HERMES Run II

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On Behalf Of The HERMES Collaboration

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The 2 main physics objectives for HERMES running in the years 2002-2006 are:

(1) Study of the transverse spin structure of the nucleon

(2) Measurement of asymmetries in exclusive reactions to access Generalized Parton Distributions

Physics Motivation

Transverse Spin Structure of the Nucleon

Last missing piece in the leading spin structure of the nucleon

• New information on the dynamics of quarks inside hadrons

• Study validity of untested QCD predictions:
1) Tensor charge >> axial charge
2) Transversity has weaker Q^2 evolution than helicity distribution

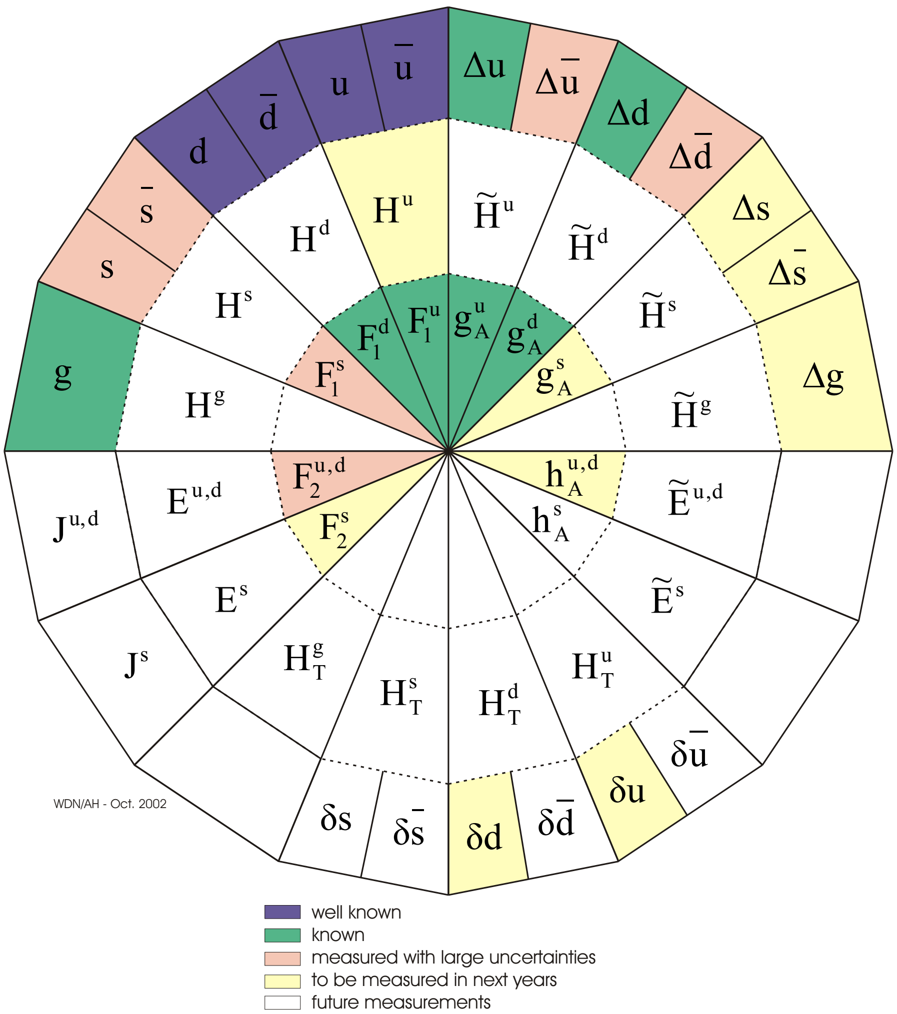
Access to Generalized Parton Distributions

Exclusive processes bear qualitatively new information on structure of the nucleon

• Dependence of GPDs on momentum transfer t allows conclusions on parton distribution(s) transverse to nucleon's direction of motion
$\Rightarrow$ 3-dimensional picture of the nucleon

• 2nd moment of 'unpolarized' GPDs H and E allows, in limit of vanishing t, determination of total angular momentum, carried by quarks

Exp. Status on Parton Distr.'s



(cf. W.-D. N., hep-ex/0210409)

Generalized Parton Distributions:

$H^q, \tilde{H}^q, E^q, \tilde{E}^q$	chirally-even quark GPDs
$H^q_T, \tilde{H}^q_T, E^q_T, \tilde{E}^q_T$	chirally-odd quark GPDs

Forward Parton Distributions:

$q(x, Q^2)$	quark number density distribution (f_1^q)
$\Delta q(x, Q^2)$	quark helicity distribution (g_1^q)
$\delta q(x, Q^2)$	quark transversity distribution (h_1^q)

How to Study the Nucleon's Transverse Spin Structure ?

- Transversity h_1^q: chirally-odd function
- Cross section is chirally-even

$\Rightarrow$ Access to h_1^q needs a chirally-odd 'partner':
  - a 2nd (chirally-odd) distribution function (in Drell-Yan) or
  - a chirally-odd fragmentation function, e.g. the 'Collins Function' $H_1^\perp$

- h_1^q, f_1^q, g_1^q don't depend on quark's $k_\perp$
- there exist several $k_\perp$-dependent distribution functions (vanishing in DIS when integrating over $k_\perp$), e.g. the 'Sivers function' $f_{1T}^\perp$

$\Longrightarrow$ need 'quark polarimetry'

$$\boxed{\text{Measure Single Spin Asymmetries in Semi-inclusive DIS } (\rightarrow \text{SIDIS})}$$

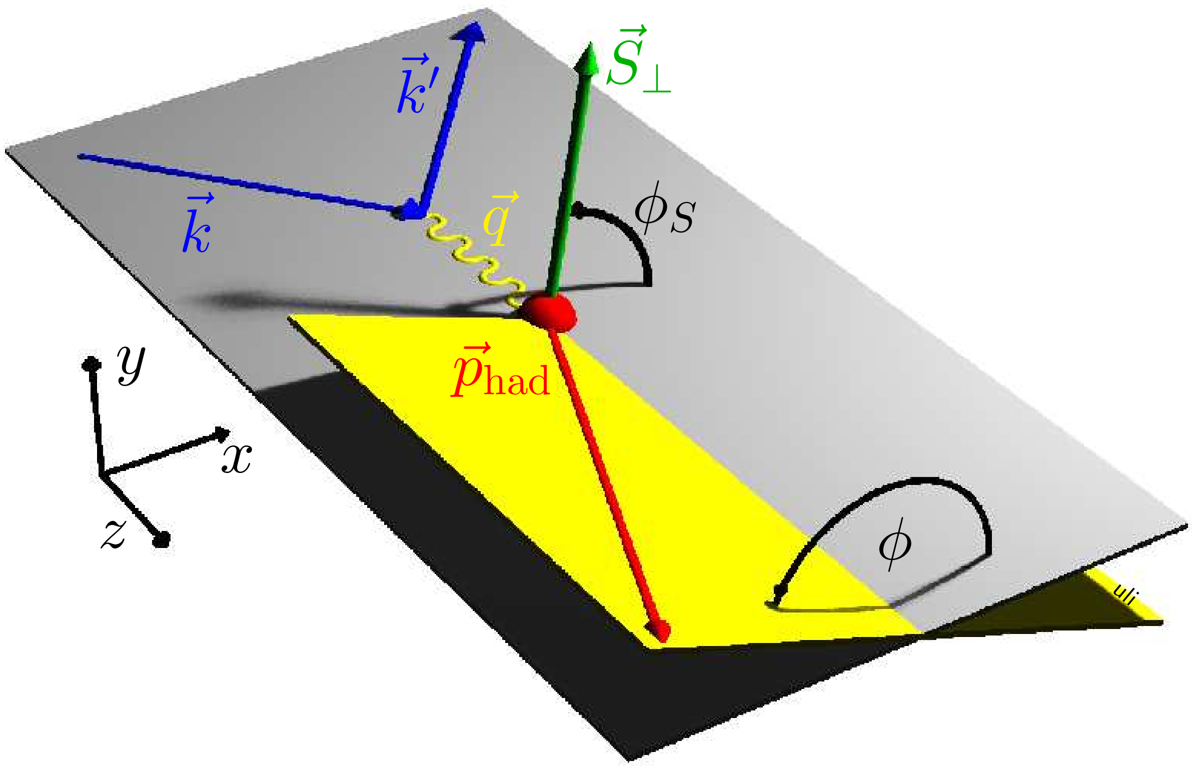
SSA on Transv. Pol. Target

Reaction: $ep^{\uparrow} \longrightarrow e'\pi X$

Study azimuthal distribution of π's:

$$A(\Phi) = \frac{1}{\langle P \rangle} \cdot \frac{N^{+}(\Phi) - N^{-}(\Phi)}{N^{+}(\Phi) + N^{-}(\Phi)}$$

Use unpolarized beam (U) and transversely polarized target (T)



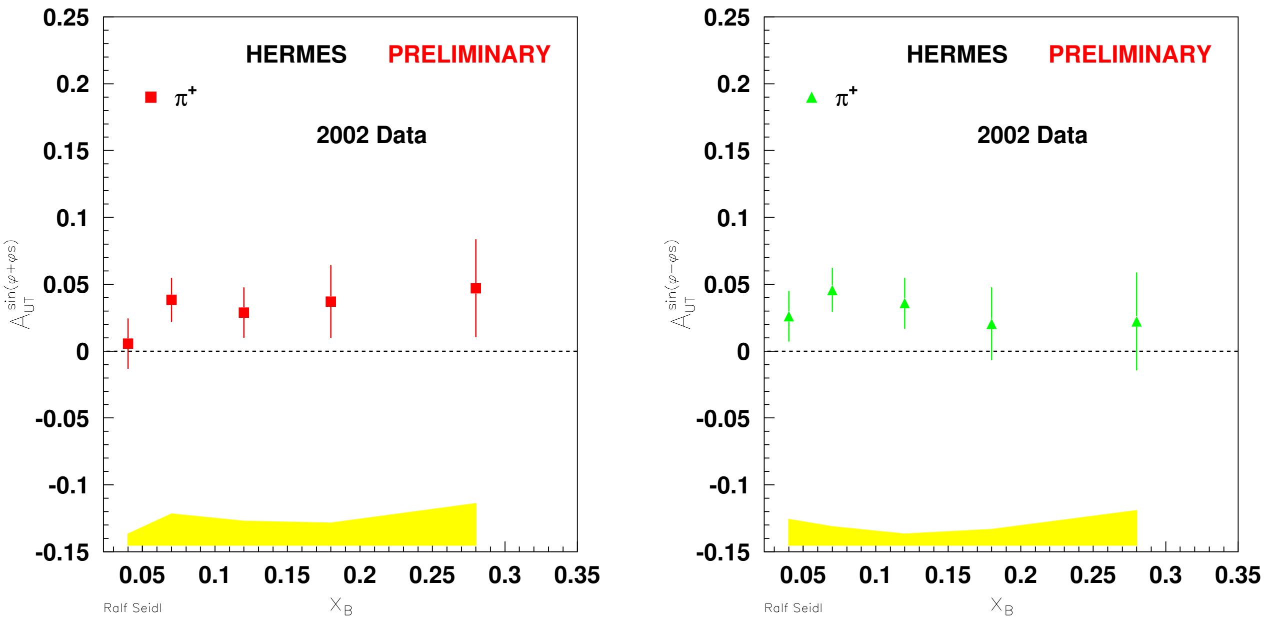
Collins: $A_{UT}^{\sin(\phi+\phi_S)} \sim \sum_q e_q^2 h_1^q(x) H_1^{\perp(1),q}(z)$

Sivers: $A_{UT}^{\sin(\phi-\phi_S)} \sim \sum_q e_q^2 f_{1T}^{\perp(1),q} D_1^q(z)$

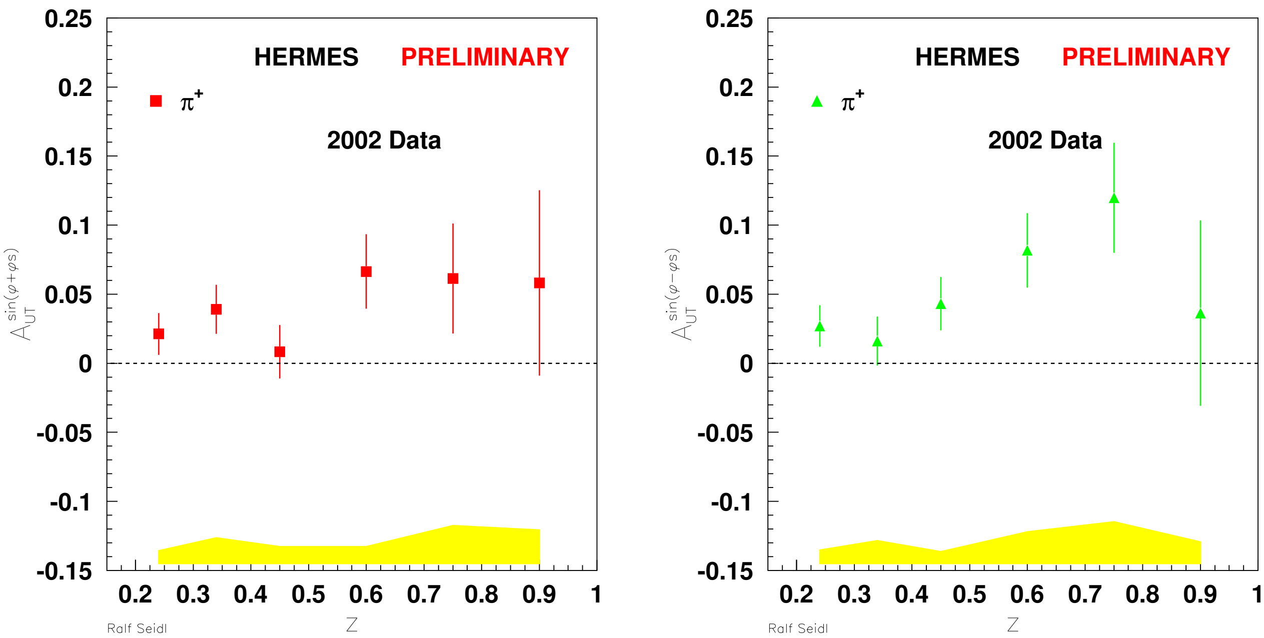
HERMES PRELIMINARY: π^+ SSA

LEFT: Collins SSA RIGHT: Sivers SSA

x-Dependence



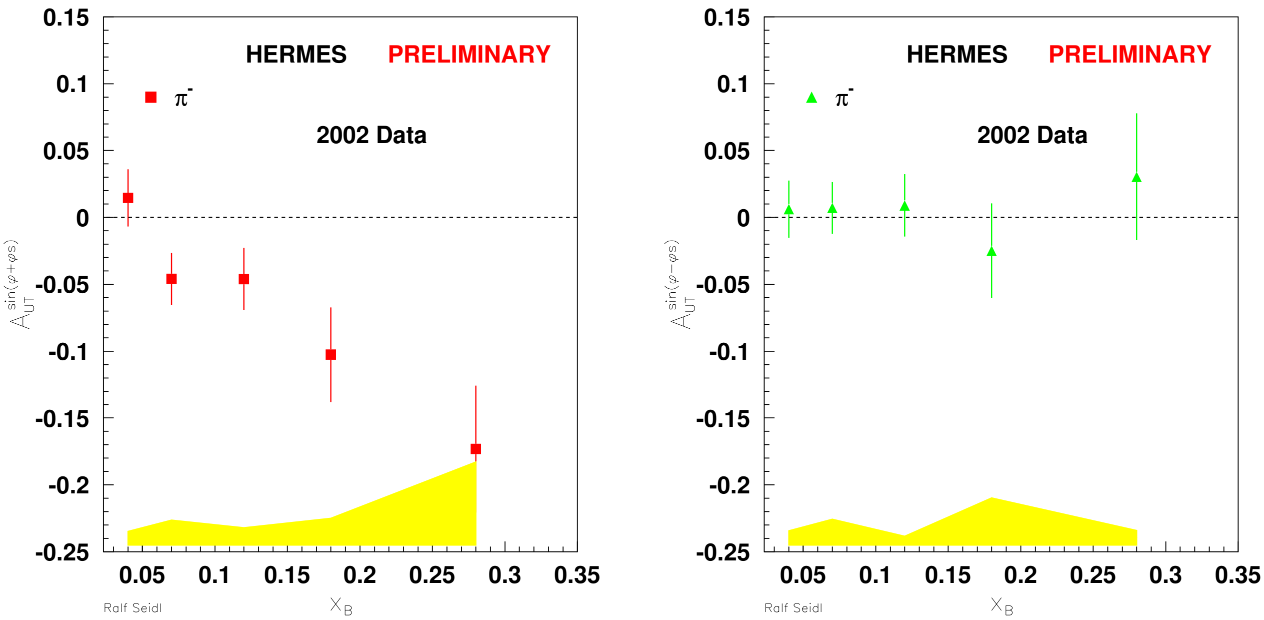
z-Dependence



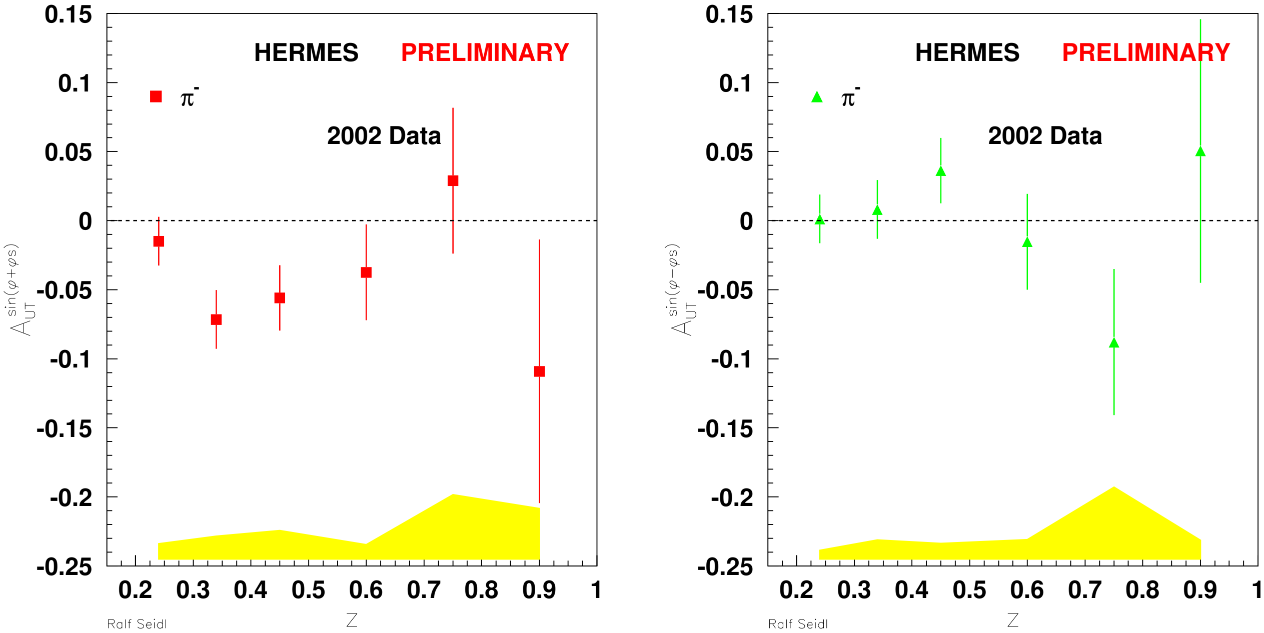
HERMES PRELIMINARY: π^- SSA

LEFT: Collins SSA RIGHT: Sivers SSA

x-Dependence



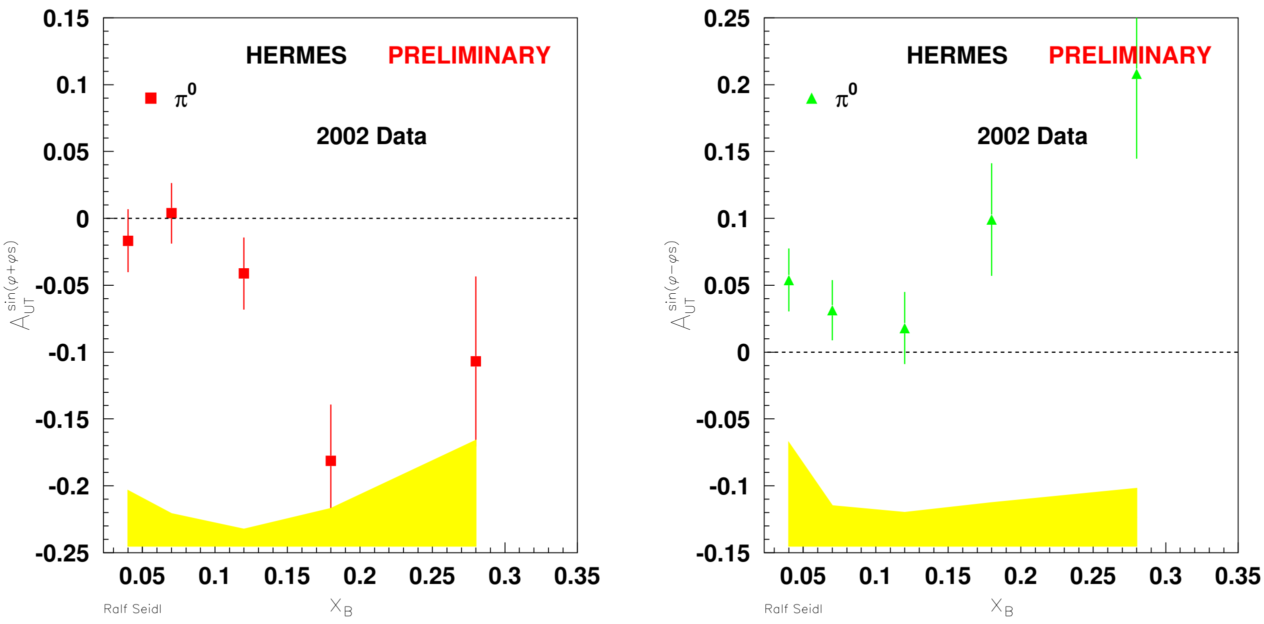
z-Dependence



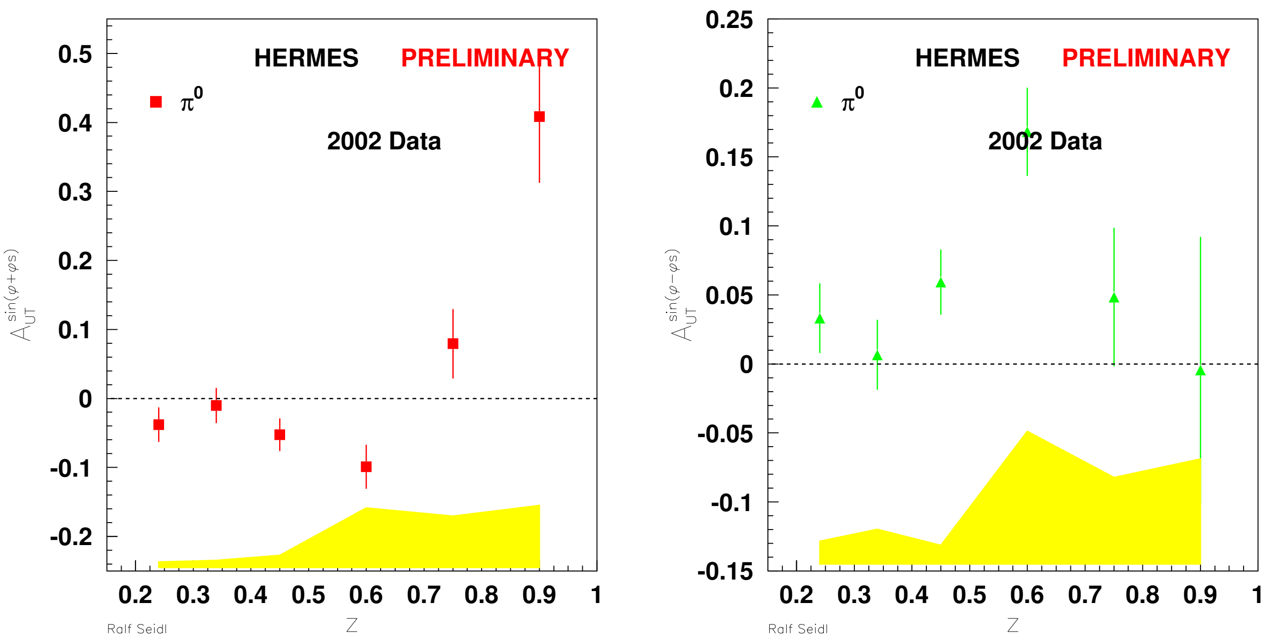
HERMES PRELIMINARY: π^0 SSA

LEFT: Collins SSA   RIGHT: Sivers SSA

x-Dependence



z-Dependence



What Can be Concluded from the prel. HERMES SSA Results ???

BOTH Sivers and Collins effect exist in the data

	COLLINS	SIVERS
π^+	+5% effect; almost flat in x and z	up to +5% at $x = 0.1$; +10% 'peak' at $z = 0.8$
π^-	falls to -15% at $x = 0.3$; -10% 'peak' at $z = 0.3$	no effect
π^0	falls to -15% at medium x; strong rise at $z = 0.9$!?	rises to +20% at $x = 0.3$; +20%'peak' at $z = 0.6$

COLLINS

$\Downarrow$

$A_{\pi^-} >> A_{\pi^+}$:

- neg. d-quark transversity ($\longrightarrow$ NEGATIVE tensor charge of the nucleon !?)
- large DISfavoured Collins fragmentation function !?

SIVERS

$\Downarrow$

no clear prediction for $f_{1T}^{\perp}$

1st model (hep/ph-0301018):

- u-quark (π^+): flat x-dep., as seen;
- vanishing d-quark (π^-): no agreement

Future HERMES Data Taking with Transv. Pol. Target

Resume HERA operation (with polarized beam) in fall 2003, continue 2004.

$\Rightarrow$ additional statistics allows analysis of different channels to access transversity:

- 2-Meson correlations
- Spin-1 fragmentation (ρ)
- Spin-$\frac{1}{2}$ fragmentation (transverse Λ polarization)
- Double Spin Asymmetry in pion production (transversity h_1^q and twist-3 fragmentation function $\hat{e}^q$)

Generalized Parton Distributions and DVCS

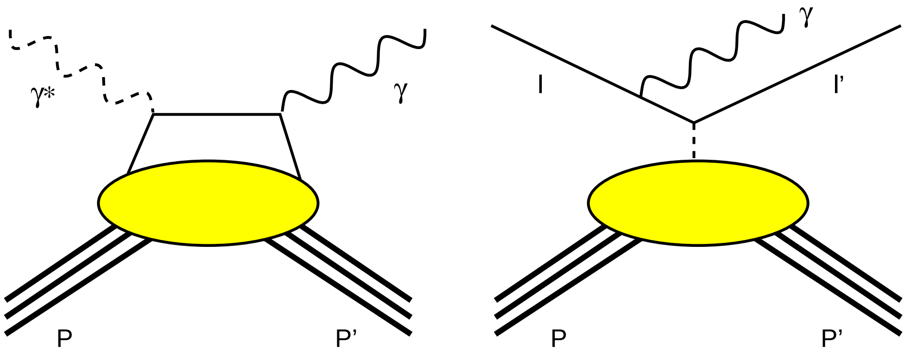
Generalized Parton Distributions:

Unified theoretical description of inclusive and (hard) exclusive processes

Simplest hard exclusive process: $ep \longrightarrow ep\gamma$
$(\gamma^* p \longrightarrow \gamma p)$

Consider $\gamma^* p$ in Bjorken limit $\Longrightarrow$
Deeply Virtual Compton Scattering

- Highly virtual quark in γ^* scattering
  $\longrightarrow$ propagates perturbatively
- Simplest (and dominating) QCD mechanism to form Compton final state: quark radiates real γ and falls back to nucleon ground state
  ('hand-bag' subprocess in pQCD)
  $\Downarrow$



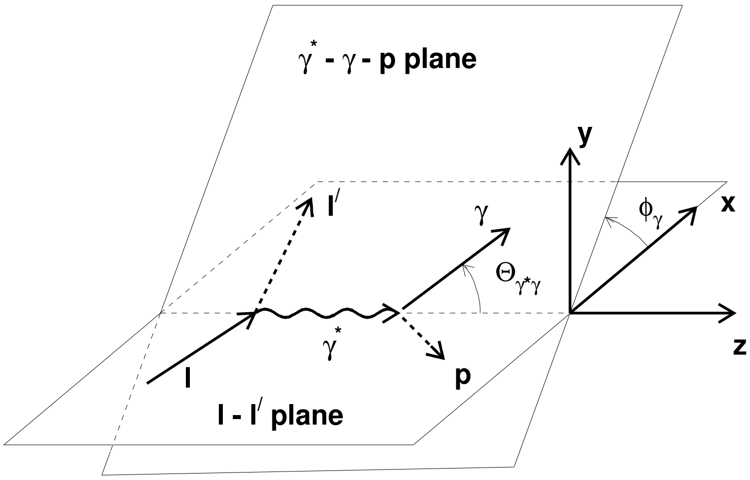
DVCS Bethe-Heitler

$\Rightarrow$ Interference gives access to DVCS amplitudes

DVCS dominated by BH in most of kin. region !
$\Rightarrow$ Use BH as a vehicle to study DVCS

ϕ-DEPENDENCE OF ASYMMETRIES

DVCS KINEMATICAL CONFIGURATION:



ϕ_γ: azimuthal angle between scattering and reaction plane.

ϕ_γ: ASYMMETRIES SHOW DIFFERENT CHARACTERISTICS

A) MEASURE LEPTON CHARGE ASYMMETRY:
unpolarized beam, unpolarized target (A_{ch})

$$\Delta_{\rm ch} d\sigma^{\rm unpol} \equiv d\sigma(e^+ p) - d\sigma(e^- p)$$
$$\sim \cos(\phi_\gamma) \times \mathrm{Re}\left\{ F_1 \mathcal{H}_1 + \frac{x_B}{2 - x_B}(F_1 + F_2)\widetilde{\mathcal{H}}_1 - \frac{\Delta^2}{4M^2} F_2 \mathcal{E}_1 \right\}$$

$\Rightarrow$ ACCESS TO REAL PART OF $\mathcal{H}_1, \widetilde{\mathcal{H}}_1$

B) MEASURE LEPTON HELICITY ASYMMETRY:
long. polarized beam, unpolarized target (A_{LU})

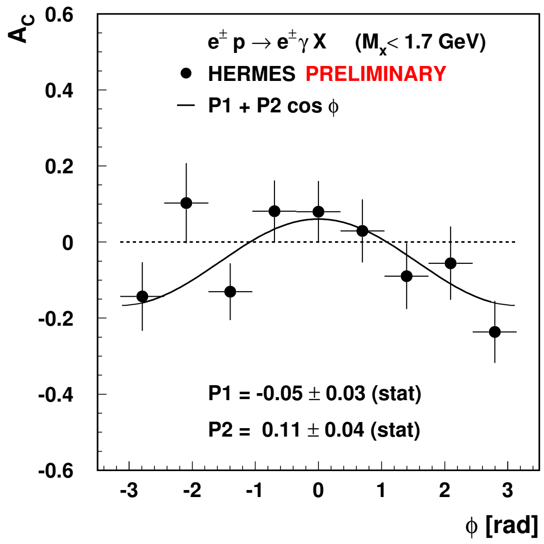
$$\Delta d\sigma \equiv d\sigma(\overrightarrow{e^+} p) - d\sigma(\overleftarrow{e^+} p)$$
$$\sim \sin(\phi_\gamma) \times \mathrm{Im}\left\{ F_1 \mathcal{H}_1 + \frac{x_B}{2 - x_B}(F_1 + F_2)\widetilde{\mathcal{H}}_1 - \frac{\Delta^2}{4M^2} F_2 \mathcal{E}_1 \right\}$$

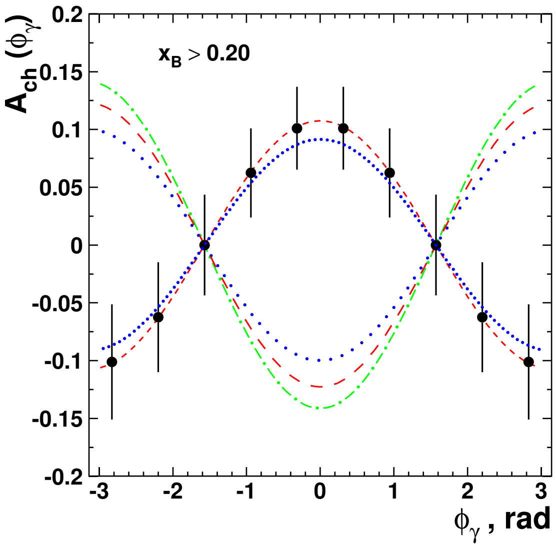
$\Rightarrow$ ACCESS TO IMAGINARY PART OF $\mathcal{H}_1, \widetilde{\mathcal{H}}_1$

HERMES DVCS Results and 2006 Asymmetry Projections

A) Lepton charge asym. (unpol. beam, unpol. target):

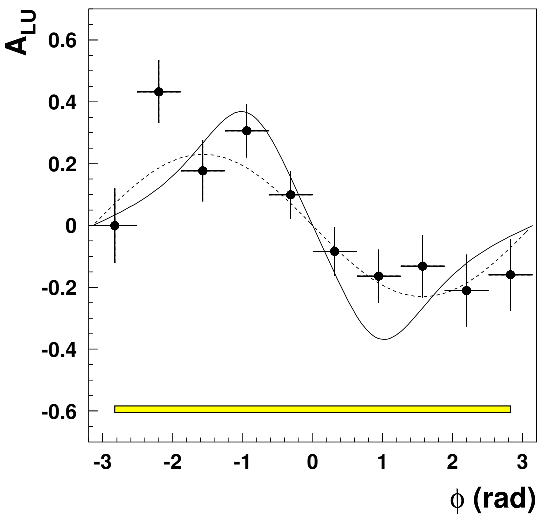
Prel. result 2002 | Projection* ($x_B > 0.2$)

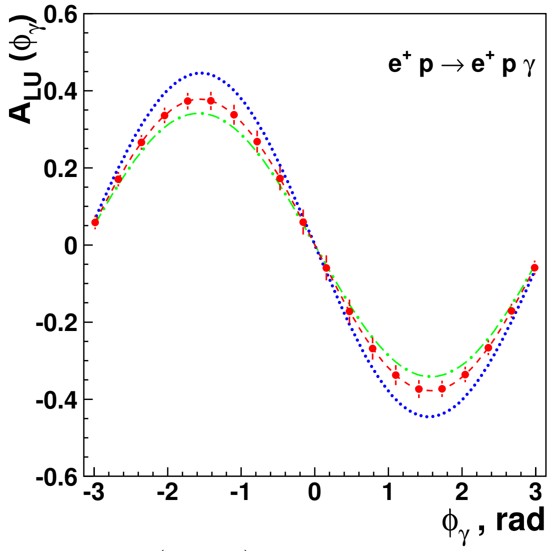




B) Lepton helicity asym. (pol. beam, unpol. target):

PRL 87 (2001) 182001 | Projection*





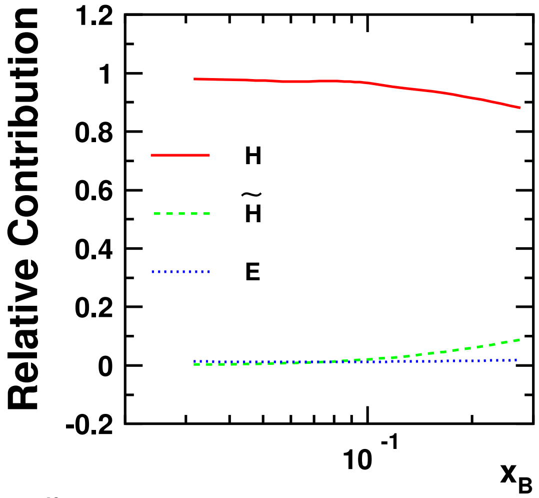
*) Projections: V. Korotkov, W.-D. N., EPJC 23 (2002), 455

Im$\mathcal{H}$ Measurement in 2006 ? *

Lepton helicity asymmetry: $A_{LU}^{sin\phi} \approx \mathcal{C}_{unp}^{\mathcal{I}} / \mathcal{C}_{unp}^{DVCS}$ with

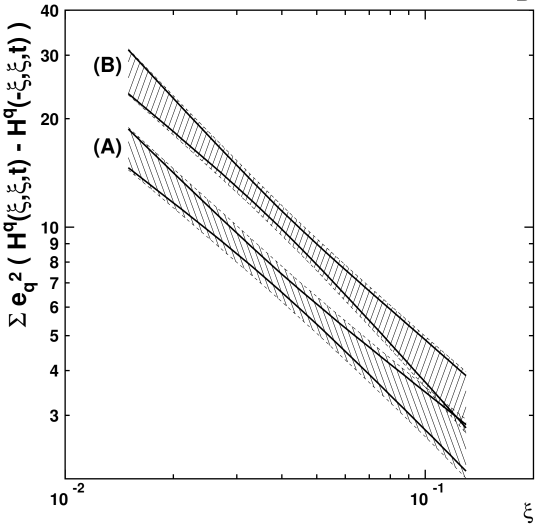
$$\mathcal{C}^{\rm DVCS}_{\rm unp} = \frac{1}{(2-x_{\rm B})^2}\Big\{4(1-x_{\rm B})\left(\mathcal{H}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{H}}^*\right) - x_{\rm B}^2\left(\mathcal{H}\mathcal{E}^* + \mathcal{E}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{E}}^* + \widetilde{\mathcal{E}}\widetilde{\mathcal{H}}^*\right) - \left(x_{\rm B}^2 + (2-x_{\rm B})^2\frac{t}{4M^2}\right)\mathcal{E}\mathcal{E}^* - x_{\rm B}^2\frac{t}{4M^2}\widetilde{\mathcal{E}}\widetilde{\mathcal{E}}^*\Big\}.$$

$$\mathcal{C}^{\mathcal{I}}_{\rm unp} = F_1\mathcal{H} + \frac{x_{\rm B}}{2-x_{\rm B}}(F_1+F_2)\widetilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E}$$



At $-t < 0.15$ GeV^2:

Relative contribution of GPD H dominates
$\Rightarrow$ Asymmetry $A_{LU}^{sin\phi}$ mainly depending on Im$\mathcal{H}$



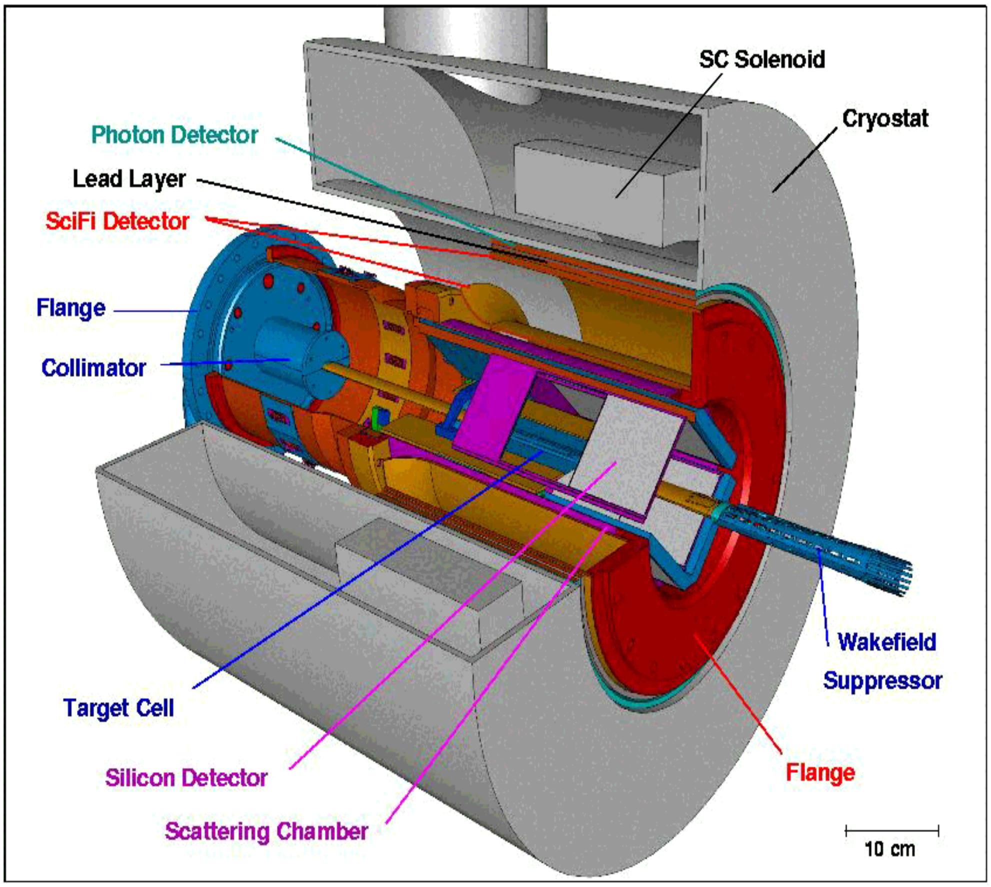
Extraction of Im$\mathcal{H}$ possible:

$\Leftarrow$ Two different bands for different GPD param.'s
$\Leftarrow$ Solid line: 1σ stat. errors
$\Leftarrow$ Dashed line: syst. extraction uncertainty added

*) Projections: V. Korotkov, W.-D. N., NPA 711, 175c, (2002)

A new Recoil Detector for Hard Exclusive Reactions

DVCS	$\gamma^* p \longrightarrow \gamma\ p$	$\mathbf{H}\ \tilde{\mathbf{H}}\ \mathbf{E}\ \tilde{\mathbf{E}}$
exclusive pseudoscalar meson production	$\gamma^* p \longrightarrow \pi^0\ p$ $\gamma^* p \longrightarrow \pi^+\ n$	$\tilde{\mathbf{H}}\ \ \tilde{\mathbf{E}}$
exclusive vector meson production	$\gamma^* p \longrightarrow \rho^0\ p$ $\gamma^* p \longrightarrow \omega\ p$ $\gamma^* p \longrightarrow \phi\ p$	$\mathbf{H}\ \ \mathbf{E}$



SUMMARY

- A great variety of Single Spin Asymmetries will be measured in semi-inclusive DIS on a transversely polarized proton target. This will allow to determine the leading TRANSVERSE SPIN STRUCTURE of the proton.

- A new RECOIL DETECTOR in combination with an unpolarized proton target will lead to significant improvements in resolution and statistics in measuring hard exclusive reactions (DVCS, pseudoscalar and vector meson production) towards an extraction of GENERALIZED PARTON DISTRIBUTIONS

- A broad spectrum of highly interesting FURTHER PHYSICS TOPICS will come 'for free' when realizing the above program