Transversity measurements at HERMES

Lepton scattering with polarization

Benedikt Zihlmann[1]

[1]Dept. Subatomic Physics
University of Gent

PANIC 2005

Outline

Transversity at HERMES

azimuthal single spin asymmetry

Transversity Results

one hadron final state $\rightarrow \delta q H_1^{\perp}$

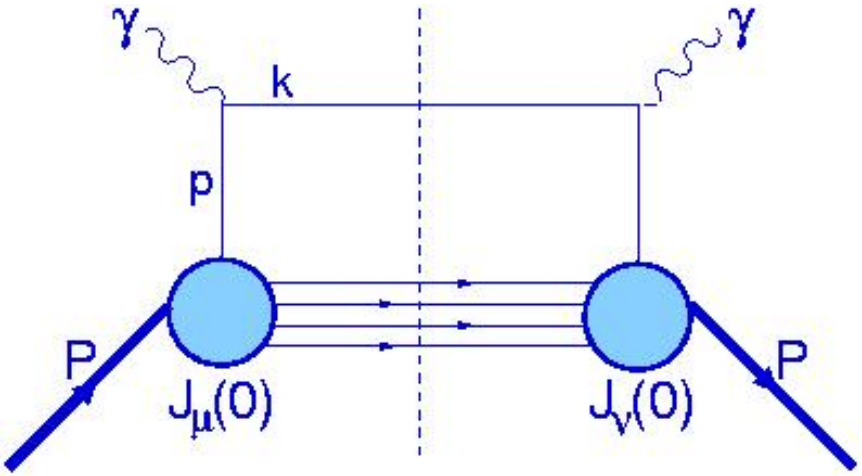
Two Hadron production

two hadron final state $\rightarrow \delta q H_1^{\sphericalangle}$

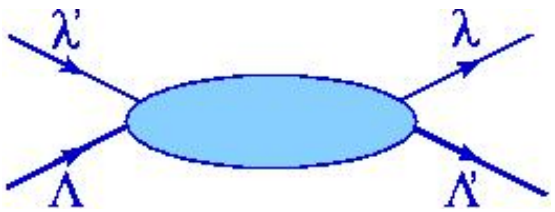
Outlook

Helicity amplitudes

The tool: Lepton scattering (DIS) Separate the scattering into a hard and soft part:



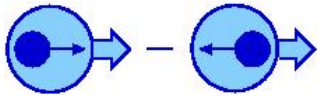
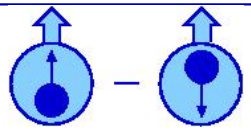
Helicity amplitude $A_{\Lambda\lambda,\Lambda'\lambda'}$



- describe soft processes with helicity amplitudes
- use helicity and parity conservation

3 independent amplitudes survive $A_{++,++}$, $A_{+-,+-}$ and $A_{+-,-+}$

Leading Twist Quark Distributions

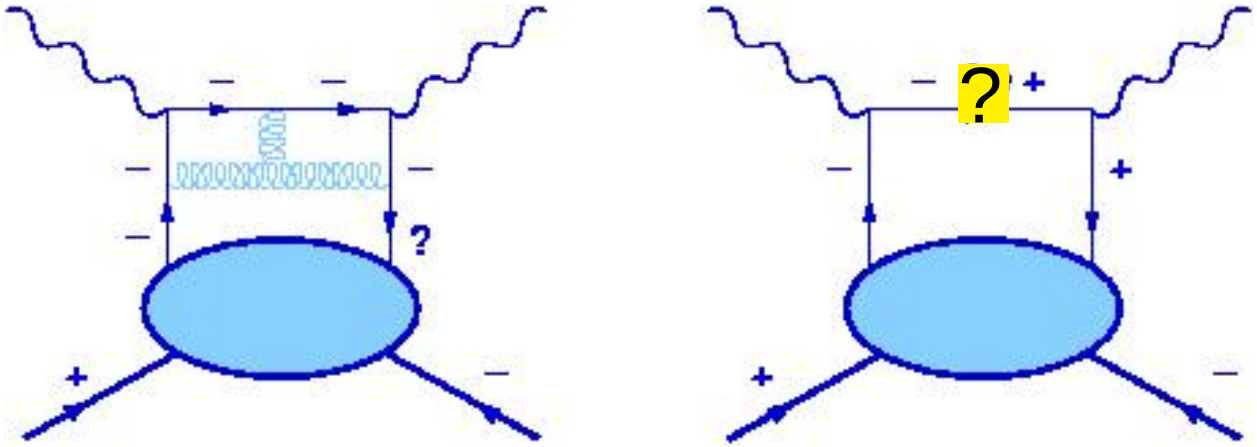
momentum distribution $q(x,Q^2)$	helicity distribution $\Delta q(x,Q^2)$	transversity distribution $\delta q(x,Q^2)$
forward quark-nucleon amplitudes: (in helicity basis)		
$\sim \mathrm{Im}\,(\mathbf{A}_{++,++} + \mathbf{A}_{+-,+-})$ measures spin average	$\sim \mathrm{Im}\,(\mathbf{A}_{++,++} - \mathbf{A}_{+-,+-})$ measures helicity difference	$\sim \mathrm{Im}\,(\mathbf{A}_{+-,-+})$ measures helicity flip
probabilistic interpretation:		
(in helicity basis)	 (in helicity basis)	 (in basis of transverse spin eigenstates)

$\Rightarrow$ complete description of quark momentum (**P**) and spin (**S**) :

$$\Phi(x) = \frac{1}{2}\left\{q(x,Q^2)\not{P} + \lambda_N \Delta q(x,Q^2)\gamma_5\not{P} + \delta q(x,Q^2)\not{P}\gamma_5 S_\perp\right\}$$

$\rightarrow$ The full picture of the nucleon needs transversity

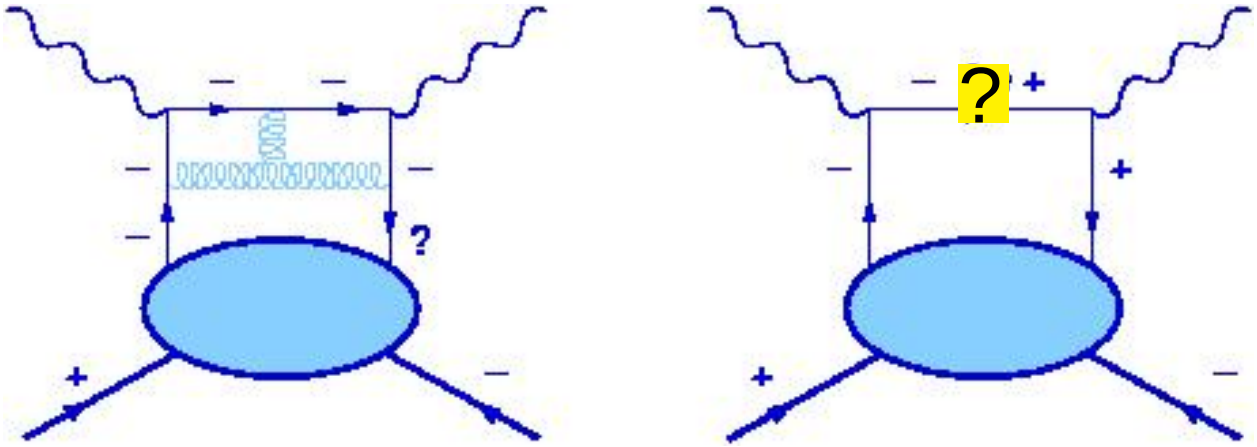
Transversity



- Transversity distribution is chiral-odd (helicity flip)
- DIS conserves helicity $O(\frac{m}{Q^2})$

$\Rightarrow$ need another chiral-odd function

Transversity



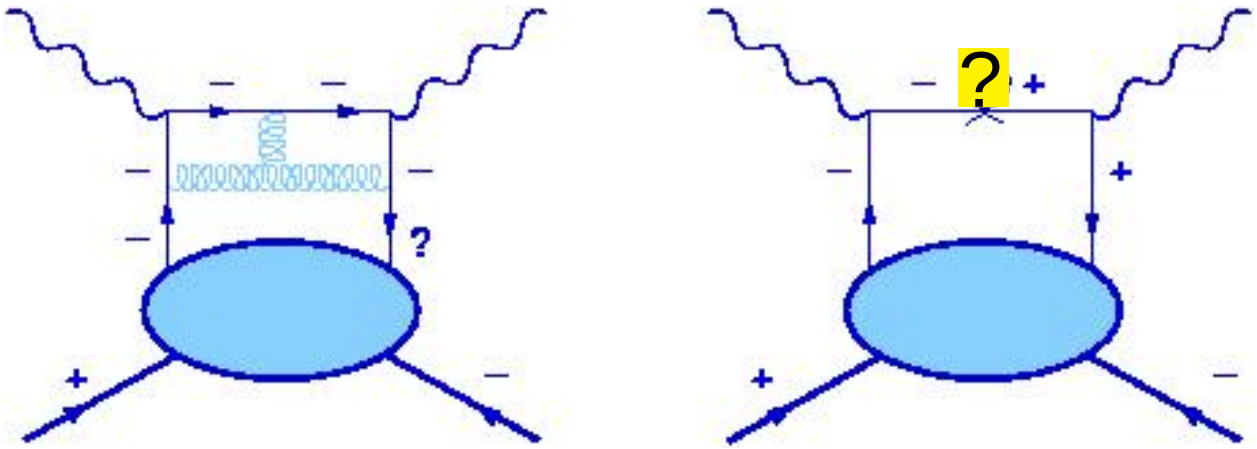
- Transversity distribution is chiral-odd (helicity flip)
- DIS conserves helicity $O(\frac{m}{Q^2})$

$\Rightarrow$ need another chiral-odd function

- In SIDIS: Collins fragmentation function $H_1^{\perp}(z, (-z\mathbf{k_T})^2)$

$\Rightarrow$ need semi inclusive processes (SIDIS)

Transversity



- Transversity distribution is chiral-odd (helicity flip)
- DIS conserves helicity $O(\frac{m}{Q^2})$

$\Rightarrow$ need another chiral-odd function

- In SIDIS: Collins fragmentation function $H_1^{\perp}(z, (-z\mathbf{k_T})^2)$

$\Rightarrow$ need semi inclusive processes (SIDIS)

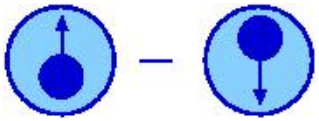
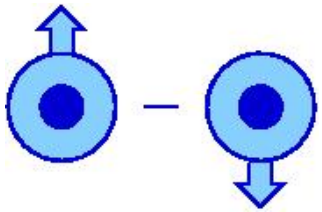
At HERMES

$$\delta q(x, Q^2) \times H_1^{\perp}(z, (-z\mathbf{k_T})^2)$$

accessible in azimuthal single spin asymmetries in SIDIS

Azimuthal single spin asymmetries

- Transversely polarized hydrogen target
- Single spin azimuthal asymmetry (SSA)
- Two combinations of DF and FF contribute
- Collins AND Sivers

Collins mechanism	Sivers mechanism
$\delta q(x, Q^2) \times H_1^{\perp}(z, (-z\mathbf{k_T})^2)$	$f_{1T}^{\perp}(x, p_T^2) \times D_1^{\perp q}$
fragmentation function	distribution function
	
chiral odd	chiral even
	implies non zero L^q
azimuthal single spin asymmetry	azimuthal single spin asymmetry

Azimuthal Asymmetries

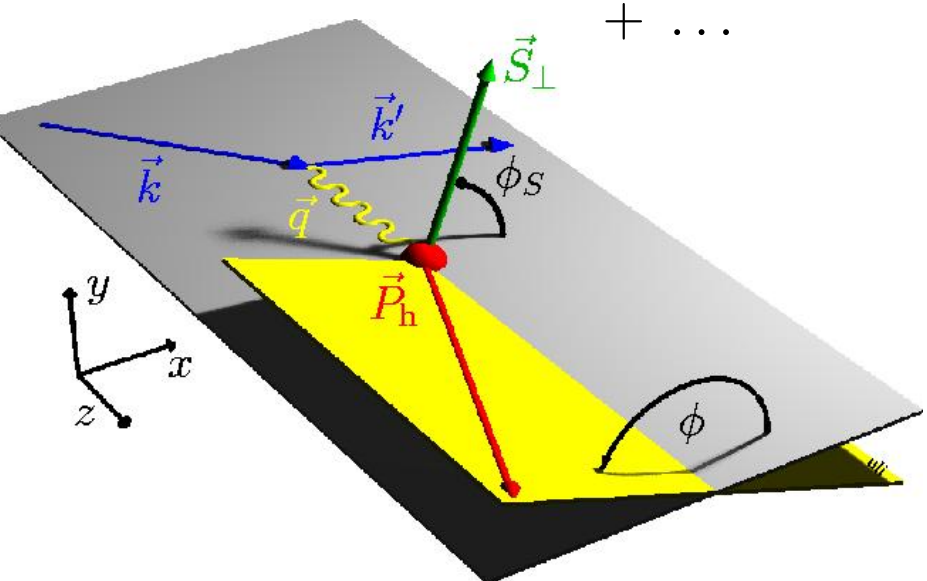
Measurement of cross section asymmetries depending on the azimuthal angles ϕ and ϕ_S

$$A_{UT}(\phi,\phi_S) = \frac{1}{S_\perp}\frac{N^\uparrow(\phi,\phi_S)-N^\downarrow(\phi,\phi_S)}{N^\uparrow(\phi,\phi_S)+N^\downarrow(\phi,\phi_S)}$$

$$\sim \ldots \sin(\phi+\phi_S)\sum_q e_q^2 \cdot \delta q(x) \cdot H_1^{\perp(1/2)\,q}(z)$$

$$+ \ldots \sin(\phi-\phi_S)\sum_q e_q^2 \cdot f_{1T}^{\perp(1/2)\,q}(x) \cdot D_1^q(z)$$

$$+ \ldots$$



Azimuthal Asymmetries

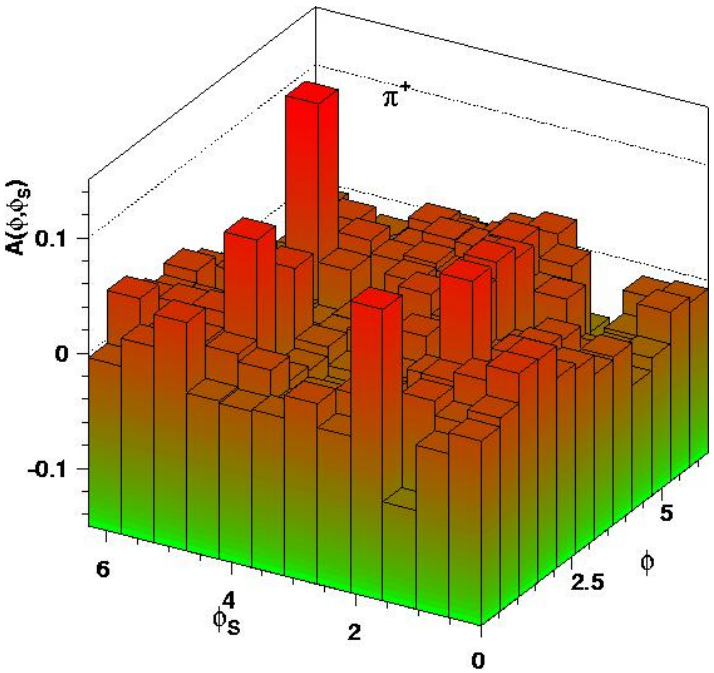
Measurement of cross section asymmetries depending on the azimuthal angles ϕ and ϕ_S

$$A_{UT}(\phi,\phi_S) = \frac{1}{S_\perp}\frac{N^\uparrow(\phi,\phi_S)-N^\downarrow(\phi,\phi_S)}{N^\uparrow(\phi,\phi_S)+N^\downarrow(\phi,\phi_S)}$$

$$\sim \ldots \sin(\phi+\phi_S)\sum_q e_q^2 \cdot \delta q(x) \cdot H_1^{\perp(1/2)\,q}(z)$$

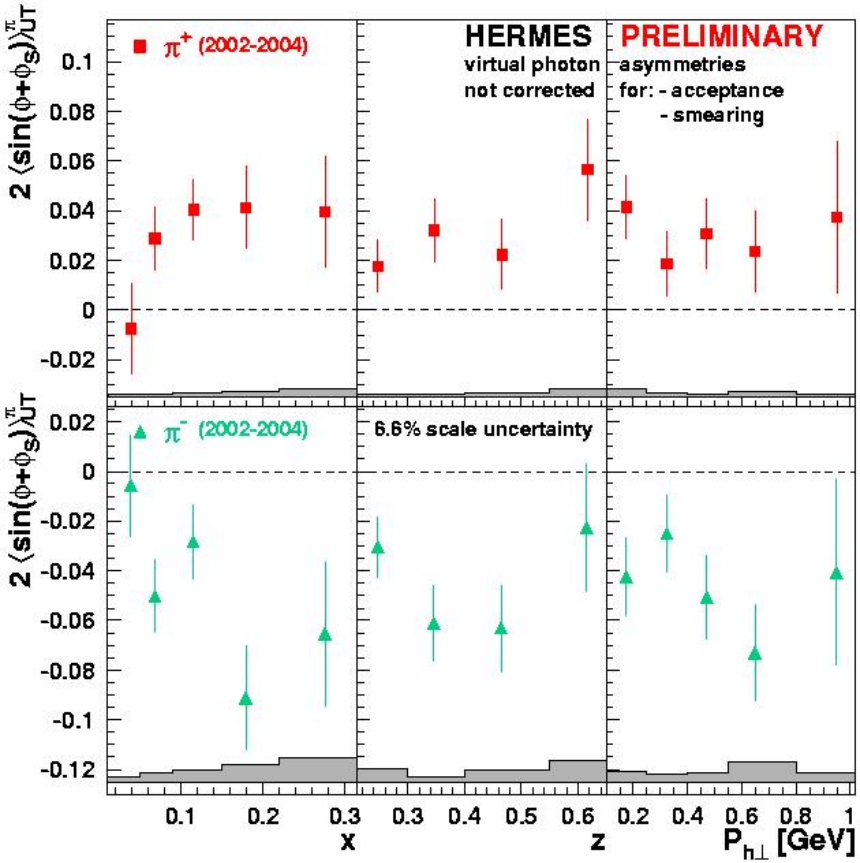
$$+ \ldots \sin(\phi-\phi_S)\sum_q e_q^2 \cdot f_{1T}^{\perp(1/2)\,q}(x) \cdot D_1^q(z)$$

asymmetry ampl. $A_{\mathrm{UT}}^{\sin(\phi+\phi_S)}$ and $A_{\mathrm{UT}}^{\sin(\phi-\phi_S)}$



bin $A_{\mathrm{UT}}(\phi,\phi_S)$ in 12×12 bins, perform two dimensional fit

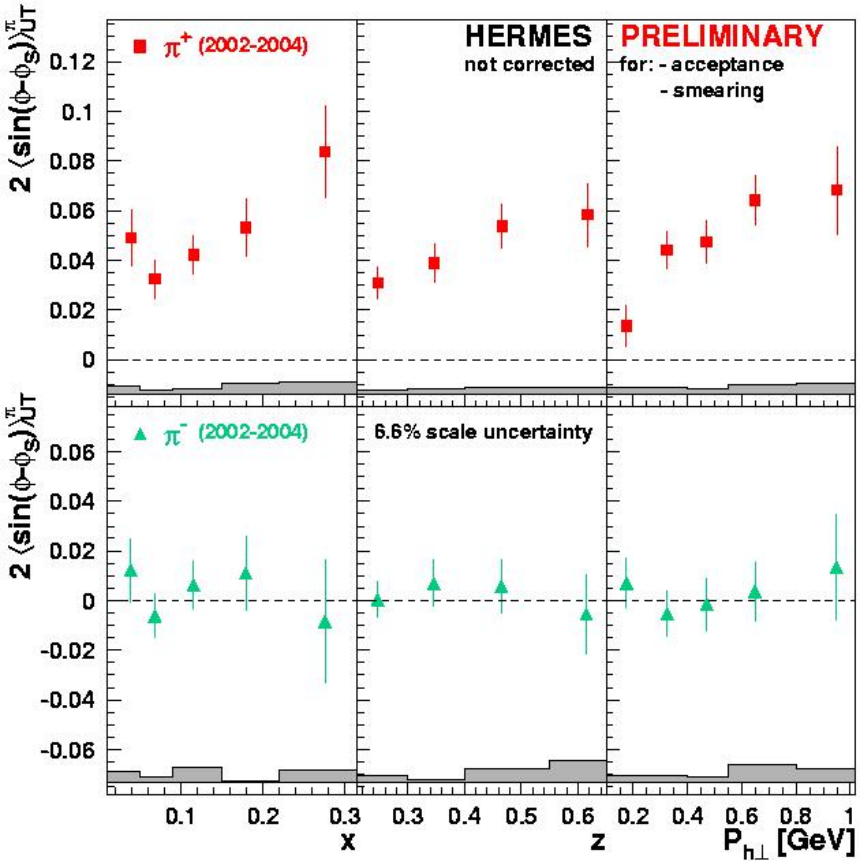
Unweighted Collins Moment



Results of 2002–2004 data

- Collins moment is positive for π^+ and negative for π^-.
- The large negative π^- moment is unexpected.
- unfavored FF same size opposite sign?
- Collins fragmentation function is needed
- BELLE data analyzed extraction of FF in progress
- Result is consistent with published Collins moments.

Unweighted Sivers Moment

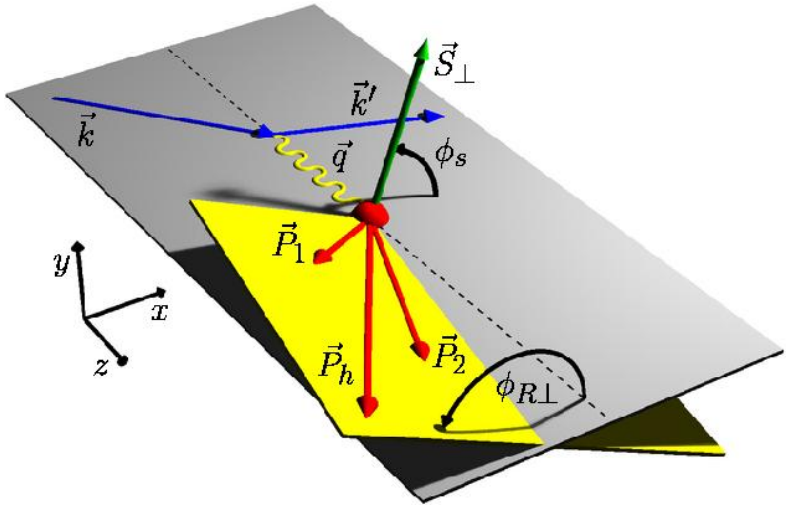


Results of 2002–2004 data:

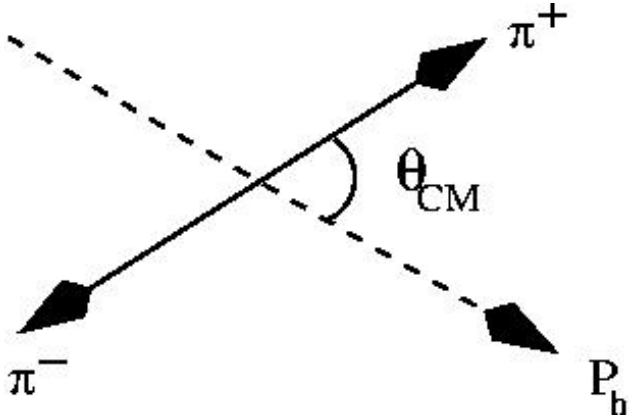
- Sivers moment is significantly positive for π^+ and implies a non-vanishing orbital angular momentum $\mathbf{L_z^q}$.
- Sivers moment for π^- is consistent with zero.
- fragmentation function known, extraction of Sivers function possible.
- Sivers function has opposite sign in Drell/Yan (QCD prediction)
- Result is consistent with published Sivers moments.

SSA with two hadrons on the proton

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



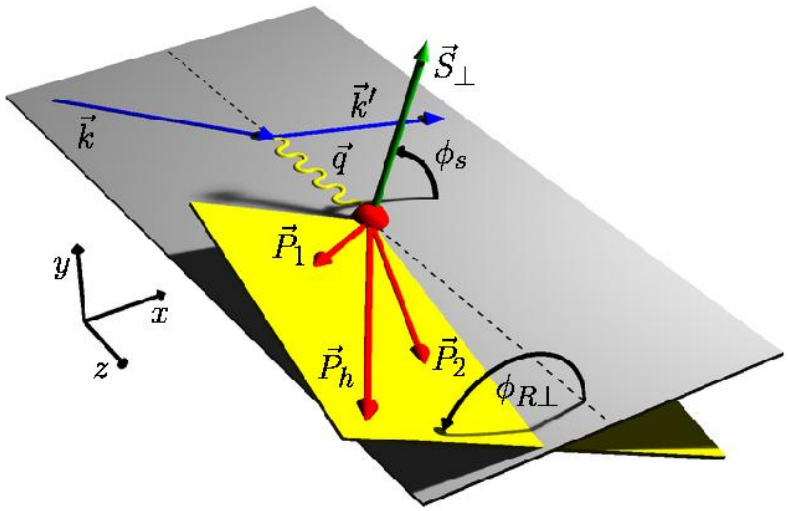
$$\vec{P}_h = \vec{P}_1 + \vec{P}_2$$



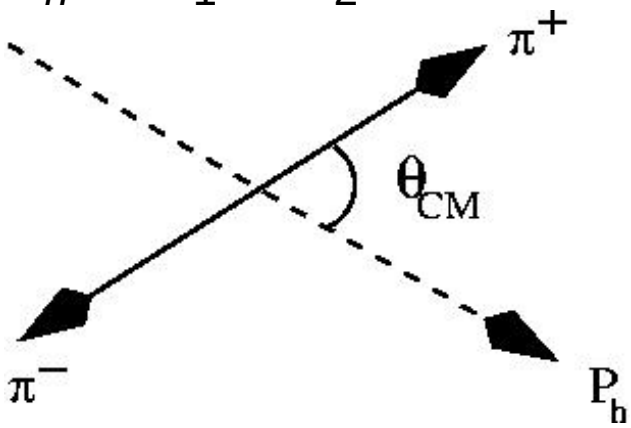
$$A_{UT}(\phi_{R\perp}, \phi_S, \theta) = \frac{1}{|S_T|}\frac{N^{\uparrow}(\phi_{R\perp}, \phi_S, \theta) - N^{\downarrow}(\phi_{R\perp}, \phi_S, \theta)}{N^{\uparrow}(\phi_{R\perp}, \phi_S, \theta) + N^{\downarrow}(\phi_{R\perp}, \phi_S, \theta)}$$

SSA with two hadrons on the proton

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



$$\vec{P}_h = \vec{P}_1 + \vec{P}_2$$



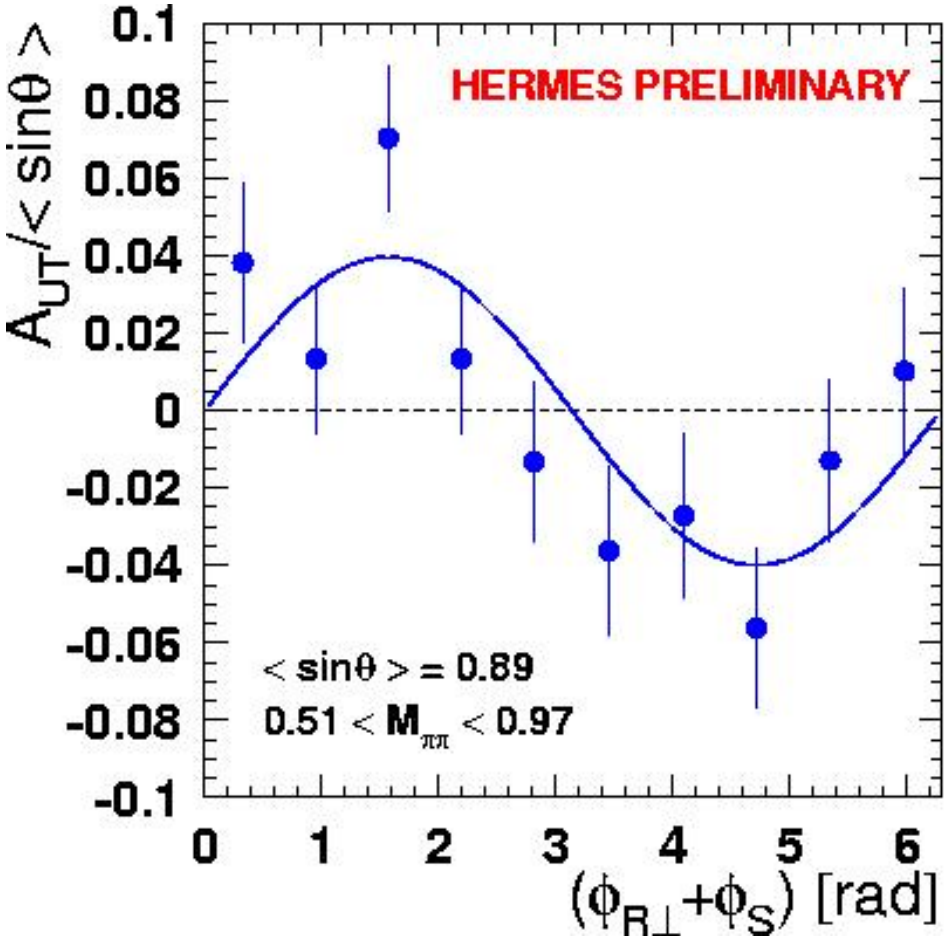
Another way to access δq

- two hadrons in the final state
- complementary process
- but new unknown fragmentation function

$$H_1^{\sphericalangle}(z, \cos(\theta), M^2_{\pi\pi}) = \underbrace{H_1^{\sphericalangle,sp}(z, M^2_{\pi\pi})}_{} + \cos(\theta)\underbrace{H_1^{\sphericalangle,pp}(z, M^2_{\pi\pi})}_{}$$

s- and p-wave interference of 2 pions

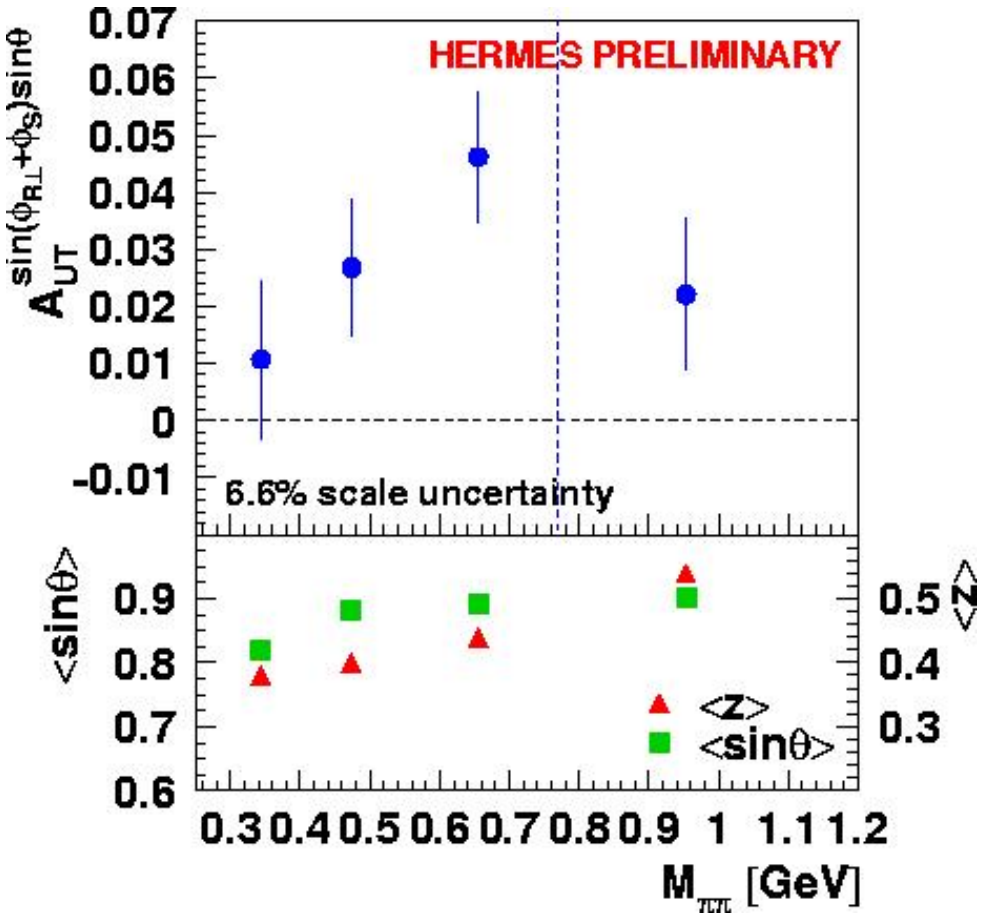
A_{UT} with two pions on Hydrogen



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

- Hydrogen target
- clear $\sin(\phi_{R\perp}+\phi_S)$ signal
- $A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin(\theta)} = 0.040 \pm 0.009(stat) \pm 0.003(sys)$

A_{UT} with two pions on Hydrogen

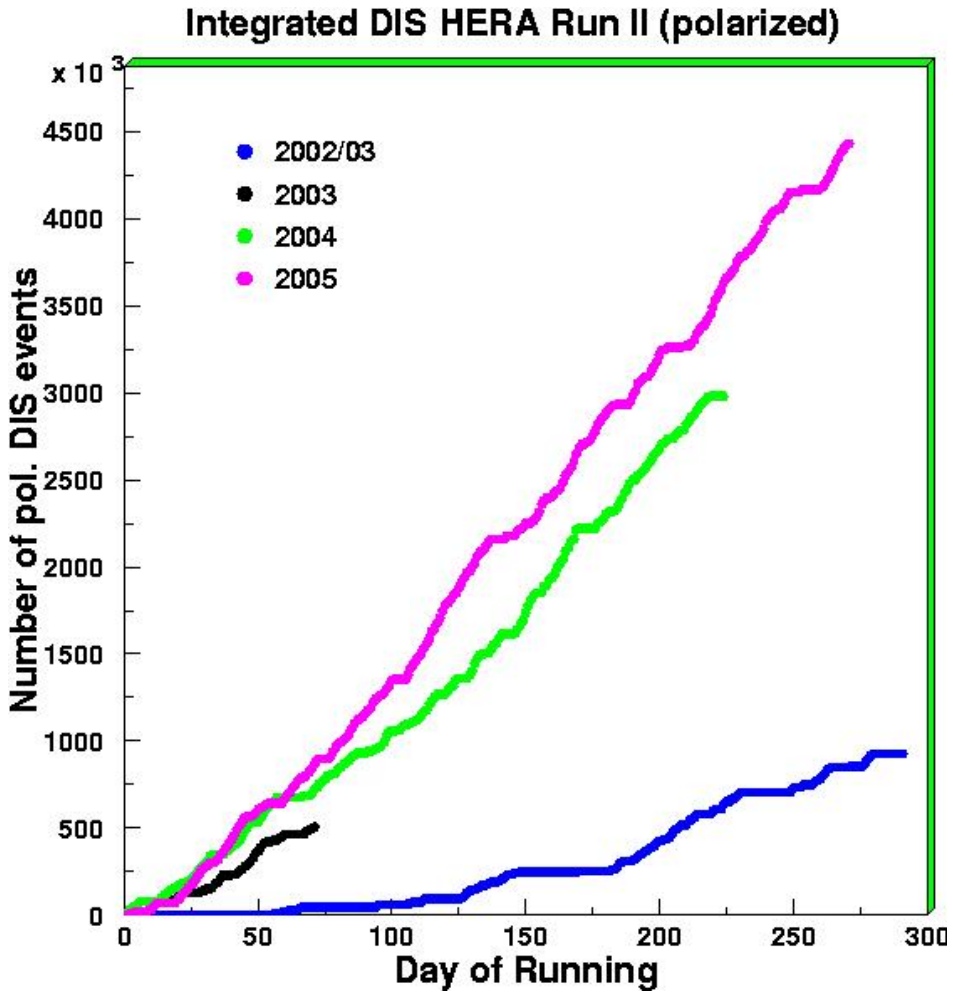


$A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin(\theta)}$

- Hydrogen target
- clear $\sin(\phi_{R\perp}+\phi_S)$ signal
- $A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin(\theta)} = 0.040 \pm 0.009(stat) \pm 0.003(sys)$
- positive signal for all mass bins
- bin center at average mass 0.25-0.4-0.55-0.77-2.0

HERMES Outlook

Current DIS statistics on transverse polarized Hydrogen target



Prospects

- results based on 3 Mil. DIS
- 2005 more than doubled statistics
- results on $K^{\pm}$ and π^{o} soon