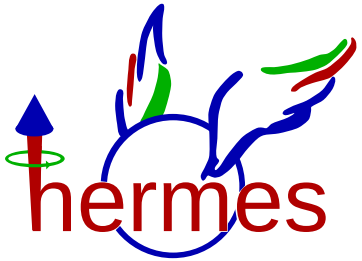
Single-spin asymmetry in interference fragmentation on a transversely polarized hydrogen target at HERMES



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Contents

- Transversity &
  Semi-inclusive DIS with transversely polarized target
- SSA in HERMES (data taking period : 2002~2004)
- Conclusion

Motivation

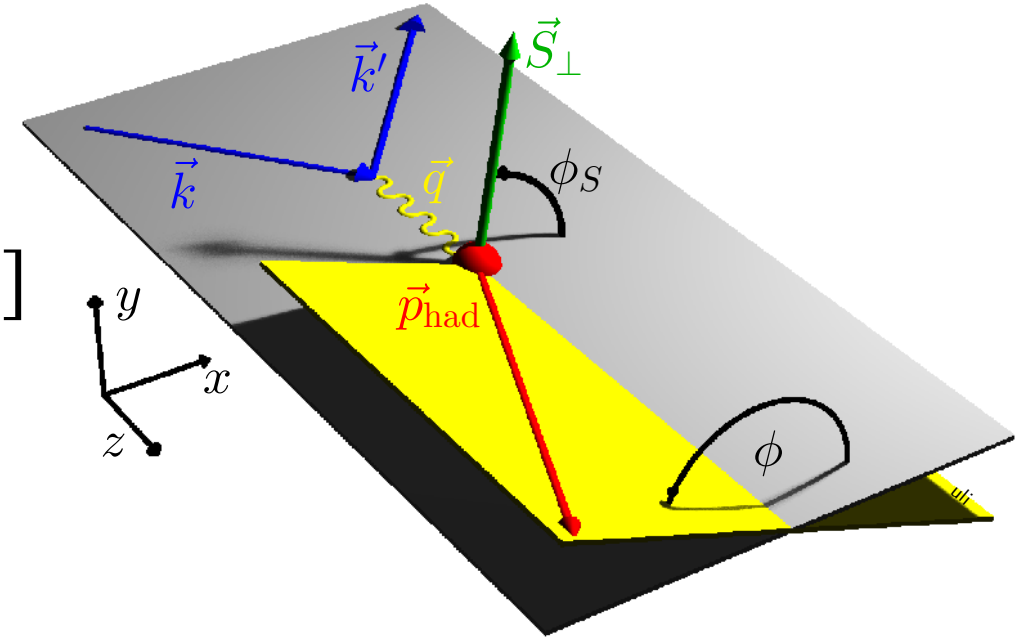
Understand spin structure of the nucleon

Quark transversity is one of the important aspects of relativistic nature of quarks inside the nucleon.

Access to transversity h_1

1 hadron semi-inclusive DIS

$$A_{UT}^{\sin(\phi+\phi_S)} \sim I\left[\frac{\mathrm{k_T}\cdot\hat{\mathrm{P}}_{\mathrm{h}\perp}}{M} h_1 H_1^{\perp}\right]$$



$H_1^{\perp}$: Collins FF (chiral odd)

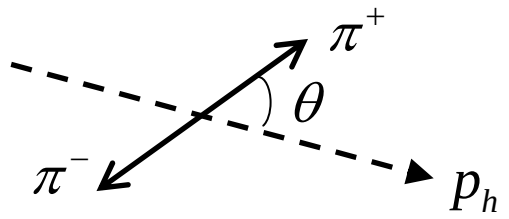
$$I[...] = \int d^2\mathrm{p_T}\, d^2\mathrm{k_T}\, \delta^{(2)}\left(\mathrm{p_T} - \frac{\mathrm{P}_{\mathrm{h}\perp}}{\mathrm{z}} - \mathrm{k_T}\right)[...]$$

2 hadron semi-inclusive DIS

Access to transversity h_1

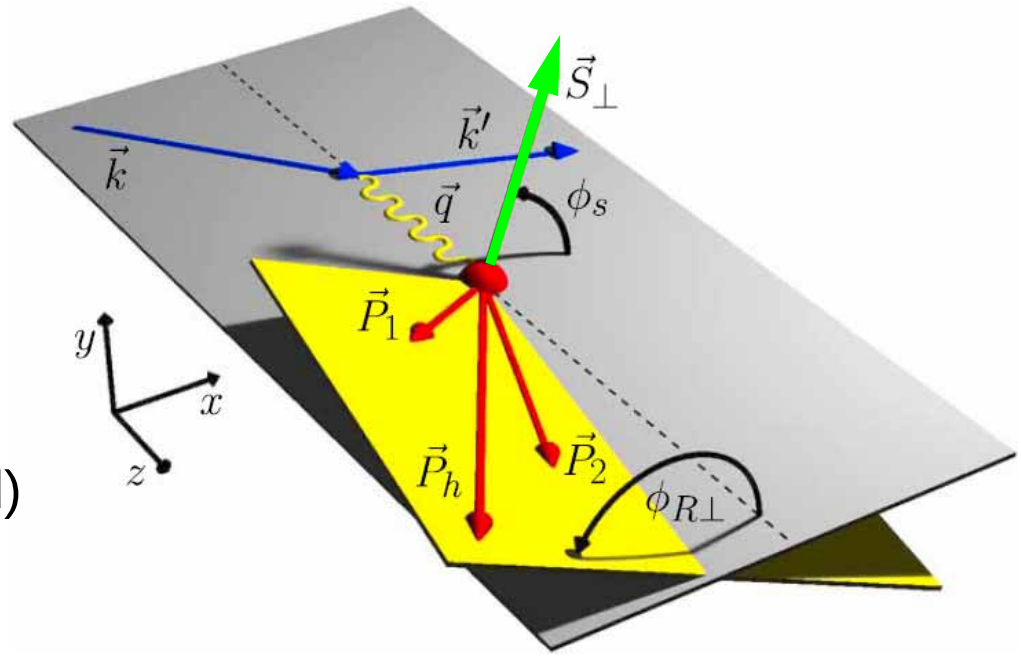
2 hadron semi-inclusive DIS

A. Bacchetta and M. Radici, Proceedings of DIS'2004 (2004), hep-ph/0407345



$$A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin\theta} \sim h_1 H_1^{\sphericalangle}$$

$$A_{UL}^{\sin\phi_{R\perp}} \sim h_L H_1^{\sphericalangle} + A g_1 \tilde{G}^{\sphericalangle}$$



$H_1^{\sphericalangle}$: Interference FF (chiral odd)

$h_1 H_1^{\sphericalangle}$ are not convoluted with $\mathrm{p_T}, \mathrm{k_T}$.

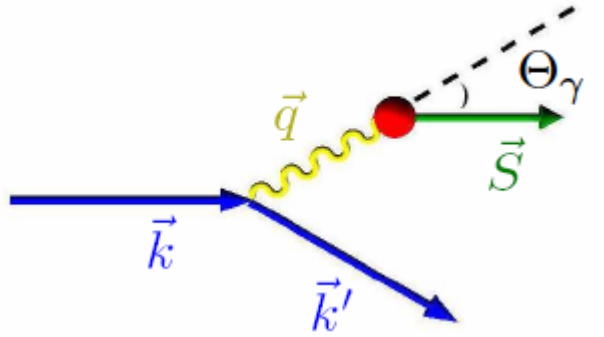
Longitudinally polarized deuterium target

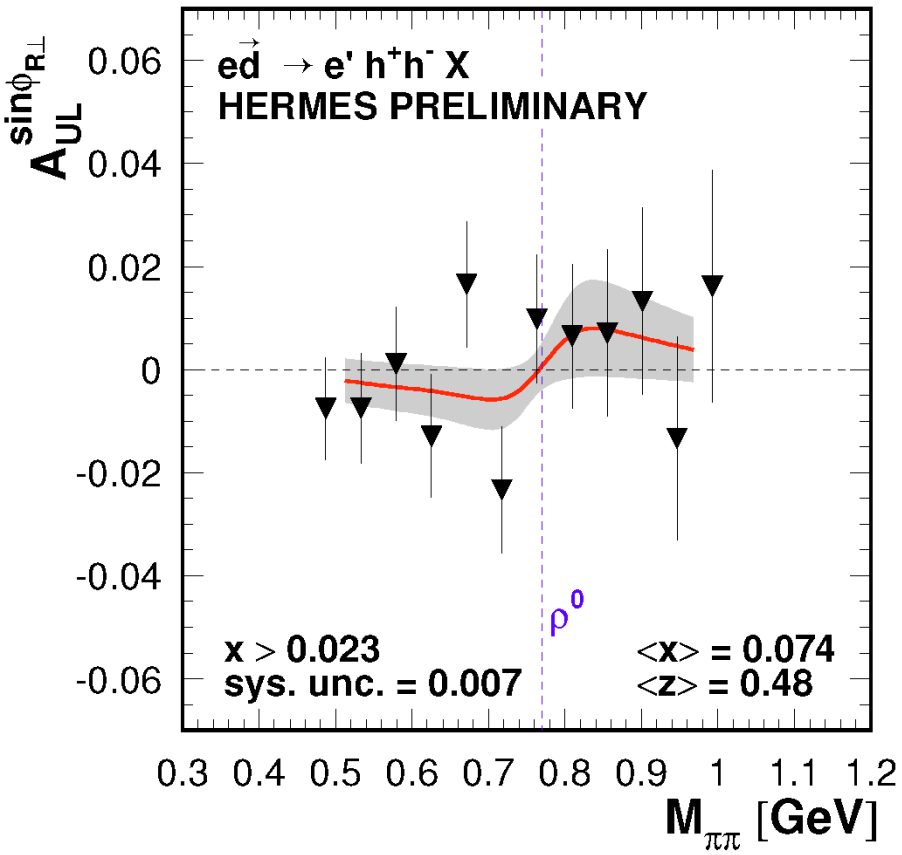
$$e(k)+\vec{d}\rightarrow e(k')+\pi^{+}(P_1)+\pi^{-}(P_2)+X$$

$$A'_{UL}=\cos\theta_{\gamma}A_{UL}-\sin\theta_{\gamma}A_{UT}$$

w.r.t. beam direction

v.r.t. virtual photon direction





$$A_{UL}^{\prime\,\sin\,\phi_{R\perp}}$$

$$\sim\ h_L H_1^{\sphericalangle} + Ag_1 G^{\sphericalangle} + Bh_1 H_1^{\sphericalangle}$$

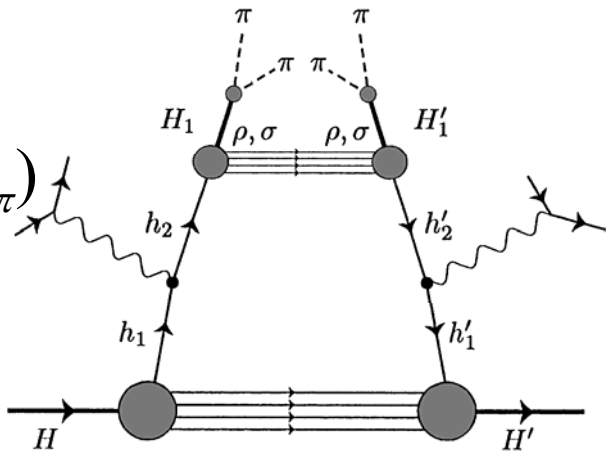
First measurement of $A_{UL}^{\sin\phi_{R\perp}}$

Small asymmetry is observed

$H_1^{\sphericalangle}$, s-p wave interference in **π π** scattering theory

Partial wave expansion

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

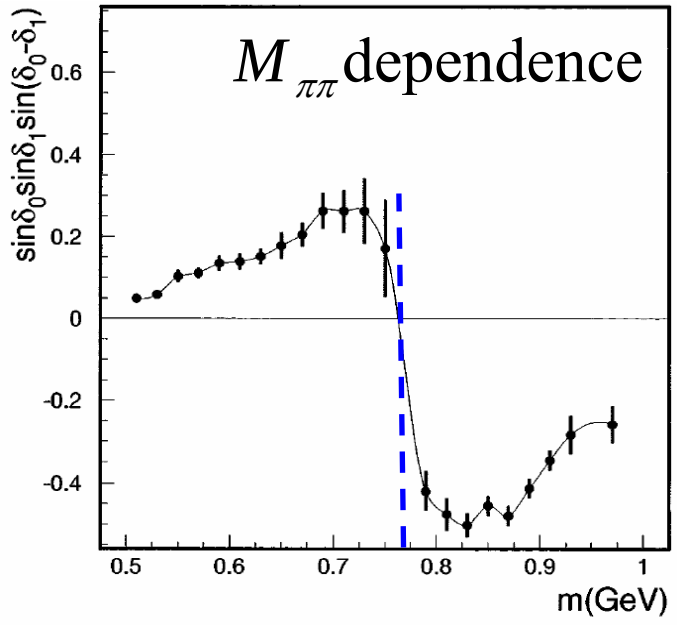


$M_{\pi\pi}$ dependence of Interference FF

R. L. Jaffe, Xuemin Jin, and Jian Tan, Phys. Rev. Lett. 80, 1166 (1998)

$$H_1^{\sphericalangle,sp}(z,M_{\pi\pi}^2)=\sin\delta_0\sin\delta_1\sin(\delta_0-\delta_1)H_1^{\sphericalangle,sp'}(z)$$

$\pi\pi$ phase shift analysis using $\pi^- p \to \pi^-\pi^+ n$ scattering

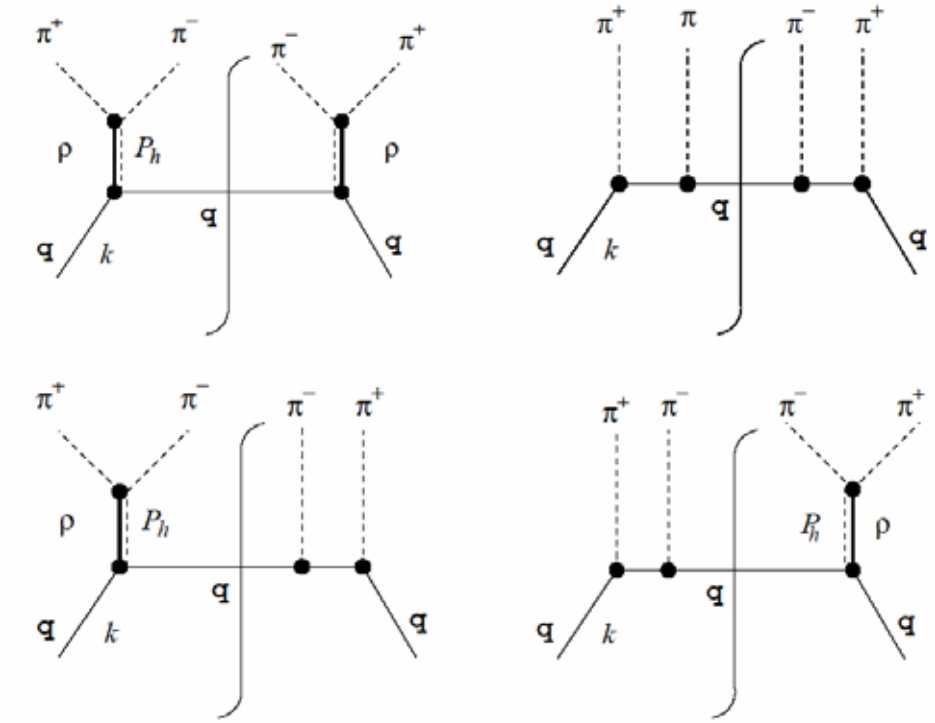


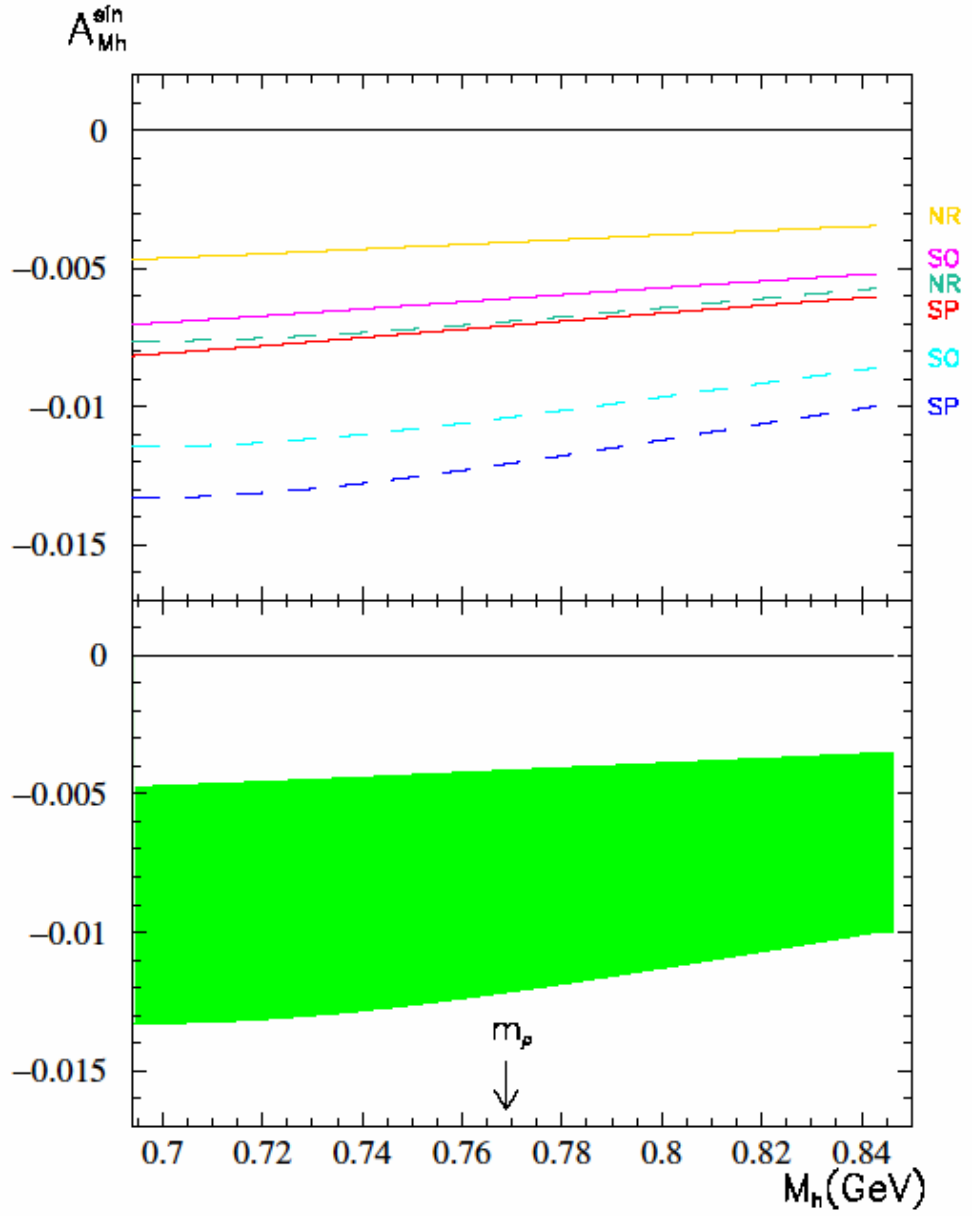
P. Estabrooks and A. D. Martin, Nucl. Phys. B79, 301 (1974)

The sign changes at $M_{\pi\pi}=M_{\rho 0}$

Spectator model for $\pi^+\pi^-$ fragmentation

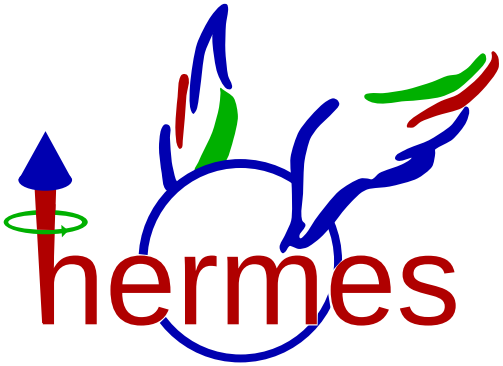
Radici et al., hep/ph-0110252





No strong $M_{\pi\pi}$ dependence.

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



Event selection

Data set : 2002~2004

SIDIS events with at least pion pair(π^+, π^-) appeared were analyzed. $ep^{\uparrow} \rightarrow e'\pi^+\pi^- X$

Kinematic cuts :

Q^2 ≥ 1 GeV²

W^2 ≥ 4 GeV²

x ≥ 0.023

0.1 < y < 0.85

p_{track} > 2.5 GeV (for DIS lepton)

p_{track} > 1 GeV (for Hadron)

To cut exclusive channel.

ΔE > 2 GeV, where $\Delta E = \dfrac{M_x^2 - M_p^2}{2M_p}$

Evaluate A_{UT}

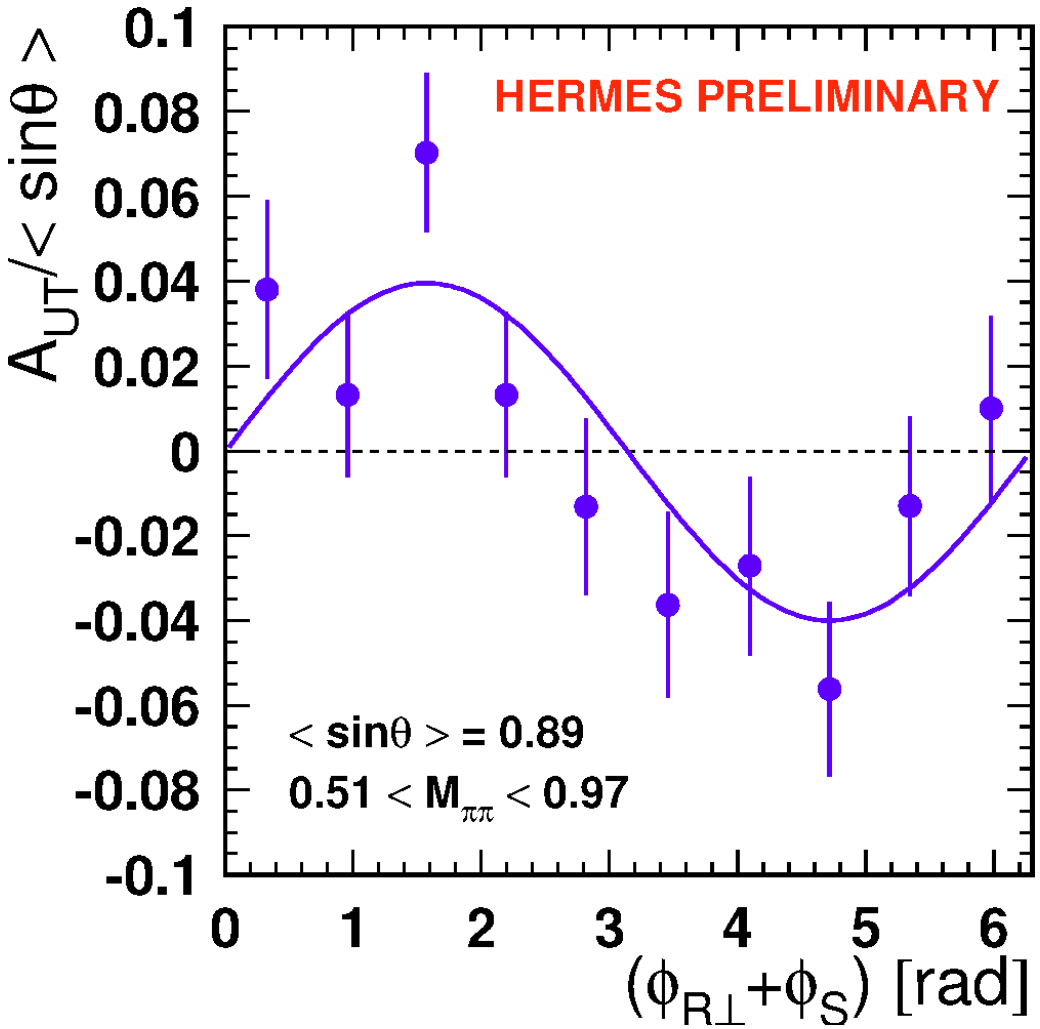
What is measured

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

$$\sim \sin(\phi_{R\perp}+\phi_S)\sin\theta\ h_1 H_1^{\sphericalangle}+\ldots\ ,$$

where $|S_T|$ is the average target polarization. ($|S_T|=75.4\pm5.0$)

$A_{UT} / \langle \sin\theta \rangle$ vs. $(\phi_{R\perp} + \phi_S)$



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

Fit $\frac{A_{UT}}{\langle \sin\theta \rangle} \sim \sin(\phi_{R\perp} + \phi_S) h_1 H_1^{\sphericalangle}$

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

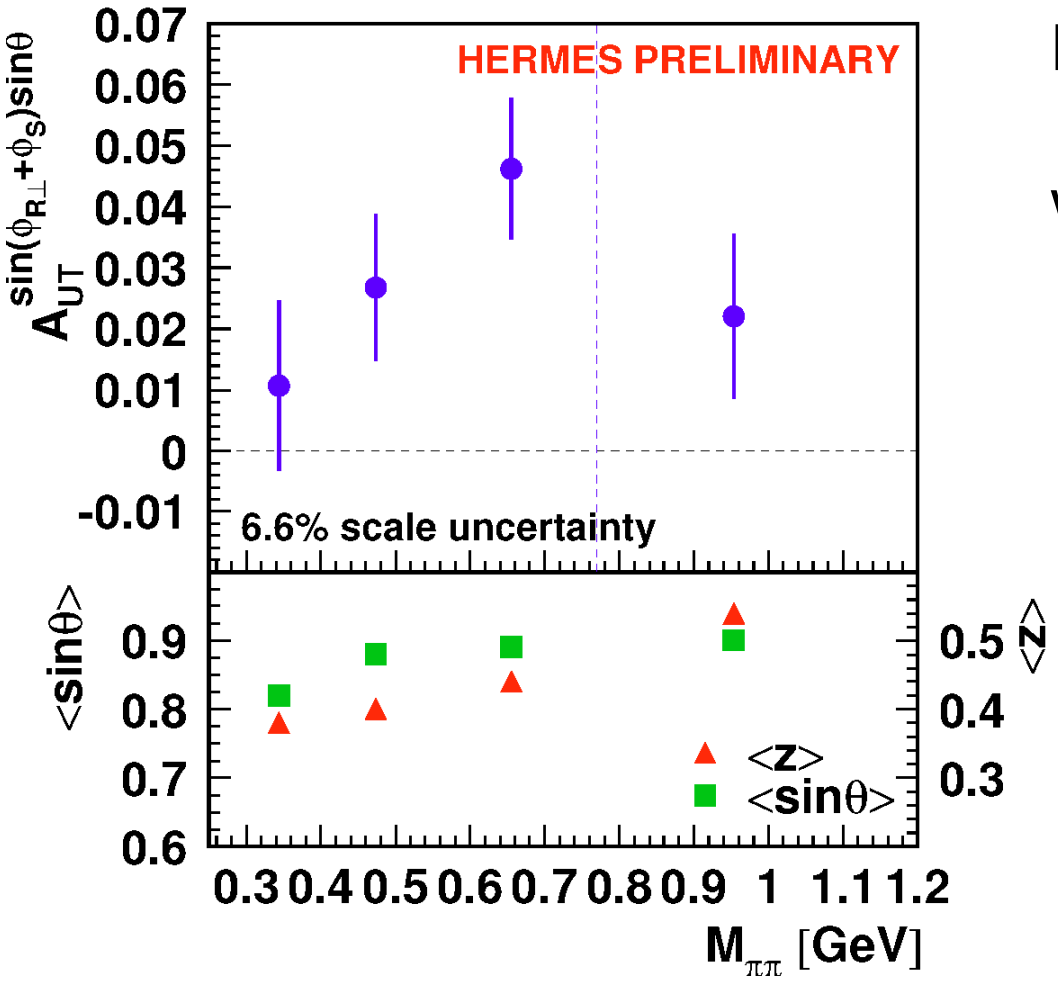
$a_0 = 0.000 \pm 0.006$

$a_1 = 0.040 \pm 0.009$

$$\frac{A_{UT}^{\sin(\phi_{R\perp}+\phi_S)}}{\langle \sin\theta \rangle} = a_1 = 0.040 \pm 0.009$$

$$h_1 H_1 \neq 0$$

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



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

Fit

$$A_{UT} \sim \sin(\phi_{R\perp}+\phi_S)\sin\theta\; h_1 H_1^{\sphericalangle}$$

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

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

Sign of the asymmetry does not change around $M_{\pi\pi} = M_{\rho 0}$.

Conclusion

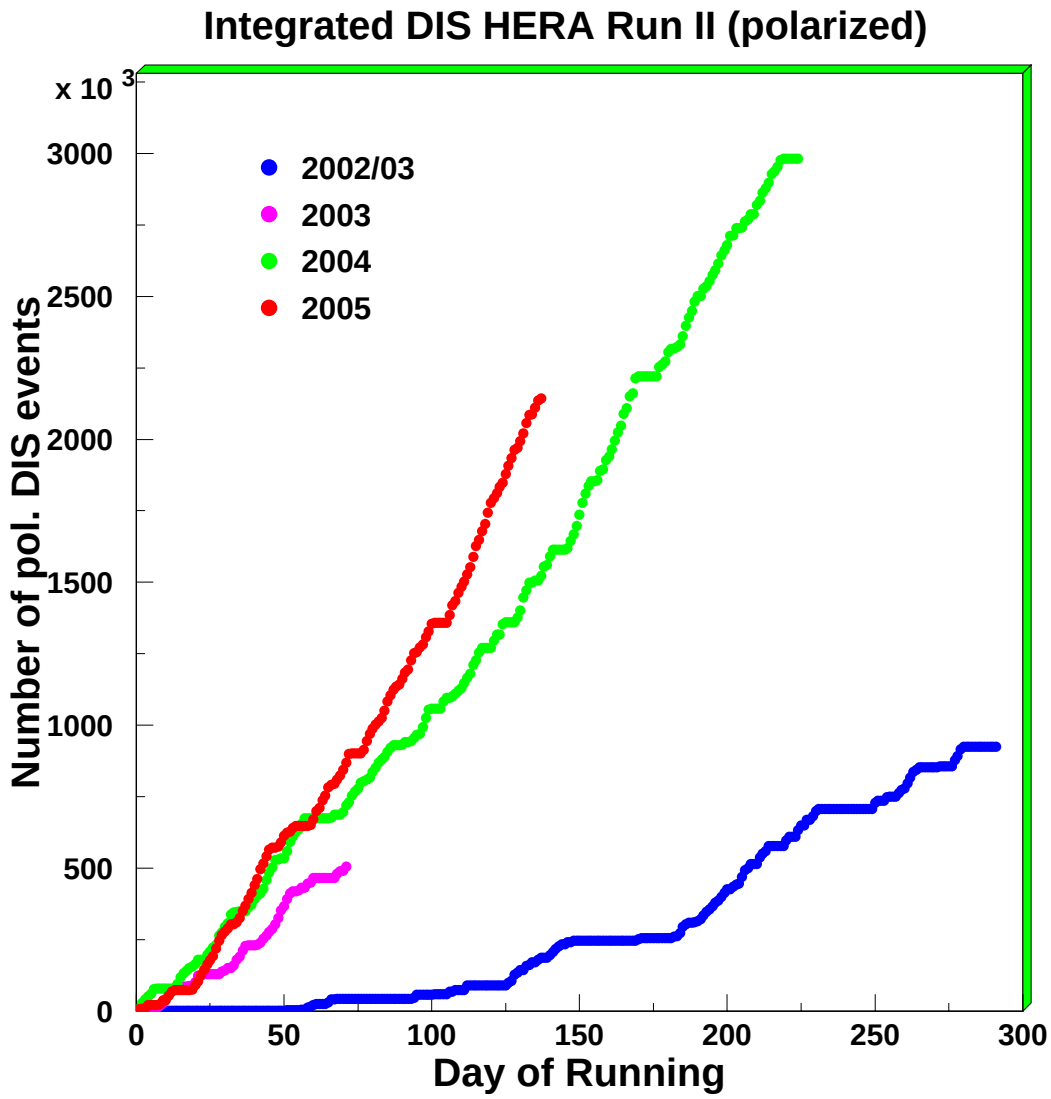
- Transversity and interference fragmentation function are related to SSA : $A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin\theta} \propto h_1 H_1^{\sphericalangle}$
- HERMES has been taking data with transversely polarized hydrogen target since 2002.
- SIDIS events with at least two hadrons (π^+, π^-) were analyzed.
- Asymmetry of order 4% is observed.

$$\frac{A_{UT}^{\sin(\phi_{R\perp}+\phi_S)}}{\langle \sin\theta \rangle} = 0.040 \pm 0.009$$

- Around $M_{\pi\pi} = M_{\rho 0}$, asymmetry becomes large.
- No sign change is observed.

Outlook

- 3.5 M DIS evens in 2002~2004.
- 3~3.5 M events is expected in 2005.

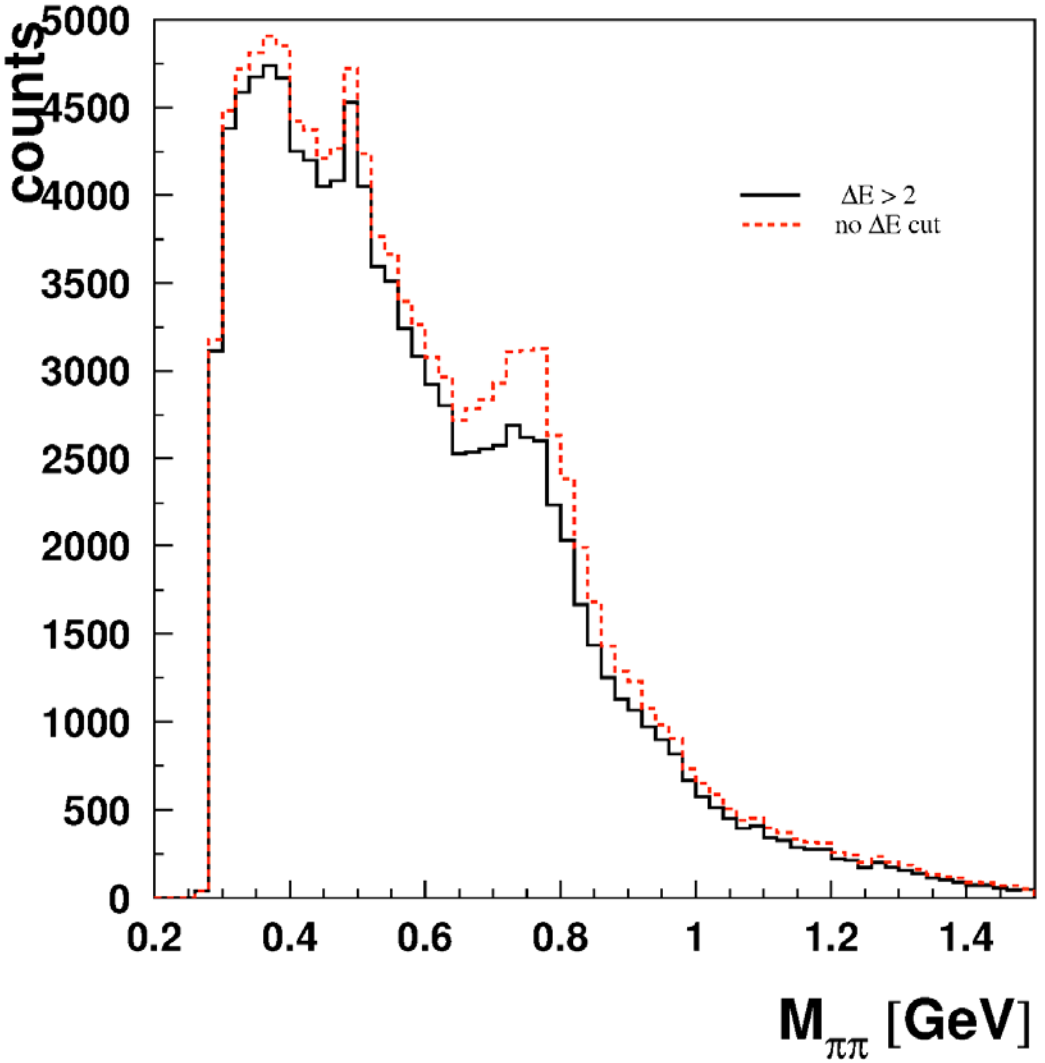


backup

$M_{\pi\pi}$ spectrum

With or without $\Delta E > 0.2[\mathrm{GeV}]$ cut

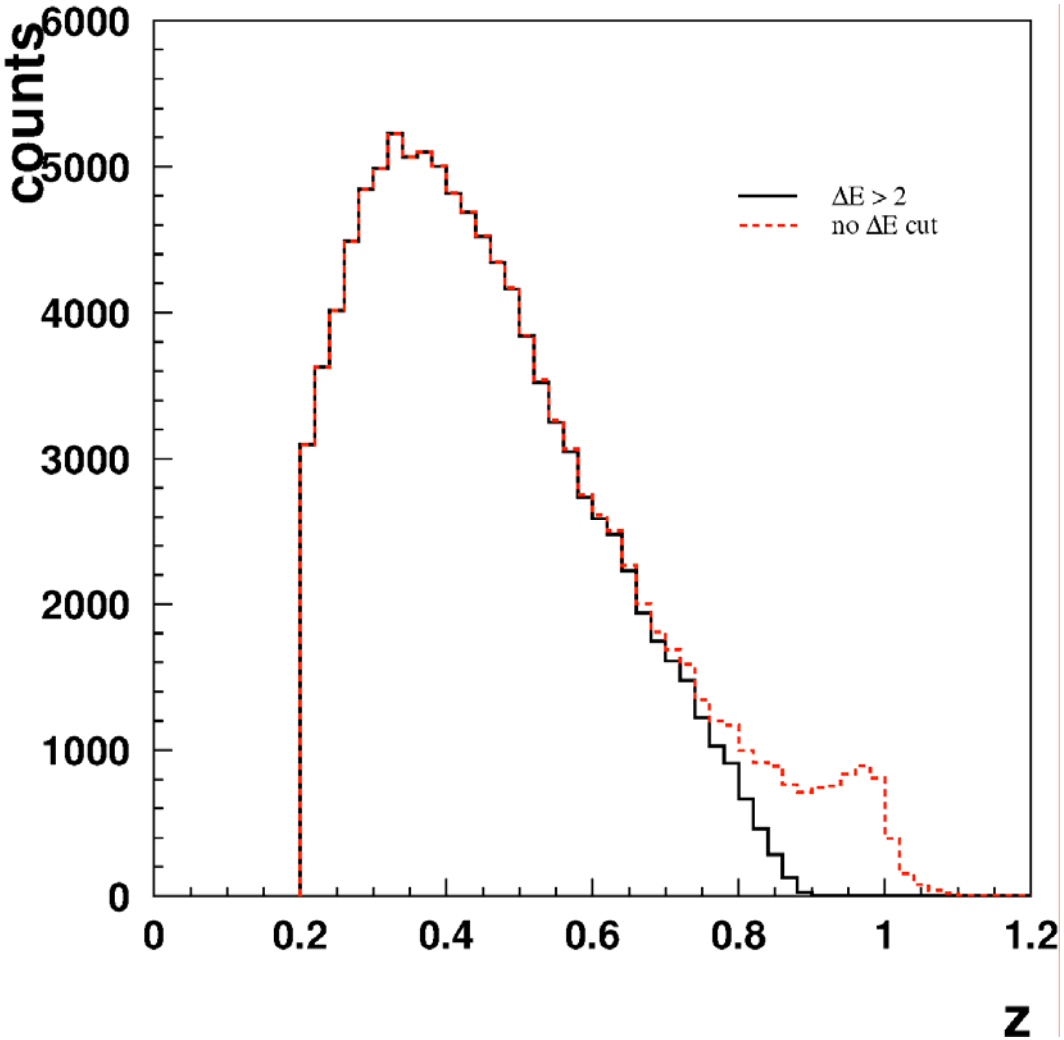
$$\Delta E = \frac{M_x^2 - M_p^2}{2M_p}$$



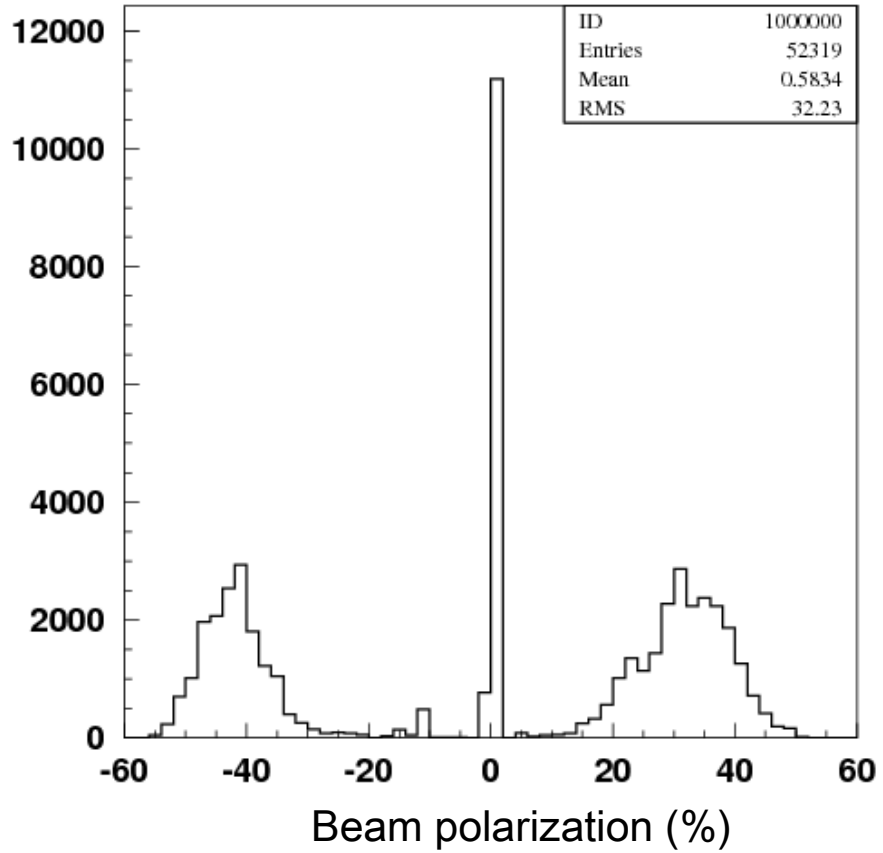
z spectrum

With or without $\Delta E > 0.2[\mathrm{GeV}]$ cut

$$\Delta E = \frac{M_x^2 - M_p^2}{2M_p}$$



double spin asymmetry



Fit

$$A_{UT} \sim \sin(\phi_{R\perp} + \phi_S)\sin\theta\; h_1 H_1^{\sphericalangle}$$

for both beam polarization.

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

$$= 0.041 \pm 0.011 \text{ for } P_{beam} \geq 0$$

$$= 0.040 \pm 0.012 \text{ for } P_{beam} \leq 0$$

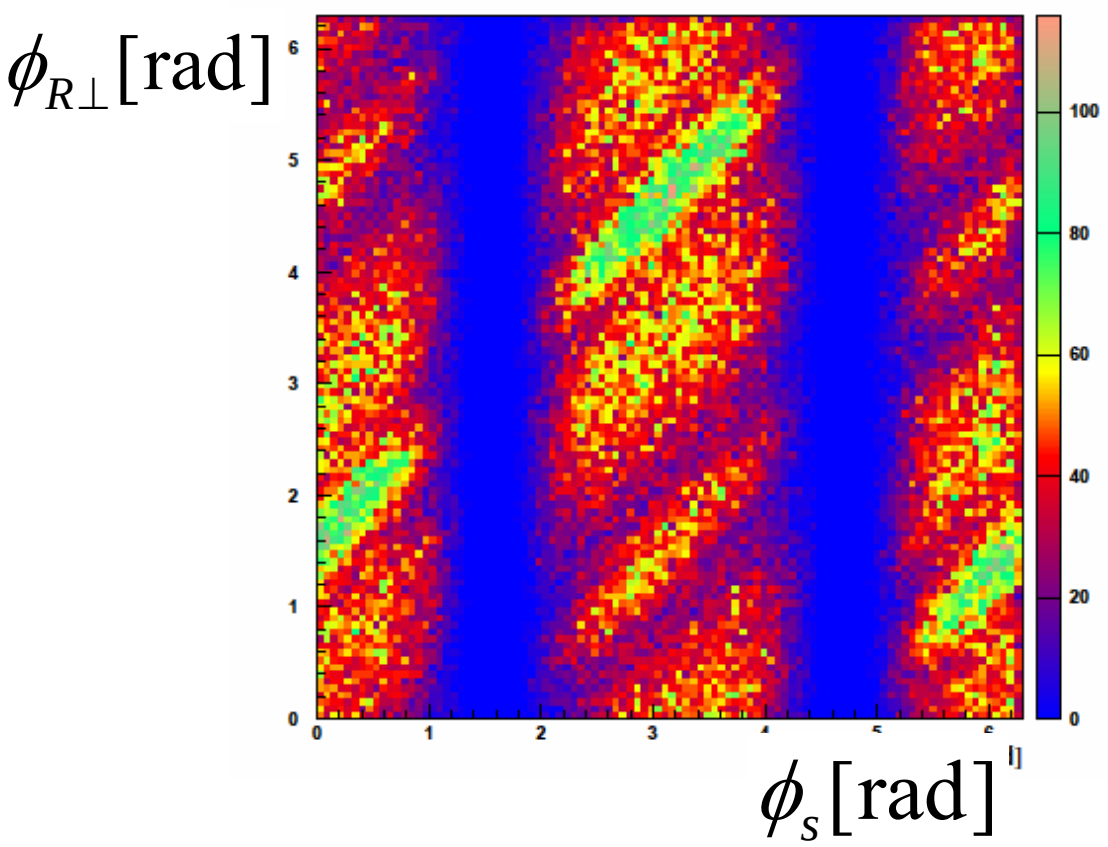
No double spin asymmetry

$$a + b\sin(\phi_{R\perp} + \phi_S)\sin\theta + c\sin(\phi_{R\perp} - \phi_S)\sin\theta$$

	a	b	c	< pol >
pol >= 0	0.002 ± 0.007	0.041 ± 0.011	0.020 ± 0.012	21.49
pol <= 0	0.002 ± 0.008	0.040 ± 0.012	0.017 ± 0.013	-23.97

Beam polarization don't affect to the asymmetry

Angle distribution $(\phi_{R\perp}, \phi_S)$

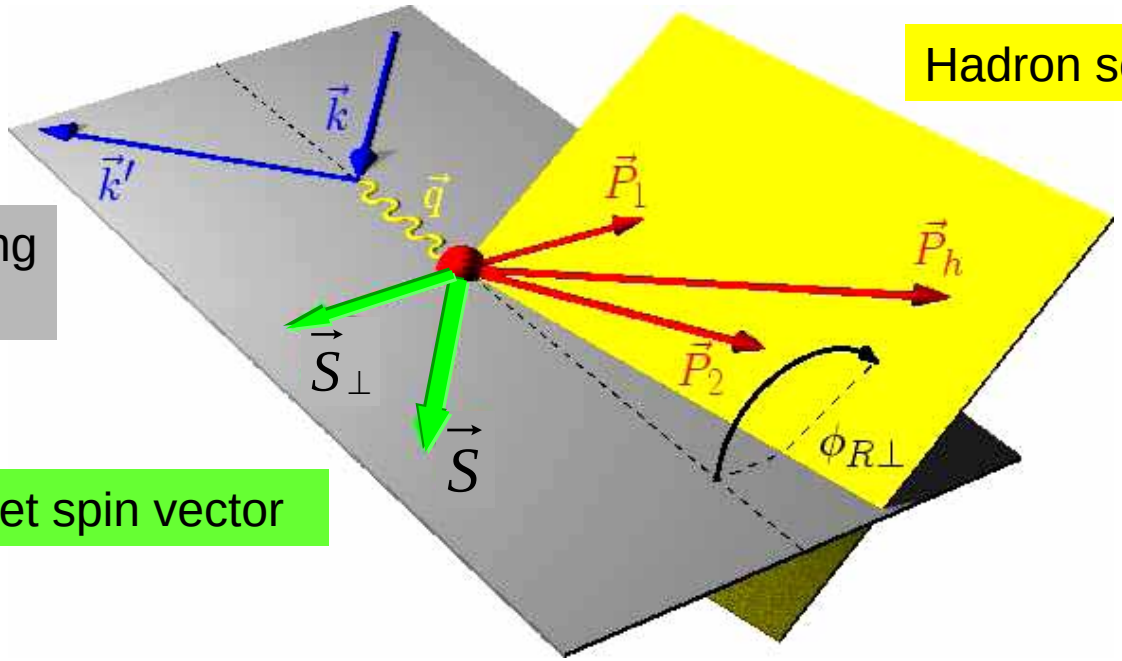


Correlation in the $(\phi_{R\perp}, \phi_S)$ distribution due to the HERMES acceptance and spectrometer magnet field.

Monte Carlo studies show : no face asymmetries
Due to those correlations

Single spin asymmetry $A_{UL}^{\sin\phi_{R\perp}}$

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



$$A_{UL}(\phi_{R\perp})=\frac{1}{|P_T|}\frac{N^{\leftarrow}(\phi_{R\perp})/N^{\leftarrow}_{\mathrm{DIS}}-N^{\rightarrow}(\phi_{R\perp})/N^{\rightarrow}_{\mathrm{DIS}}}{N^{\leftarrow}(\phi_{R\perp})/N^{\leftarrow}_{\mathrm{DIS}}+N^{\rightarrow}(\phi_{R\perp})/N^{\rightarrow}_{\mathrm{DIS}}}$$

fit with $f(\phi_{R\perp})=a_0+a_1\sin\phi_{R\perp}+b\cos\phi_{R\perp}+\ldots$ $\Rightarrow$ $A_{UL}^{\sin\phi_{R\perp}}=a_1$

Abstract (memo)

Date : May 19th, 17:50 - 18:10 (15min. talk and 5min. discussion)

Title:
Single Spin Asymmetry in Interference fragmentation
on a transversely polarized hydrogen target at HERMES

Abstract:
HERMES has been taking data with transversely polarized target since 2002. Single spin asymmetries in the azimuthal distribution of two pion pairs around the virtual photon direction have been observed. These asymmetries can be explained in terms of transversity in conjunction with the interference fragmentation function. Preliminary results of the single spin asymmetry will be shown.

Slide: 12 pages