Transversity Measurements at HERMES From Single Spin Asymmetries to Transverse Quark Distributions

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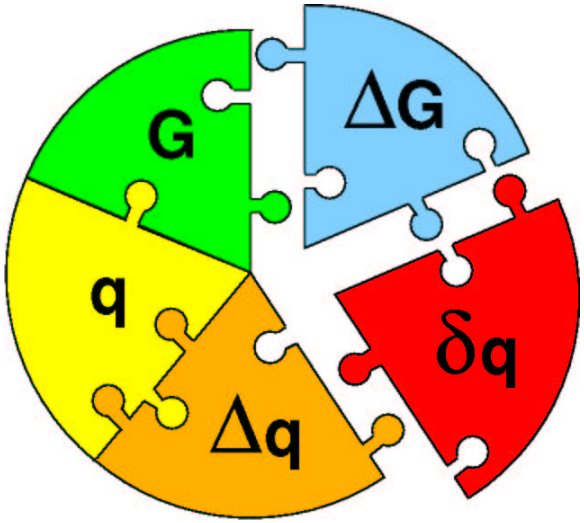
on behalf of the hermes Collaboration



HERMES 1995-2000

Longitudinally polarized target

$\swarrow$ $\qquad$ $\searrow$

Δq $\qquad$ (ΔG)

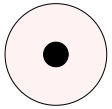
Now: Transversely polarized target

$\Longrightarrow$ **measure remaining quark distribution:** δq

up to now unmeasured

Twist-2 Quark Distribution Functions

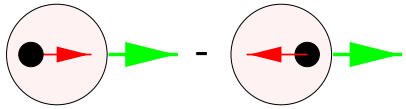
Unpolarized quarks in unpolarized nucleons

f_1^q = 

$\Longrightarrow$ **q(x): spin averaged (well known)**

HERMES 1995-2000

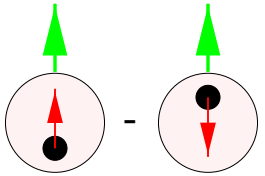
Longitudinally polarized quarks in longitudinally polarized nucleons

g_1^q = 

$\Longrightarrow$ **Δq(x): helicity difference (known)**

HERMES 2002...

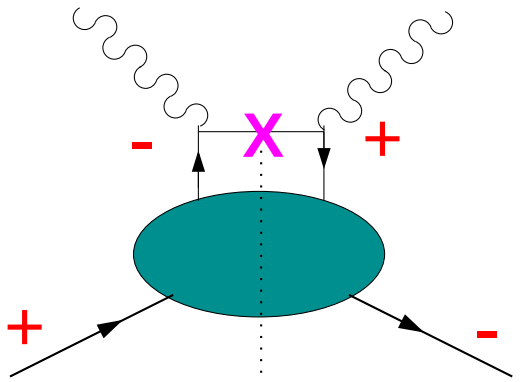
Transversely polarized quarks in transversely polarized nucleons

h_1^q = 

$\Longrightarrow$ **δq(x): helicity flip (unmeasured)**

Transversity

- Non-relativistic quarks: $\Delta q(x) = \delta q(x)$
  $\Rightarrow \delta q$ probes relativistic nature of quarks
- $\delta q(x)$ charge conjugation odd $\Rightarrow$ valence quarks
- δq does not mix with gluons $\Rightarrow$ different Q^2 evolution for g_1 and h_1
- obvious bound: $|\delta q(x)| \leq q(x)$, Soffer bound: $|\delta q(x)| \leq \frac{1}{2}[q(x) + \Delta q(x)]$
- Sum Rule: first moment $\rightarrow$ tensor charge reliably calculable in lattice QCD:
  $\delta\Sigma = \sum_f \int_0^1 dx(\delta q_f - \delta\bar{q}_f) = 0.562 \pm 0.088$
  (at $Q^2 = 2GeV^2$)



- transverse quark distributions CHIRAL ODD

$\hookrightarrow$ No Access In Inclusive DIS

Transversity Measurements

How can one measure transversity? **Need another chiral-odd object!**

Semi-Inclusive DIS $\longrightarrow$ HERMES with transversely polarized target

$$\sigma^{ep\to ehX} = \sum_q f^{H\to q} \otimes \sigma^{eq\to eq} \otimes D^{q\to h}$$

$\Downarrow$ **chiral-odd** **DF**

$\Downarrow$ **chiral-odd** **FF**

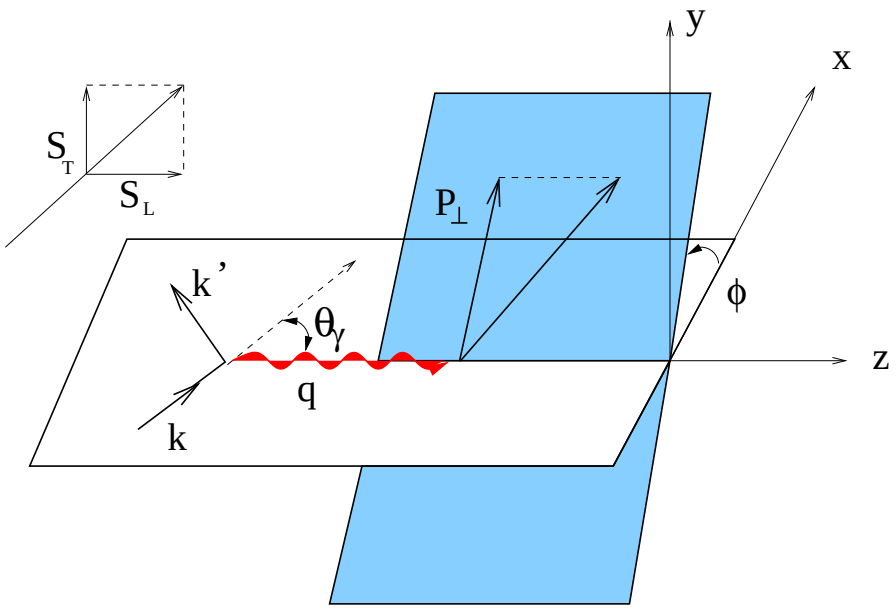
1. $ep^{\uparrow} \longrightarrow e'\pi(k_{\perp})X$
2. $ep^{\uparrow} \longrightarrow e'\Lambda^{\uparrow}X$
3. $ep^{\uparrow} \longrightarrow e'\pi\pi X$

$\Leftarrow$ **Favoured process** $\Rightarrow$ **Signature:**
Single Spin Azimuthal Asymmetry

1. Collins,93, Kotzinian,95, Mulders et al,96
2. Baldracchini,82, Jaffe,96
3. Jaffe et al,97

Single Spin Azimuthal Asymmetries

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



study azimuthal distribution of π's:

$$A^{\sin\Phi} = \frac{\frac{L^+}{L_P^+}\sum_{i=1}^{N^+}\sin\Phi_i - \frac{L^-}{L_P^-}\sum_{i=1}^{N^-}\sin\Phi_i}{\frac{1}{2}(N^+ + N^-)}$$

with transversely polarized target:

$$A_T^{\sin\Phi} \propto \frac{\sum_q e_q^2 \delta q(x) H_1^{\perp,q}(z)}{\sum_q e_q^2 q(x) D_1^q(z)}$$

$P_\perp$: π **transverse momentum**

$\Phi = \phi + \phi_s^l$ **Collins angle**

$H_1^\perp(z)$ **Collins fragmentation function**
(T-odd, chiral odd)

Single Spin Asymmetries at HERMES

HERMES 1996/97: longitudinal polarized proton target

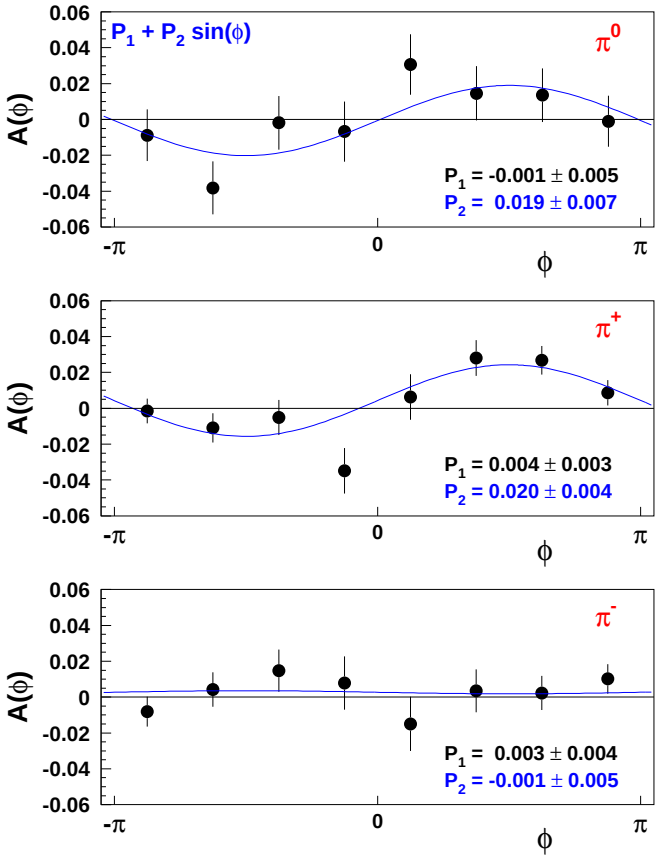
transverse component S_T of target spin:

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

$\Rightarrow$ **glimpse on transversity?!**

Longitudinal target SSA:

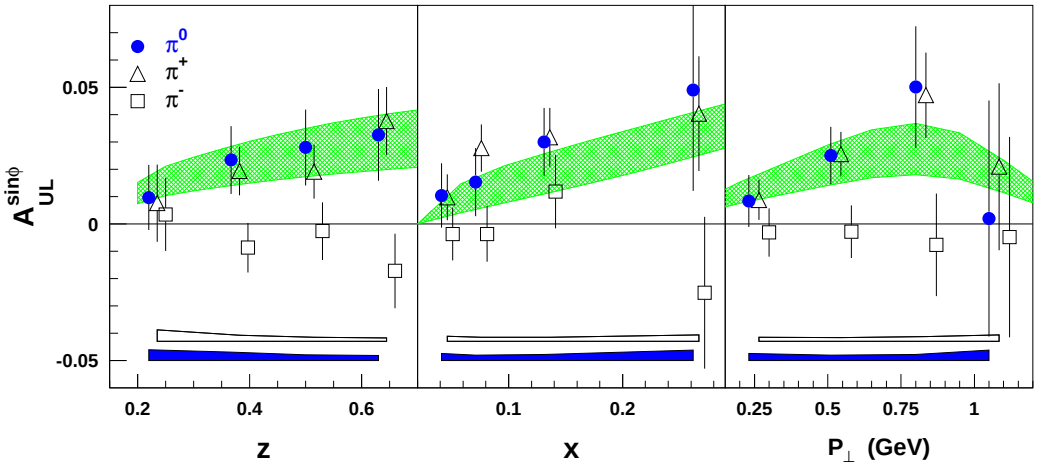
$$A_{UL}(\phi) = \frac{1}{\langle P \rangle} \cdot \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$



SSA with longitudinal polarized target

$$\langle \sin\phi \rangle_{UL} \propto \mathbf{S_L} \frac{2(2-y)}{Q\sqrt{1-y}} \sum_q e_q^2 x h_L^q(x) H_1^{\perp,q}(z) + \mathbf{S_T}(1-y) \sum_q e_q^2 x h_1^q(x) H_1^{\perp,q}(z)$$

Indication from LEP $\Rightarrow |\frac{H_1^\perp}{D_1}| \simeq 6.3 \pm 1.7\%$

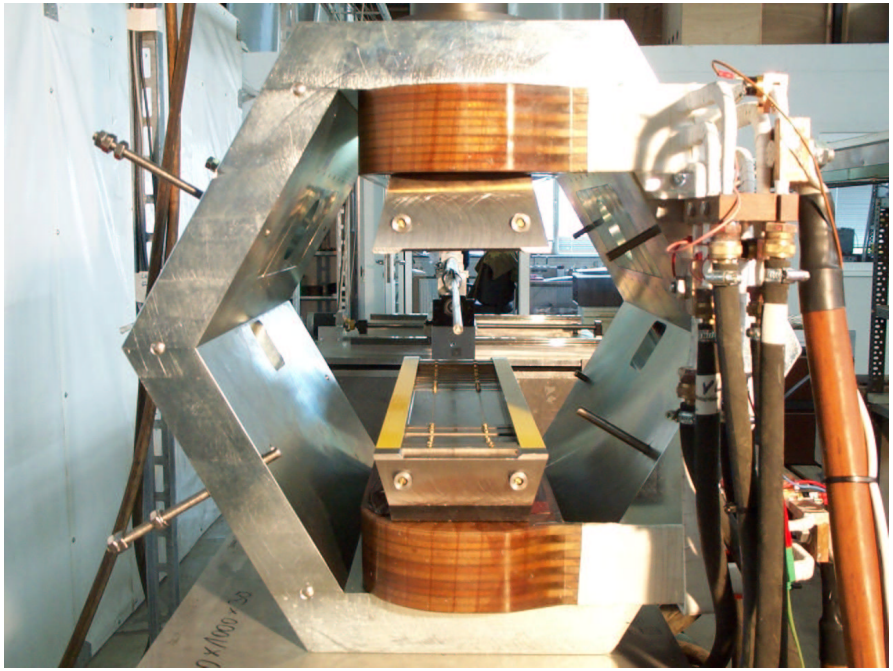


HERMES: hep-ex/0104005, hep-ex/9910062

- **Larger for π^+, π^0 than for π^- (u-quark dominance in case of proton target)**
- **Peak around $x = 0.3$ (valence quark dominance)**
- **Grow with $p_\perp$ and peak around $1GeV$ (dominant role of intrinsic $k_\perp$)**

HERMES runs Transverse

$\Rightarrow$ **New Target Magnet**



- $B = 0.295T$ **field**
- **High uniformity along beam direction:** $\Delta B \leq 4.5 \cdot 10^{-5} T$
- **Uniformity along** x**- and** y**-direction:** $\Delta B \leq 6.5 \cdot 10^{-4} T$
- **Correction coil has been designed in case of need**
- **Target polarization above 80%**

Transversity Measurement at HERMES

- **study π^+ production from a transversely polarized proton target**

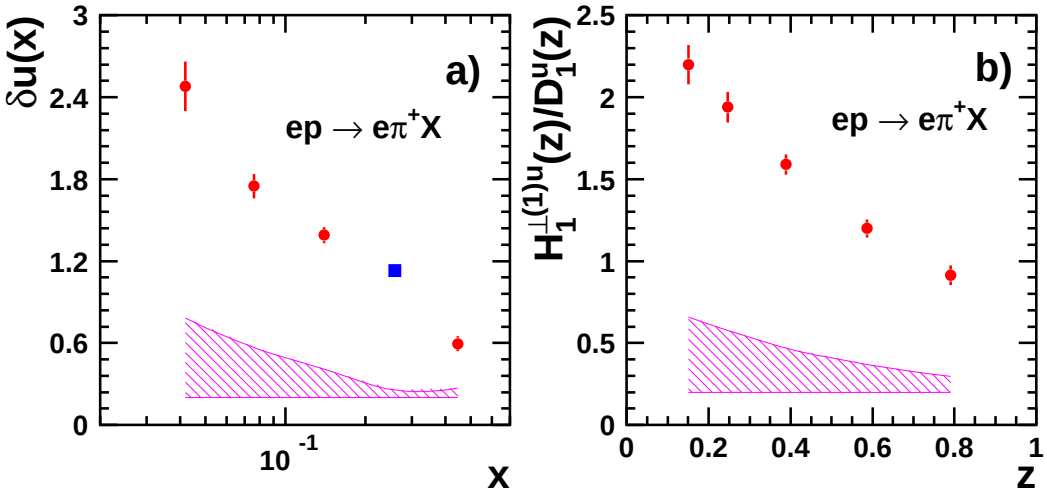
$\Rightarrow$ **exploit u-quark dominance :** $A_T^{\pi^+} \propto \frac{\delta u(x)}{u(x)} \cdot \frac{H_1^{\perp,u}(z)}{D_1^u(z)}$

- **$\delta u(x)$ and $H_1^\perp(z)$ unknown, but factorize in x and z!**

$\Rightarrow$ **can extract shape but need normalization**

- **use** $\delta q(x_0) = \Delta q(x_0)$ **at** $x_0 = 0.25$ **for relative normalization**

Expected Precision



- **Transversely polarized proton target**
- $P_T = 0.75$
- **Statistics: 7 Million DIS (about 2 years of running)**

Final Comments

- **running with transversely polarized deuterium $\Rightarrow$ access to $\delta u + \delta d$**
- **$H_1^{\perp,q}(z)$ measured at e^+e^- removes normalization ambiguity**
- **other possibilities to probe transversity at HERMES**

HERMES ready to take data on a transversely polarized proton target

$\Downarrow$

HERMES will make first measurement of transverse u-quark distribution

- **first data on exclusive reactions with transversely polarized target**
- **continue program of unpolarized physics with high luminosity "end-of-fill" runs**