Transversity signals at COMPASS

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on behalf of the COMPASS Collaboration

Outline

- The COMPASS experiment
- Results on:
  - Collins/Sivers asymmetries :

    positive and negative leading hadrons

    $\pi^{\pm}$, K$^{\pm}$
  - Two hadron asymmetries

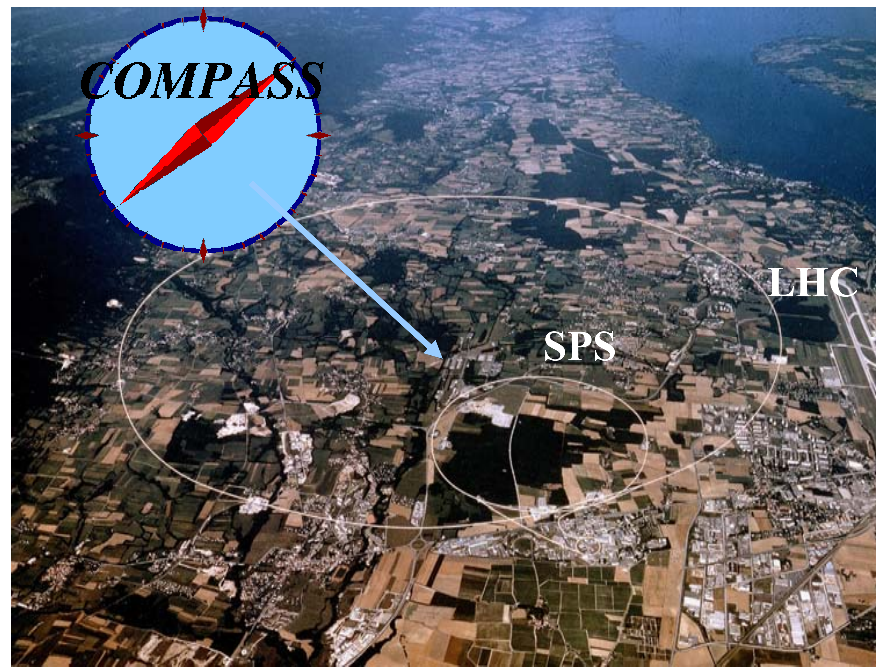
QCD MONTPELLIER

Quantum Chromo-Dynamics

The COMPASS experiment

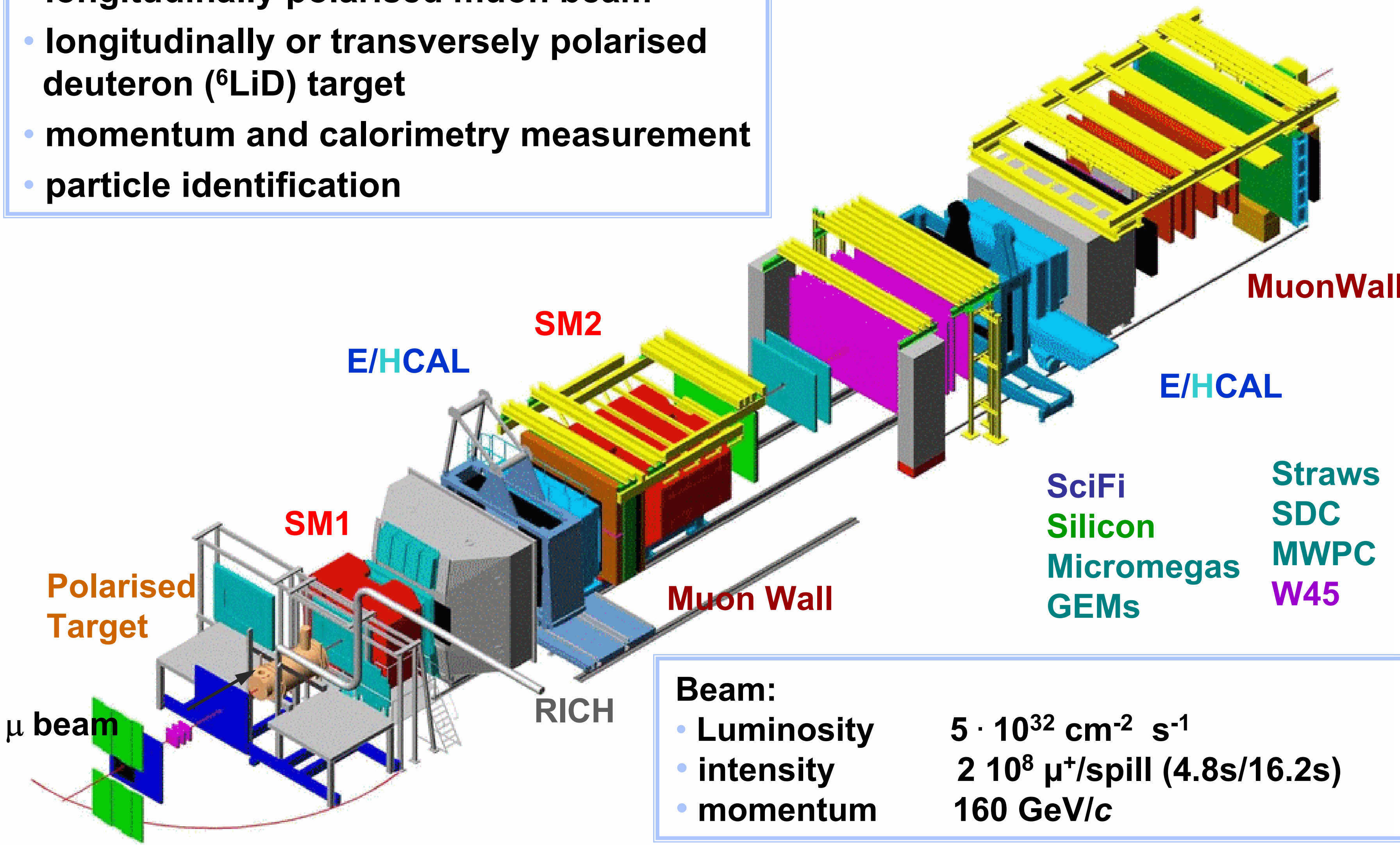
Fixed target experiment at the CERN SPS:
240 physicists from 28 institutes, 11 Countries.

Very broad physics program focused on **nucleon spin structure** and on **hadron spectroscopy.**



COMPASS spectrometer

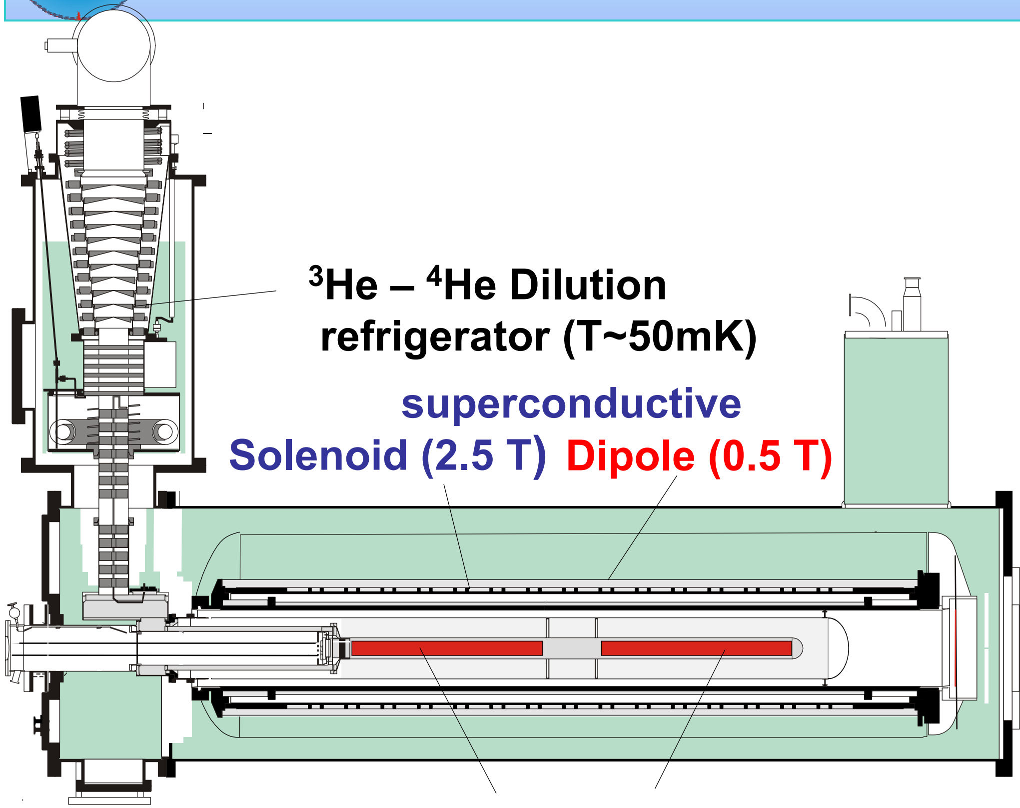
- **longitudinally polarised muon beam**
- **longitudinally or transversely polarised deuteron (^{6}LiD) target**
- **momentum and calorimetry measurement**
- **particle identification**



Beam:

- **Luminosity** $5 \cdot 10^{32}$ cm^{-2} s^{-1}
- **intensity** $2\ 10^8$ μ^+/spill (4.8s/16.2s)
- **momentum** 160 GeV/c

The polarized target



^{6}LiD

- **Target polarization ~ 50%**
- **Dilution factor ~ 0.38**

For transversity:

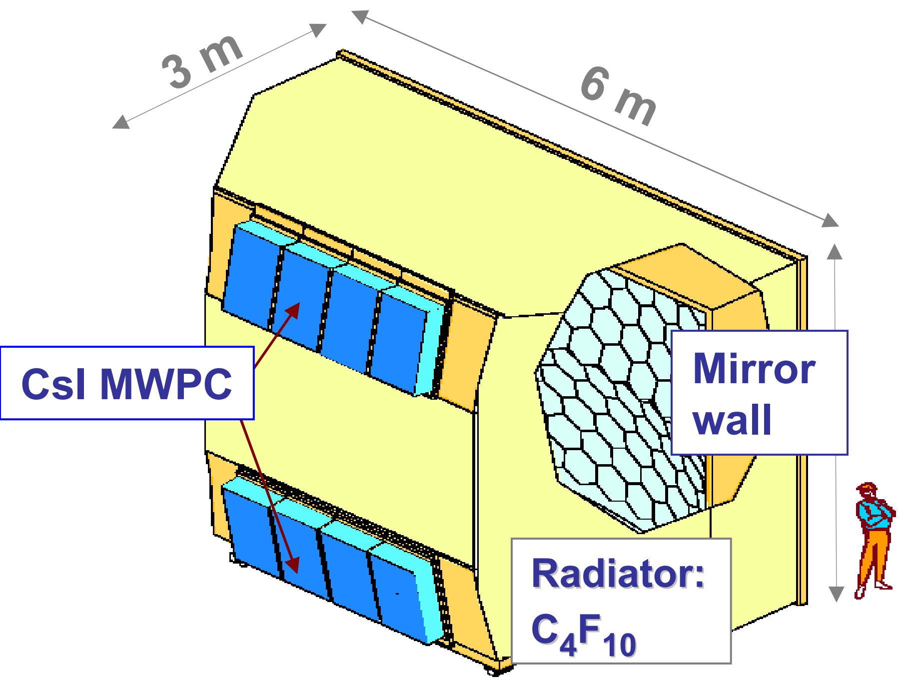
1) ⇧ ⇩

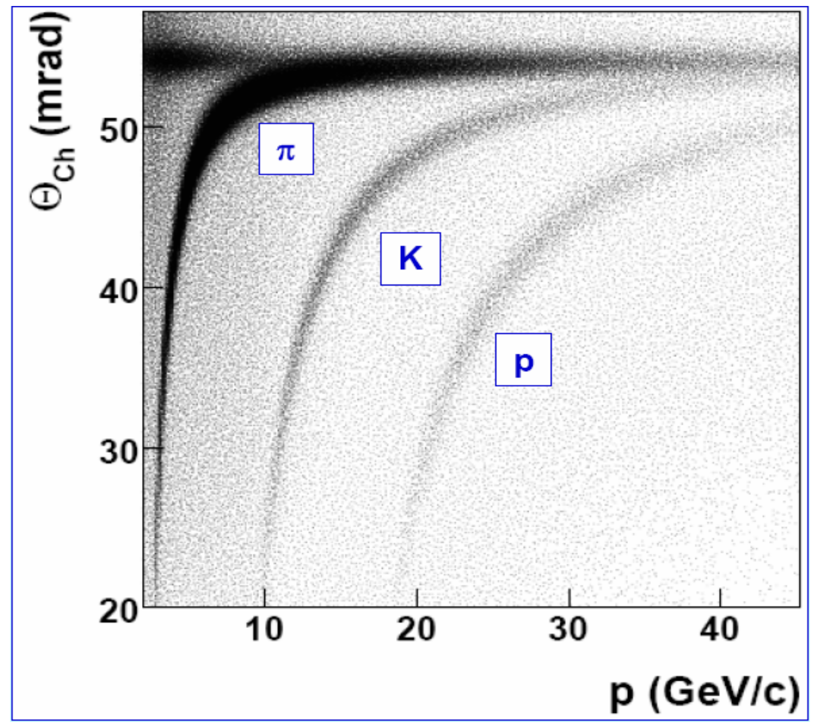
2) ⇩ ⇧

Reversed once a week
(relaxing time > 2000h)

COMPASS RICH-1

- RICH-1 fully efficient for transversity data since 2003
- Cherenkov thresholds: $\pi \sim 3$ GeV/c
  K ~ 9 GeV/c
  p ~ 17 GeV/c
- 2 σ π/K separation at 43 GeV/c





Single hadron asymmetries

Two azimuthal asymmetries:

- **Collins effect:** fragmentation of transversely polarized quarks to unpolarized hadrons :

$$N_h^{\pm}(\Phi_C) = N_h^0 \cdot \left\{ 1 \pm A_C^h \cdot \sin\Phi_C \right\}$$

$$\boxed{A_{Coll} = \frac{A_C^h}{f \cdot P_T \cdot D_{nn}} = \frac{\sum_q e_q^2 \cdot \Delta_T q \cdot \Delta_T^0 D_q^h}{\sum_q e_q^2 \cdot q \cdot D_q^h}}$$

- **Sivers effect:** modulation of transverse momentum of unpolarized quarks in the transverse polarized nucleon

$$N_h^{\pm}(\Phi_S) = N_h^0 \cdot \left\{ 1 \pm A_S^h \cdot \sin\Phi_S \right\}$$

$$\boxed{A_{Siv} = \frac{A_S^h}{f \cdot P_T} = \frac{\sum_q e_q^2 \cdot \Delta_0^T q \cdot D_q^h}{\sum_q e_q^2 \cdot q \cdot D_q^h}}$$

Single hadron asymmetries

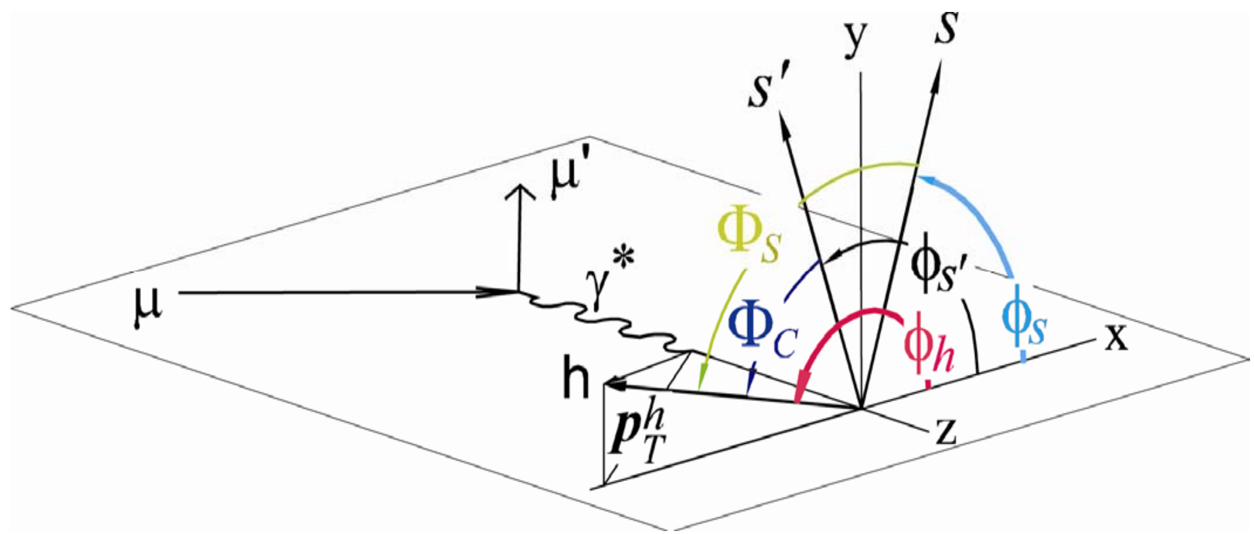
Collins and Sivers terms in SIDIS cross sections depend on different combination of angles:

$$\boxed{\Phi_C = \phi_h - \phi_{s'}}$$

Collins angle

$$\boxed{\Phi_S = \phi_h - \phi_s}$$

Sivers angle



ϕ_h azimuthal angle of the hadron

ϕ_s azimuthal angle of the transverse spin of the initial quark

$\phi_{s'}$ azimuthal angle of the transverse spin of the fragmenting quark

$\phi_{s'} = \pi - \phi_s$ ***(spin flip)***

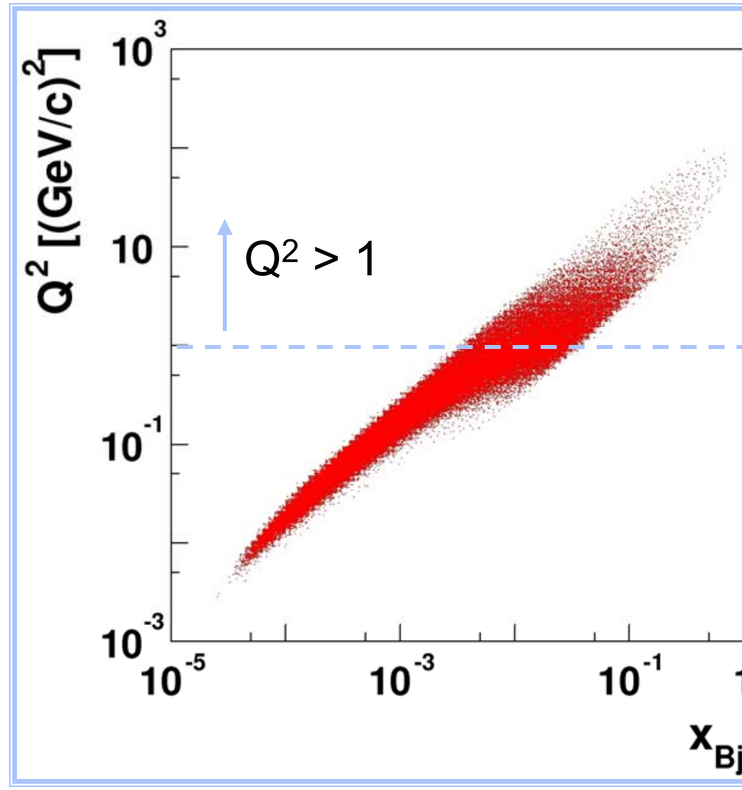
Event selection

DIS cuts:

- $Q^2 > 1$
- $0.1 < y < 0.9$
- $W > 5$ GeV/c

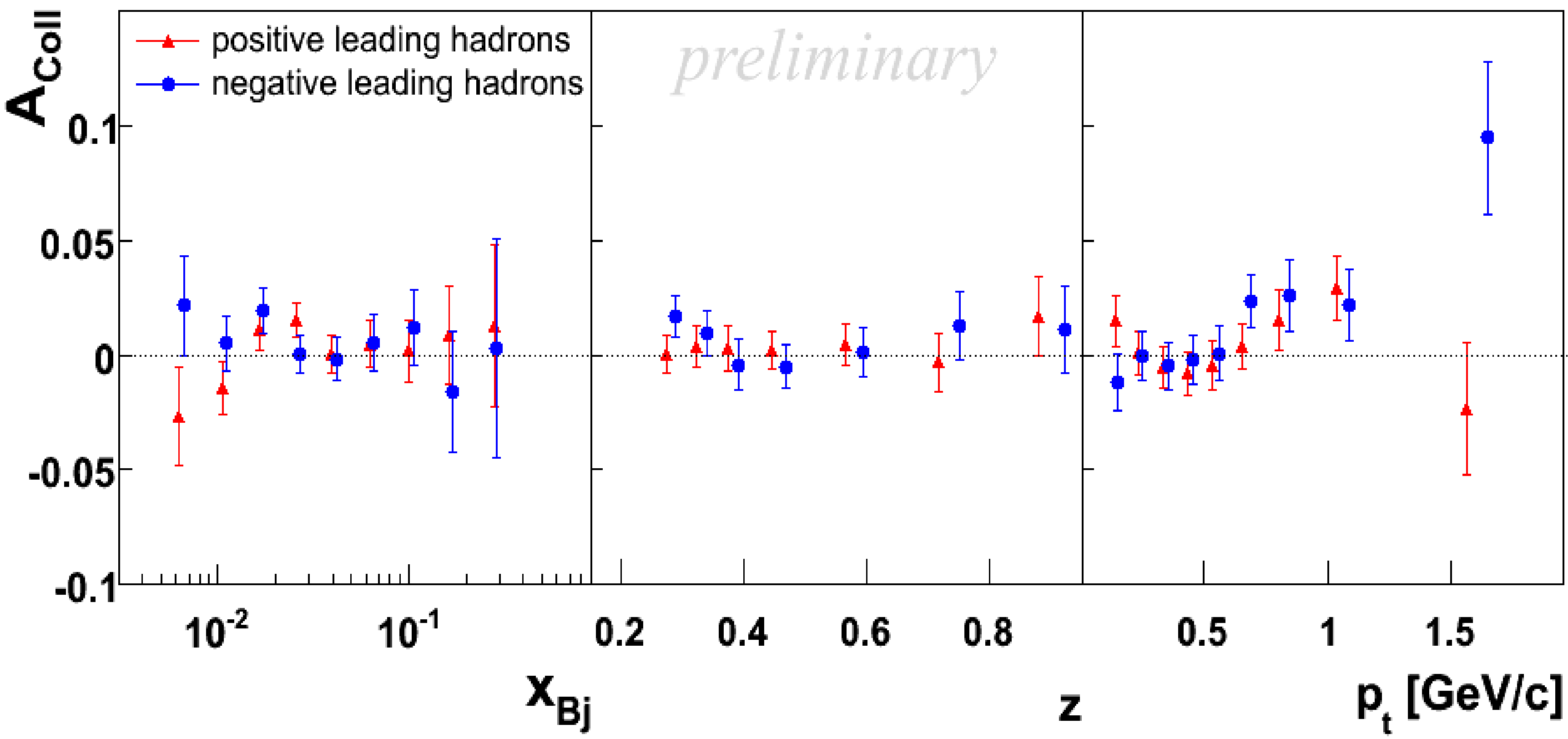
Leading hadron selection:

- $z > 0.25$
- $p_t > 0.1$



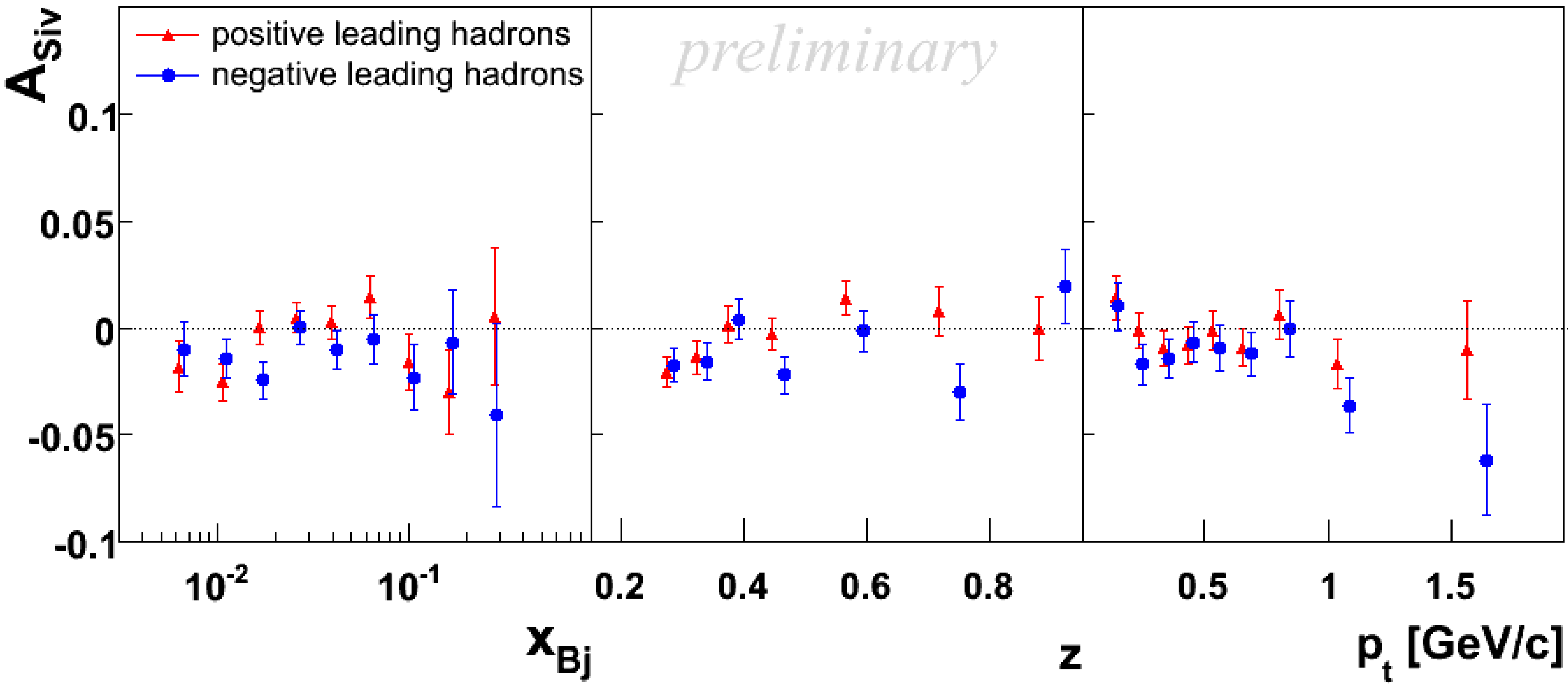
Statistics 2002 - 2004:
5.8 * 10^6 positive leading hadrons
4.6 * 10^6 negative leading hadrons

Collins asymmetries 2002-2004 data



- only statistical errors shown (systematic errors considerably smaller)
- Small asymmetries (possible explanation: cancellation between p and n)

Sivers asymmetries 2002-2004 data



- **only statistical errors shown (systematic errors considerably smaller)**
- **Small asymmetries (possible explanation: cancellation between p and n)**

Interpretation

Phenomenological models can describe at the same time the Hermes (proton) and COMPASS (deuteron) data:

- Anselmino et al. (hep-ph/0507181),
- Vogelsang and Yuan (hep-ph/0507266),
- Efremov, Goeke and Schweitzer (hep-ph/0603054)

implying for deuteron a cancellation

between protons and neutrons.

Hadron identification

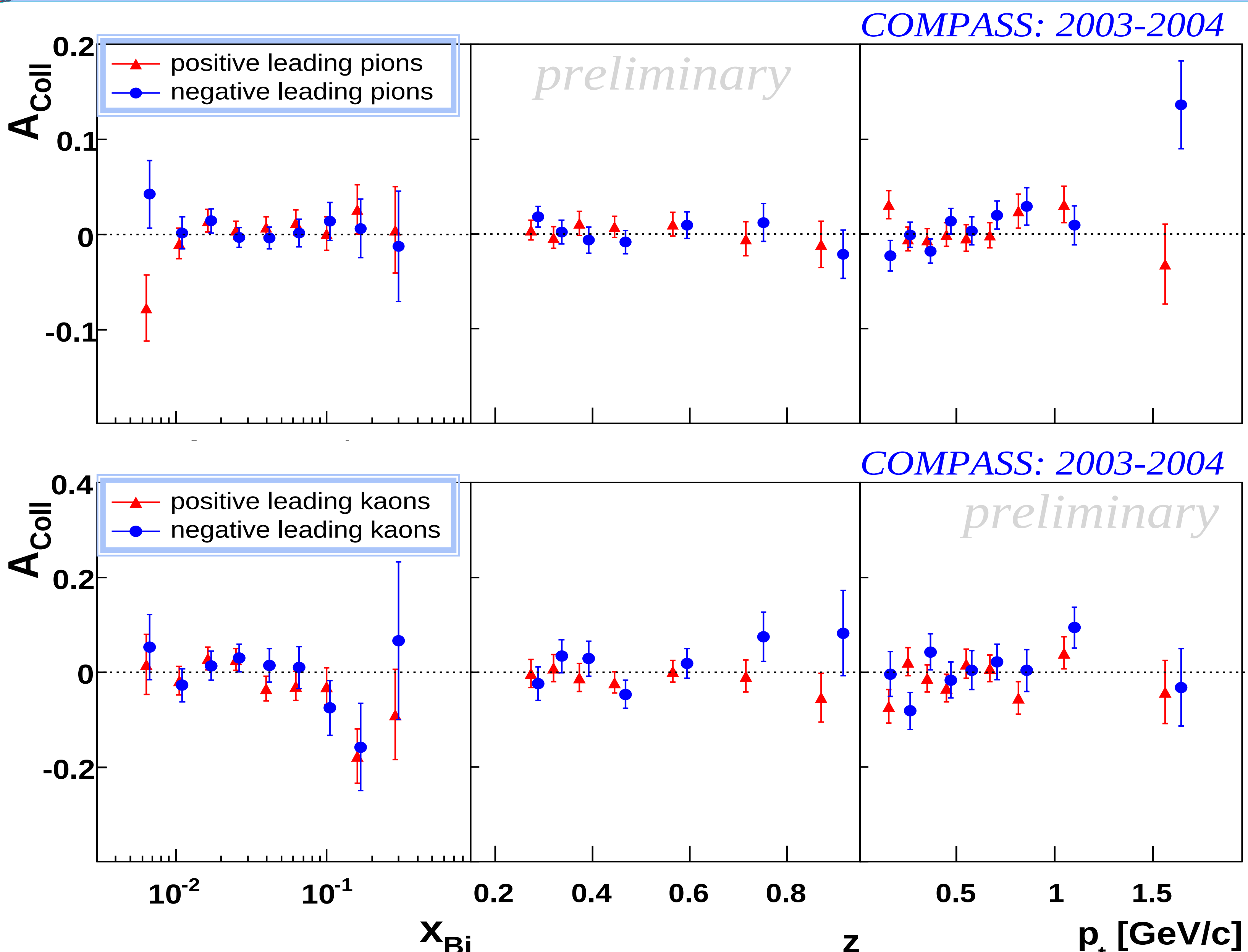
- Hadron identification is based on RICH response: several studies performed on the stability in time of the detector.
- In the leading hadron sample:

  ~76% pions

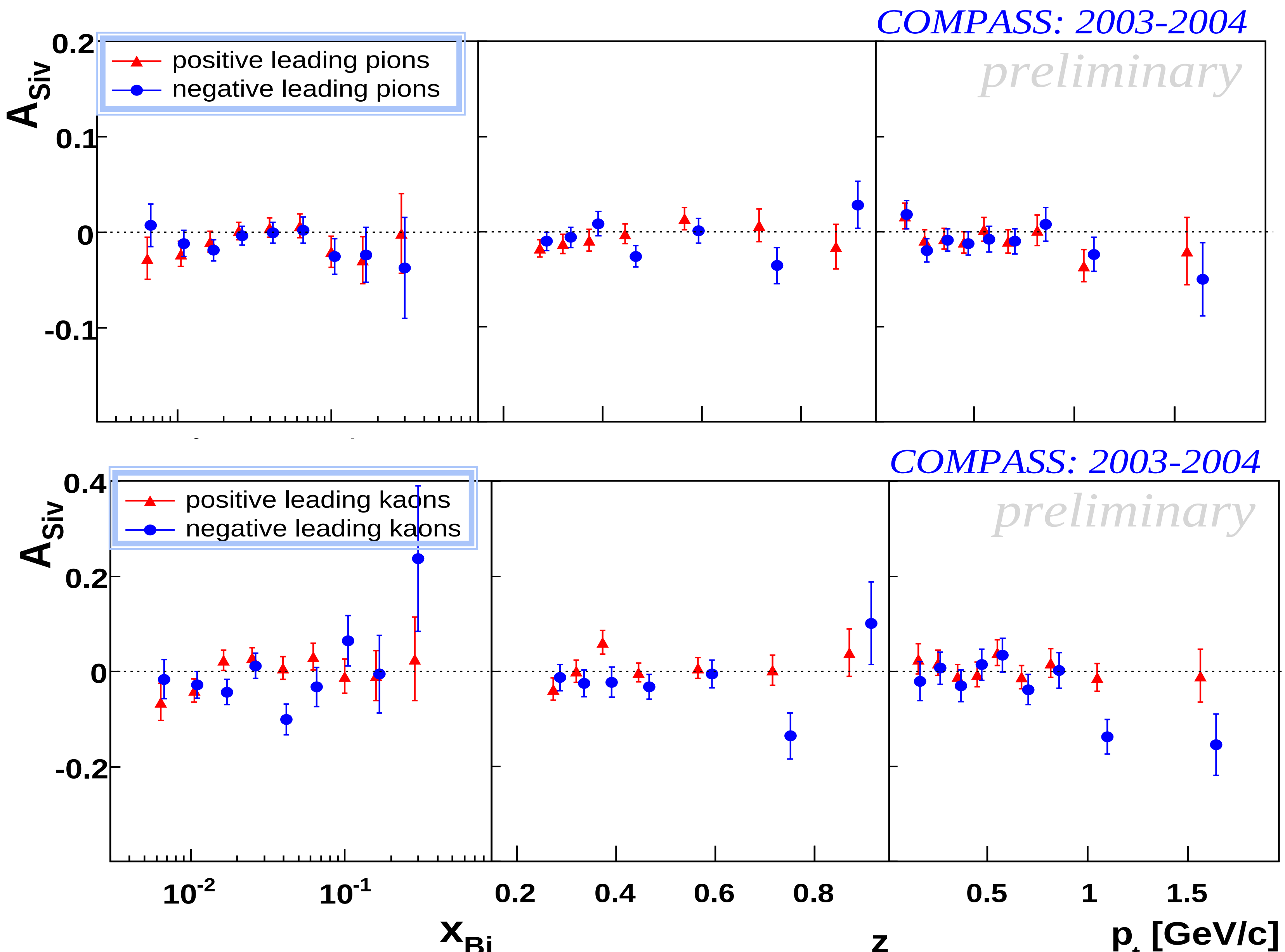
  ~12% kaons
- Statistics 2003 + 2004:

	positive	negative
leading π	3.4M	2.8M
leading K	0.7M	0.4M

Collins asymmetries 2003-2004 data

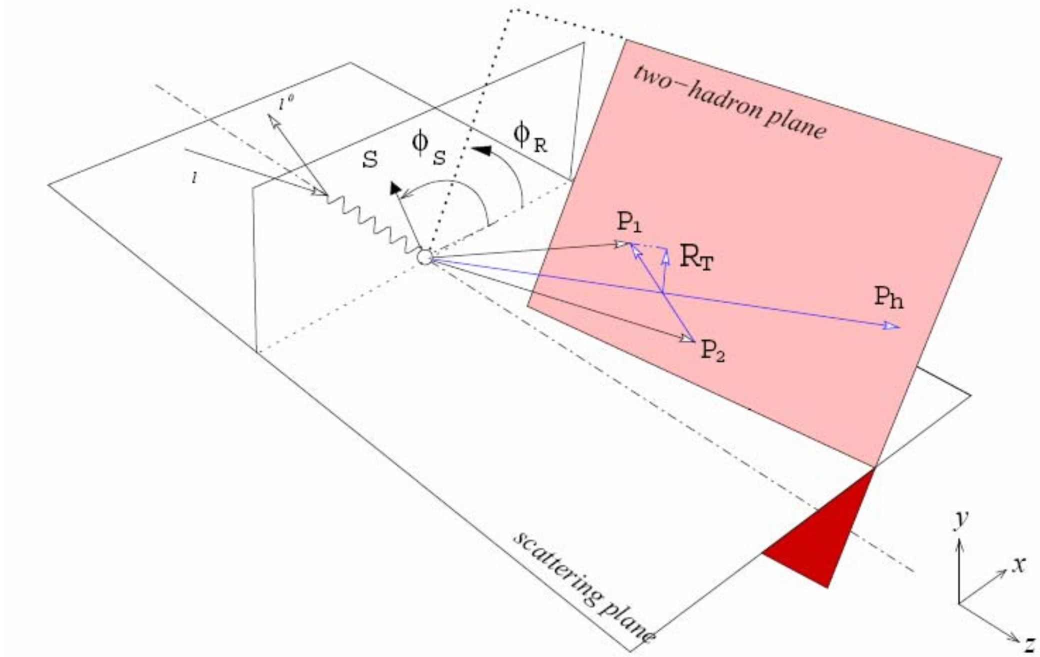


Sivers asymmetries 2003-2004 data



Two Hadron Asymmetries

looking at two hadron production, a different asymmetry can be measured



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

$$\vec{R}_T = \frac{z_2 \vec{P}_{1T} - z_1 \vec{P}_{2T}}{z_1 + z_2}$$

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

ϕ_R azimuthal angle of $\vec{R}_T$

$\phi_{S'} = \pi - \phi_S$ azimuthal angle of the spin of the fragmenting quark

$$N^{\pm}(\Phi_{RS}) = N^0 \cdot \{ 1 \pm A \cdot \sin\Phi_{RS} \}$$

$$\boxed{A_{RS} = \frac{1}{f \cdot P_T \cdot D} \cdot A = \frac{\sum_q e_q^2 \cdot \Delta_T q(x) \cdot H_q^{\angle}(z, M_h^2)}{\sum_q e_q^2 \cdot q(x) \cdot D_q^h(z, M_h^2)}}$$

$$z = z_1 + z_2$$

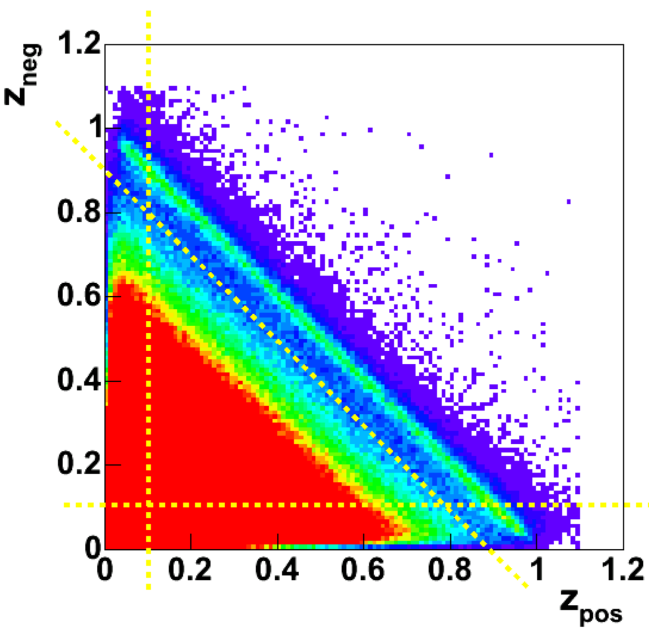
A. Bacchetta, M. Radici, hep-ph/0407345
X. Artru, hep-ph/0207309

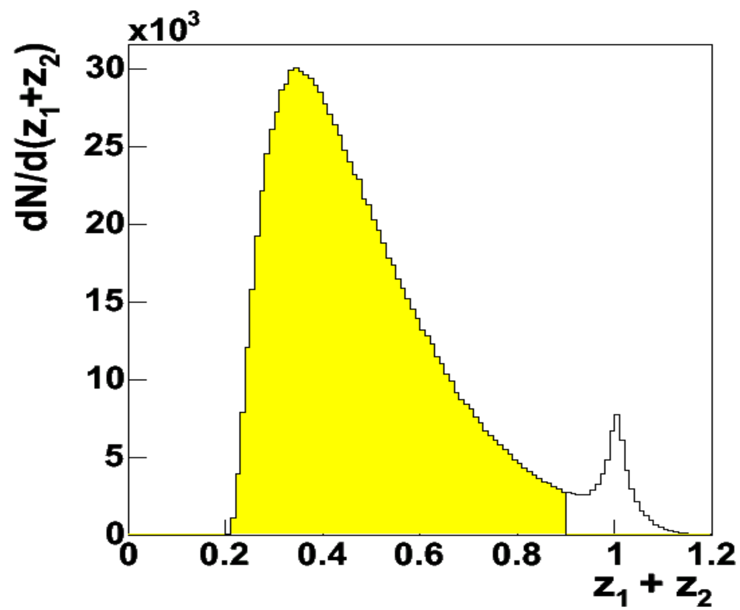
Two hadron selection

Selection of all combinations of positive and negative hadrons in DIS events with:

- $z_{1\,,\,2} > 0.1, \quad z_1 + z_2 < 0.9$
- $x_{f1,\,f2} > 0.1$

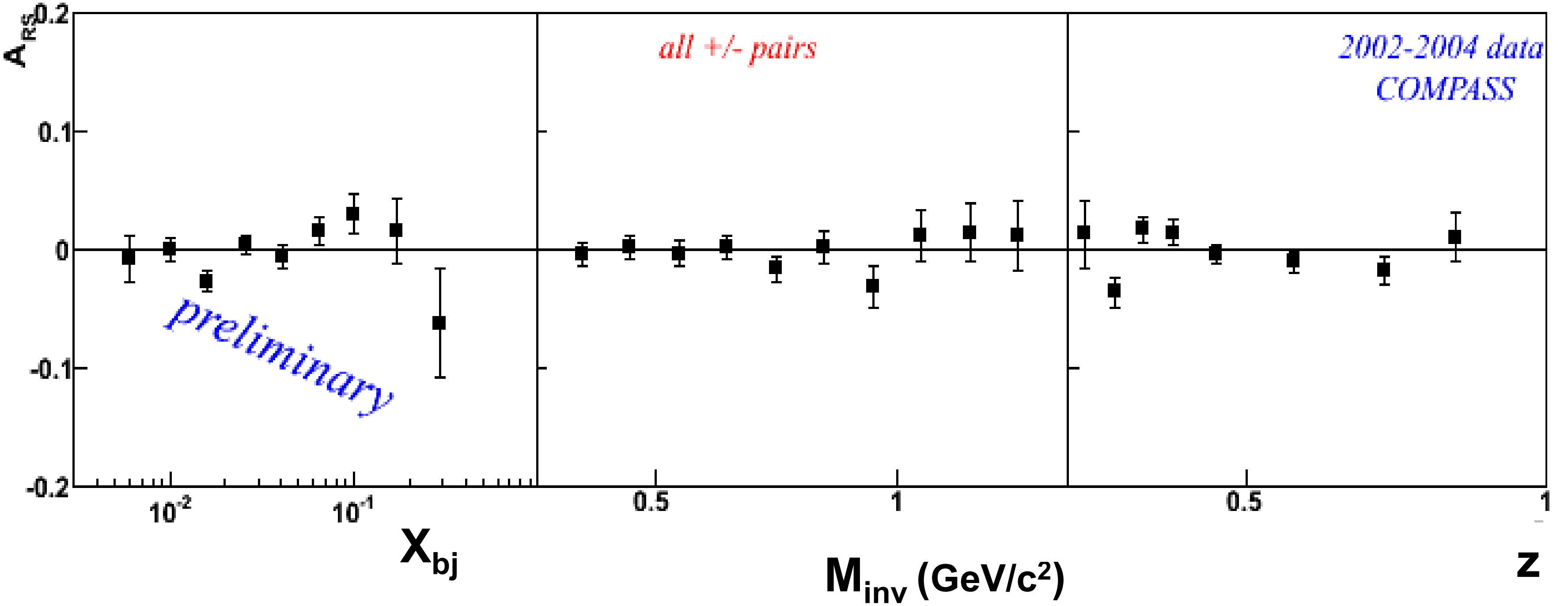
total statistics 2002-2004: 6.1 M combinations (~1.3/ev)





Two Hadron Asymmetries

All combinations of positive (h_1) and negative (h_2) hadrons:



- **only statistical errors shown (systematic errors considerably smaller)**
- **Small asymmetries**

Conclusions

- In all the channels investigates up to now:
  - Collins/Sivers asymmetries on positive and negative h, $\pi^{\pm}$, $K^{\pm}$
  - Two hadron asymmetries

  the **measured asymmetries on a ^{6}LiD polarized target are very small and compatible with zero** within the statistical errors;

- Collins/Sivers:

  Phenomenological models can describe at the same time the Hermes (proton) and COMPASS (deuteron) data;

Outlook:

- RICH identification for the 2 hadrons analysis is planned;
- In 2006 complementary mesurement with a proton target is planned at COMPASS: data of comparable statistics will be collected on a transversely polarized proton target (NH_3).

Just in case...

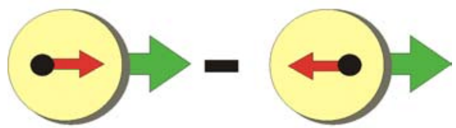
TRANSVERSE SPIN PHYSICS

3 distribution functions are necessary to describe the structure of the nucleon at LO:

q(x)

momentum distribution

Δq(x)



helicity distribution

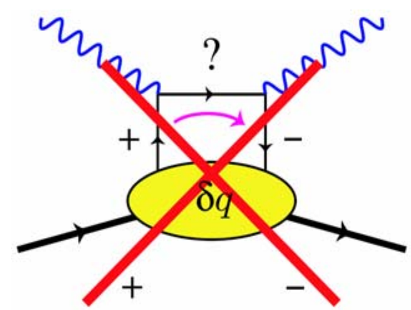
all of equal importance!

Δ_Tq(x)

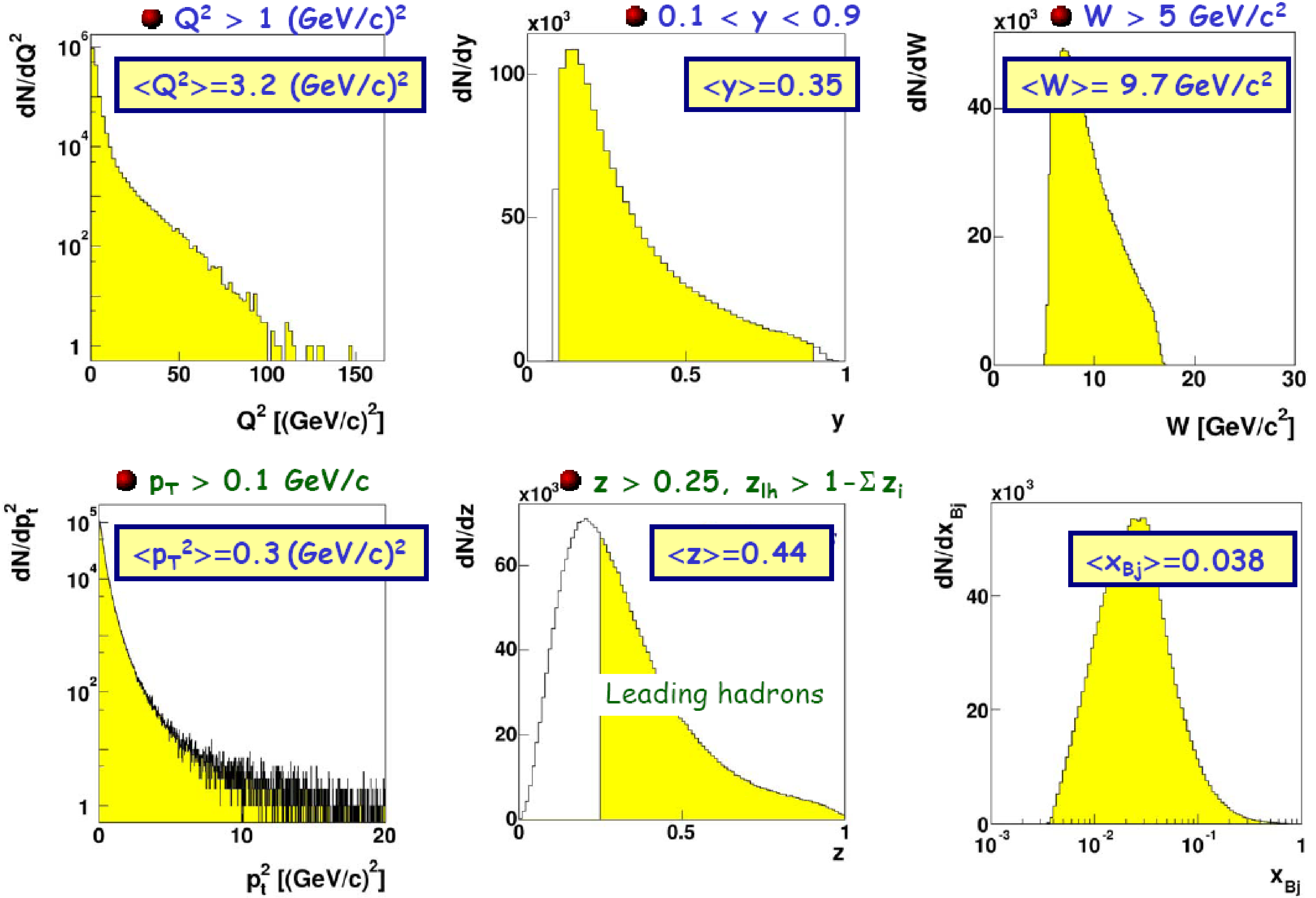
transversity distribution

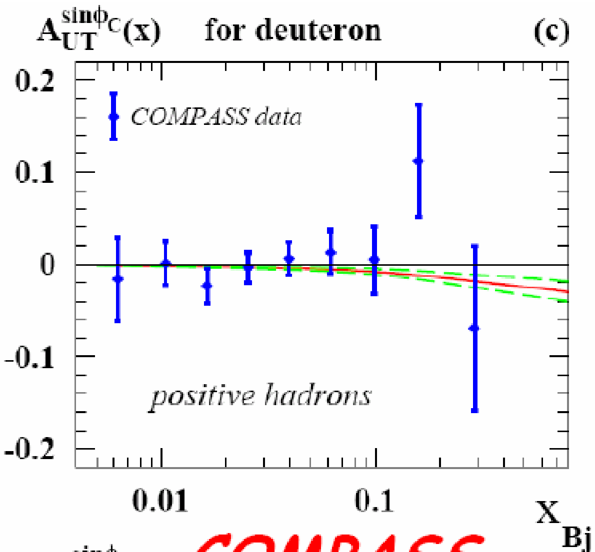
h_1(x) decouples from leading twist DIS because helicity of quark must flip

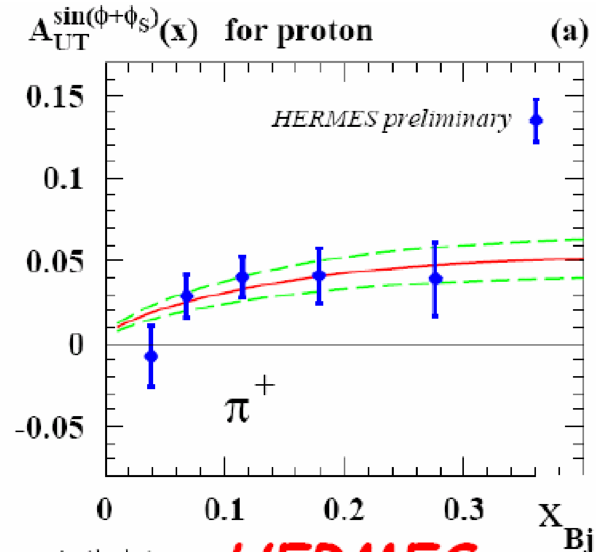
NO MIXTURE WITH GLUON



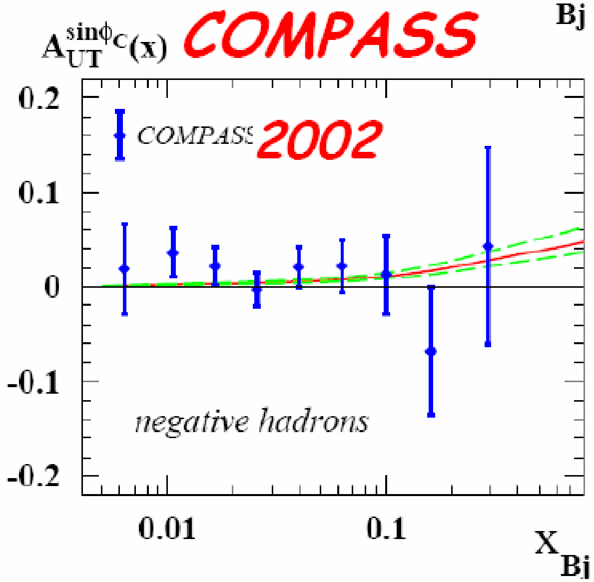
Event selection

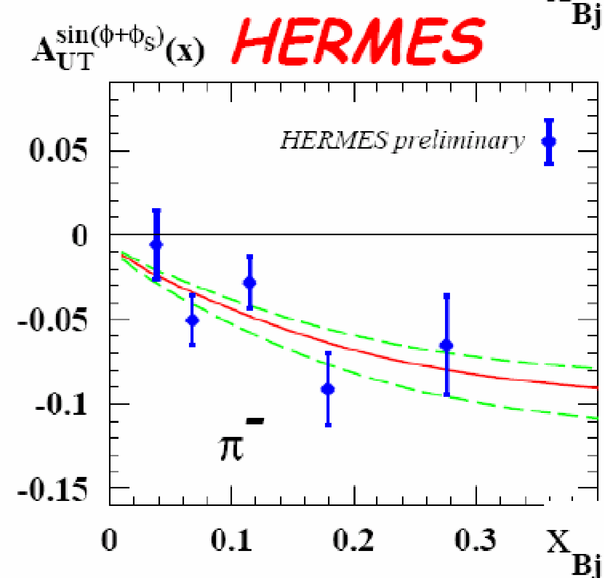




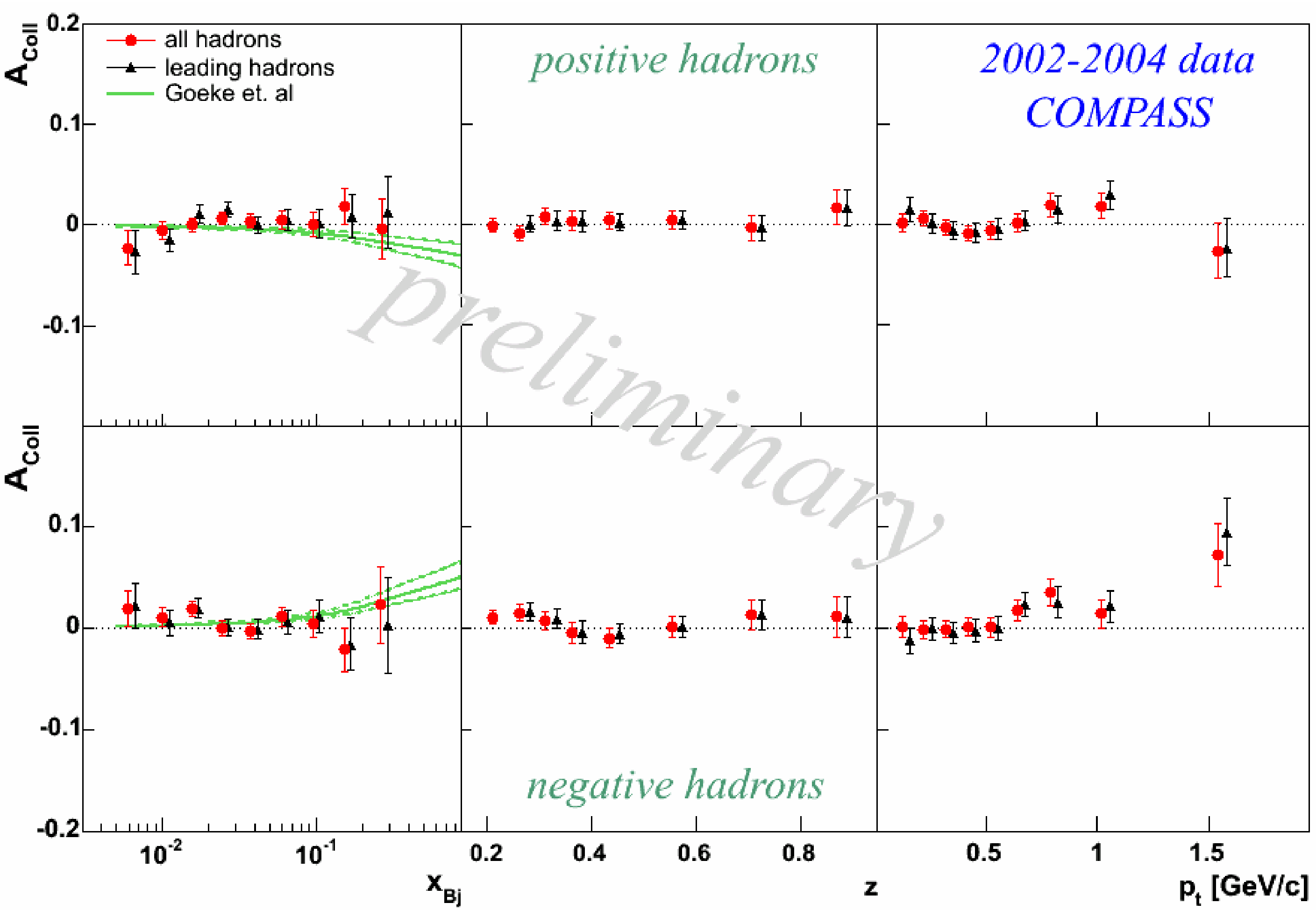


Collins





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



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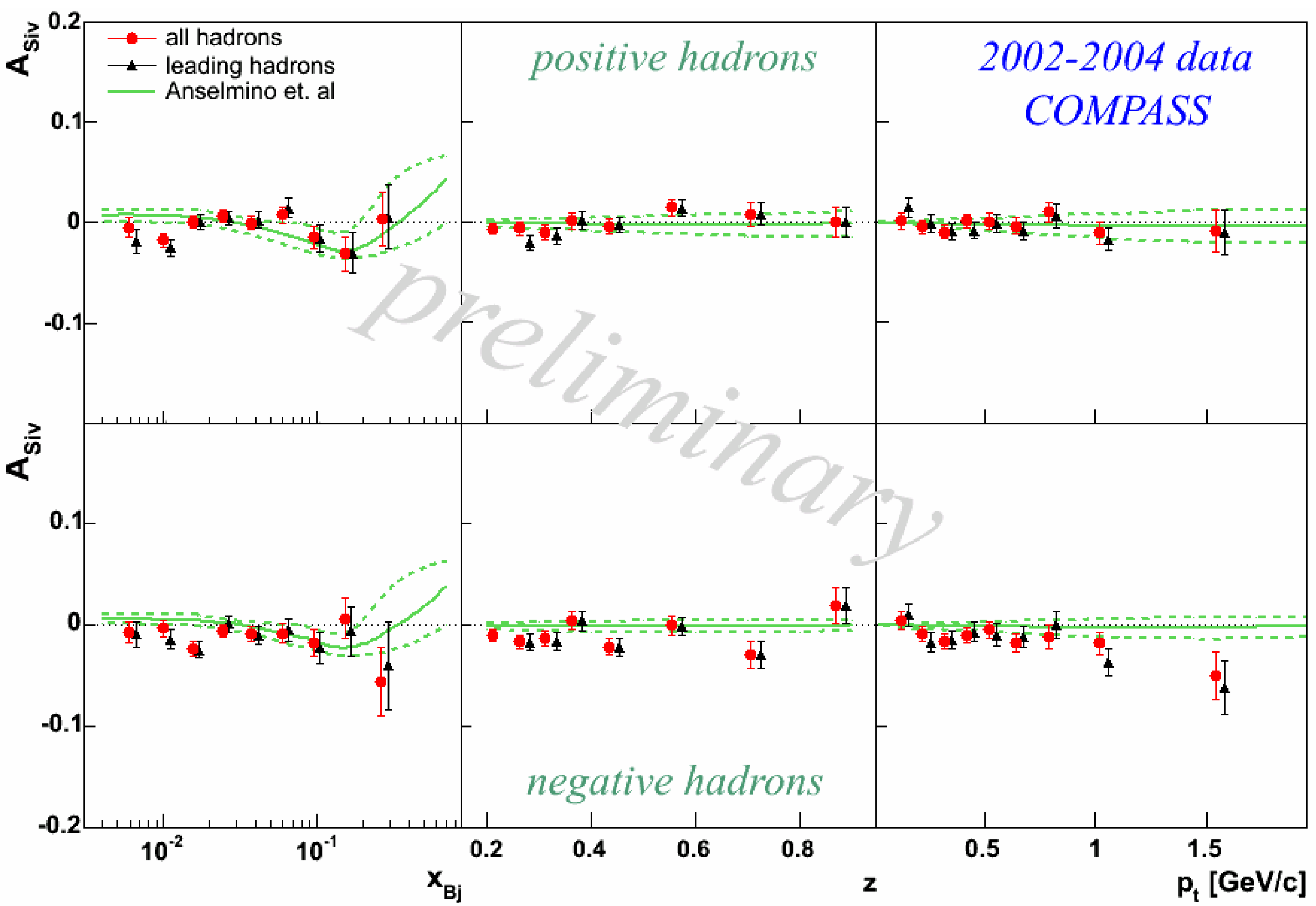

M. Anselmino et al.
Sivers on Deuterium (hep-ph/0507181)