

Azimuthal single-spin asymmetries on a transversely polarized hydrogen target at HERMES



For the HERMES collaboration

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Contents

- Quark distribution functions
- Single-spin asymmetries in 1-hadron semi-inclusive DIS
- Single-spin asymmetries in 2-hadron semi-inclusive DIS
- Conclusion, outlook

Quark distribution functions



At leading twist

Quark momentum distribution: $q(x) =$ 

Quark Helicity: $\Delta q(x) =$ 

Quark Transversity: $\delta q(x) =$ 

$\delta q(x)$: **unknown**
chiral odd

• quark's relativistic nature $\Rightarrow \delta q(x) \neq \Delta q(x)$

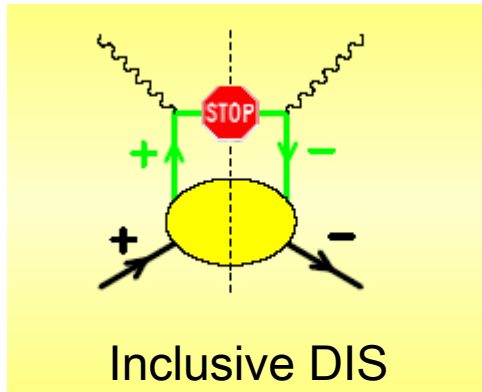
• positivity bound : $|\delta q(x)| \leq q(x)$

Soffer bound : $|\delta q(x)| \leq \frac{1}{2} [q(x) + \Delta q(x)]$

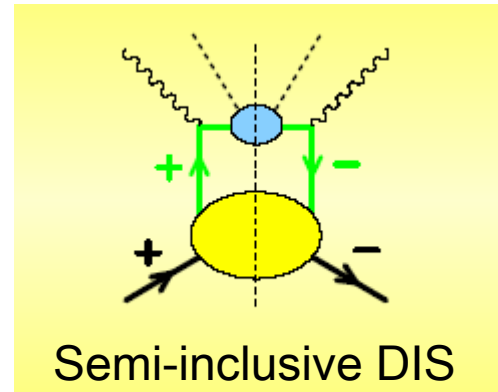
Access to transversity



$\delta q(x)$: chiral odd \Rightarrow Need another chiral odd objects.



Not accessible



accessible

Transversity couples to ...

- Collins fragmentation FF
- 2-hadron interference FF
- Polarized Lambda FF
- Spin-1 FF

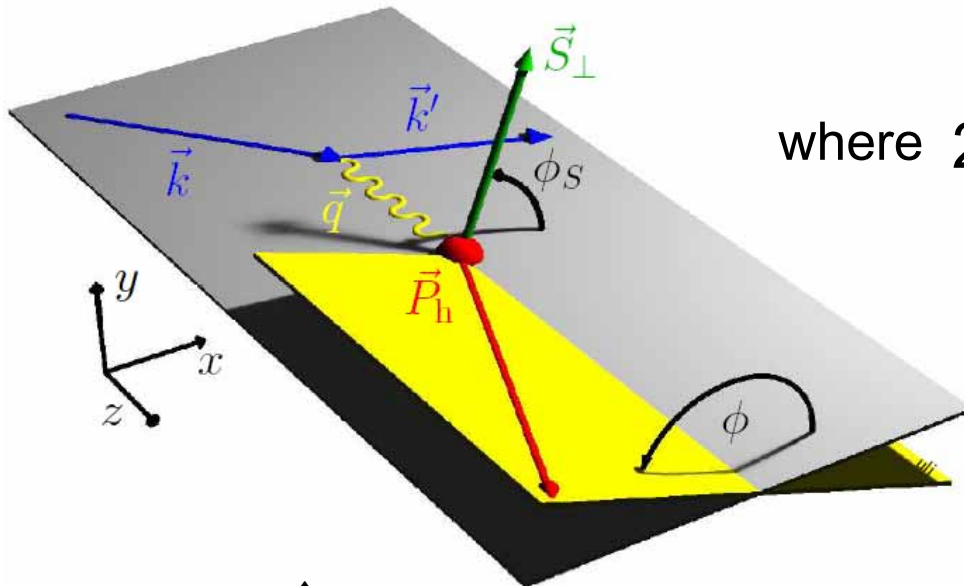
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1-hadron semi-inclusive DIS



Azimuthal single-spin asymmetries

$$A_{UT}(\phi, \phi_S) = \frac{1}{\langle S_T \rangle} \frac{N^\uparrow(\phi, \phi_S) - N^\downarrow(\phi, \phi_S)}{N^\uparrow(\phi, \phi_S) + N^\downarrow(\phi, \phi_S)} \stackrel{\text{fit}}{=} \frac{B(\langle y \rangle)}{A(\langle x \rangle, \langle y \rangle)} 2 \langle \sin(\phi + \phi_S) \rangle_{UT} \sin(\phi + \phi_S) + \dots$$



where $2 \langle \sin(\phi + \phi_S) \rangle_{UT} \sim \delta q(x) H_1^\perp(z)$

Transversity Collins FF

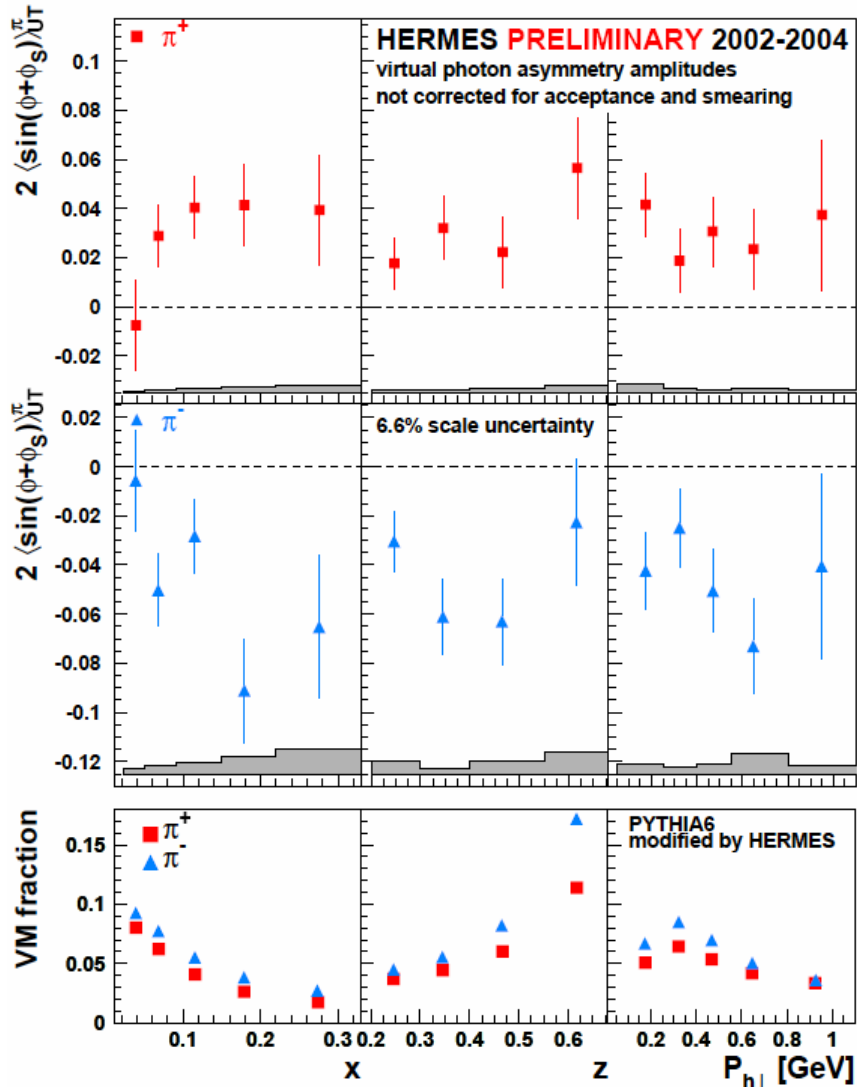
It's possible to extract $\delta q(x)$ using $H_1^\perp(z)$ measured by BELLE.

$$e(k) + p^\uparrow \rightarrow e(k') + h(P_h) + X$$

1-hadron semi-inclusive DIS



Collins asymmetry [A. Airapetian et al, Phys. Rev. Lett. 94 (2005) 012002]



- Significant asymmetries observed for π^+ and π^-
- Expected sign of the asymmetries
- Unexpected large asymmetry for π^-
- \longleftrightarrow role of disfavoured FF
- Contribution from exclusive vector meson is estimated with PYTHIA MC

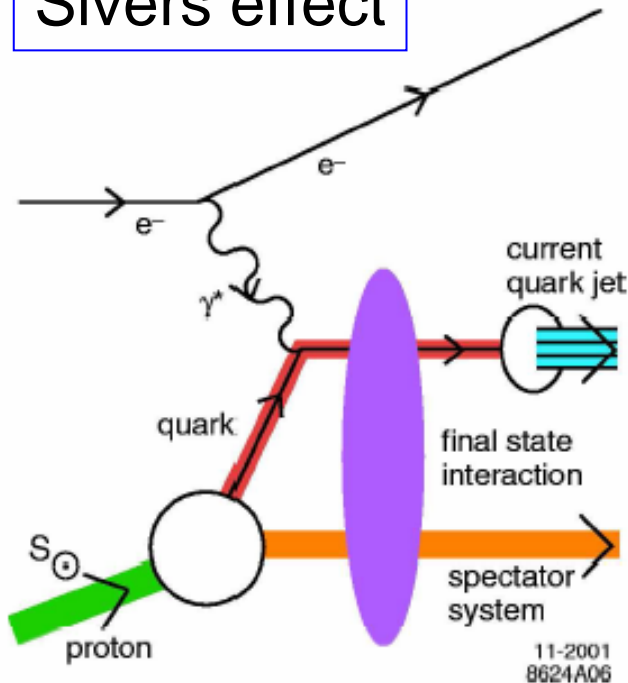
1-hadron semi-inclusive DIS



Azimuthal single-spin asymmetries

$$A_{UT}(\phi, \phi_S) = \frac{1}{\langle S_T \rangle} \frac{N^\uparrow(\phi, \phi_S) - N^\downarrow(\phi, \phi_S)}{N^\uparrow(\phi, \phi_S) + N^\downarrow(\phi, \phi_S)} \stackrel{fit}{=} \frac{B(\langle y \rangle)}{A(\langle x \rangle, \langle y \rangle)} 2 \langle \sin(\phi + \phi_S) \rangle_{UT} \sin(\phi + \phi_S) + 2 \langle \sin(\phi - \phi_S) \rangle_{UT} \sin(\phi - \phi_S) + \dots$$

Sivers effect



where $2 \langle \sin(\phi - \phi_S) \rangle_{UT} \sim f_{1T}^\perp(x) D_1(z)$

- **Sivers function** (naïve T-odd, chiral even) describes unpolarized quarks in transversely polarized nucleon:

$$f_{1T}^\perp(x) = \odot - \ominus$$

- Non-vanishing Sivers function requires quark orbital angular momentum L_q
- Azimuthal asymmetry can arise from quark rescattering via soft gluons

1-hadron semi-inclusive DIS



Sivers asymmetry [A. Airapetian et al, Phys. Rev. Lett. 94 (2005) 012002]

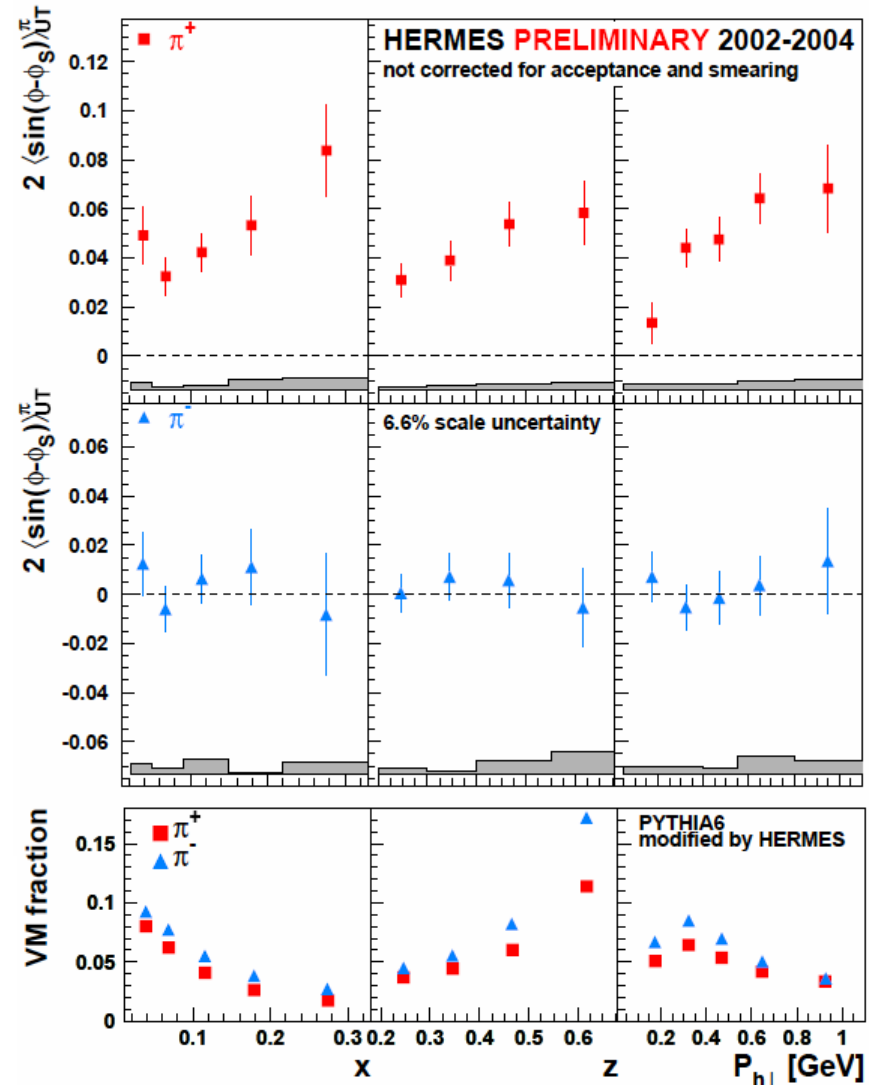
- π^+ asymmetry significantly positive

First evidence of T-odd Sivers distribution in DIS.



Indication of non-zero quark orbital angular momentum

- π^- asymmetry consistent with zero



2-hadron semi-inclusive DIS

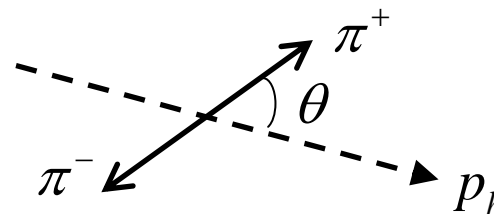
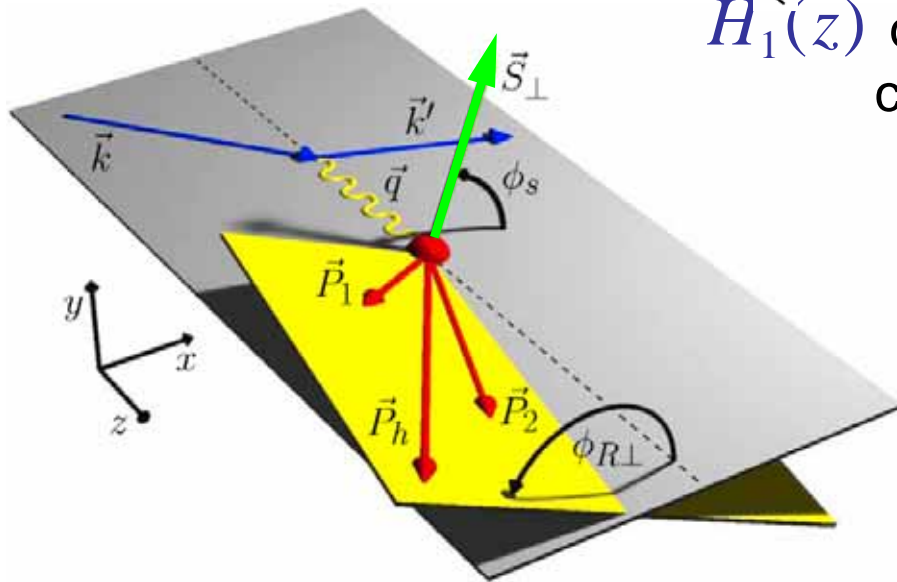


Azimuthal single-spin asymmetries

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

↑ Transversity ↑ Interference FF (chiral odd)

$H_1^{\Delta}(z)$ describes interference between pion pairs coming from different production channels.

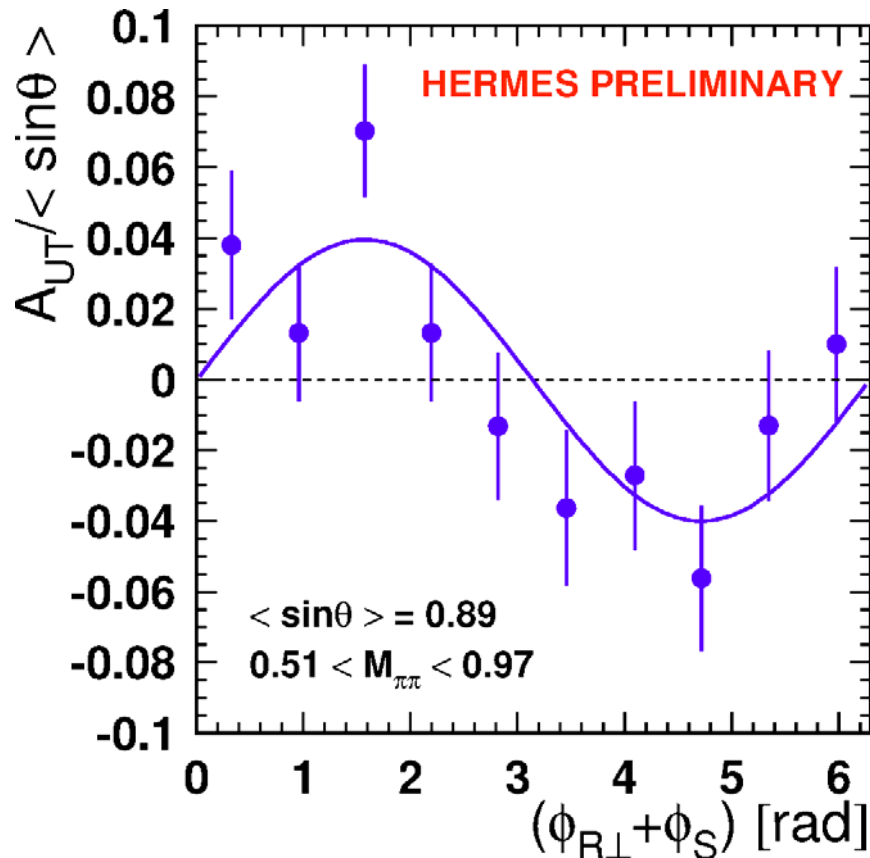


$$e(k) + p^{\uparrow} \rightarrow e(k') + \pi^+(P_1) + \pi^-(P_2) + X$$

2-hadron semi-inclusive DIS



Single-spin asymmetries



$0.51 < M_{\pi\pi} < 0.97$ GeV

First observation of transverse asymmetries in IFF

$$\text{Fit } \frac{A_{UT}}{\langle \sin\theta \rangle} \sim \sin(\phi_{R\perp} + \phi_S) \delta q H_1^{\triangleleft}$$

$$\text{with } a_0 + a_1 \sin(\phi_{R\perp} + \phi_S)$$

$$a_0 = 0.000 \pm 0.006$$

$$a_1 = 0.040 \pm 0.009$$



Amplitude of the asymmetry modulation

$$a_1 = 0.040 \pm 0.009_{\text{Stat}} \pm 0.003_{\text{Syst}}$$

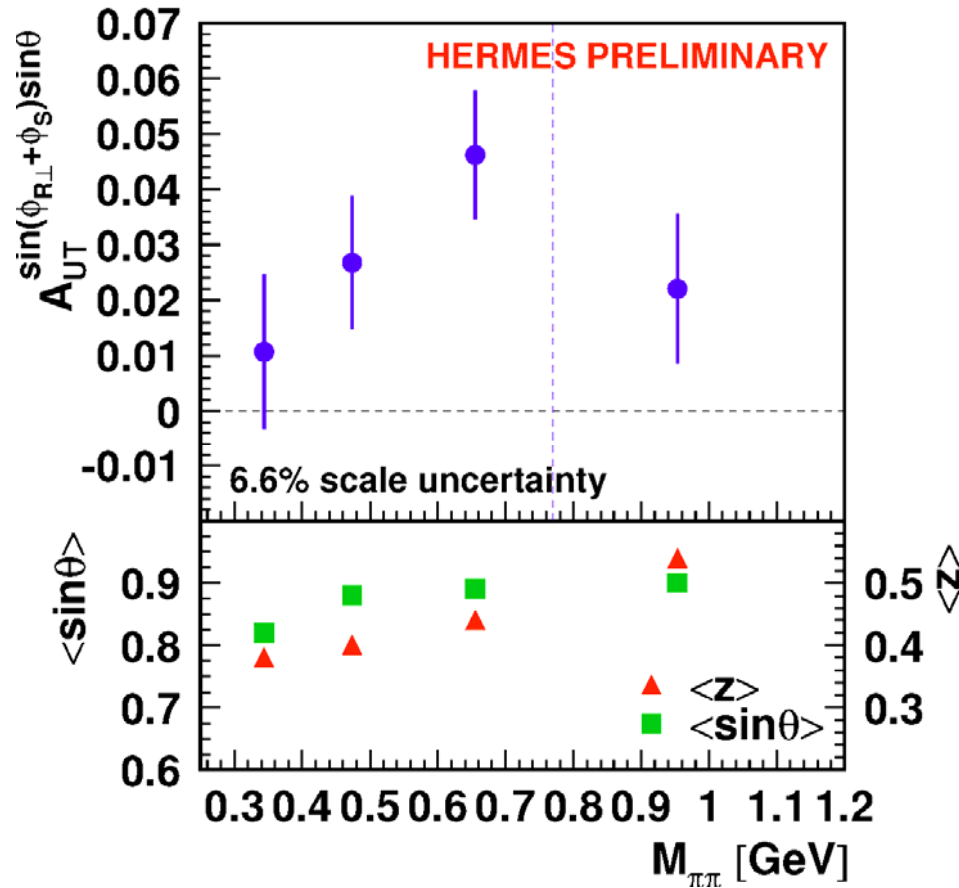
$$\delta q H_1^{\triangleleft} \neq 0$$

2-hadron semi-inclusive DIS



$M_{\pi\pi}$ dependence of $A_{UT}^{\sin(\phi_{R\perp} + \phi_S) \sin \theta}$

$M_{\pi\pi}$: invariant mass of pion pair



Asymmetry is fitted with

$$a_0 + a_1 \sin(\phi_{R\perp} + \phi_S) \sin \theta$$



$$A_{UT}^{\sin(\phi_{R\perp} + \phi_S) \sin \theta} = a_1$$

$M_{\pi\pi}$ binning : 0.25, 0.40, 0.55, 0.77, 2.0 [GeV]

Positive asymmetry is observed around $M_{\pi\pi} = M_{\rho 0}$

Conclusion



1-hadron semi-inclusive DIS

Collins asymmetry is measured

- Significant asymmetries observed for π^+ and π^-
- Large asymmetry for π^-

Significant role of disfavoured Collins FF

Sivers asymmetry is measured

- First evidence of T-odd Sivers distribution in DIS
- Significantly positive asymmetry for π^+

Indicates non-zero orbital angular momentum

2-hadron semi-inclusive DIS

- First observation of transverse asymmetries in IFF
- Positive asymmetry is observed for measured invariant mass range

Outlook



- 3.5 M DIS events in 2002~2004
- 3~4 M DIS events is expected in 2005 with transversely polarized target
- Asymmetries for π^0 and K^\pm are under study

