Single Spin Asymmetry with a Transversely Polarized Hydrogen Target at HERMES

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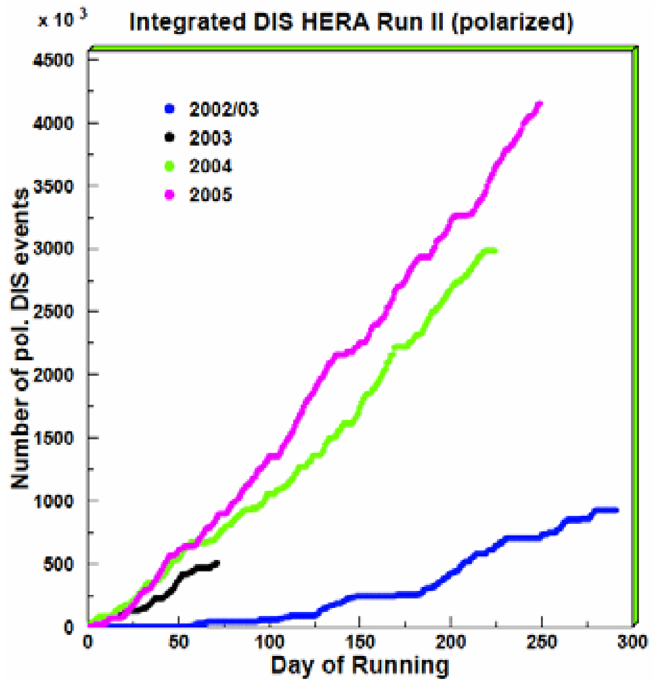
- Physics with DIS on Transversely Polarized Targets
- HERMES Experiment
- Separation of Collins Effect and Sivers Effect

A. Airapetian et al, HERMES,
Phys. Rev. Lett. 94 (2005) 012002

Single-Spin Asymmetries in Semi-inclusive Deep-Inelastic Scattering on a Transversely-Polarized Hydrogen Target

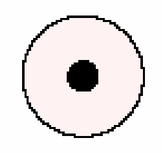
+ update including the 2004 data



Quark Distribution Functions

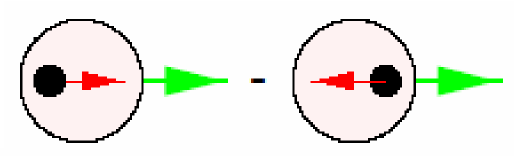
At leading twist

$$\boldsymbol{q(x)} =$$



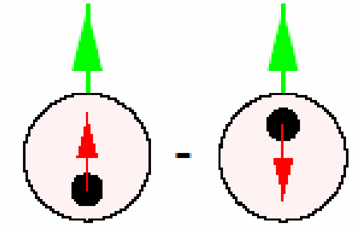
Quark Momentum Distribution

$$\Delta \boldsymbol{q(x)} =$$



Quark Helicity Distribution

$$\delta \boldsymbol{q(x)} =$$



Quark Transversity Distribution

$$\delta \boldsymbol{q(x)}:$$

Positivity Bound $$|\delta q(x)| \le q(x)$$

Soffer Bound $$|\delta q(x)| \le \frac{1}{2}\left[q(x) + \Delta q(x)\right]$$

Why Are Quark Transversity Distributions $\delta q(x)$ Interesting?

$\delta q(x) \neq \Delta q(x) \Rightarrow$ **proves Quark's Relativistic Nature in the Nucleon**

Because of Lack of Transversity of Gluon, Q^2 Evolution Should Be Different From That of $q(x)$ and $\Delta q(x)$.

Chiral Odd. So Far Never Measured

$$h_1(x,p_T^2)\, H_1^{\perp}(z,k_T^2)$$

p_T **initial quark transverse momentum**
k_T **final quark transverse momentum**

Sivers Effect: **could be related to orbital motion of quarks**

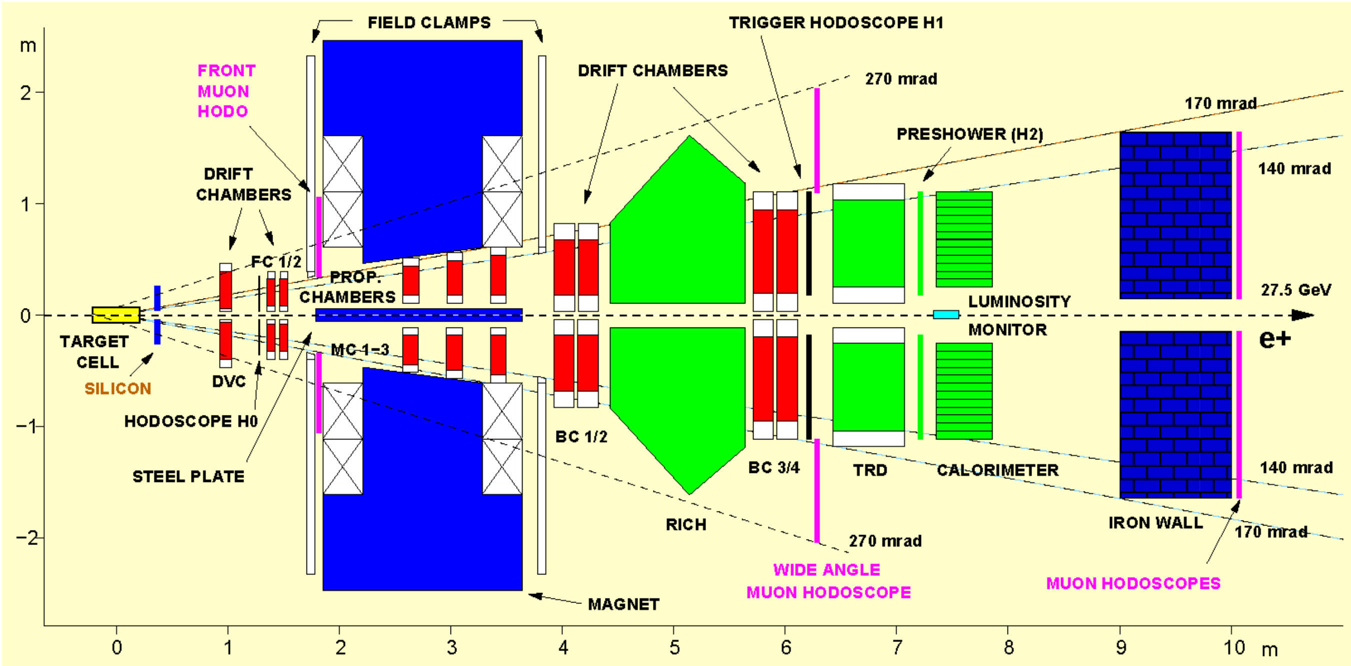
$$f_{1T}^{\perp}(x,p_T^2)\, D_1(z,k_T^2)$$

The separation of the two effects was carried out for the first time.

HERMES Detector

e+

27.5 GeV



Kinematical Range

$0.02 \leq x \leq 0.8$ at $Q^2 \geq 1\,\mathrm{GeV}^2$ and $W^2 \geq 10\,\mathrm{GeV}^2$,

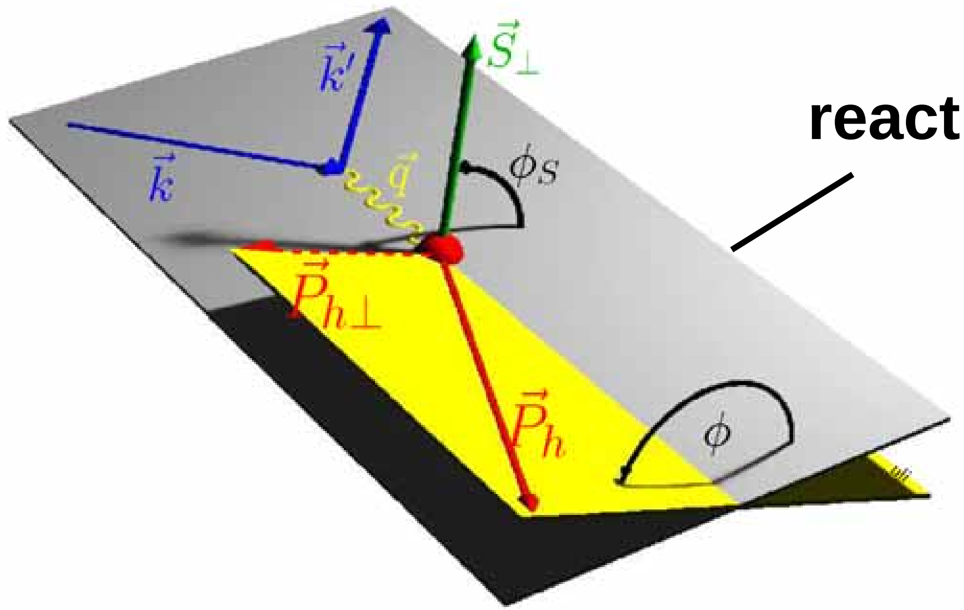
$\theta_x \leq 170\,\mathrm{mrad}$, $40\,\mathrm{mrad} \leq \theta_y \leq 140\,\mathrm{mrad}$

Reconstruction

$\delta p(x)/p(x) = 1.0 - 2.0\%$,

$\delta\theta \leq 1.0$ mrad

Two Azimuthal Angles ϕ_s , ϕ in Semi-inclusive Measurement with a Transversely Polarized Target



$0.2 < z < 0.7$, $\theta_{\gamma h} > 0.02$ rad

Target $P = 0.78 \pm 0.04$

Azimuthal Single Spin Asymmetry

Asymmetry around the virtual photon direction

$$A_{UT}(\phi,\phi_s) = \frac{1}{< S_\perp >} \frac{N_h^+(\phi,\phi_S) - N_h^-(\phi,\phi_S)}{N_h^+(\phi,\phi_S) + N_h^-(\phi,\phi_S)}$$

$$\approx \sin(\phi+\phi_s) \sum_q e_q^2 \int [h_{1T}^q(x,p_T^2)\, H_1^{\perp,q}(z,k_T^2)] \qquad \text{Collins}$$

$$+ \sin(\phi-\phi_s) \sum_q e_q^2 \int [f_{1T}^{\perp,q}(x,p_T^2)\, D_1^q(z,k_T^2)] \qquad \text{Sivers}$$

$$+ \ldots.$$

$\int [\ \ldots.\ ]$ means convolution Integral over initial (p_T) and final (k_T) quark transverse momentum

Fit in 2-dimension (ϕ,ϕ_s) in each x bin

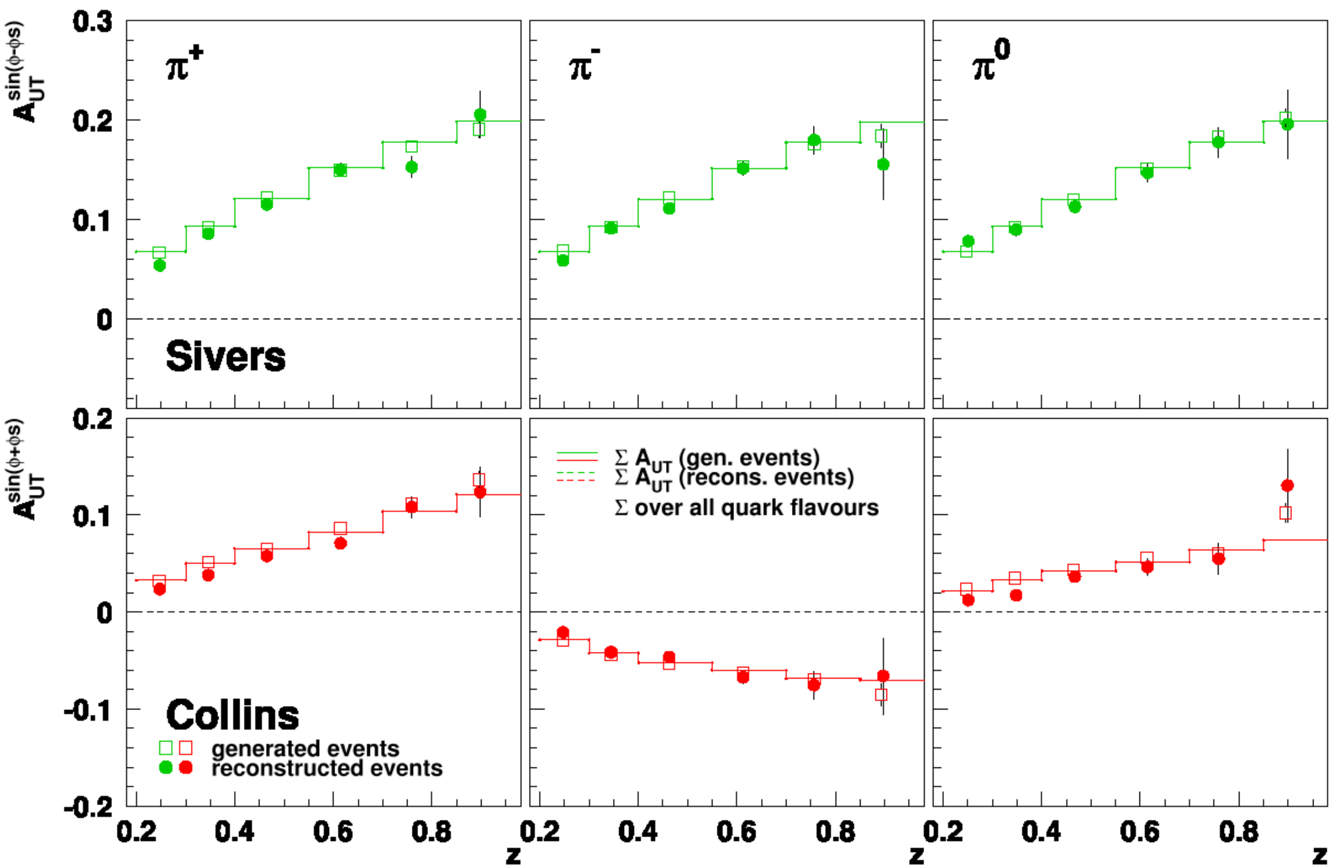
Fourier Component

$$A_{UT}(\phi,\phi_s) = 2 < \sin(\phi+\phi_s) >_{UT}^1 \sin(\phi+\phi_s) \qquad \text{Collins}$$

$$+ 2 < \sin(\phi-\phi_s) >_{UT}^1 \sin(\phi-\phi_s) \qquad \text{Sivers}$$

Monte Carlo Test of Extraction Method

1) generate Collins and Sivers Asymmetries (Gaussian Ansatz in P_t^2)
2) analyse MC data like experimental data and extract Asymmetries



• **Collins-Sivers cross contamination is negligible**

Collins Asymmetry $\propto -h_1(x, p_T^2)\, H_1^{\perp}(z, k_T^2)$

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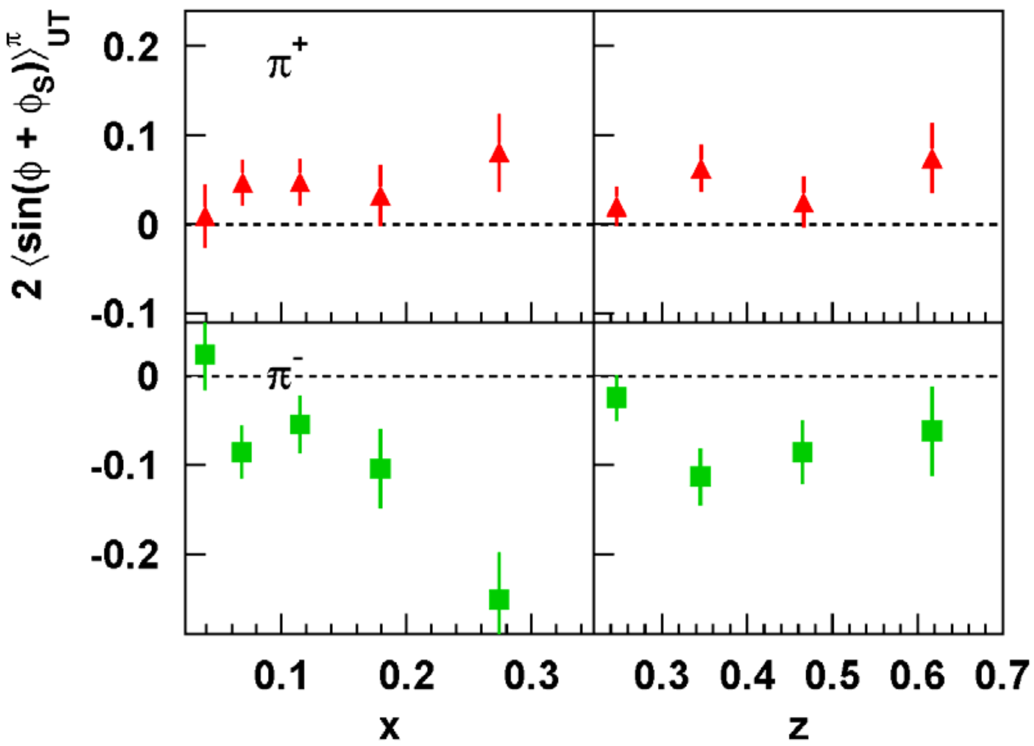
$< Q^2 >= 2.41\,\mathrm{GeV}^2,\ < P_{\pi\perp} >= 0.41\,\mathrm{GeV}$



Positive π^+ Asymmetry

0.021 ± 0.007

Negative π^- Asymmetry
The magnitude is larger.

- 0.038 ± 0.008

Sivers Asymmetry $\propto -f_{1T}^{\perp}(x,p_T^2)\, D_1(z,k_T^2)$

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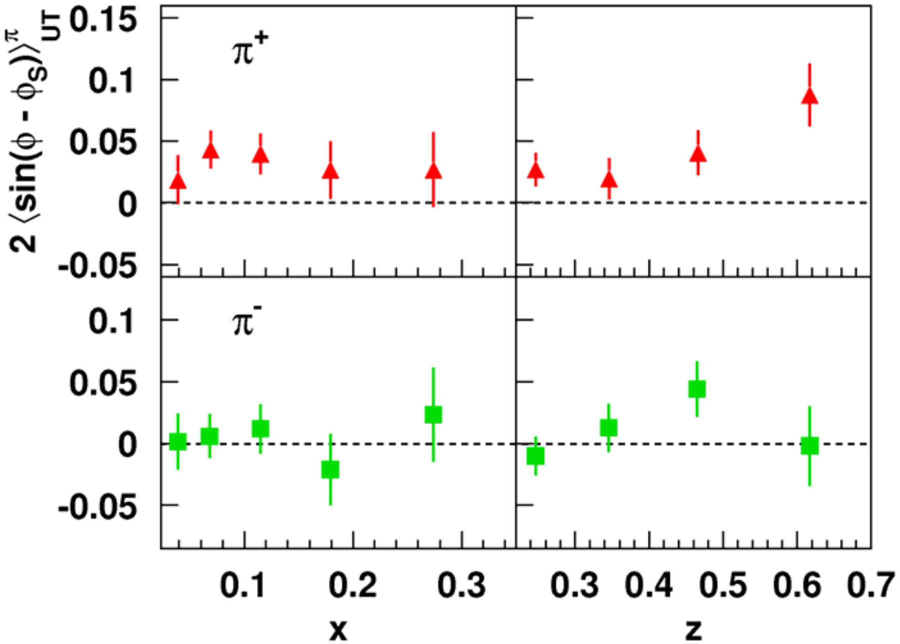
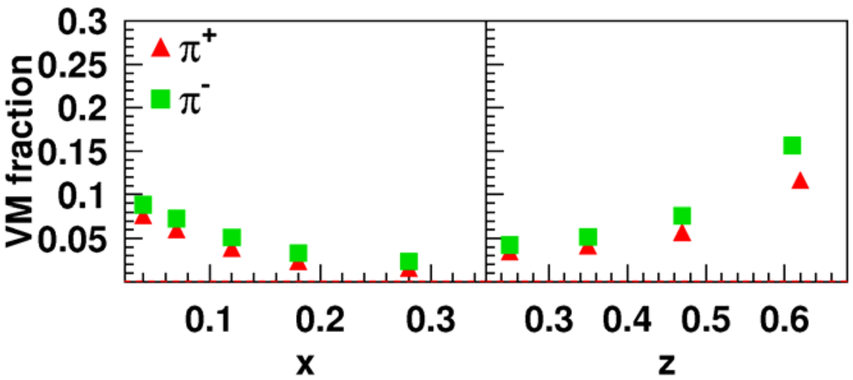


Positive π^+ Asymmetry

0.017 ± 0.004

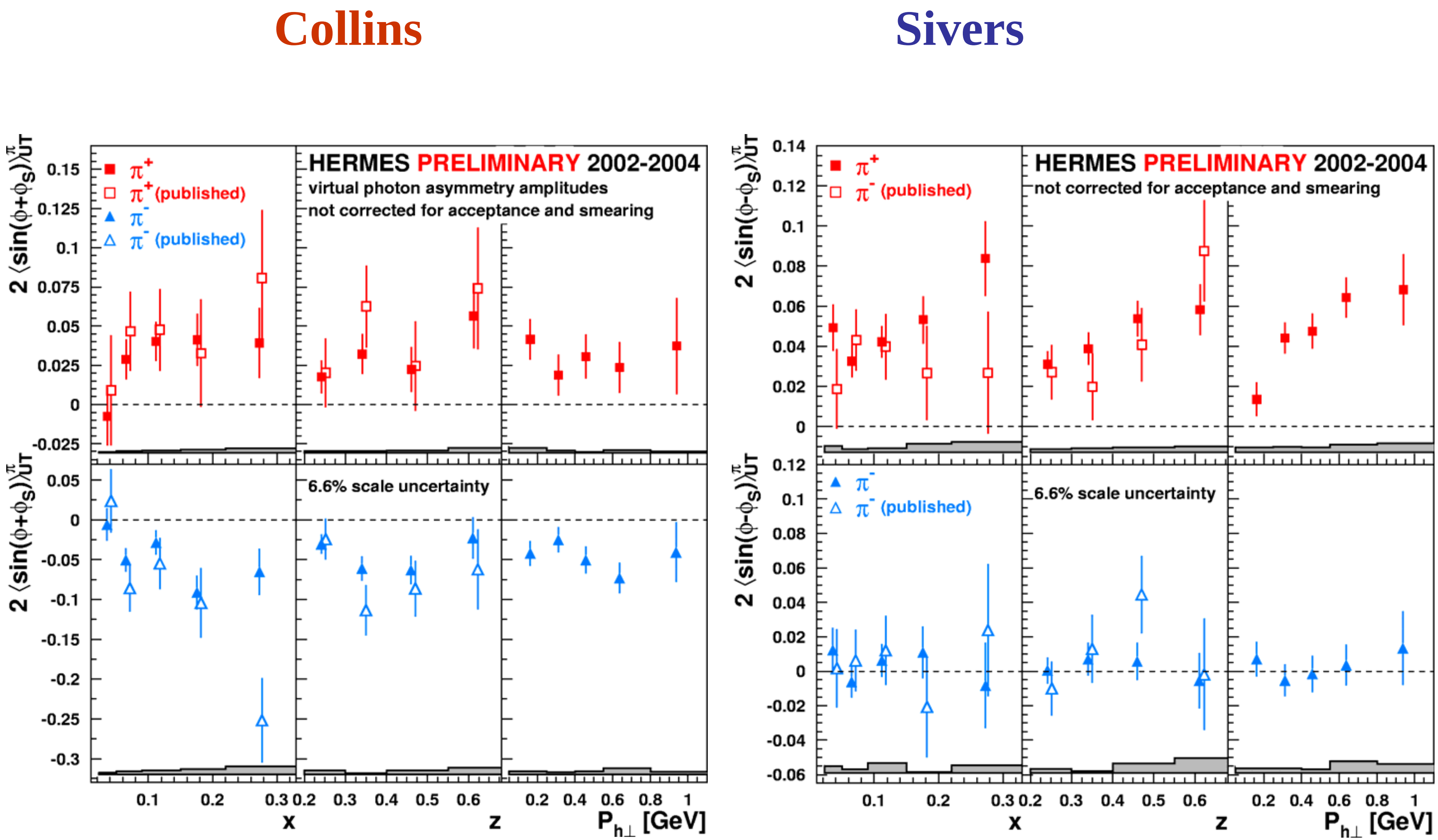
π^- Asymmetry is nearly 0

0.002 ± 0.005



Effects of Exclusive Vector Meson Production were studied.

Update including Data 2004



Conclusions

- The separation of Collins effect and Sivers effect was carried out for the first time.

- Non-zero asymmetry is observed for Collins asymmetry. Positive π^+ asymmetry, negative π^- asymmetry are compatible with helicity distribution $\Delta q(x)$. But the amplitude of π^- asymmetry is large.

- π^+ asymmetry is positive, and π^- asymmetry is nearly 0 for Sivers asymmetry. The effects of exclusive vector meson production were investigated and found to be negligible.

outlook:

Statistics will be about doubled by the end of 2005.