Status and Prospects of the Transverse Target Run at HERMES

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For the hermes Collaboration
Polarized Beam at HERA

- 27.5 GeV $e^+/e^-$ beam
- Self-polarizing through Sokolov-Ternov-Effect
- Average beam polarization of about 55%
• Internal storage cell: pure gas target
• Forward acceptance spectrometer: $40 \text{ mrad} \leq \Theta \leq 220 \text{ mrad}$
• Tracking: 57 tracking planes: $\frac{\delta P}{P} = (0.7 - 1.3)\%$, $\delta \Theta \leq 0.6 \text{ mrad}$
• 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 ...)

\[ \langle p_T \rangle \approx 0.90 \]
Functions Surviving on Integration over Transverse Momenta

- The others are sensitive to intrinsic $<k_t>$ in the nucleon & in the fragmentation process

**Distribution Functions**

- $f_1 = \text{.....}$
- $g_{1L} = \text{.....}$
- $h_{1T} = \text{.....}$
- $f_{1T} = \text{.....}$
- $g_{1T} = \text{.....}$
- $h_{1L} = \text{.....}$
- $h_{1T} = \text{.....}$

**Fragmentation Functions**

- $D_1 = \text{.....}$
- $G_{1L} = \text{.....}$
- $H_{1T} = \text{.....}$
- $D_{1T} = \text{.....}$
- $G_{1T} = \text{.....}$
- $H_{1L} = \text{.....}$
- $H_{1T} = \text{.....}$
The Need for Semi-Inclusive Measurements

- $h_1$ chiral odd
  ⇒ not accessible in inclusive DIS
  ⇒ need some sort of quark polarimetry

- $k_\perp$-dependent distribution functions
  (besides $f_1, g_1, h_1$)
  ⇒ vanish when integrating over $k_\perp$ (i.e. inclusive DIS)
  ⇒ need to access $k_\perp$-dependence

Azimuthal Single Spin Asymmetries in Semi-Inclusive DIS
Single Spin Asymmetries

\[ e^p \rightarrow e' \pi X \]

study azimuthal distribution of \( \pi \)'s:

\[
A(\phi) = \frac{1}{\langle P \rangle} \cdot \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}
\]

with transversely polarized target:

( unpolarized beam )

\[
A_{\text{UT}}^{\sin \Phi} \propto \frac{\sum_q e_q^2 h_q^q(x) H_{1,-q}^1(z)}{\sum_q e_q^2 f_1^q(x) D_q^1(z)}
\]

\( \Phi = \phi + \phi_S \) Collins angle
**Single Spin Asymmetries**

\[ e^p \uparrow \rightarrow e' \pi X \]

study azimuthal distribution of $\pi$'s:

\[ A(\phi) = \frac{1}{\langle P \rangle} \cdot \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)} \]

with transversely polarized target:

(unpolarized beam)

\[ A^{\sin \Phi}_{UT} \propto \sum_q e_q^2 h_1^q(x) H_1^{\perp q}(z) \]

with longitudinally polarized target:

\[ A^{\sin \Phi}_{UL} \propto \ldots \]

\( \Phi = \phi \) Collins angle
SSA on Longitudinal Polarized Target

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

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

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

Longitudinally polarized in experiment (along beam direction)

$L/T$ polarized in theory (along virtual gamma direction)
transverse component $S_T$ of target spin (w.r.t. virtual photon):

$$S_T \propto \sin \Theta \gamma \approx \frac{2 M x}{Q} \sqrt{1 - y} \approx 0.15$$

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

$$\langle \sin \phi \rangle_{UL} \sim \frac{1}{Q} \sum_{q} e_q^2 (h_{L}^{q}(x) H_{1}^{\perp(1),q}(z) - \frac{1}{z} h_{1L}^{\perp(1),q}(x) \tilde{H}(z))$$
**SSA on Longitudinal Polarized Target**

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

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

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

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

$$\langle \sin \phi \rangle_{UT} \sim \sum_q e_q^2 h_1^q(x) H_{1}^{(1),q}(z) \quad \text{but} \quad S_T \sim \frac{1}{Q} \quad \text{like twist-3}$$
SSA on Longitudinal Polarized Target

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

$$S_T \propto \sin \Theta \gamma \approx \frac{2 M x}{Q} \sqrt{1 - y} \sim 0.15$$

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

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

$$\langle \sin \phi \rangle_{UT} \sim \sum_q e_q^2 \left( h_1^q(x) H_{1T}^{(1),q}(z) \right)$$

Collins

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

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
  \[
  \langle \sin(\phi_h^l - \phi_s^l) \rangle \text{ moment}
  \]
  \[
  f_{1T}^{\perp,q}(x)
  \]

- Collins
  \[
  \langle \sin(\phi_h^l + \phi_s^l) \rangle \text{ moment}
  \]
  \[
  h_1^{\perp,q}(x), \ H_1^{\perp,q}(z)
  \]

Additionally: \[
\langle \sin(3\phi_h^l - \phi_s^l) \rangle \text{ moment} \Rightarrow h_{1T}^{\perp,q}(x), \ H_1^{\perp,q}(z)
\]
New Target Magnet for HERMES

- Transverse target ($B = 0.295T$)
- Transversely polarized hydrogen
- Target polarization above 80%
Ongoing Data Taking

- Presently: \( \simeq 500 \text{K DIS events} \)
- Goal (March 2003): 1.3M DIS

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Gunar Schnell (DESY), HERMES Collaboration

ESOP Topical Workshop on SSA – Amsterdam, December 13th, 2002
Beyond March 2003

- additional data taking
- detector upgrade ($\Lambda$-Wheels)

Additional statistics allows analysis of different channels to access transversity:

- 2-Meson-Correlations
- Spin-1 Fragmentation ($\rho$)
- Spin-1/2 Fragmentation (transverse $\Lambda$ polarization)

- polarized beam $\Rightarrow$ BSA in $\pi$ production
  (measurement of twist-3 fragmentation function and transversity)
Extracting Quark Distributions – Purity Formalism

\[ A_{UT}^{\sin \phi, h}(x) = \frac{\int dy S_T(1 - y) \sum_q e_q^2 h_1^q(x) \int dz H_{1,q,h}^1(z, Q^2) A(x, Q^2, z)}{\int dy \frac{1 + (1 - y)^2}{2} \sum_q e_q^2 \int dz D_{1,q,h}^q(z, Q^2) A(x, Q^2, z)} \]

\[ = C \cdot \sum_q e_q^2 f_1^q(x) \cdot H_{1,q,h}^1(z, Q^2, x) \cdot \frac{h_1^q}{f_1^q}(x) \]

\[ = C \cdot \sum_q P_q^h(x) \cdot \frac{h_1^q}{f_1^q}(x) \]

- purities are completely unpolarized objects → actual MC-tunes can be used
- probabilistic interpretation of purities possible
- these purities still depend on parametrization of Collins function
- easier: Sivers ← fragmentation function \((D_1)\) known
Summary

- HERMES is taking data with transversely polarized hydrogen target
- Spring 2003: 1.3 Million recorded DIS events feasible
- Transverse Asymmetries ⇒ disentangle Sivers and Collins contributions
- Purity formalism ⇒ extraction of quark distributions $f_{1T}^{q}$ and $h_{1}^{q}$ ($q = u, d$)
- ...