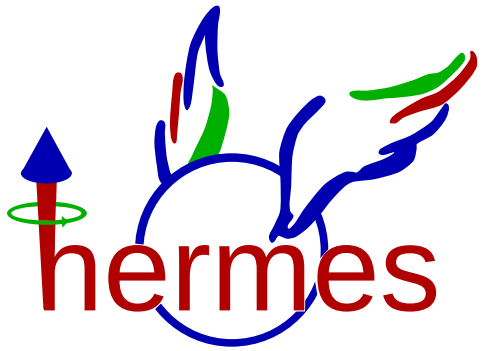
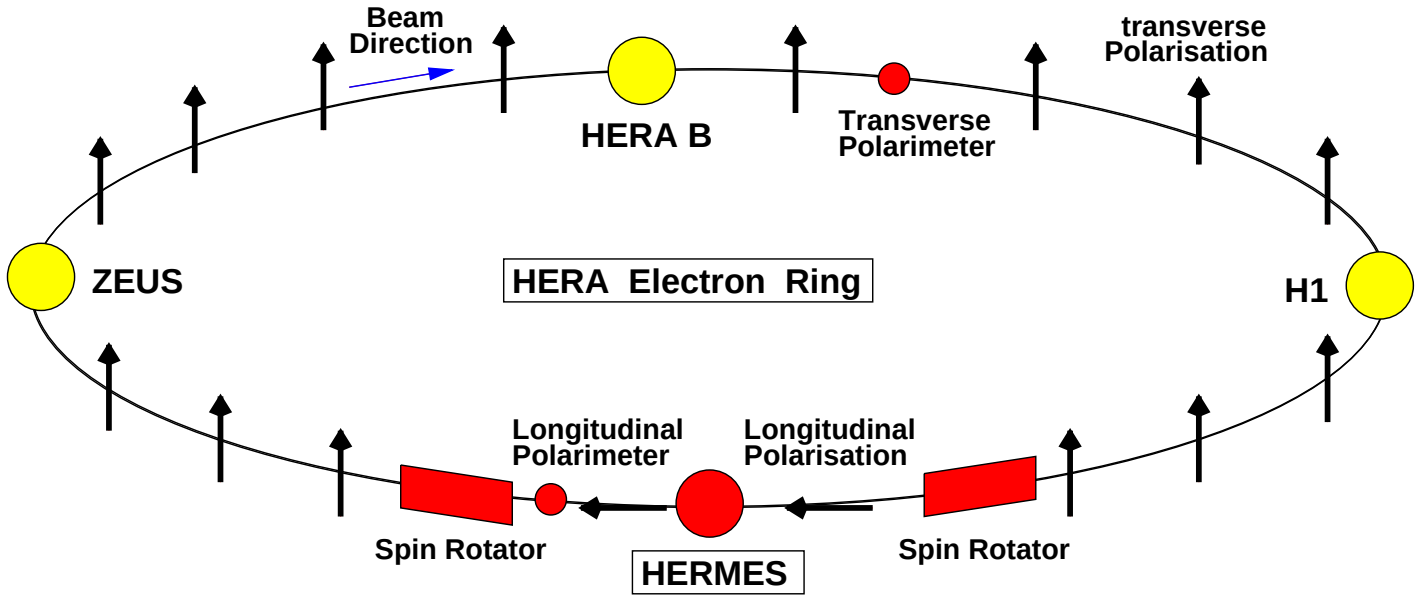
Status and Prospects of the Semi-Inclusive Transverse Target Single Spin Asymmetries at HERMES

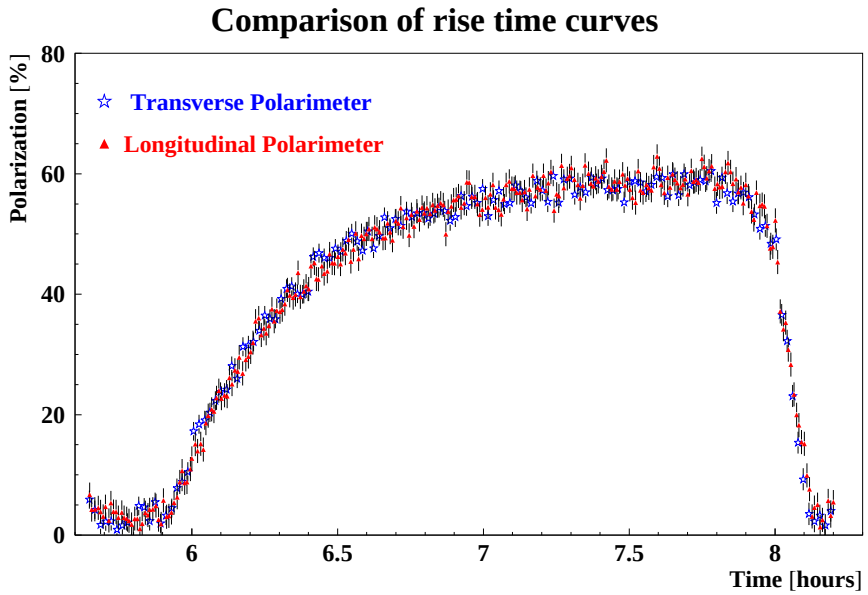
Gunar Schnell

DESY - Zeuthen

For the  Collaboration

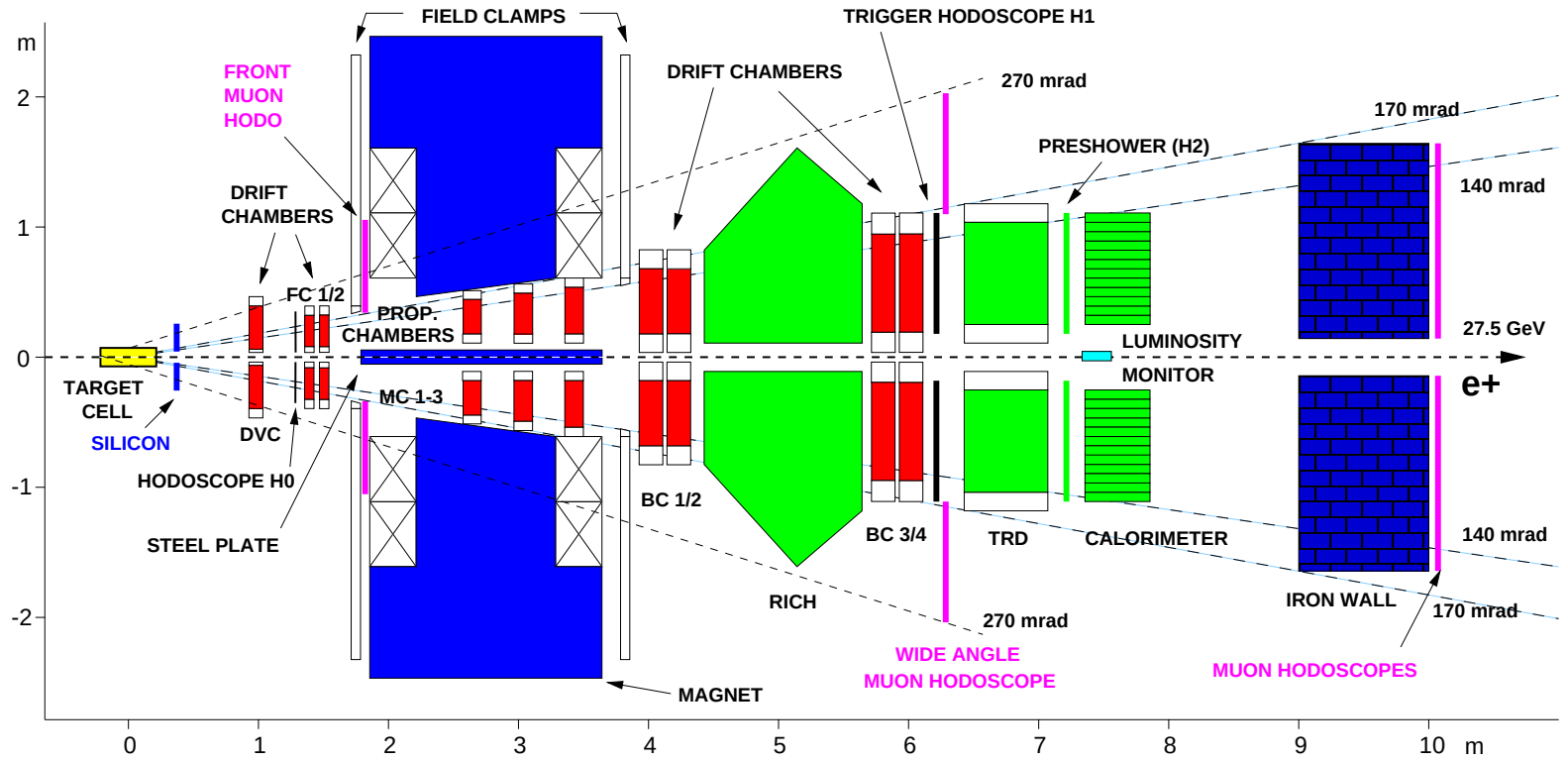
Polarized Beam at HERA





- 27.5 GeV e^+/e^- beam
- Self-polarizing through Sokolov-Ternov-Effect
- Average beam polarization of about 55%

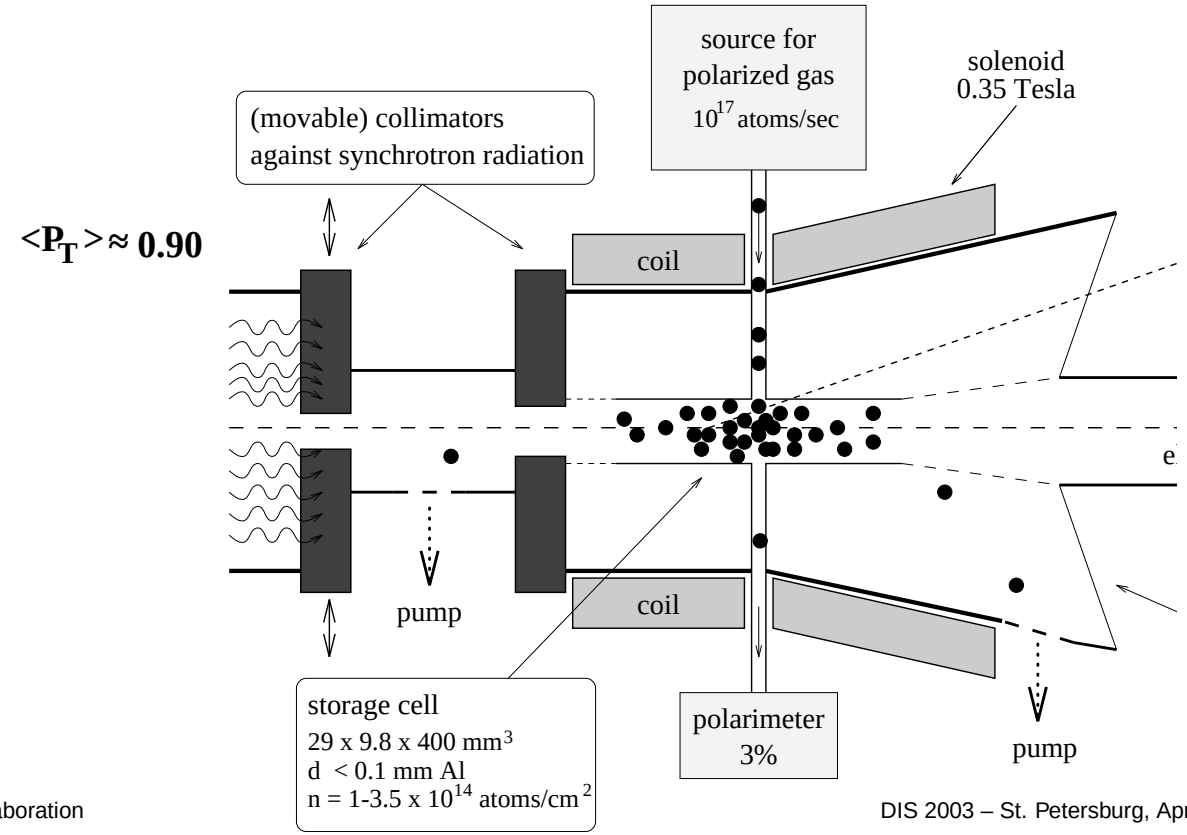
The HERMES Experiment



- Internal storage cell: pure gas target
- Forward acceptance spectrometer: 40 mrad $\leq \Theta \leq$ 220 mrad
- Tracking: 57 tracking planes: $\delta P/P = (0.7 - 1.3)\%$, $\delta\Theta \leq 0.6$ mrad
- PID: Cherenkov (RICH after 1997), TRD, Preshower, Calorimeter

HERMES Internal Gas Target

- Storage cell with atomic beam source
- Pure target (NO dilution)
- Polarized or unpolarized targets possible
- Different gas targets available (H, D, He, N, Kr ...)



Twist-2 Quark Distribution Functions

Functions surviving integration over intrinsic transverse momentum

f_1 =

g_{1L} = –

h_{1T} = –

g_{1T} = –

$f_{1T}^{\perp}$ = –

$h_1^{\perp}$ = –

$h_{1L}^{\perp}$ = –

$h_{1T}^{\perp}$ = –

Twist-2 Quark Distribution Functions

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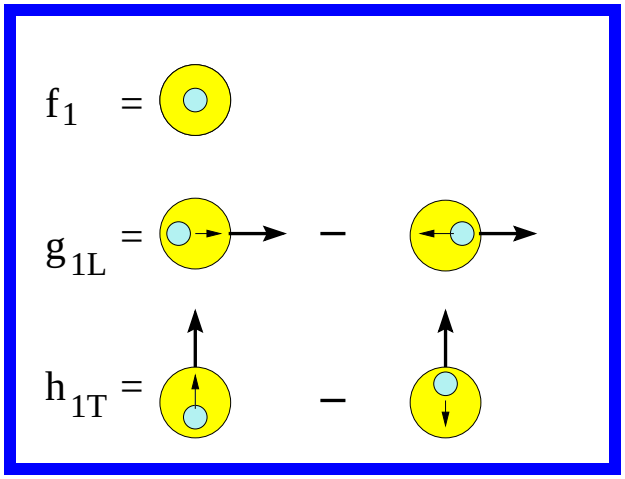
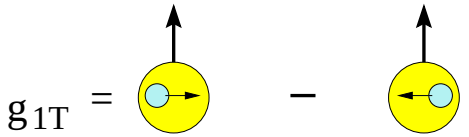
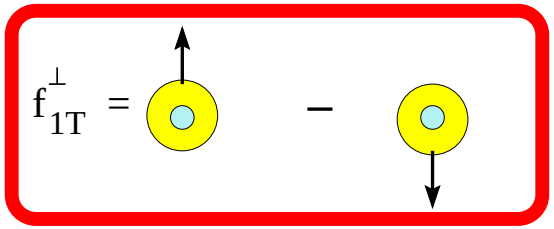
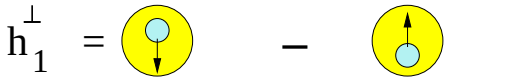
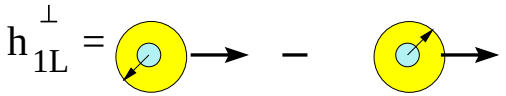


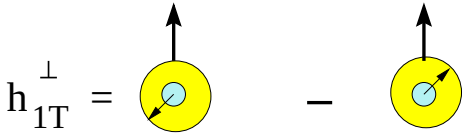




Sivers Function





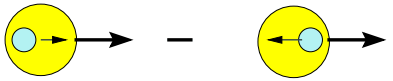


Twist-2 Fragmentation Functions

Functions surviving integration over intrinsic transverse momentum

D_1 =

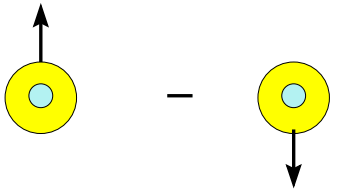
G_{1L} =



H_{1T} =

G_{1T} =

$D_{1T}^{\perp}$ =



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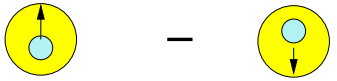
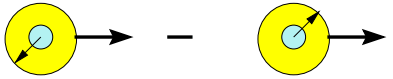


$H_{1L}^{\perp}$ =



$H_{1T}^{\perp}$ =

Twist-2 Fragmentation Functions

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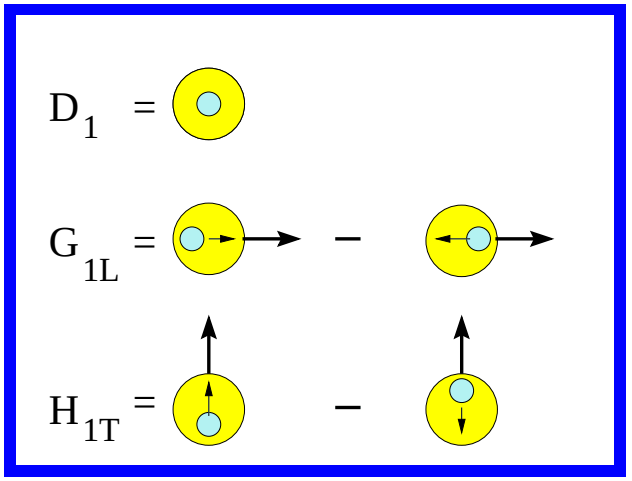
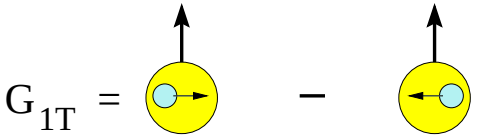
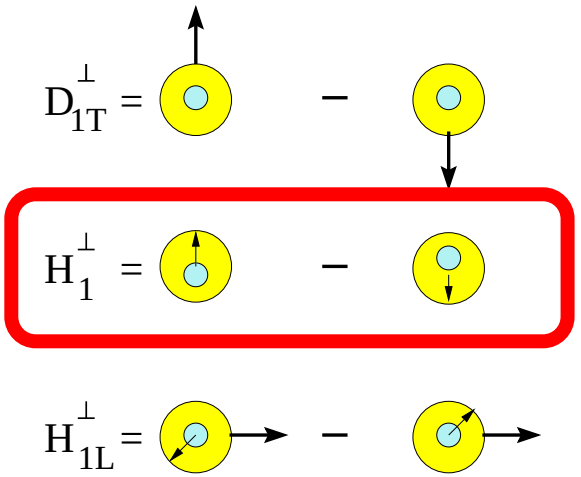
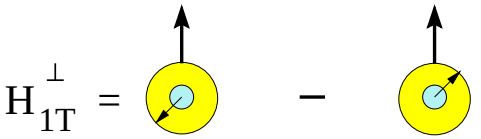






Collins Function



The Need for Semi-Inclusive Measurements

- h_1 chiral odd
  $\Rightarrow$ not accessible in inclusive DIS
  $\Rightarrow$ need some sort of quark polarimetry
- $k_\perp$-dependent distribution functions (besides f_1, g_1, h_1)
  $\Rightarrow$ vanish when integrating over $k_\perp$ (i.e. inclusive DIS)
  $\Rightarrow$ need to access $k_\perp$-dependence

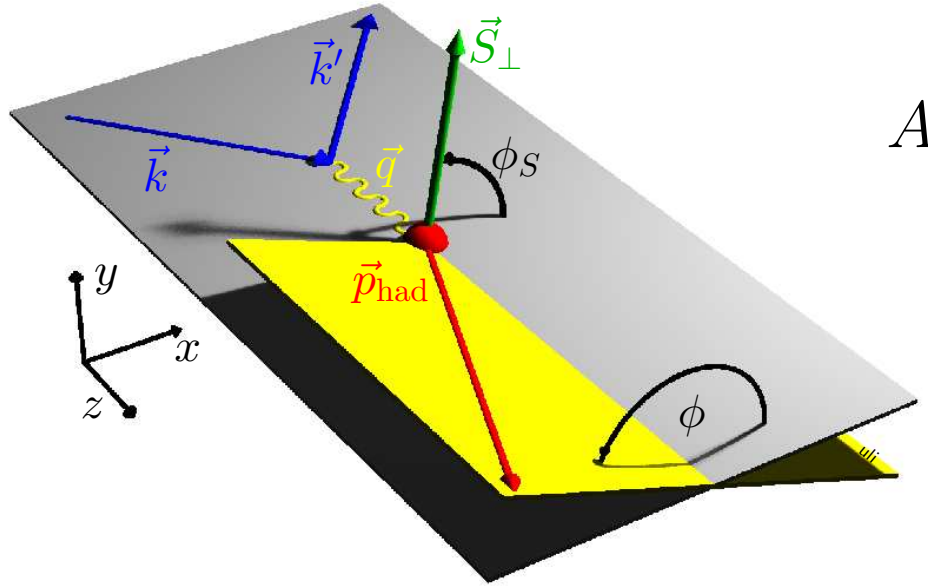
Azimuthal Single Spin Asymmetries in Semi-Inclusive DIS

Single Spin Asymmetries

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

study azimuthal distribution of π's:

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



$\Phi = \phi + \phi_S$ Collins angle

with transversely polarized target:
(unpolarized beam)

$$A_{UT}^{\sin\Phi} \propto \frac{\sum_q e_q^2 h_1^q(x) H_1^{\perp,q}(z)}{\sum_q e_q^2 f_1^q(x) D_1^q(z)}$$

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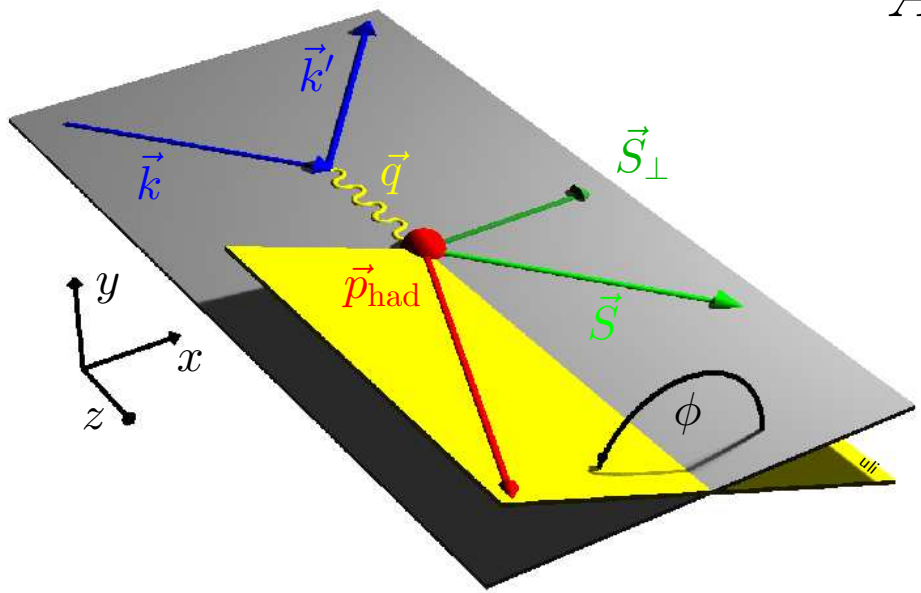

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with longitudinally polarized target:

$$A_{UL}^{\sin\Phi} \propto \ldots$$

Longitudinally Polarized Target

transverse component $\mathbf{S_T}$ of target spin (w.r.t. virtual photon):

$$\mathbf{S_T} \propto \sin\Theta_\gamma \simeq \frac{2Mx}{Q}\sqrt{1-y} \sim \mathbf{0.15}$$

$$A_{UL}^{\sin\phi} \sim S_L \langle \sin\phi \rangle_{UL} - S_T \langle \sin\phi \rangle_{UT}$$

Longitudinally polarized in experiment

(along beam direction)

L/T polarized in theory

(along virtual gamma direction)

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$$\langle \sin\phi \rangle_{UL} \sim \frac{1}{Q}\sum_q e_q^2 (h_L^q(x) H_1^{\perp(1),q}(z) - \frac{1}{z} h_{1L}^{\perp(1),q}(x)\tilde{H}(z))$$

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$$\langle \sin\phi \rangle_{UT} \sim \sum_q e_q^2 h_1^q(x) H_1^{\perp(1),q}(z)$$ **but** $S_T \sim \frac{1}{Q}$ **like twist-3**

Longitudinally Polarized Target

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$$\langle \sin\phi \rangle_{UT} \sim \sum_q e_q^2 h_1^q(x) H_1^{\perp(1),q}(z) \qquad \text{Collins}$$

$$\langle \sin\phi \rangle_{UT} \sim \sum_q e_q^2 f_{1T}^{\perp(1),q} D_1^q(z) \qquad \text{Sivers}$$

Contributions to $A_{UL}^{\sin\Phi}$ hard to disentangle

How to do better?

Longitudinally polarized target $\Rightarrow$ Sivers and Collins effects indistinguishable

Transversely polarized target

Sivers	Collins
$\langle \sin(\phi - \phi_s) \rangle$ moment	$\langle \sin(\phi + \phi_s) \rangle$ moment
$\downarrow$	$\downarrow$
$f_{1T}^{\perp}(x)$	$h_1(x)$, $H_1^{\perp}(z)$

Additionally: $\langle \sin(3\phi_h^l - \phi_s^l) \rangle$ moment $\Rightarrow$ $h_{1T}^{\perp}(x)$, $H_1^{\perp}(z)$ and others

What do theorists expect?

Not much is known about the Collins function:

$$\left|\frac{<H_1^{\perp}>}{<D_1>}\right| = 6.3\%$$

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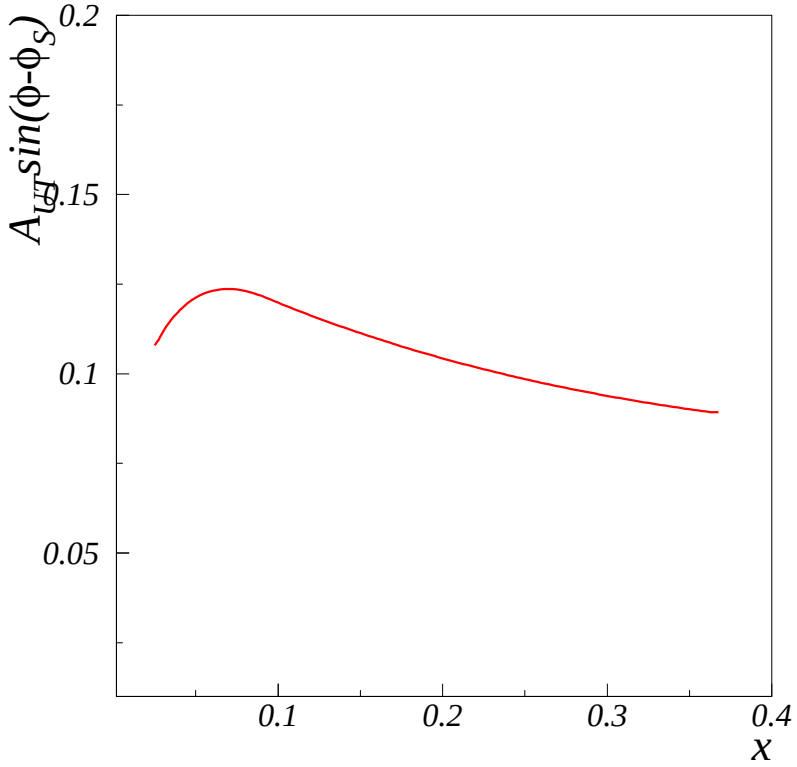
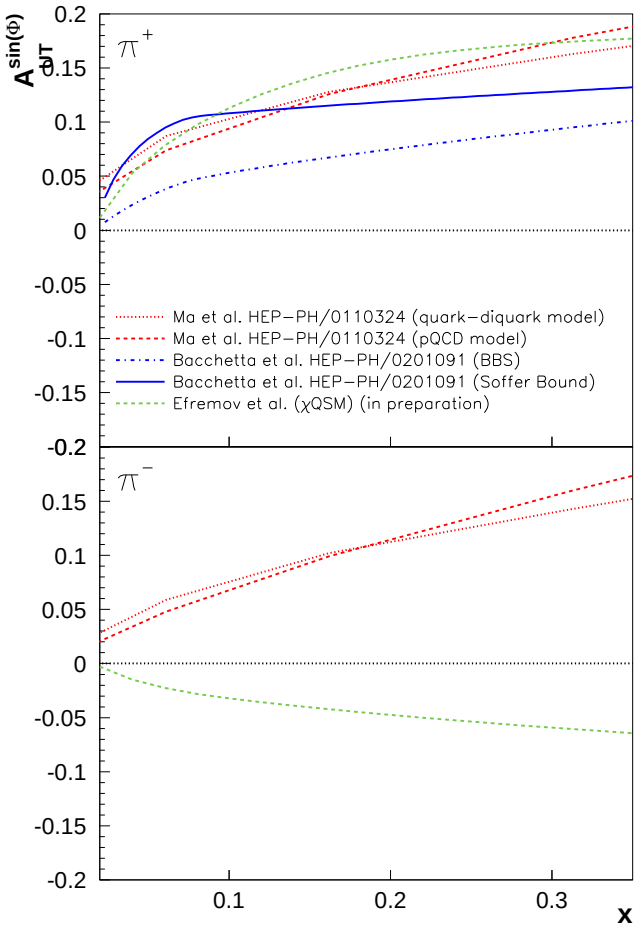
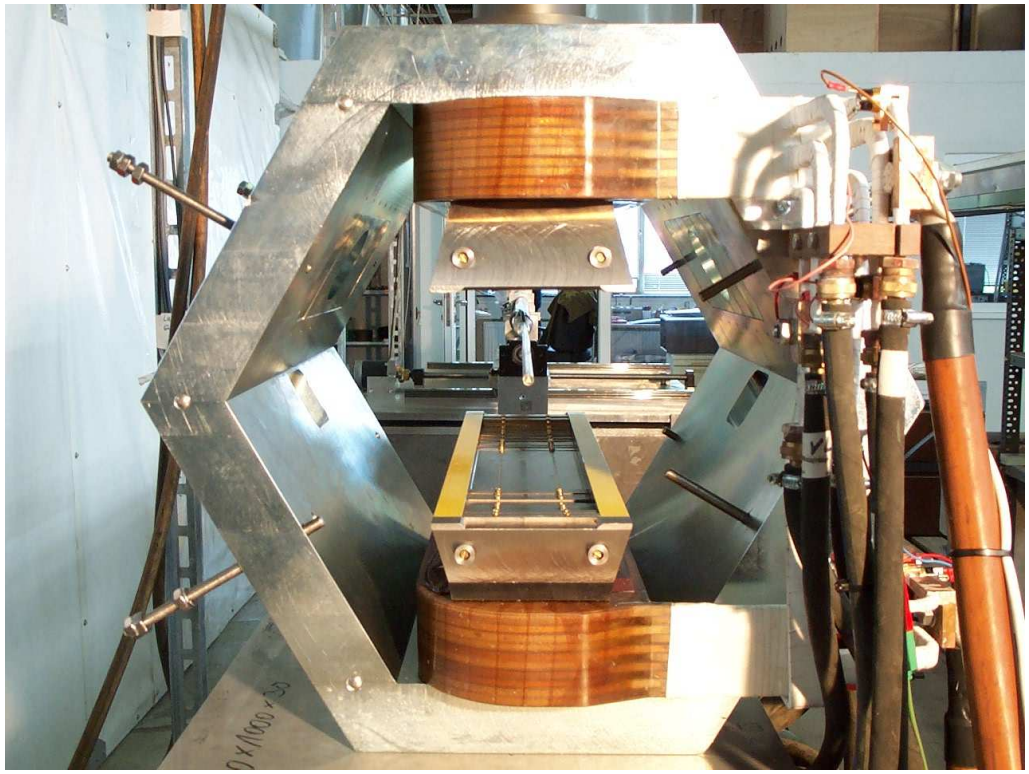




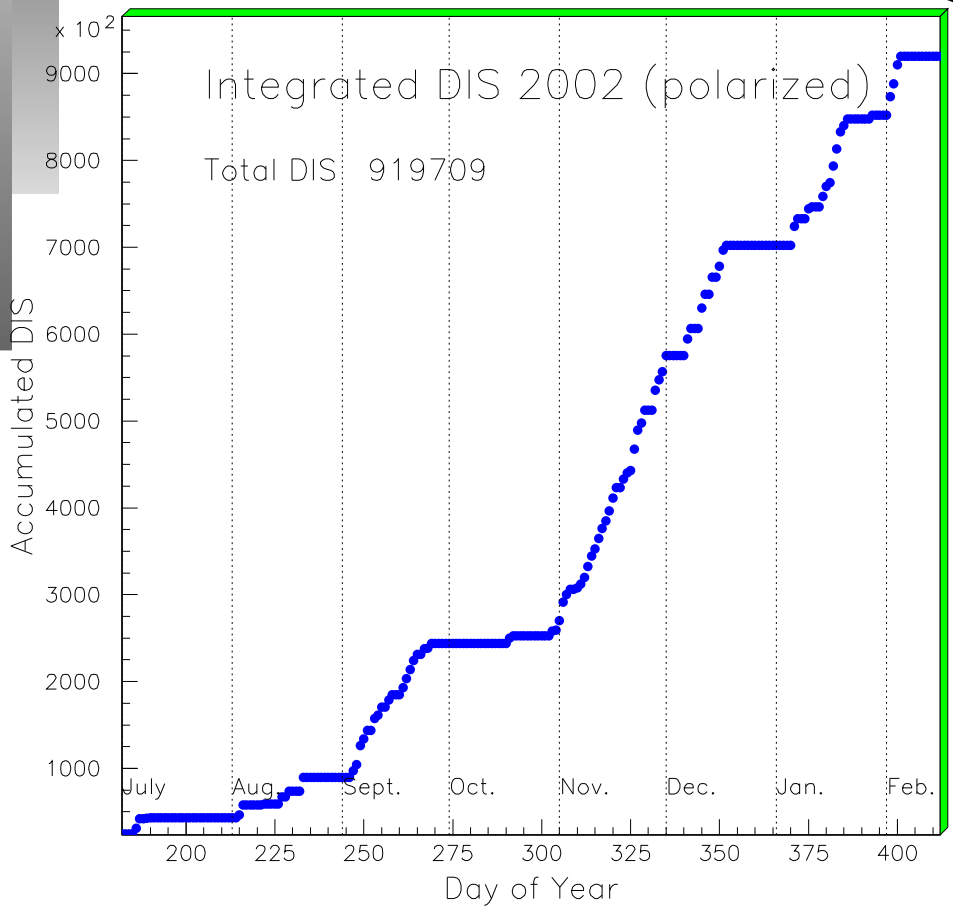
Gamberg et al. HEP-PH/0301018

New Target Magnet for HERMES

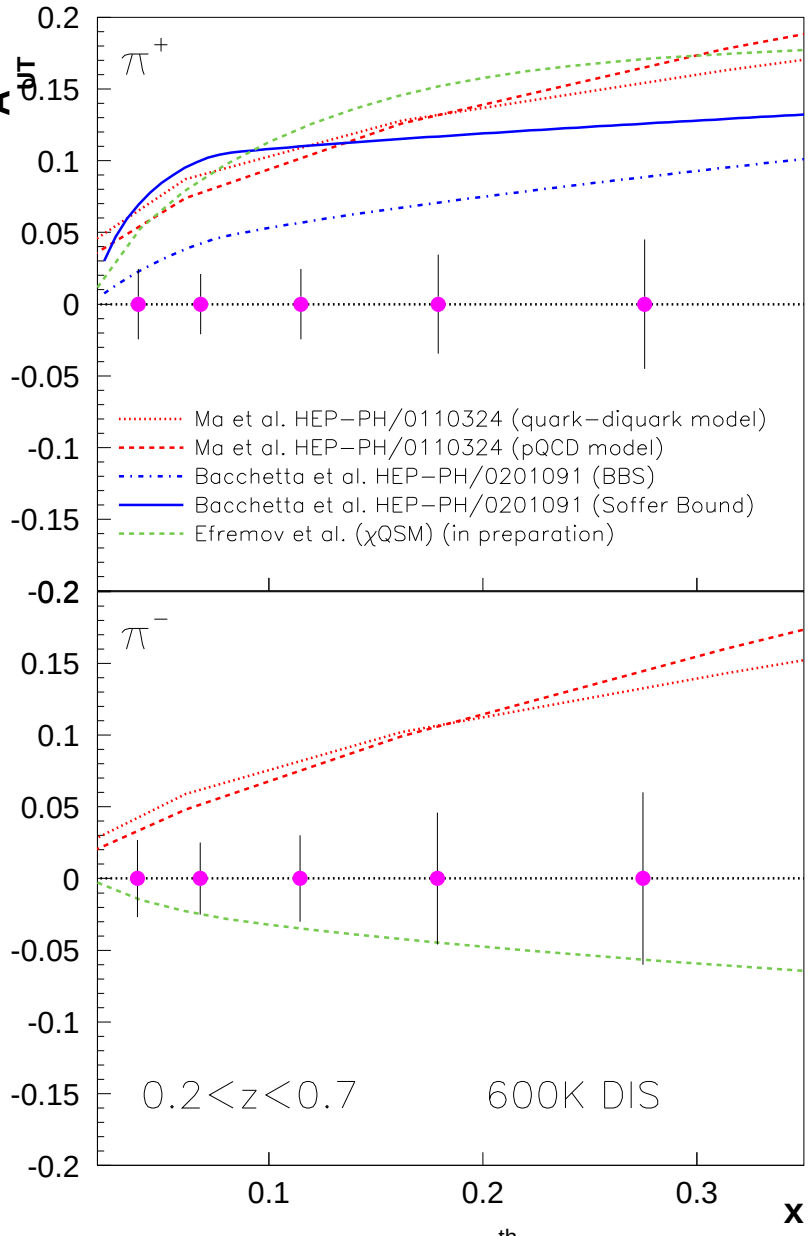


- **Transverse target ($B = 0.295T$)**
- **High uniformity along beam direction: $\Delta B \leq 4.5 \cdot 10^{-5} T$**
- **Transversely polarized hydrogen**
- **Target polarization around 75%**

Data Taking in 2002/03



Before Data Quality Cuts



Future Data Taking

- additional data taking starting 2^{nd} half of 2003
- detector upgrade (Λ-Wheels)

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

  - 2-Meson-Correlations

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  - Spin-1/2 Fragmentation (transverse Λ polarization)

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- 2-Meson-Correlations
- Spin-1 Fragmentation
- Spin-1/2 Fragmentation (transverse Λ polarization)

- polarized beam $\Rightarrow A_{LT}$ in π production (measurement of twist-3 fragmentation function and transversity)

Extracting Quark Distributions – Purity Formalism

$$A_{UT}^{\sin\phi,h}(x) = \frac{\int dy\, S_T B(y)}{\int dy\, C(y)} \frac{\sum_q e_q^2\, h_1^q(x) \int dz\, H_1^{\perp,q,h}(z,Q^2)\mathcal{A}(x,Q^2,z)}{\sum_{q'} e_{q'}^2\, f_1^{q'}(x) \int dz\, D_1^{q',h}(z,Q^2)\mathcal{A}(x,Q^2,z)}$$

$$= \mathcal{C} \cdot \sum_q \frac{e_q^2\, f_1^q(x)\, \mathcal{H}_1^{\perp q,h}(z,Q^2,x)}{\sum_{q'} e_{q'}^2\, f_1^{q'}(x)\, \mathcal{D}_1^{q',h}(z,Q^2,x)} \cdot \frac{h_1^q}{f_1^q}(x)$$

$$= \mathcal{C} \cdot \sum_q \mathcal{P}_q^h(x) \cdot \frac{h_1^q}{f_1^q}(x)$$

- purities are completely unpolarized objects $\rightarrow$ present MC-tunes can be used
- probabilistic interpretation of purities possible
- these purities still depend on parametrization of Collins function
- easier: Sivers $\leftarrow$ fragmentation function (D_1) known

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Summary

- HERMES has taken data with a transversely polarized hydrogen target
- Presently more than 600k DIS events after data quality cuts
- Transverse Asymmetries $\Rightarrow$ disentangle Sivers and Collins contributions
- Purity formalism $\Rightarrow$ extraction of quark distributions $f_{1T}^{\perp,q}$ and h_1^q ($q = u, d$)
- $p_\perp$-weighted asymmetries
- ...