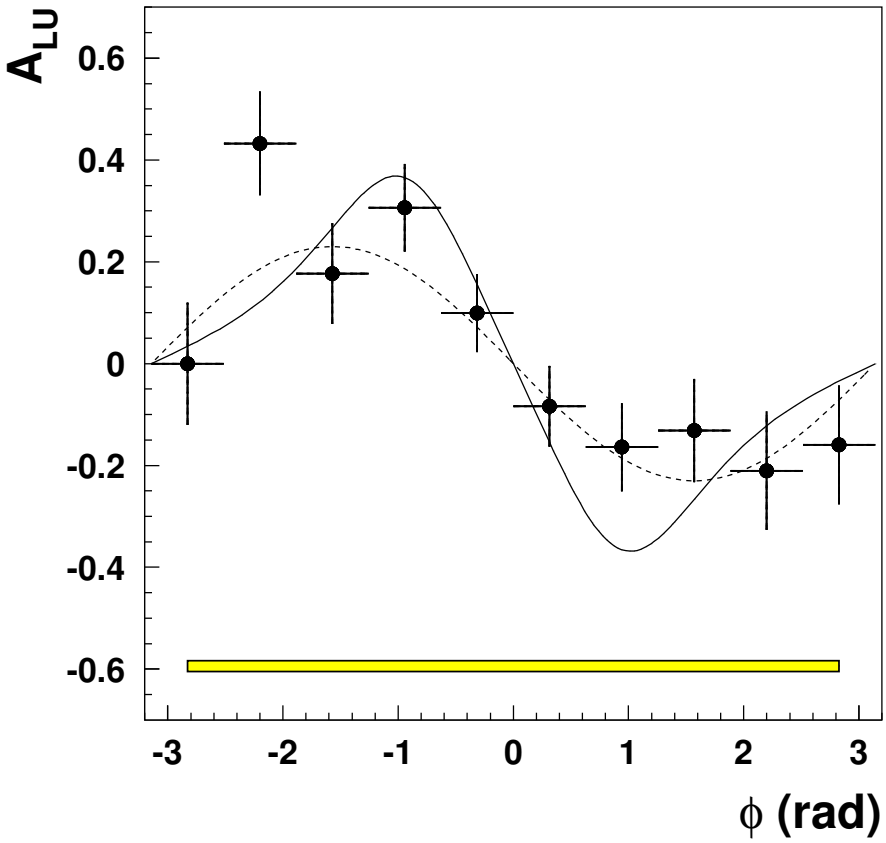


$$M_x^2 = (q + P_p - p)^2$$

$M_x^2 = -\sqrt{-M_x^2}$ due to finite resolution in q and p

Monte Carlo simulation of photons from fragmentation and Bethe–Heitler processes compared with data (+)

Single Spin Asymmetry in DVCS



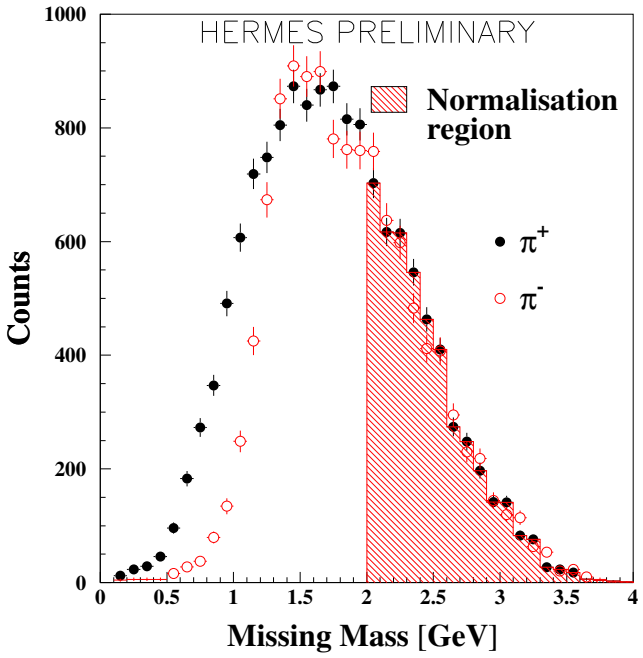
$$A_{LU}(\phi) = \frac{1}{\langle |P_B| \rangle} \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)} = 0.23 \pm 0.04$$

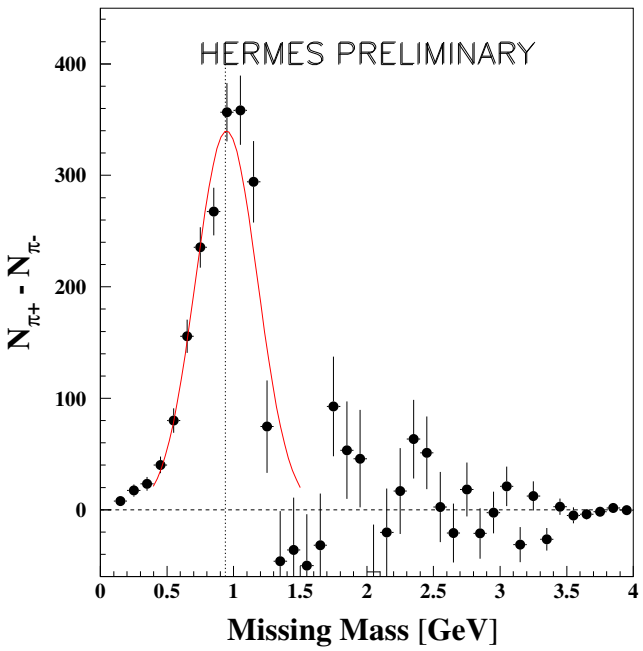
$\langle Q^2 \rangle = 2.6$ GeV^2 $\quad \langle x_B \rangle = 0.11$ $\quad \langle -t \rangle = 0.27$ GeV^2

— GPD calculations: N. Kivel et al.
(Phys. Rev. **D 63** (2001) 114014)

- - $\sin\phi$ fit to HERMES data (•) (hep-ex/0106086)

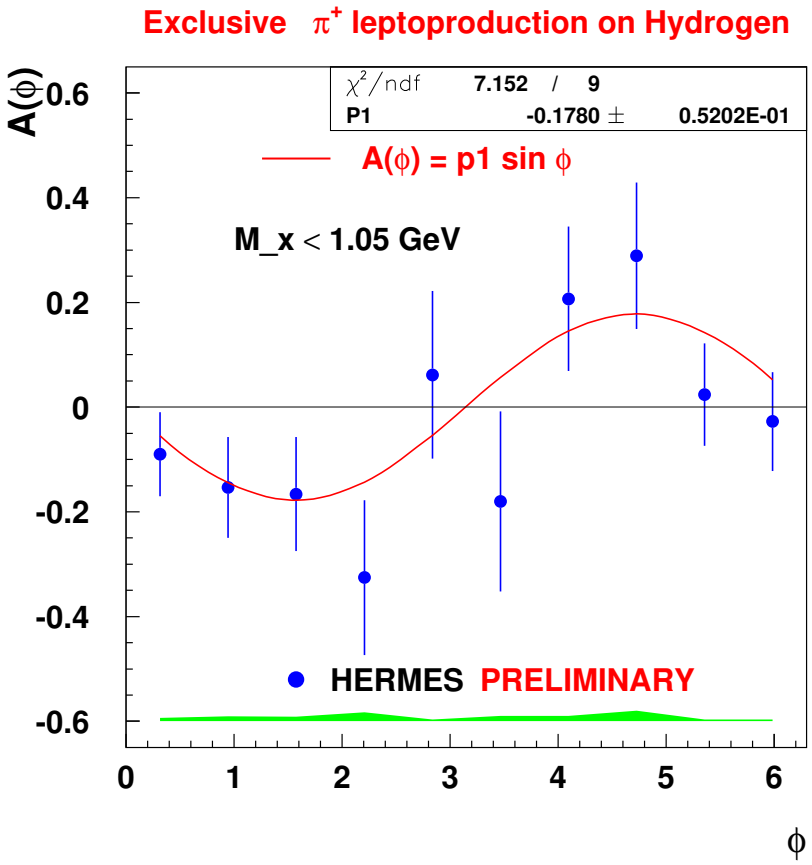
Exclusivity for π^+





- Normalize π^- to π^+ for $M_x > 2$ GeV
- Clear M_x peak around nucleon mass
- Small debt at $M_x \approx 1.3 - 1.6$ due to different σ $e + p \to e + \Delta^\circ + \pi^+$ and $e + p \to e + \Delta^{++} + \pi^-$
- SSA for Semi–Inclusive Region $\approx 2.8 \pm 1.4\%$ incl. into systematic error

SSA in excl. π^+

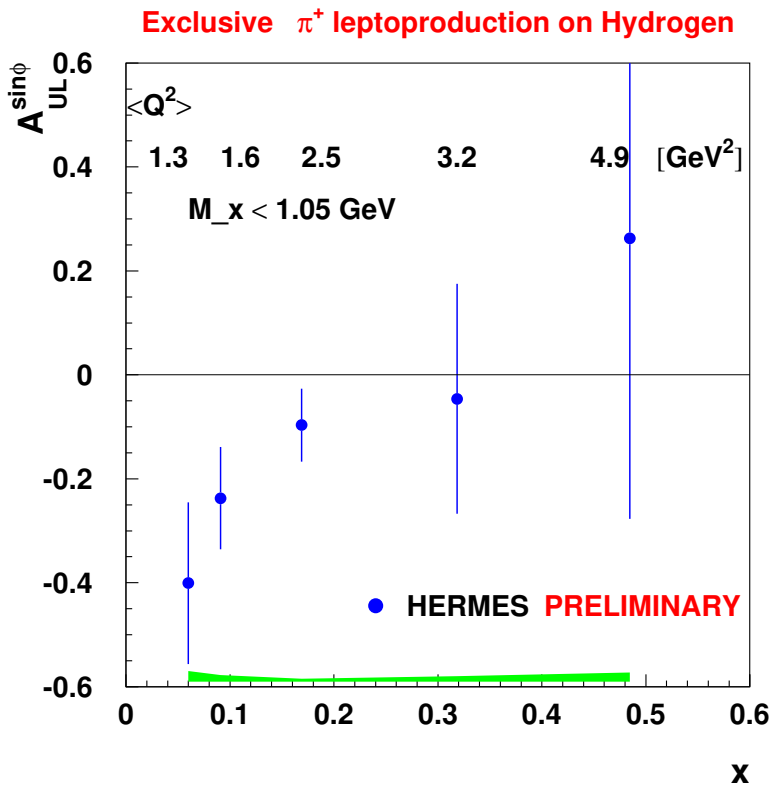


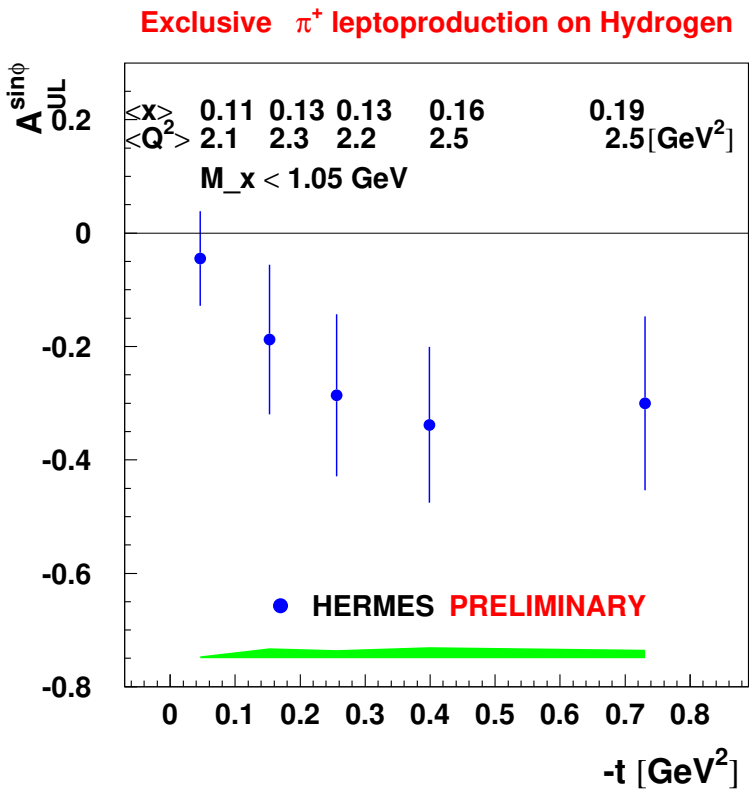
$$A_{UL}(\phi) = \frac{1}{\langle |P_T| \rangle} \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)} = -0.18 \pm 0.05$$

$$\langle Q^2 \rangle = 2.2 \text{ GeV}^2 \qquad \langle x_B \rangle = 0.15 \qquad \langle -t \rangle = 0.46 \text{ GeV}^2$$

No predictions available !

Dependence on Q^2 and t





in agreement with QCD counting rules and pion pole expectations

One setup to address many open questions:

- DVCS: SSA with polarized beam and unpolarized target has been measured $\rightarrow$ glimpse on GPDs
- excl. π^+: SSA with long. pol. target and unpolarized beam has been measured, kinematical dependence as expected from general GPD foundations, sizeable twist–3 contribution needed to explain data
- In addition: HERMES vector meson data sensitive to GPD calculations

The HERMES road to GPDs:

- from data on tape: $\gamma, \pi^{\pm}, \pi^{\circ}, \eta, K, \ldots$ on proton and deuteron (SSA (UL/LU), $d\sigma/dt$, DVCS charge asymmetry)
- HERMES Run II: will start with a transversely polarized target and give direct access to many GPD predictions
- In Future: HERMES plans to install a recoil detector to ensure the exclusivity of the events