Transversity results from HERMES and COMPASS

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COMPASS results

prepared by Rainer Joosten

Transverse Spin Physics

3 possible quark polarimeters suggested using SIDIS:

- Azimuthal distribution of single (leading) hadrons

  paper on 2002 data published Phys. Rev. Lett. 94, 202002 (2005)

- Azimuthal dependence of the plane containing hadron pairs

- Measurement of transverse polarization of baryons

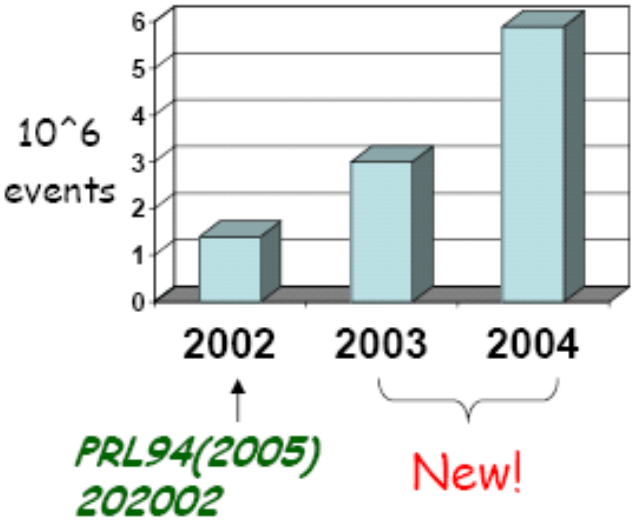
  (e.g. Λ hyperon)

Transversity Data Sample

Target: ^{6}LiD (deuterium)

2002: 12+7 days of data taking

- $1.8 * 10^{9}$ raw events



2003: 14 days of data taking

trigger upgrade to gain on
large x_{Bj} & large Q^2 events !

- 2002 data doubled

2004: 14 days of data taking

DAQ improved and online filter added

- ~ 2003 data doubled

Single hadron production

Two possible azimuthal asymmetries:

(a) fragmentation of transversely polarized quarks with finite transverse momentum to unpolarized hadrons

→ **Collins effect --- (access to transversity)**

(b) modulation of transverse momentum of unpolarized quarks in the transverse polarized nucleon

→ **Sivers effect**

Collins:

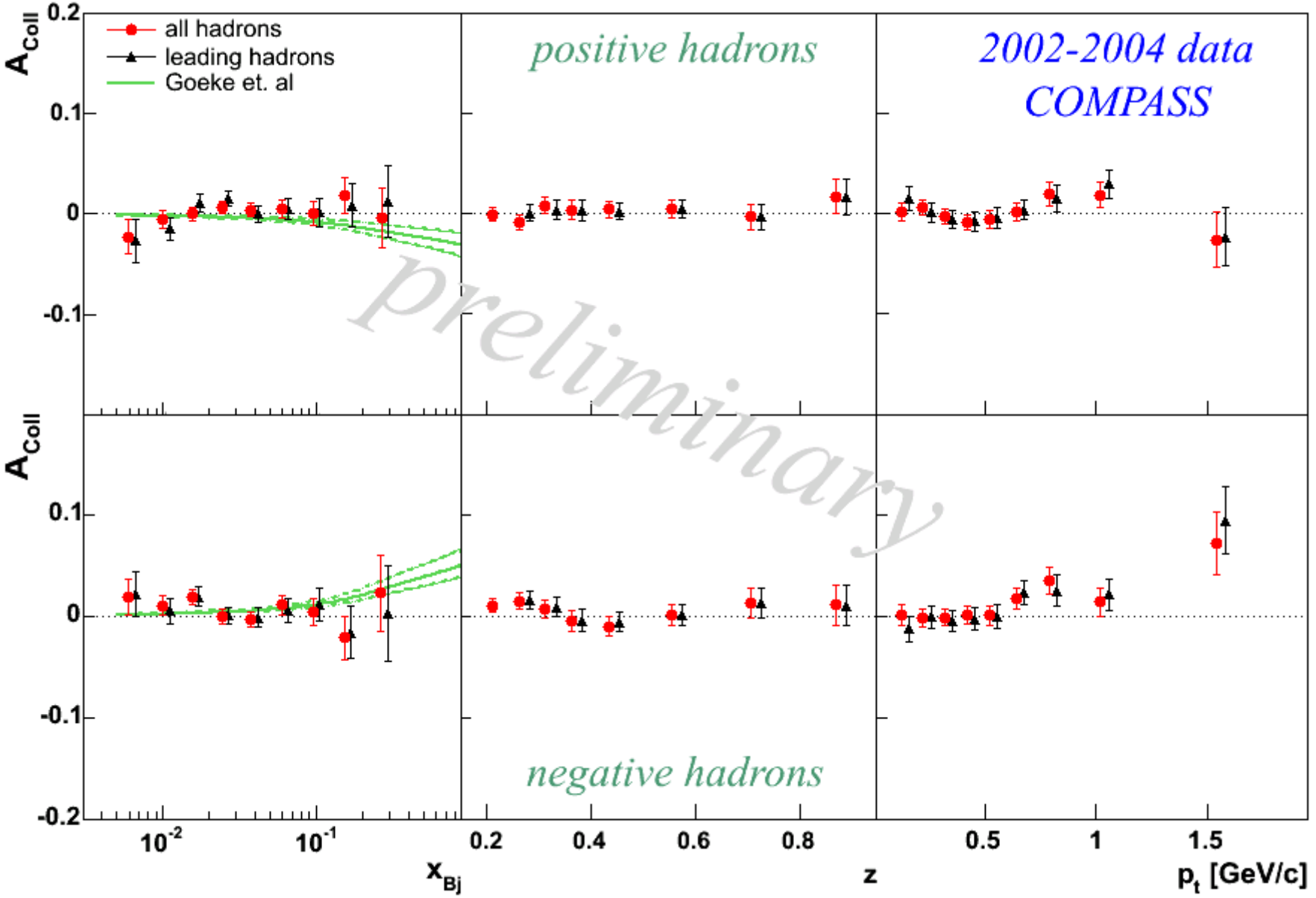
$$A_{Coll} = \frac{A_{UT}^{\sin\Phi_{Coll}}}{D_{NN} \cdot f \cdot P} = \frac{\sum_a e_a^2 \cdot \Delta_T q_a \Delta_T D_a^h}{\sum_a e_a^2 \cdot q_a \cdot D_a^h}$$

Sivers:

$$A_{Siv} = \frac{A_{UT}^{\sin\Phi_{Siv}}}{f \cdot P} = \frac{\sum_a e_a^2 \cdot f_{1T\,a}^{\perp} \cdot D_a^h}{\sum_a e_a^2 \cdot q_a \cdot D_a^h}$$

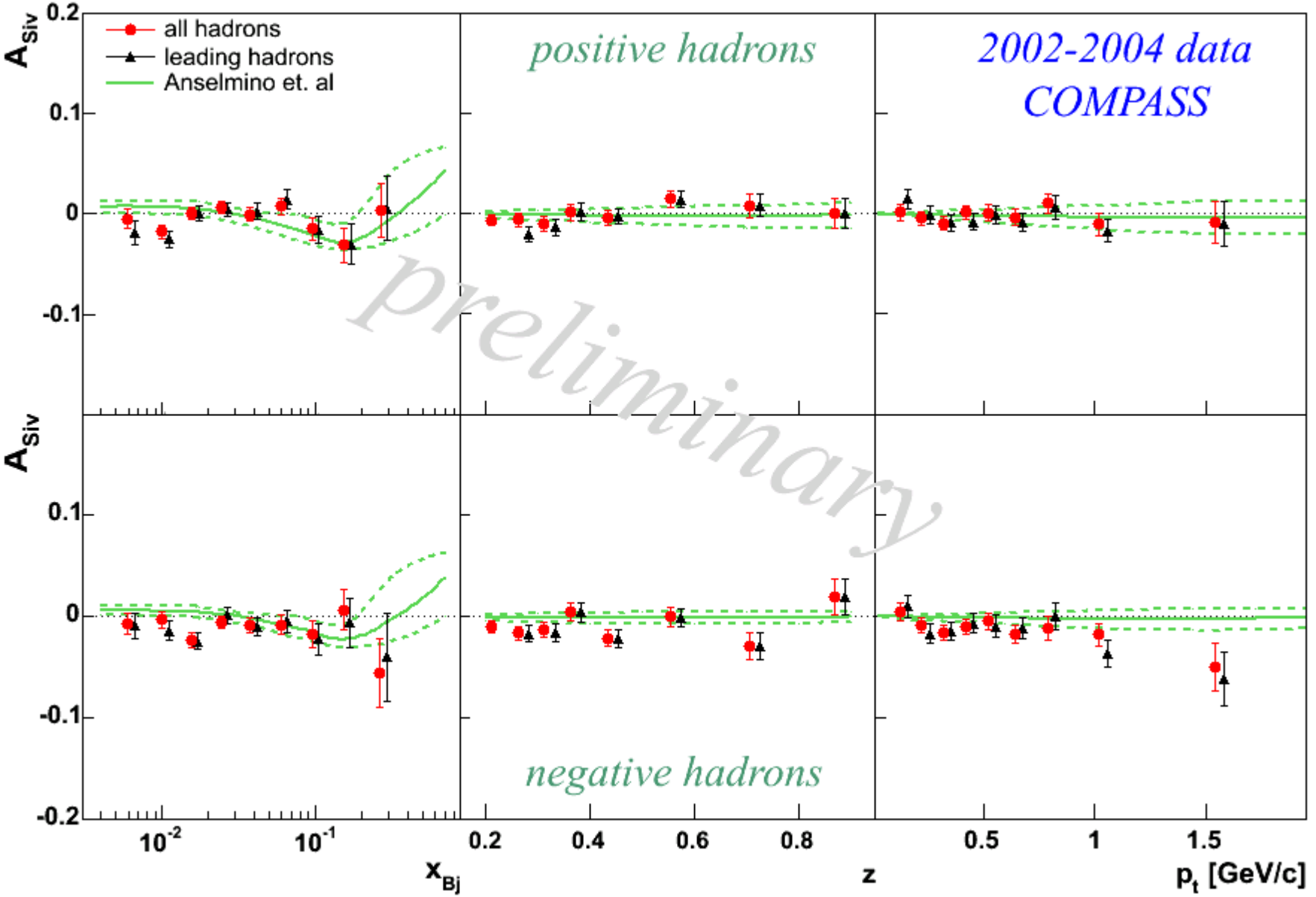
f dilution factor; P target polarization; $D_{NN} = (1-y)/(1-y+y^2/2)$ Depolarization factor

Collins Asymmetries



A. V. Efremov, K. Goeke and P. Schweitzer, Collins on Proton and Deuterium (hep-ph/0603054)

Sivers Asymmetries



M. Anselmino et al.
Sivers on Deuterium (hep-ph/0507181)

Conclusion (1)

- A first measurementof Collins and Sivers asymmetries has been performed with a polarized deuteron (^{6}LiD) target.
- The measured asymmetries are very small and compatible with zero within the current statistical errors.
- Investigations of systematic effects prove them to be small compared to the statistical error
- Both COMPASS (deuteron) and HERMES (proton) data can be described by the same model, implying for deuteron a cancellation between protons and neutrons. Existing phenomenological models are in a good agreement with COMPASS and HERMES data;

Transverse Spin Physics

3 possible quark polarimeters suggested using SIDIS:

- Azimuthal distribution of single (leading) hadrons
- Azimuthal dependence of the plane containing hadron pairs

  First results on the effect proposed by e.g.

  Collins et al., Nucl. Phys. B 420 (1994) 565.

  Jaffe et al., Rev. Lett. 80 (1998) 1166.

- Measurement of transverse polarization of baryons

  (e.g. Λ hyperon)

2 hadron asymmetries

$$\sigma_{UT} \propto \sum_i e_i^2 |S_T| \sin\theta \sin\phi_{RS} \Delta_T q_i(x) H_i^{\sphericalangle h}(z, M_h^2) \propto A_{UT}^{\sin\phi_{RS}} \cdot \sin\phi_{RS}$$

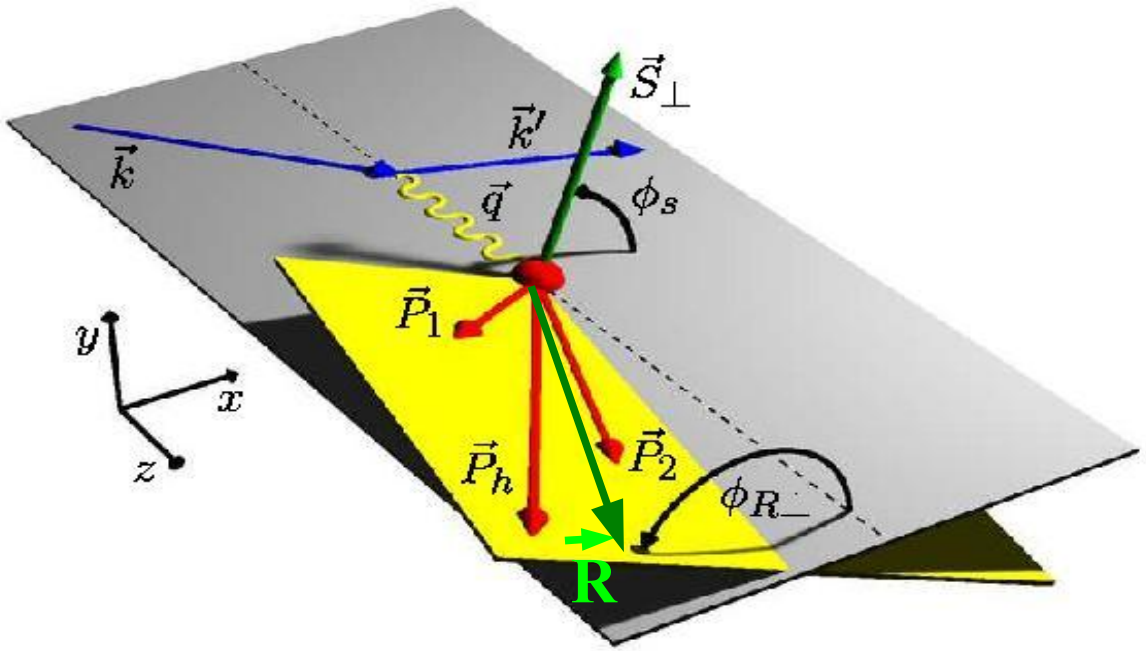
Integrated over $P_{h\perp}$:

$$\frac{A_{UT}^{\sin\phi_{RS}}}{D_{NN} \cdot f \cdot P} = A_{RS} = \frac{\sum_i e_i^2 \Delta_T q_i(x) H_i^{\sphericalangle h}(z, M_h^2)}{\sum_i e_i^2 q_i(x) D_i^h(z, M_h^2)}$$

$$\phi_{RS} = \phi_R - \phi_{S'}$$

$$= \phi_R + \phi_S - \pi$$

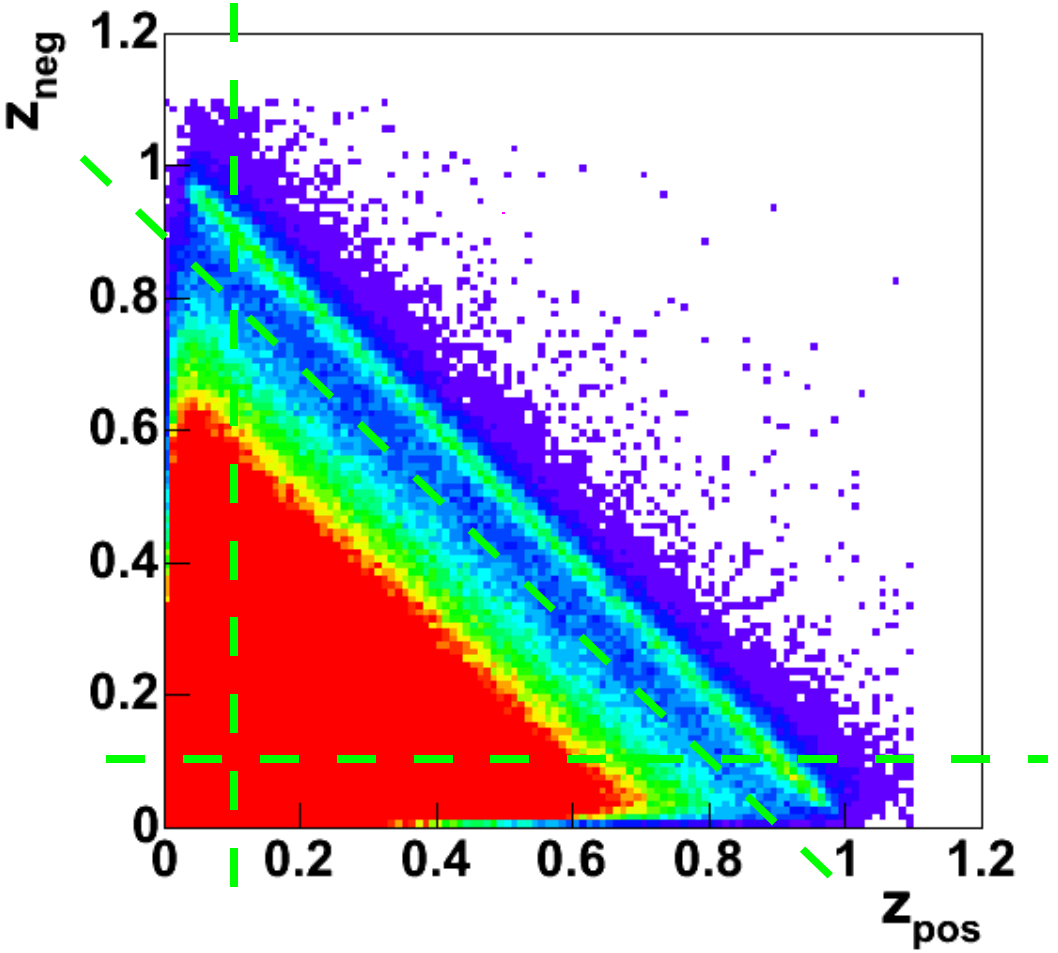
$$R = (z_1 \mathbf{p}_2 - z_2 \mathbf{p}_1)/(z_1 + z_2)$$



Selection of Hadron Pairs

Select all combinations of positive (h_1) and negative (h_2) hadrons with:

- $z_1 > 0.1$ & $z_2 > 0.1$ and $x_{f1} > 0.1$ & $x_{f2} > 0.1$
- $z = z_1 + z_2 < 0.9$

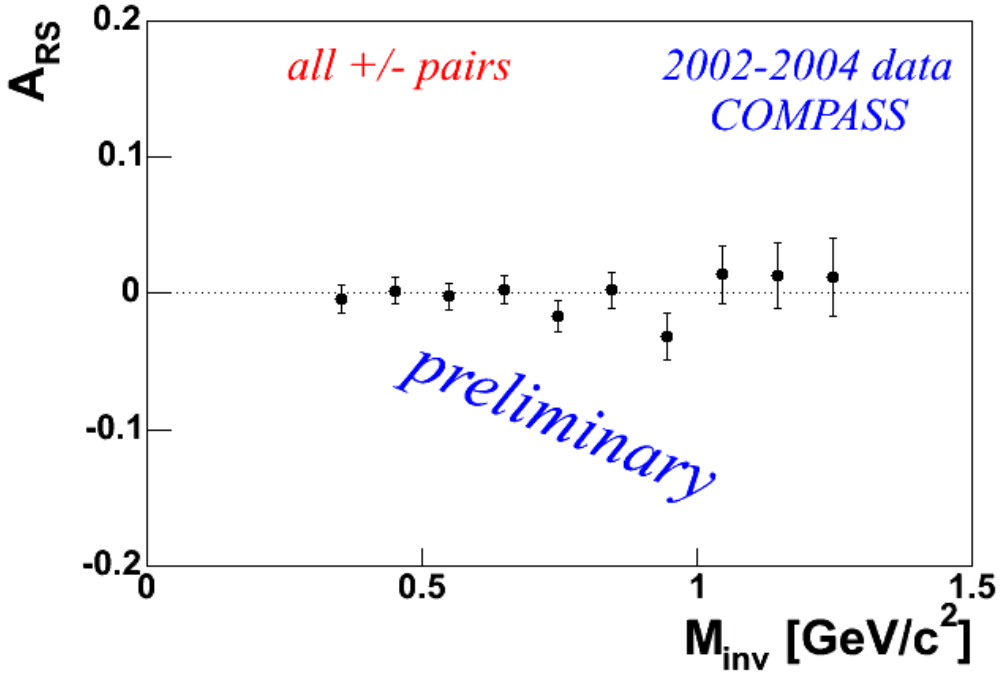


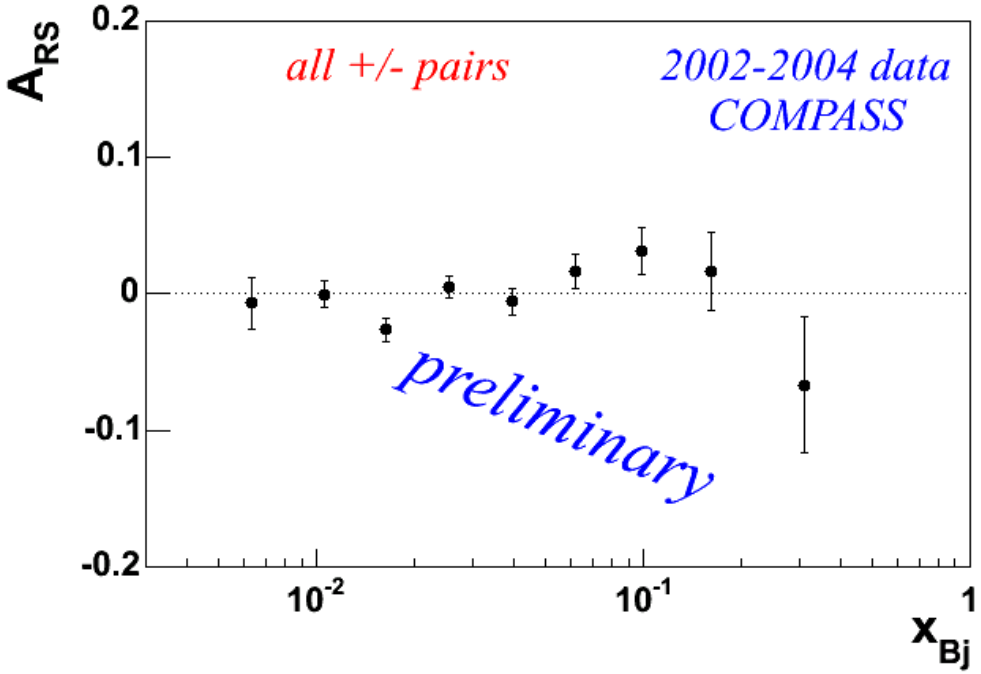
Presently no π / K / p separation by RICH

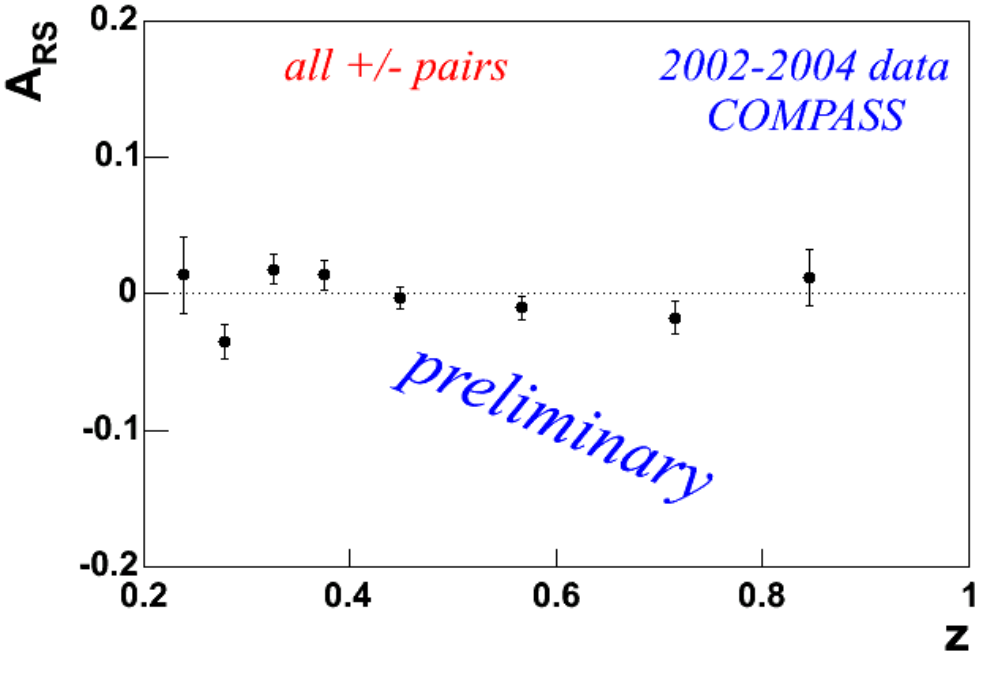
2-Hadron Asymmetries

$$A_{RS} = \frac{A_{UT}^{\sin\phi_{RS}}}{D_{NN} \cdot f \cdot P}$$

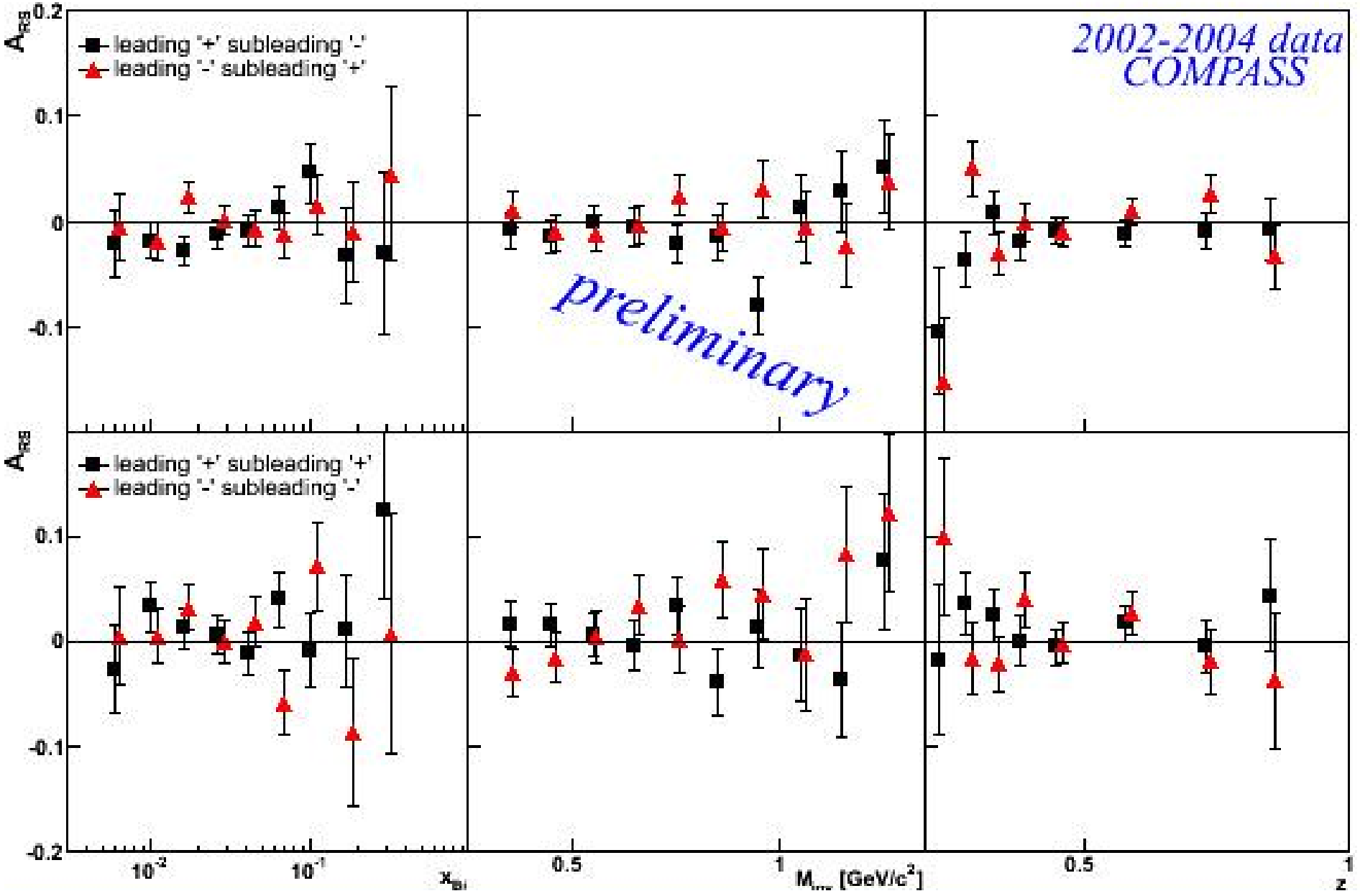
2002-2004 data







2-Hadron Asymmetries (z ordered pairs)



Conclusion (2)

- First results of the analysis of our transverse target data concerning two hadron asymmetries were shown.
- The observed asymmetries are small.
- Systematics checks performed on the data show, that systematic effects are smaller than the statistical error.

$\Delta_T q(x)$ from Λ polarization

Introducing the chiral-odd fragmentation function $\Delta_T D_{\Lambda/q}(z)$, the Λ polarization is related to $\Delta_T q(x)$ by:

$$P_T^{\Lambda} = f P_T D(y) \frac{\sum_a e_a^2 \cdot \Delta_T q_a(x) \cdot \Delta_T^0 D_{\Lambda/q}(z)}{\sum_a e_a^2 \cdot q_a \cdot D_{\Lambda/q}(z)}$$

In the self- analyzing decay: $\Lambda \rightarrow p\,\pi^-$ B.R. $\cong 64\,\%$

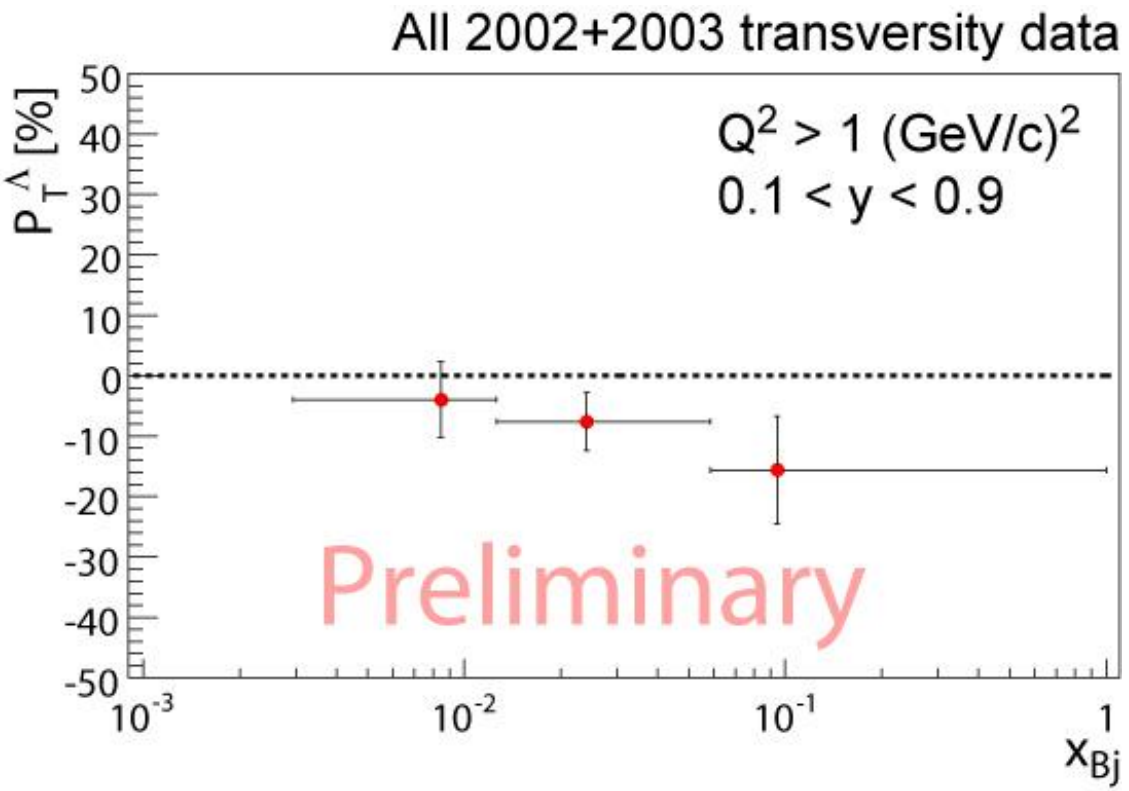
the Λ polarisation along the spin direction S is measured by

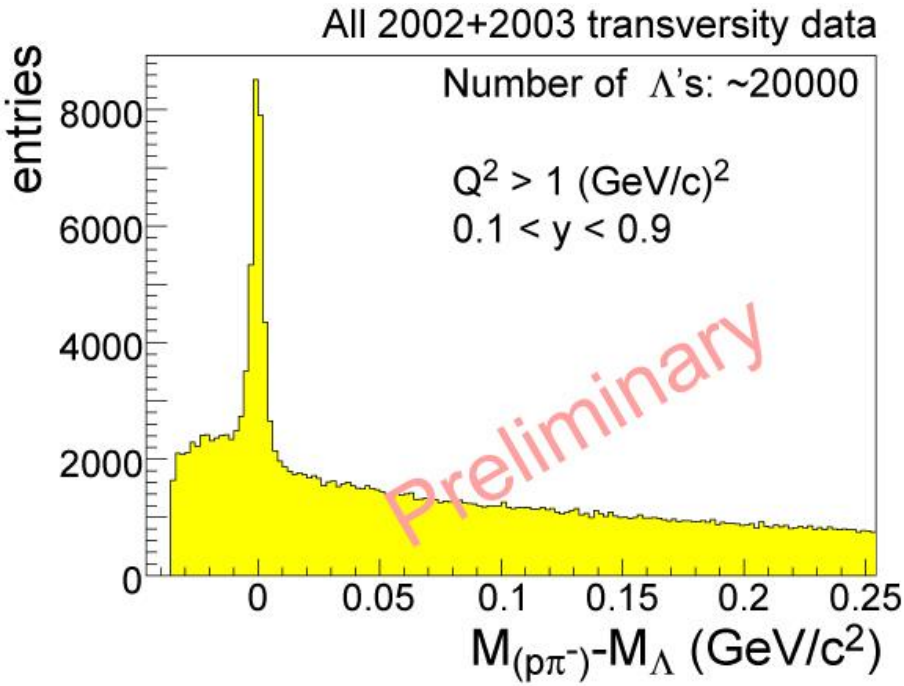
$$W(\vartheta^*) \propto (1 + \alpha\, P_s^{\Lambda} \cos(\vartheta^*))\ \ Acc(\vartheta^*)$$

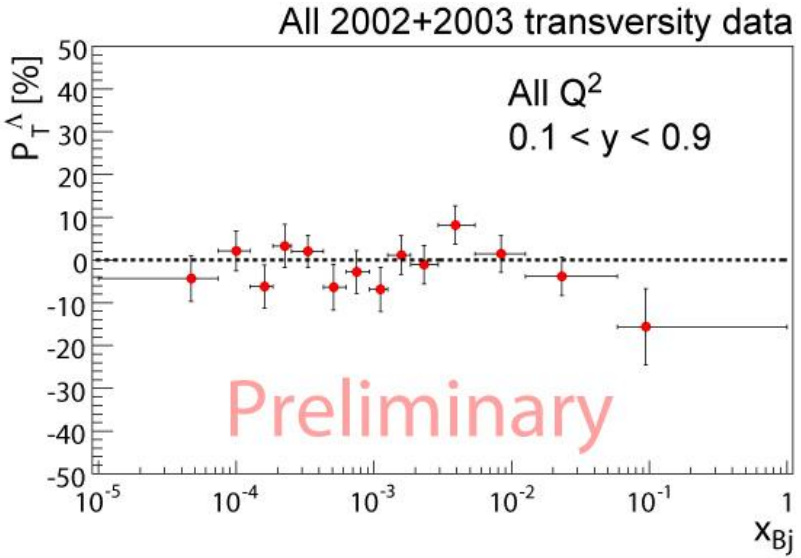
ϑ^* proton emission angle w.r.t. to S in the Λ rest frame

$Acc(\vartheta^*)$ the experimental acceptance

$\Delta_T q(x)$ from Λ polarization





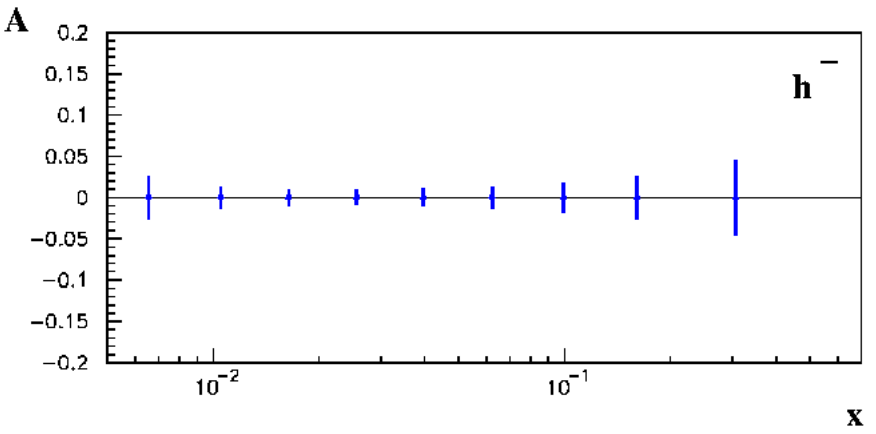


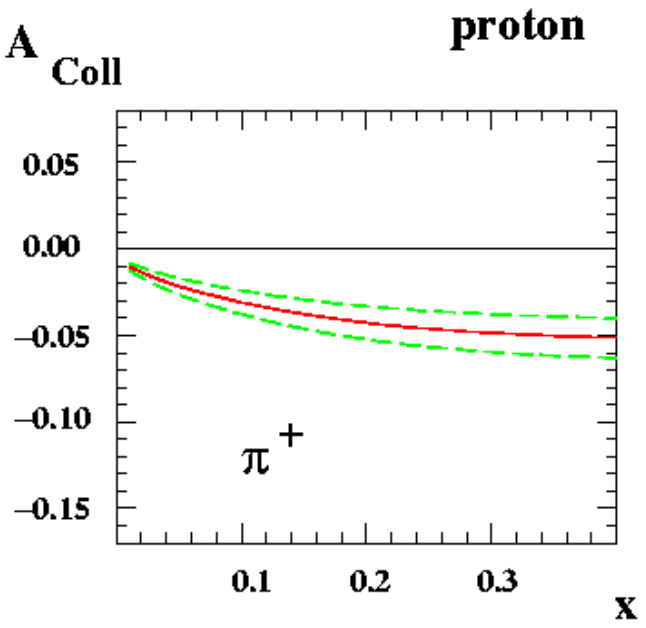
Conclusion (3)

- P_T^{Λ} has been measured in the COMPASS 2002+2003 transversity data sample.
- The statistics in the most interesting region ($x_{Bj} > 0.1$) is still poor.
- The study of systematic effects show that they are not larger than the statistical errors
- Including the 2004 data will improve the statistics by a factor of two.

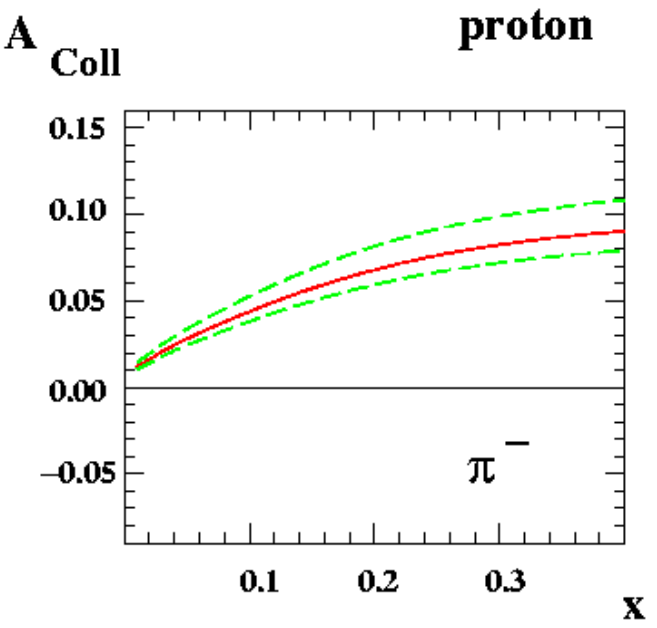
Expected signal for proton running

Expected signal for
~30 days running on NH_3





Collins effect

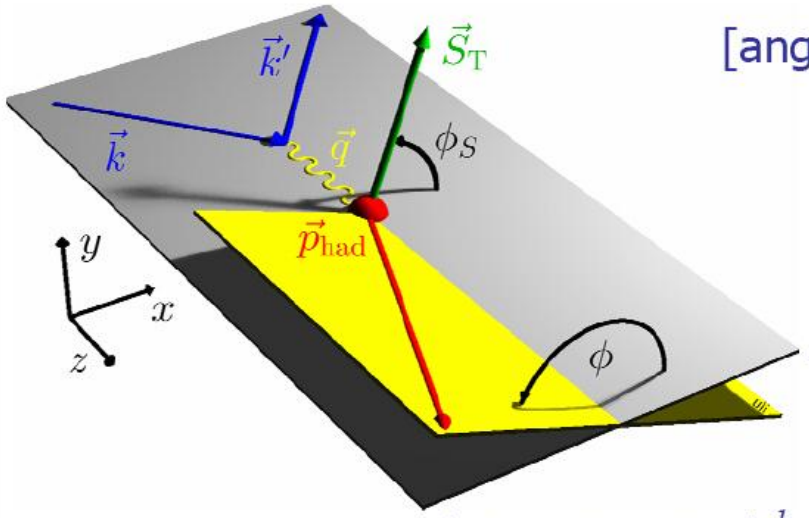


A. V. Efremov, K. Goeke and P. Schweitzer (hep-ph/0603054)

HERMES results

prepared by Delia Hasch

asymmetries and moments



[angle and moments definitions according to Trento conventions]

$$A_{UT}^{h}(\phi,\phi_S)=\frac{1}{|S_T|}\frac{N_h^{\uparrow}(\phi,\phi_S)-N_h^{\downarrow}(\phi,\phi_S)}{N_h^{\uparrow}(\phi,\phi_S)+N_h^{\downarrow}(\phi,\phi_S)}=$$

$$\approx 2\langle \sin(\phi+\phi_S)\rangle_{UT}^{h}\sin(\phi+\phi_S)+2\langle \sin(\phi-\phi_S)\rangle_{UT}^{h}\sin(\phi-\phi_S)+\cdots$$

Collins moment

$$\propto \delta q(x)H_1^{\perp q}(z)$$

Sivers moment

$$\propto f_{1T}^{\perp q}(x)D_1^{q}(z)$$

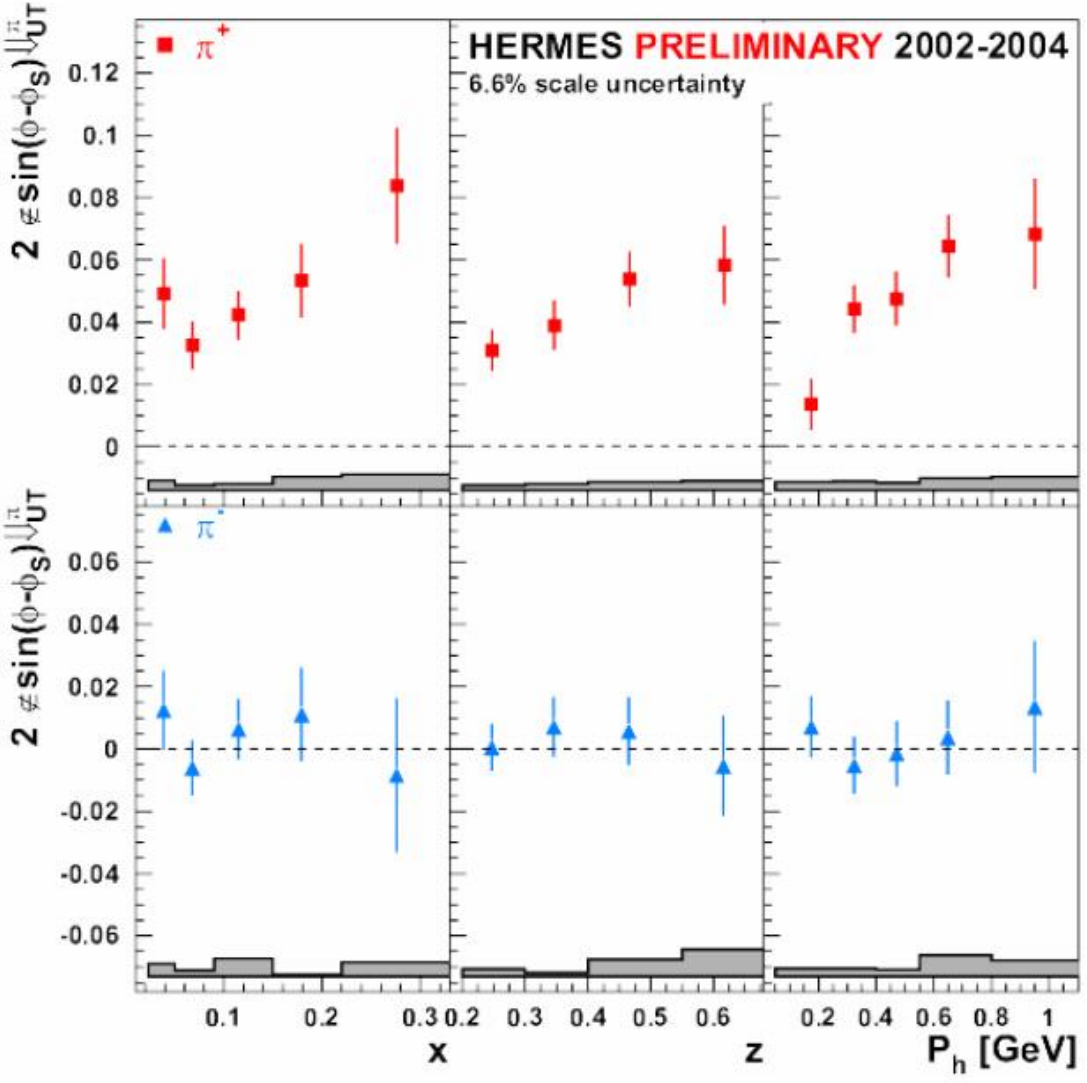
Collins and Sivers moments extracted by fitting the asymmetry with:

$$A_{UT}^{Fit}(\phi,\phi_S)=P(1)\sin(\phi+\phi_S)+P(2)\sin(\phi-\phi_S)+P(3)\sin(\phi_S)+P(4)\sin(2\phi+\phi_S)+P(5)$$

[Q2>1GeV2, W2>10GeV2, 0.1<y<0.85, 0.023<x<0.4]

Sivers asymmetries $\pi^{+/-}$

$$A_{\text{siv}}(\phi-\phi_S) \propto f_{1T}^{\perp}(x) D_1(z)$$



[systematic error includes smearing and acceptance effects and contributions from unpolarised <cos2f> and <cosf> moments]

- significantly positive π^+ asymmetry

→ requires non-zero orbital angular momentum

→ first hint of naïve T-odd DF from DIS

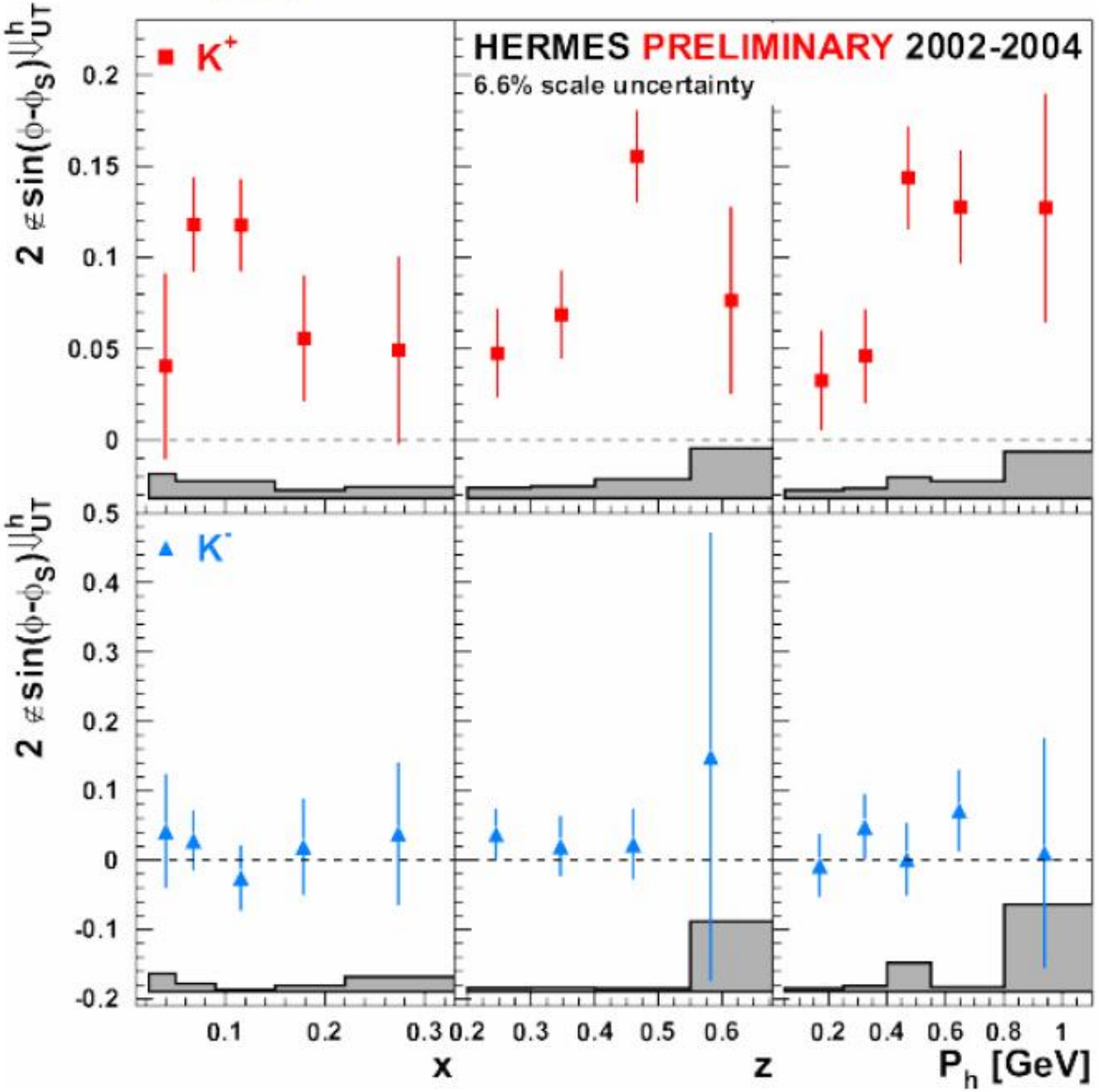
→ test of universality:

$$f_{1T}^{\perp}(x)_{\text{DIS}} = -f_{1T}^{\perp}(x)_{\text{DY}}$$

- D_1 known → Sivers DF can be extracted from HERMES data

Sivers asymmetries $K^{+/-}$

$$A_{\text{siv}}(\phi-\phi_S) \propto f_{1T}^{\perp}(x) D_1(z)$$



- significantly positive K^+ asymmetry

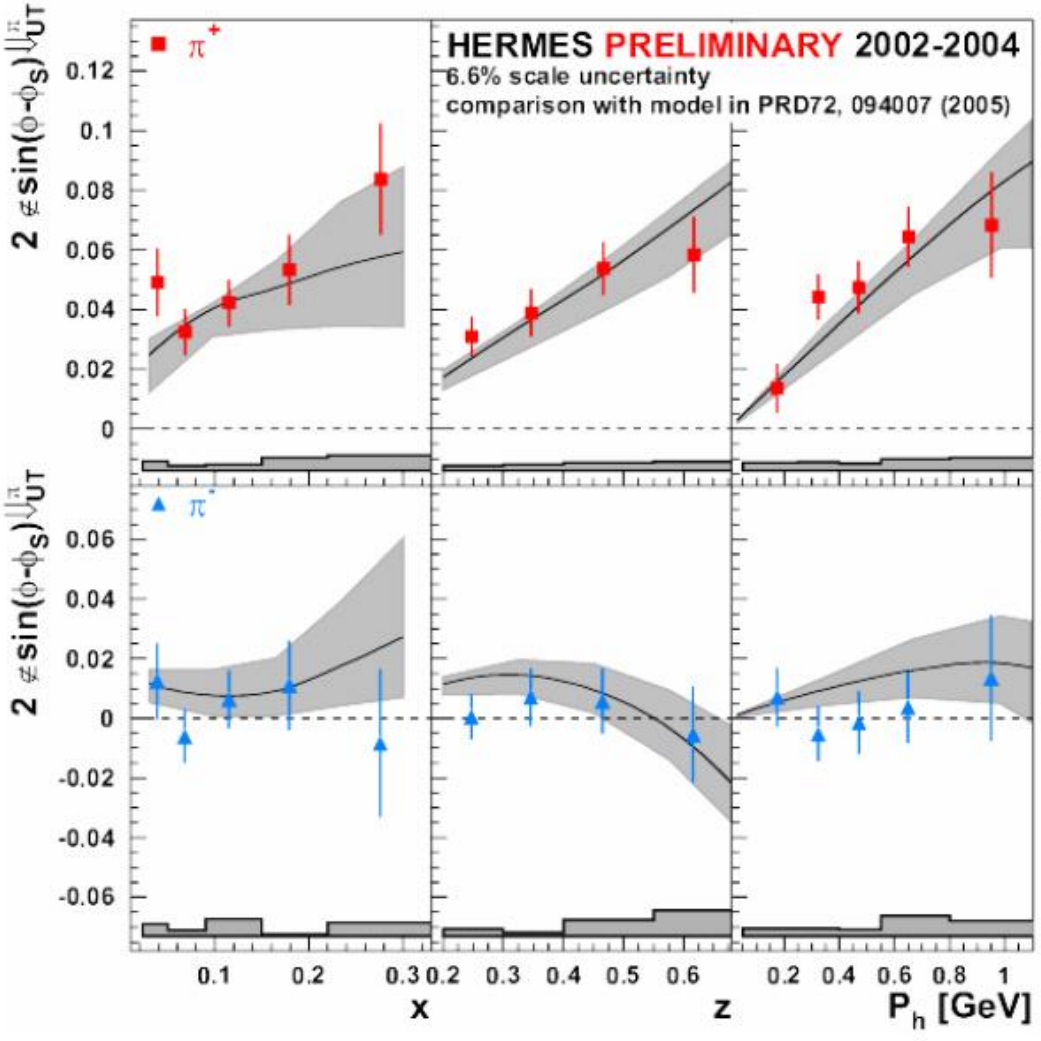
→ sea quarks may provide important contribution to Sivers function

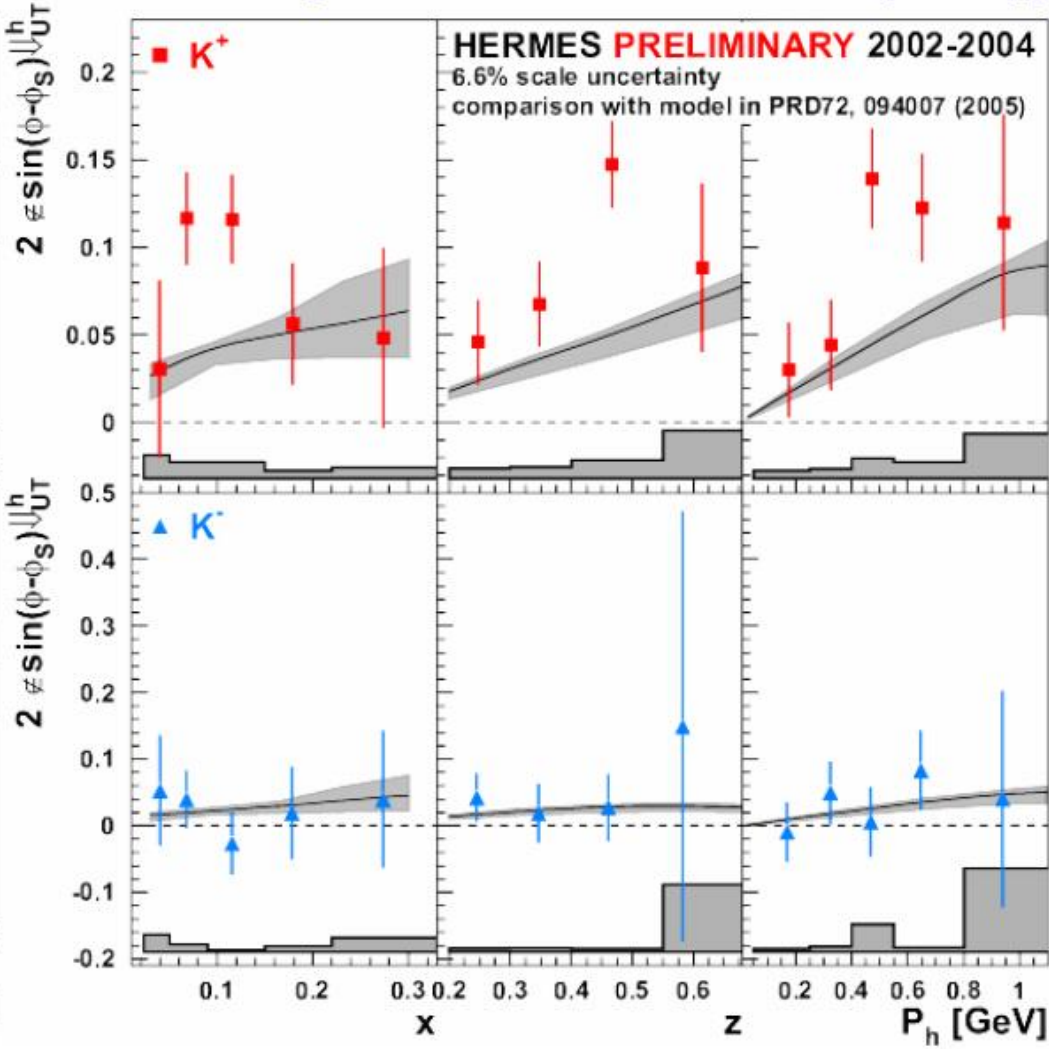
Sivers asymmetries

→ pion data fitted

→ kaon asymmetries predicted

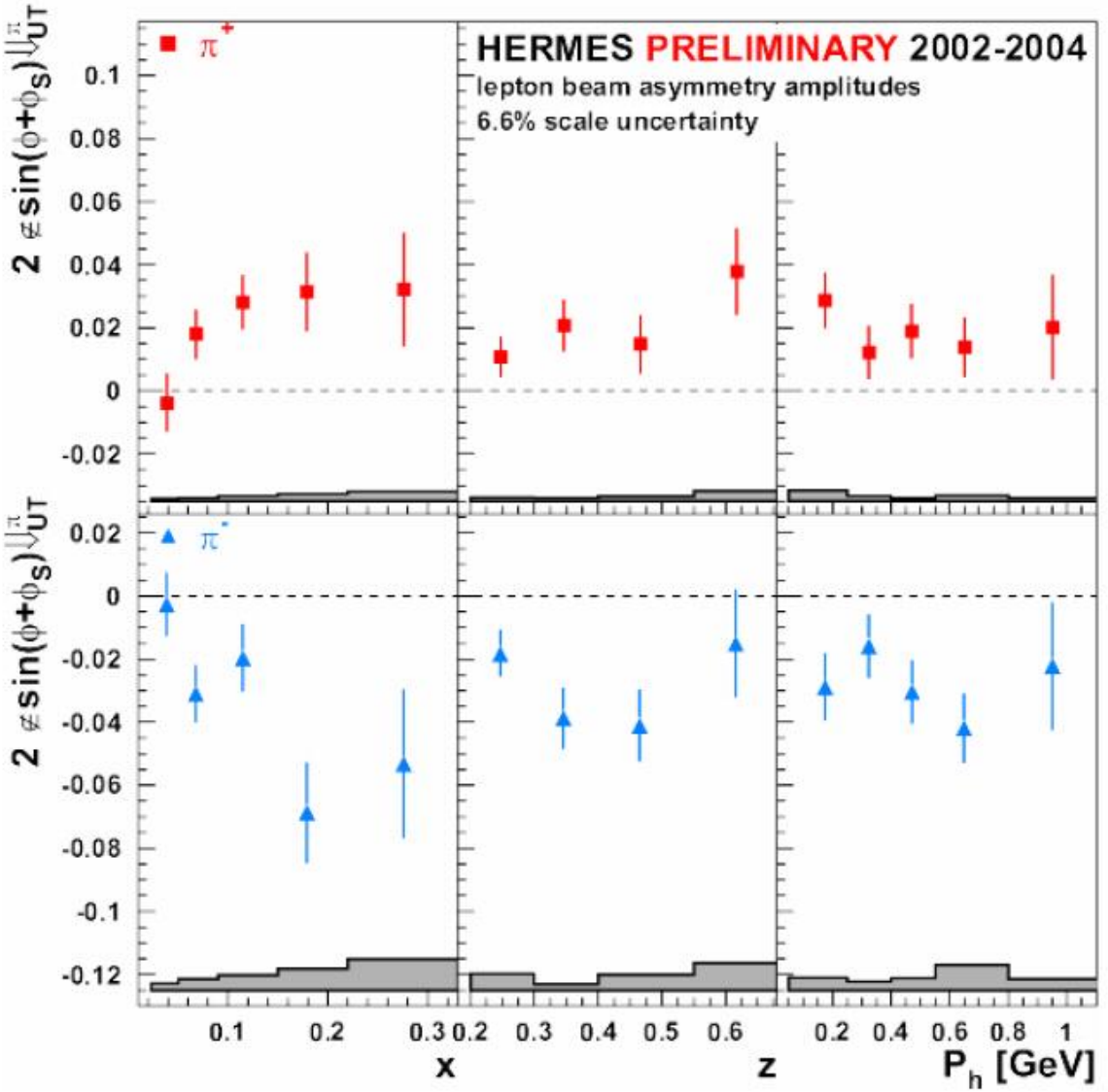
[Anselmino et al. PRD72(2005)]





Collins asymmetries $\pi^{+/-}$

$$A_{\text{coll}}(\phi+\phi_S) \propto h_1(x) H_1^{\perp}(z)$$



- positive π^+ and negative π^- asymmetries ... as maybe expected:

  ($\Delta u>0 \rightarrow \delta u>0$

  $\Delta d<0 \rightarrow \delta d<0$)

- *unexpected large* π^-

  →role of *unfavoured* fragmentation function?

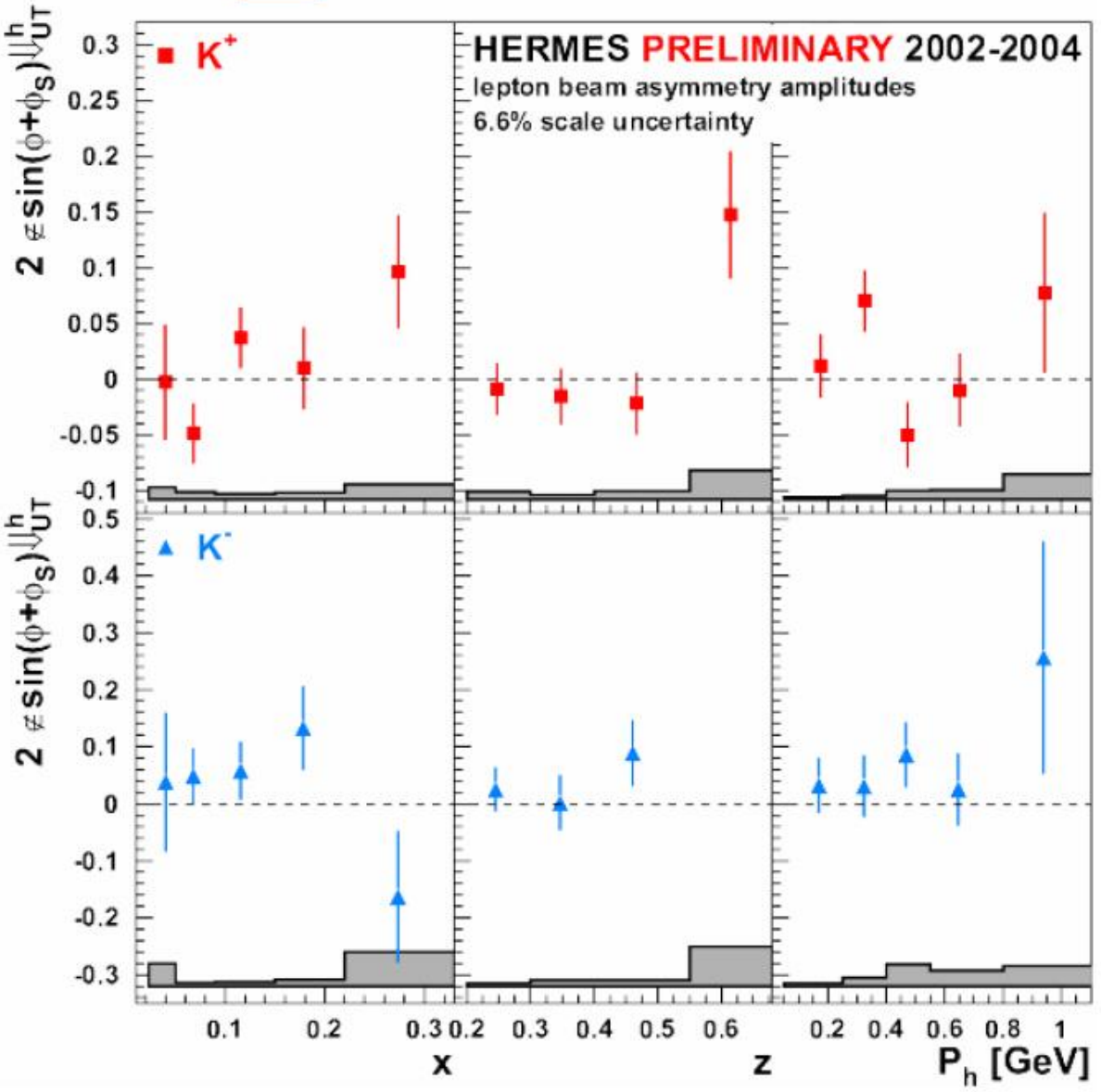
$$H_1^{\perp}(z)_{unfav.} \approx -H_1^{\perp}(z)_{fav.}$$

→ $H_1^{\perp}(z)$ *NEEDED!*

BELLE ☺

Collins asymmetries $K^{+/-}$

$$A_{\text{coll}}(\phi+\phi_S) \propto h_1(x)H_1^{\perp}(z)$$

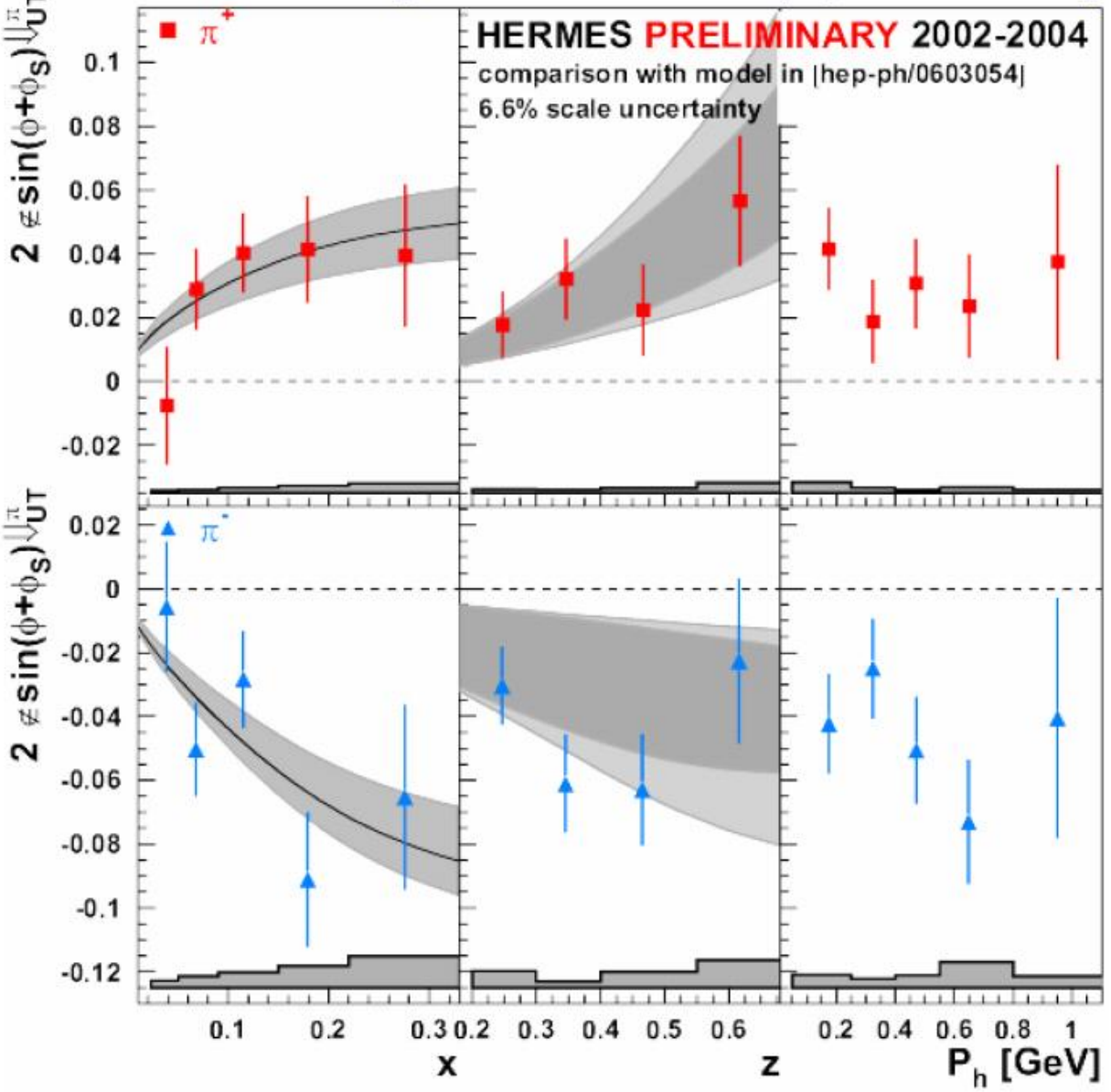


$K^+ > 0 \quad K^- > 0$

K^+ in agreement with π^+

Collins asymmetries

[Efremov et al. hep-ph/0603054]



→ h_1 from χQSM

→ Collins FF:

x-dependence:

Hermes data fitted to obtain parameter for ansatz of CollinsFF

z-dependence:

BELLE data fitted and asymmetry for Hermes calculated

complementary way to access transversity:

2hadron asymmetries

$$e\, p^{\uparrow} \rightarrow e\, \pi^{+}\pi^{-}\, X$$

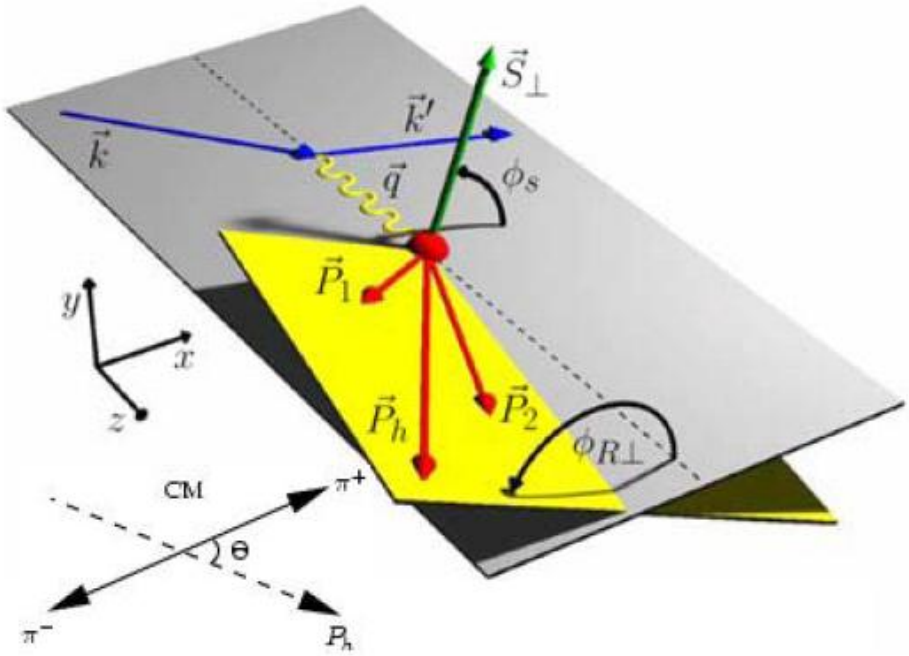
2hadron asymmetry

interference arises from different partial waves of $\pi^+\pi^-$ system

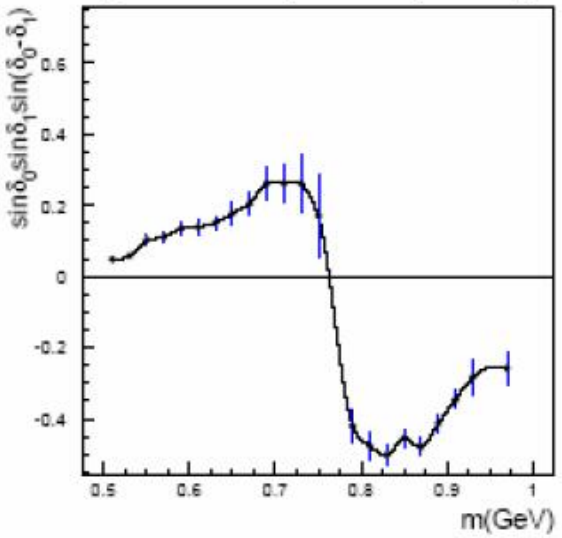
→!collinear factorisation! ← relativ. momentum: $R=(P_{\pi+}+P_{\pi-})/2$

can have transv. component even when integrating over P_T of the pair

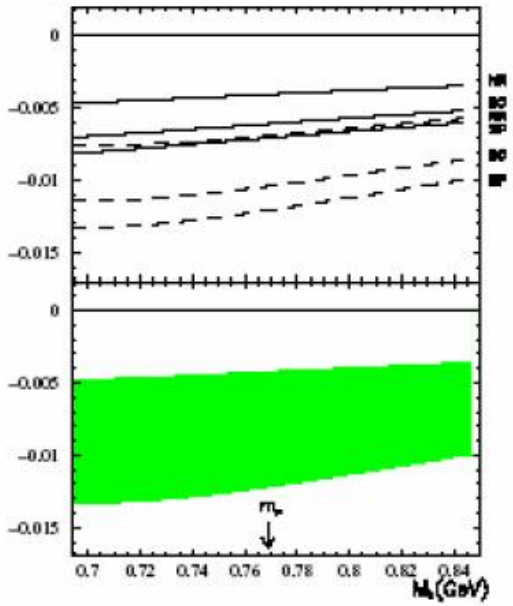
$$A_{UT}^{\sin(\phi_R-\phi_S)\sin\theta} \propto h_1(x)H_1^{\perp\sphericalangle}(z)$$



[Jaffe etal,PRL80,1998]



[Radici etal,PRD65,2002]

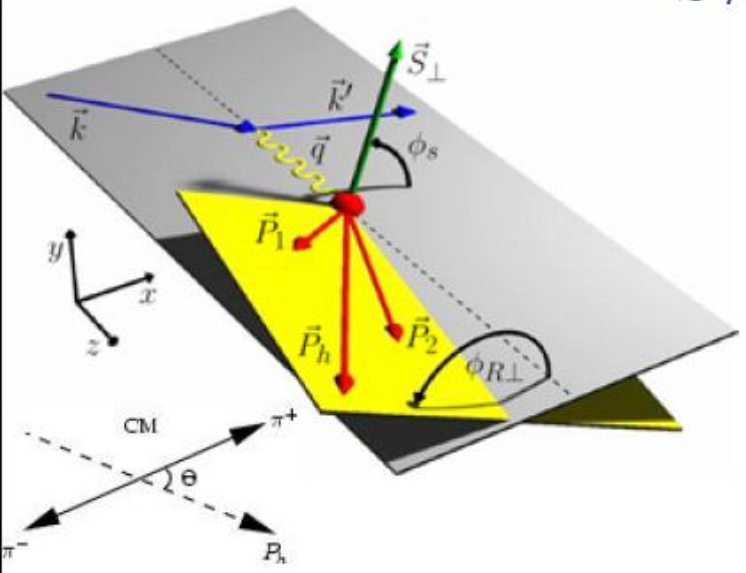


→ needs new unknown 2hadron fragmentation function

2hadron asymmetry

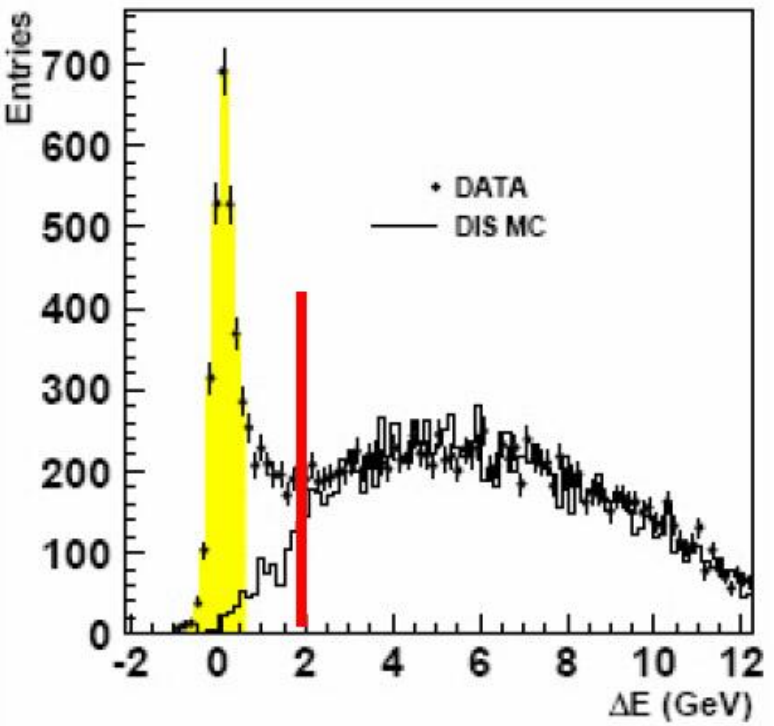
$$A_{UT}(\phi_{R\perp},\phi_S,\theta) = \frac{1}{S_T}\frac{N^{\uparrow}(\phi_{R\perp},\phi_S,\theta)/N^{\uparrow}_{\mathrm{DIS}} - N^{\downarrow}(\phi_{R\perp},\phi_S,\theta)/N^{\downarrow}_{\mathrm{DIS}}}{N^{\uparrow}(\phi_{R\perp},\phi_S,\theta)/N^{\uparrow}_{\mathrm{DIS}} + N^{\downarrow}(\phi_{R\perp},\phi_S,\theta)/N^{\downarrow}_{\mathrm{DIS}}}$$

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



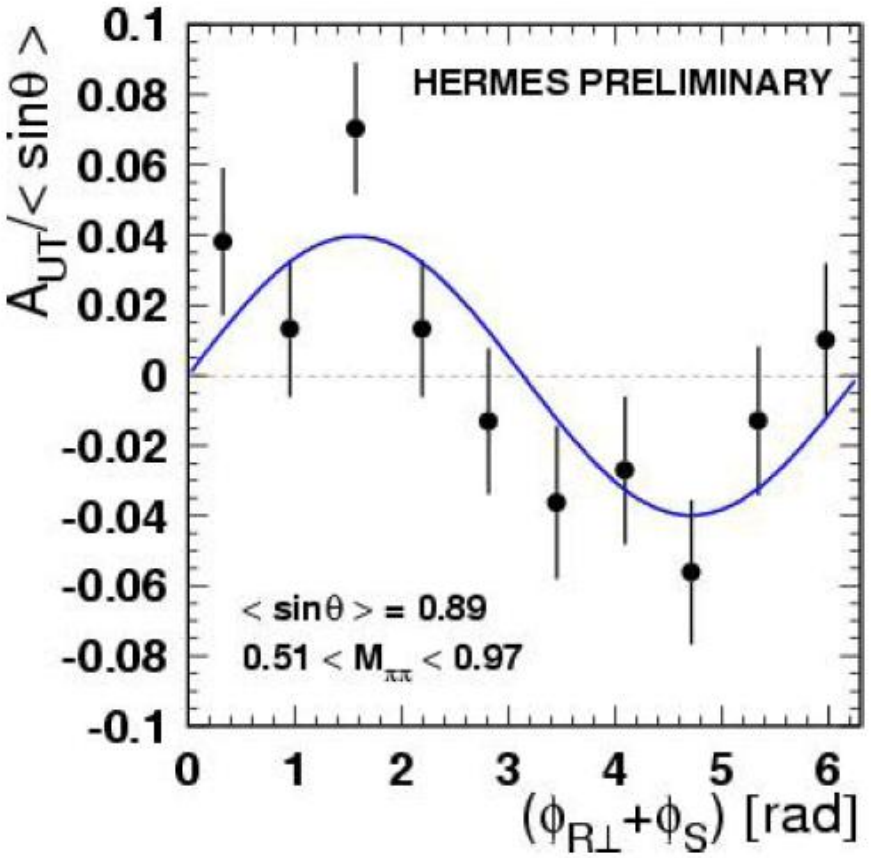
→ for >2 hadrons: all combinations

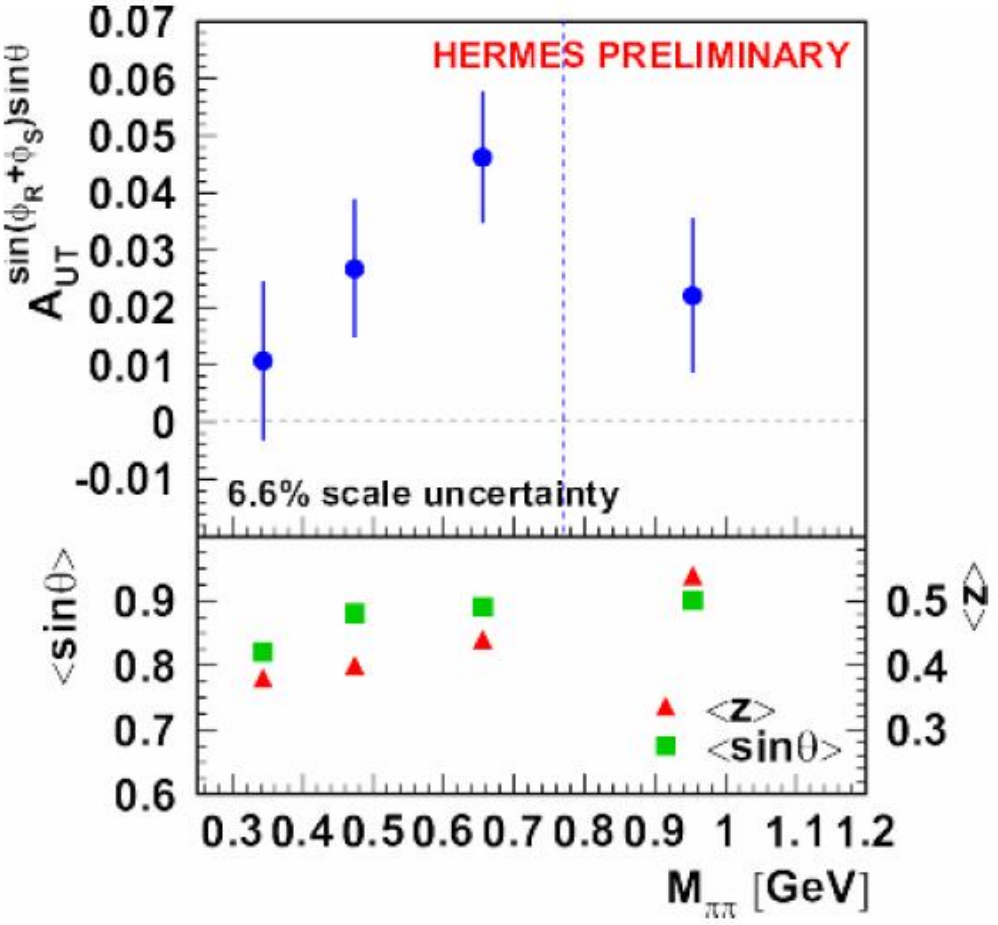
→ exclusive ρ^0 excluded



2hadron asymmetry

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



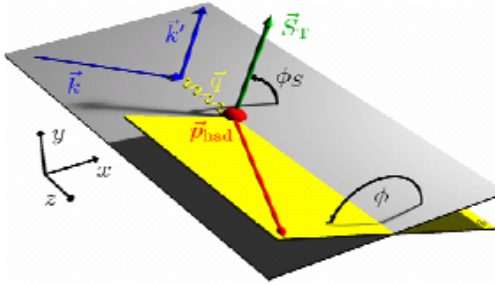


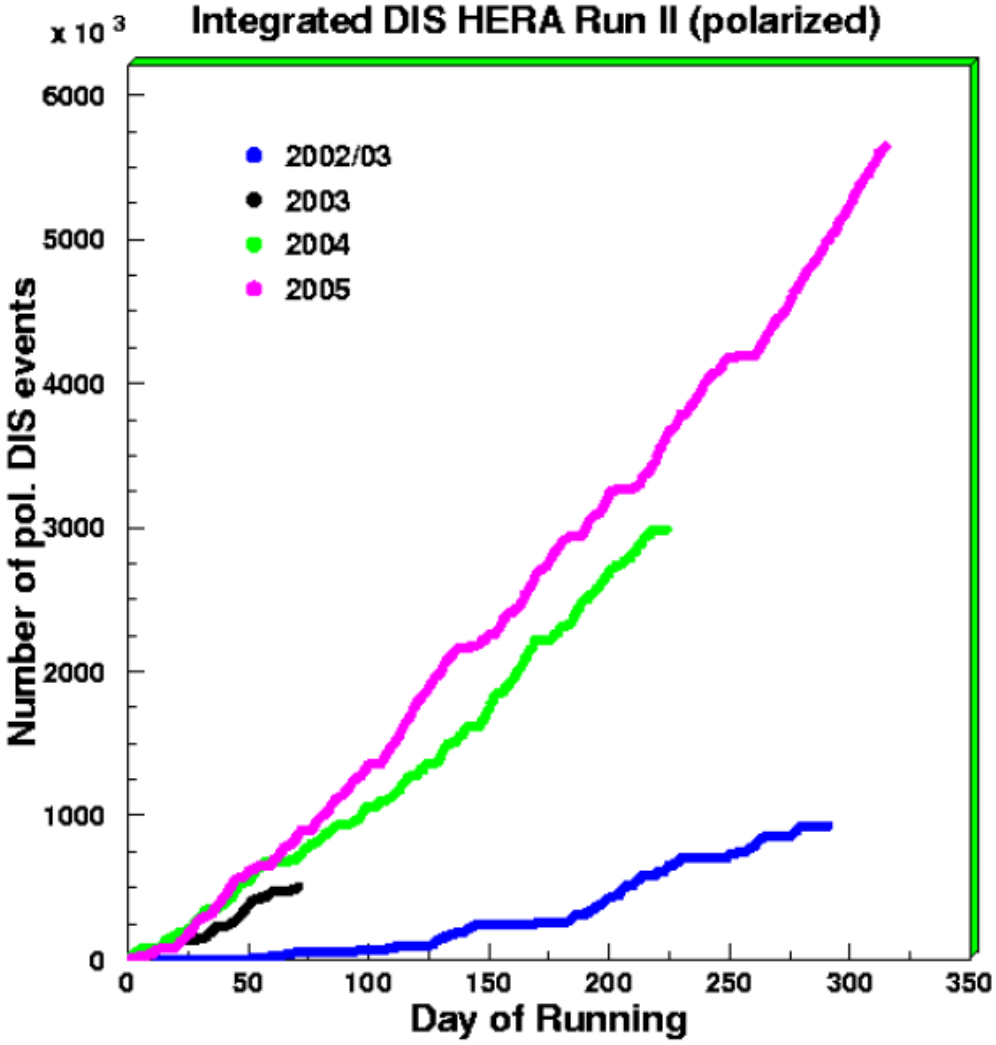
$$A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin\theta} =$$

0.040±0.009 (stat) ±0.003 (sys)

→ positive moments for all invariant mass bins

HERMES future on TMD





in 2005 statistics nearly doubled compared to 2002-04

→ 2D binning: disentangle x (pdf) and z (FF) dependence

what comes next:

→ weighted asymmetries

→ cosϕ and cos2ϕ moments

→ Sivers extraction with purity formalism

Summary

COMPASS results from 2002 -2004 with ^{6}LiD target

Collins and Sivers asymmetries compatible with zero

2-hadron asymmetries for all $h^{+}h^{-}$ pairs and z ordered pairs

Λ polarisation from 2002-2003 data

In 2006 running with NH_3 planned

HERMES results from 2002 -2004 with hydrogen target

Collins and Sivers asymmetries for pions and kaons

2-hadron asymmetries for all pairs

2005 data will double statistics