Status Report of HERMES

M.Hartig,
on behalf of the HERMES Collaboration

DESY

PRC May 2005

- First Measurement of b_1
- Exclusive Reactions
  - DVCS
  - Exclusive ρ^0 Production
- Transversity
  - Single-Spin Azimuthal Asymmetries in SIDIS
  - Interference Fragmentation Function

Polarized DIS on Deuterium

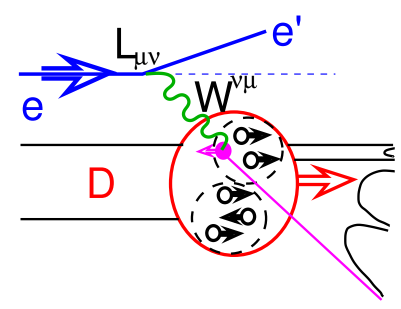
Cross section:

$$\frac{d^2\sigma}{dE'\,d\Omega} = \frac{\alpha^2}{2MQ^4}\,\frac{E'}{E}\,L_{\mu\nu}W^{\mu\nu}$$

Hadronic tensor:

$$W^{\mu\nu} = W_s^{\{\mu\nu\}}(F1, F2, \underbrace{b_1, b_2, b_3, b_4}_{target\ spin\ 1})$$

$$+ \quad W_a^{[\mu\nu]}(g1, g2)$$



Tensor structure function

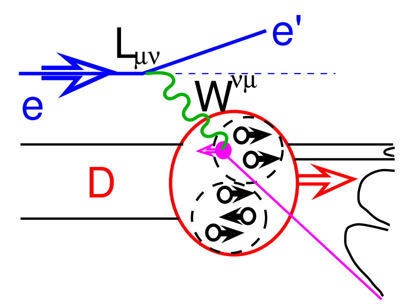
$$b_1 = \frac{1}{2}\sum_q e_q^2\left(2q^0 - (q^1_\uparrow + q^1_\downarrow)\right)$$

$$A^d_{zz} = \frac{(\sigma^{\leftrightarrows} + \sigma^{\rightrightarrows}) - 2\sigma^0}{\sigma^{\leftrightarrows} + \sigma^{\rightrightarrows} + \sigma^0} = -\frac{2}{3}\,\frac{b_1}{F_1}$$

Polarized DIS on Deuterium

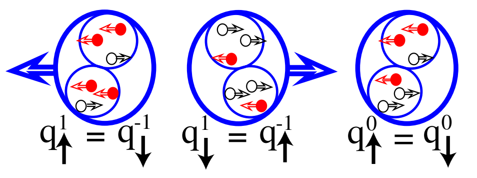
Cross section:

$$\frac{d^2\sigma}{dE'd\Omega} = \frac{\alpha^2}{2MQ^4}\frac{E'}{E}L_{\mu\nu}W^{\mu\nu}$$



Hadronic tensor:

$$W^{\mu\nu} = W_s^{\{\mu\nu\}}(F1, F2, \underbrace{b_1, b_2, b_3, b_4}_{target\ spin\ 1}) + W_a^{[\mu\nu]}(g1, g2)$$

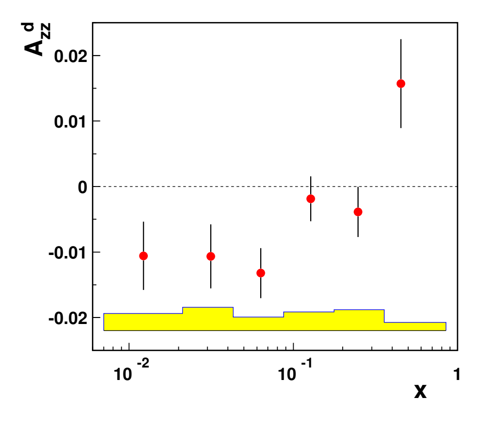


Tensor structure function

$$b_1 = \frac{1}{2}\sum_q e_q^2(2q^0 - (q^1_\uparrow + q^1_\downarrow))$$

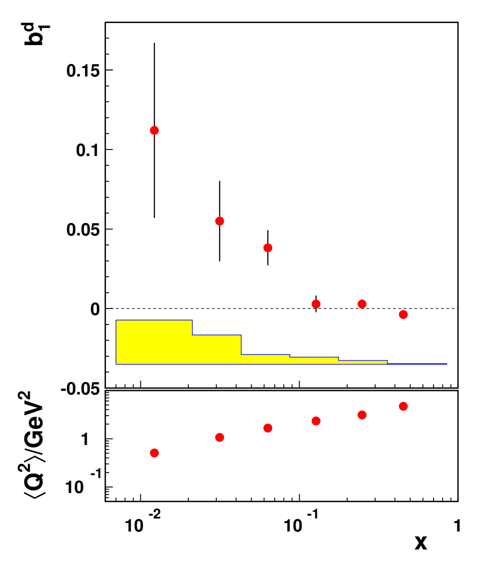
$$A^d_{zz} = \frac{(\sigma^{\Leftarrow\!\!\!\!\rightarrow} + \sigma^{\Rightarrow\!\!\!\!\rightarrow}) - 2\sigma^0}{\sigma^{\Leftarrow\!\!\!\!\rightarrow} + \sigma^{\Rightarrow\!\!\!\!\rightarrow} + \sigma^0} = -\frac{2}{3}\frac{b_1}{F_1}$$

Final Results: A^d_{zz} and b^d_1



- First measurement of A^d_{zz} and b^d_1
- $A^d_{zz} \neq 0$
- $A^d_{zz} = \mathcal{O}(1\%)$
- $b^d_1 > 0$ for small x
- First moment of $b^d_1 \neq 0$
- Qualitative agreement with coherent double-scattering models (nuclear shadowing)
- Submitted to PRL

Final Results: A_{zz}^d and b_1^d



- First measurement of A_{zz}^d and b_1^d
- $A_{zz}^d \neq 0$
- $A_{zz}^d = \mathcal{O}(1\%)$

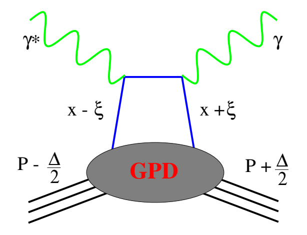
- $b_1^d > 0$ for small x
- First moment of $b_1^d \neq 0$
- Qualitative agreement with coherent double-scattering models (nuclear shadowing)
- Submitted to PRL

Exclusive Reactions

Study of hard exclusive processes leads to GPDs $\Rightarrow J_q$

unpolarized	polarized	
$H^q(x,\xi,t)$	$\widetilde{H}^q(x,\xi,t)$	conserve nucleon helicity
$E^q(x,\xi,t)$	$\widetilde{E}^q(x,\xi,t)$	flip nucleon helicity

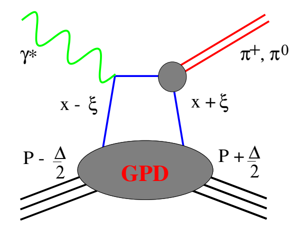
Quantum numbers of final state select different GPDs:



DVCS:

H^q, E^q, $\widetilde{H}^q$, $\widetilde{E}^q$

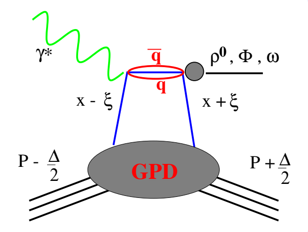
$A_C, A_{LU}, A_{UT}, A_{UL}$



Pseudo-scalar meson:

$\widetilde{H}^q$, $\widetilde{E}^q$

A_{UT}, σ_π

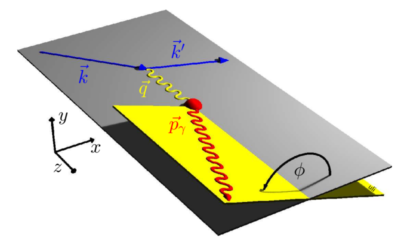


Vector meson:

E^q, H^q

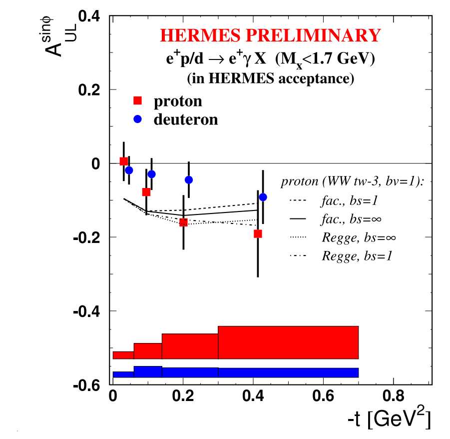
A_{UT} , $\sigma_{\rho,\phi,\omega}$

Long. Target Spin Asymmetry (LTSA)



HERMES use DVCS-BH interference:

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



- LTSA sensitive to GPD $\widetilde{H}$
- No effect from 40% coherent contribution for deuteron in first bin
- At higher $-t$: different asymmetry on neutron and proton (?)

HERA II: Exclusive VM Production

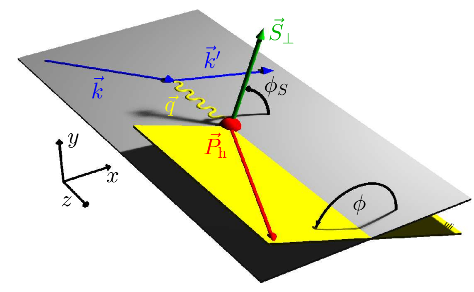
- Measurement of

$$e\,p^{\uparrow} \rightarrow e\,p\,\rho^{0}$$

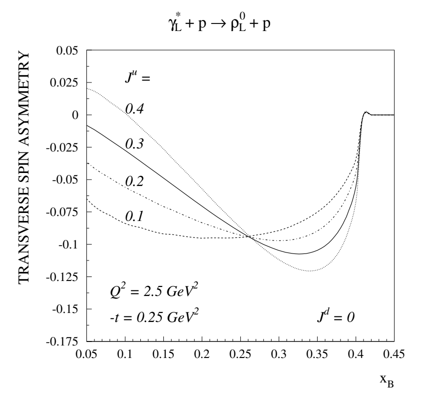
- Transverse target spin asymmetry

$$A_{UT}(\phi - \phi_s) = \frac{1}{|P_T|}\frac{N^{\uparrow} - N^{\downarrow}}{N^{\uparrow} + N^{\downarrow}}$$

- $A_{UT}(\phi - \phi_s)$ sensitive to GPD E^q



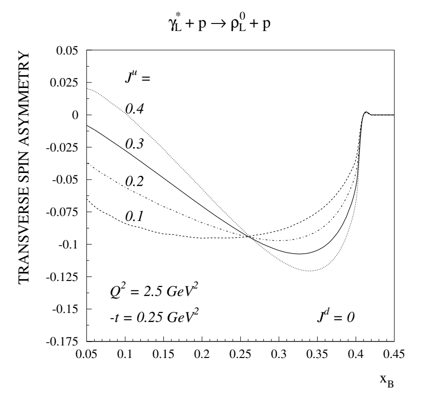
A_{UT} for Exclusive ρ^0 Production

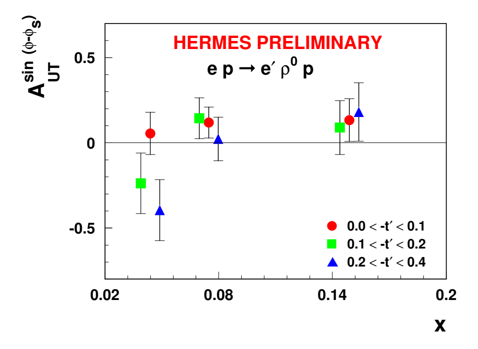


- Sensitivity to J^u
  (Goeke et al. hep-ph/0106012)
- Asymmetry $\sim -A_{UT}$
  pos. slope for HERMES ($x \approx 0.1$)

- Indication of positive slope as expected
- 2005 data $\Rightarrow \sigma_L$ - σ_T separation possible

A_{UT} for Exclusive ρ^0 Production

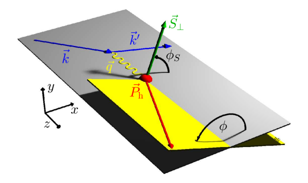




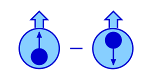
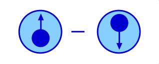
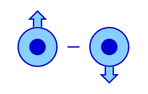
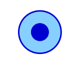
- Sensitivity to J^u
  (Goeke et al. hep-ph/0106012)
- Asymmetry $\sim -A_{UT}$
  pos. slope for HERMES ($x \approx 0.1$)

- Indication of positive slope as expected
- 2005 data $\Rightarrow \sigma_L$ - σ_T separation possible

SIDIS: Transversity / Sivers



- Transversely polarized target
- Two azimuthal angles Φ and Φ_s
- Non-vanishing $P_{h\perp} \Rightarrow$ intrinsic transverse momenta p_T and k_T

	distr. functions		frag. functions
$\sigma^{ep\to e\pi X} = \sum_q$	$f^{h\to q}$	$\otimes \sigma^{eq\to eq} \otimes$	$D^{q\to h}$
			
	$\delta q(x, Q^2)$	(Collins)	$H_1^{\perp,q}(z, Q^2)$
			
	$f_{1T}^{\perp q}(x, Q^2)$	(Sivers)	$D_1^q(z, Q^2)$

Extraction of Collins and Sivers Moments

- Determination of unweighted asymmetries for charged pions:

$$A_{UT}^{\pi^\pm}(\Phi, \Phi_S) = \frac{1}{\langle P_z \rangle} \cdot \frac{N_h^{\Uparrow}(\Phi,\Phi_S) - N_h^{\Downarrow}(\Phi,\Phi_S)}{N_h^{\Uparrow}(\Phi,\Phi_S) + N_h^{\Downarrow}(\Phi,\Phi_S)}$$

$\langle P_z \rangle = 0.754 \pm 0.050$ (average target polarization value)

- Moments are extracted in two-dimensional fit:

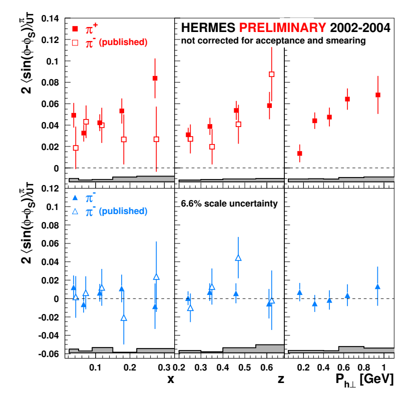
Sivers moment

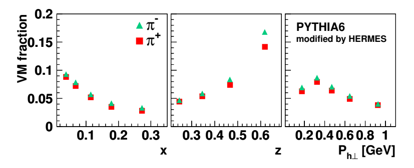
Collins moment

$$\begin{aligned} A_{UT}^{\pi^\pm}(\Phi, \Phi_S) \quad = \quad & 2 \cdot \langle \sin(\Phi - \Phi_S) \rangle_{UT}^{\pi^\pm} \cdot \sin(\Phi - \Phi_S) + \\ & 2 \cdot \langle \sin(\Phi + \Phi_S) \rangle_{UT}^{\pi^\pm} \cdot \frac{B(\langle y \rangle)}{A(\langle x \rangle, \langle y \rangle)} \sin(\Phi + \Phi_S) + \\ & c_3 \cdot \sin(2\phi - \phi_S) + c_4 \cdot \sin(\phi_S) + c_5 \end{aligned}$$

$A(\langle x \rangle, \langle y \rangle)$, $B(\langle y \rangle)$: kinematic factors; c_3, c_4, c_5: fit parameters

Unweighted Sivers Moment





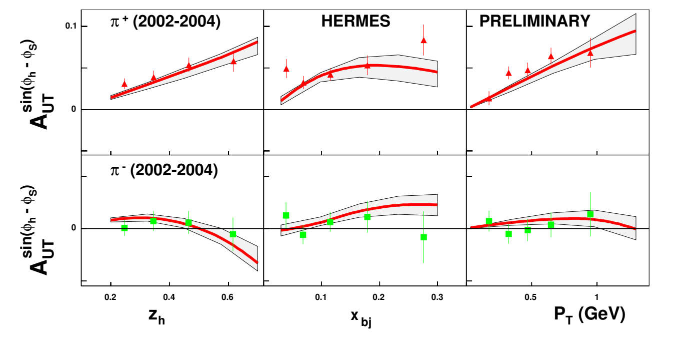
$$f_{1T}^{\perp q}(x) \otimes D_1^q(z)$$

- Consistent with published moments. Errors improved by factor 2.
- Sivers moment significantly positive for π^+ $\Rightarrow$ non-vanishing orbital angular momentum L_z^q.
- Sivers moment for π^- consistent with zero.
- Since unpolarized FFs are known, extraction of Sivers function is possible.

Systematic uncertainties:

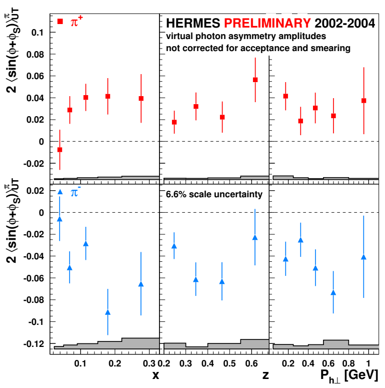
- Common scale uncertainty of 6.6% .
- Background asymmetry of exclusive VM.

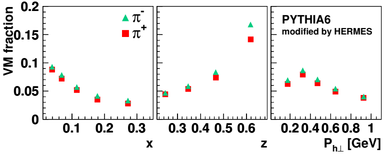
Unweighted Sivers Moment: Exp. vs. Theory



- Nice agreement between data and theoretical model
- Theory: M. Anselmino et al. hep-ph/0501196
  Intrinsic $k_\perp$ determined from unpolarized $\cos(\Phi)$ data

Unweighted Collins Moment





$$\delta q(x, Q^2) \otimes H_1^{\perp,q}(z)$$

- Consistent with published Collins moments.
- Collins moment positive for π^+ and negative for π^-.
- Large negative π^- moment is unexpected.
- Additional information on Collins FF (from BELLE) is needed to extract transversity distribution.

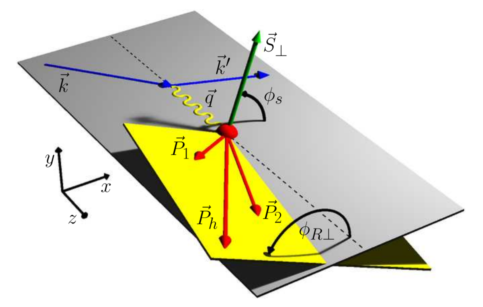
Systematic uncertainties:

- Common scale uncertainty of 6.6%.
- Background asymmetry of exclusive VM.

Interference Fragmentation Function

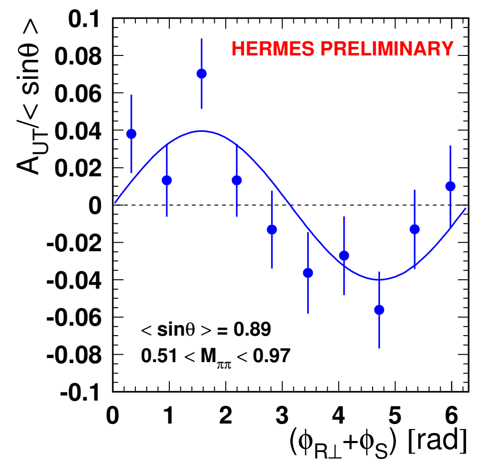
- Measurement of $ep \rightarrow h^+ h^- X$ to determine $\delta q(x, Q^2)$
- Single-spin asymmetry:

$$A_{UT} \sim \sin(\phi_{R\perp} + \phi_S)\, \sin(\theta)\, \delta q(x, Q^2)\, H_1^{\sphericalangle}$$



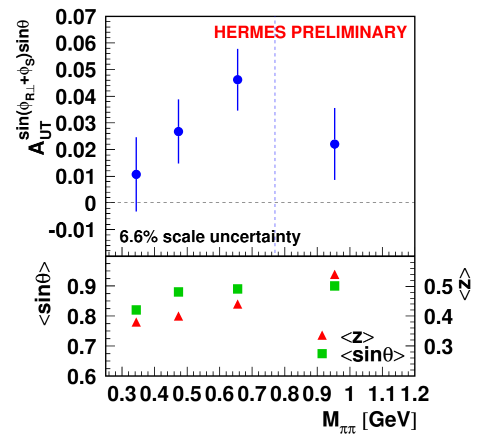
- No Collins-Sivers mixing
- Independent of SSA of $\pi^\pm$
- Less statistic
- Interference FF $H_1^{\sphericalangle}$ unknown (can be measured at Belle)
- Different model predictions for $A_{UT}^{\sin(\phi_{R\perp}+\phi_S)}$ (Jaffe et al., Radici et al.)

The A_{UT} Asymmetry



- Significant $\sin(\phi_{R\perp} + \phi_S)$ behaviour
- $A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin(\theta)} = 0.04 \pm 0.009$ (stat) $\pm\, 0.003$ (syst)
- Positive asymmetry moment for all invariant mass bins
- Result rules out predicted sign change at ρ^0 mass (Jaffe et al.)

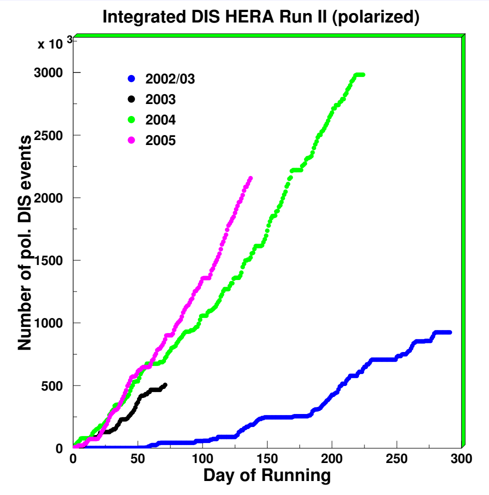
The A_{UT} Asymmetry



- Significant $\sin(\phi_{R\perp} + \phi_S)$ behaviour
- $A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin(\theta)} = 0.04 \pm 0.009$ (stat) $\pm\ 0.003$ (syst)

- Positive asymmetry moment for all invariant mass bins
- Result rules out predicted sign change at ρ^0 mass (Jaffe et al.)

2005 Data Taking

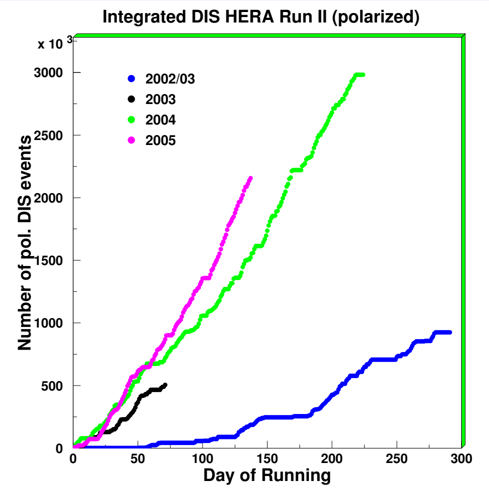


- Best data taking efficiency of HERA II
- Very good polarized target performance
- But too low beam polarization

- 1.6 Mill DIS on Xe ⇒ switch to Kr
- 2.6 Mill DIS on D

Expect More Results Soon

2005 Data Taking



- Best data taking efficiency of HERA II
- Very good polarized target performance
- But too low beam polarization

- 1.6 Mill DIS on Xe ⇒ switch to Kr
- 2.6 Mill DIS on D

Expect More Results Soon