Azimuthal Single-Spin Asymmetries on a Transversely Polarized Hydrogen Target at HERMES

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For the hermes Collaboration
Deep Inelastic Scattering

use well-known probe to study hadronic structure

$$Q^2 \overset{\text{lab}}{=} 4EE' \sin^2 \left( \frac{\Theta}{2} \right)$$

$$\nu \overset{\text{lab}}{=} E - E'$$

$$W^2 \overset{\text{lab}}{=} M^2 + 2M\nu - Q^2$$

$$y \overset{\text{lab}}{=} \frac{\nu}{E}$$

$$x \overset{\text{lab}}{=} \frac{Q^2}{2M\nu}$$

$$z \overset{\text{lab}}{=} \frac{E_h}{\nu}$$

Factorization $\Rightarrow \sigma^{ep\rightarrow ehX} = \sum_q DF^{p\rightarrow q} \otimes \sigma^{eq\rightarrow eq} \otimes FF^{q\rightarrow h}$
**Azimuthal Single-Spin Asymmetries**

\[ ep \longrightarrow e' \pi X \] — study azimuthal distribution of \( \pi \)'s:

(Transversely polarized target & Unpolarized beam)

\[
A_{UT}(\phi, \phi_S) = \frac{1}{\langle S_\perp \rangle} \cdot \frac{N^+ (\phi, \phi_S) - N^- (\phi, \phi_S)}{N^+ (\phi, \phi_S) + N^- (\phi, \phi_S)}
\]

\[
\sim \sin \Phi_C \cdot \sum_q e_q^2 \mathcal{I}\left[h_{1T}^q(x, p_T^2) \cdot H_{1T}^q(z, k_T^2)\right]
\]

\[
+ \sin \Phi_S \cdot \sum_q e_q^2 \mathcal{I}\left[f_{1T}^{\perp q}(x, q_T^2) \cdot D_{1T}^q(z, k_T^2)\right]
\]

\[ + \ldots \]

\( \Phi_C = \phi + \phi_S \) Collins angle

\( \Phi_S = \phi - \phi_S \) Sivers angle

\( \mathcal{I}[\ldots] \): convolution integral over initial \((p_T)\) and final \((k_T)\) quark transverse momenta
Resolving the Convolution Integral

A priori transverse momentum dependence not known
\[ \rightarrow \] can not resolve convolution without model assumptions
\[ \Rightarrow \] weight with transverse hadron momentum \( P_{h\perp} \):

\[
A_{UT}(\phi, \phi S) = \frac{1}{\langle S_{\perp} \rangle} \cdot \frac{\sum_{i=1}^{N^+} P_{h\perp,i}(\phi, \phi S) - \sum_{i=1}^{N^-} P_{h\perp,i}(\phi, \phi S)}{N^+(\phi, \phi S) + N^-(\phi, \phi S)}
\]

\[
\sim \sin \Phi_C \cdot \sum_q e_q^2 h_1^{q}(x) H_1^{(1),q}(z)
\]

\[
+ \sin \Phi_S \cdot \sum_q e_q^2 f_{1T}^{(1),q}(x) D_1^{q}(z)
\]

\[
+ \ldots
\]

(1) \( p_T^2/k_T^2 \)-moment of distribution / fragmentation function
• Internal storage cell: pure gas target
• Forward acceptance spectrometer: $40 \text{ mrad} \leq \Theta \leq 220 \text{ mrad}$
• Tracking: 57 tracking planes: $\delta P/P = (0.7 - 1.3)\%$, $\delta \Theta \leq 0.6 \text{ mrad}$
• PID: Cherenkov (RICH after 1997), TRD, Preshower, Calorimeter
• Transverse target magnet \( (B = 0.295 T) \)

• High uniformity along beam direction: \( \Delta B \leq 4.5 \cdot 10^{-5} T \)

• Transversely polarized hydrogen

• Target polarization around 75%
Effects of Transverse Target Magnet

- transverse target field deflects beam
  ⇒ installed compensating magnets up- and downstream of target
- target field also deflects detected particles
  ⇒ reconstructed vertex kinematics change
  ⇒ implemented tracking correction
no significant difference between resolutions with and without magnet (using TMC2)
detection of $\pi$’s from exclusively produced vector mesons:

$$E_\pi < E_\rho = E_{\gamma^*}$$
$$\leftrightarrow z_\pi < 1$$

$$E_\rho = E_{\gamma^*}$$
$$\leftrightarrow z_\rho = 1$$

$\pi$’s from exclusive VM misidentified as $\pi$’s from fragmentation
Contamination of SIDIS Sample

- GEANT based detector simulation
- PYTHIA physics generator tuned for HERMES
- radiative effects included
- identify $\pi$’s from exclusive processes ($\rho^0$, $\omega$)

small contribution for $z < 0.7$
Asymmetry Transfer from exclusive Vector Meson

π’s can have similar azimuthal distribution as parent VM

cross transfer

contamination ⊗ VM asymmetry ⊗ asymmetry transfer

Gunar Schnell, HERMES Collaboration
**Preliminary Results (unweighted)**

\[ A_{UT} \sin \Phi \propto \mathcal{I} \left[ h_1 \cdot H_1^\perp \right] \]

\[ A_{UT} \sin \Phi \propto \mathcal{I} \left[ f_{1T}^\perp \cdot D_1 \right] \]

**HERMES PRELIMINARY**

not corrected for smearing and acceptance effects

8% scale uncertainty

\[ A_{UT} \sin (\phi + \phi_s) \pi^+ \]

**Collins** angle

\[ \pi^- \]

\[ \pi^0 \]

Maximum possible effect of exclusive vector mesons

\[ x_B \]

\[ z \]}
Preliminary Results ($P_{h\perp}$ weighted)

$$A_{UT}^{\sin \Phi} \propto h_1(x) \cdot H_{1}^{\perp(1)}(z)$$

HERMES PRELIMINARY not corrected for smearing and acceptance effects

PH not weighted

8% scale uncertainty

Maximum possible effect of exclusive vector mesons

$A_{UT}^{\sin \Phi} \propto f_{1T}^{\perp(1)}(x) \cdot D_1(z)$
Conclusion and Outlook

- First HERMES data with transversely polarized target
- Effects of Target Magnet on tracking under control
- Contribution of decay particles of exclusive VM have to be considered
- First measurement of Sivers asymmetry
- Collins asymmetry sizeable
- more data coming
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