Measurements of Collins and Sivers asymmetries at COMPASS.

Plan of the talk

- Physics case
- COMPASS spectrometer and deuterium target
- The 2002 transversity data
- The selection algorithm
- The MonteCarlo studies
- The Collins and Sivers asymmetries for leading and all hadrons
- Conclusions

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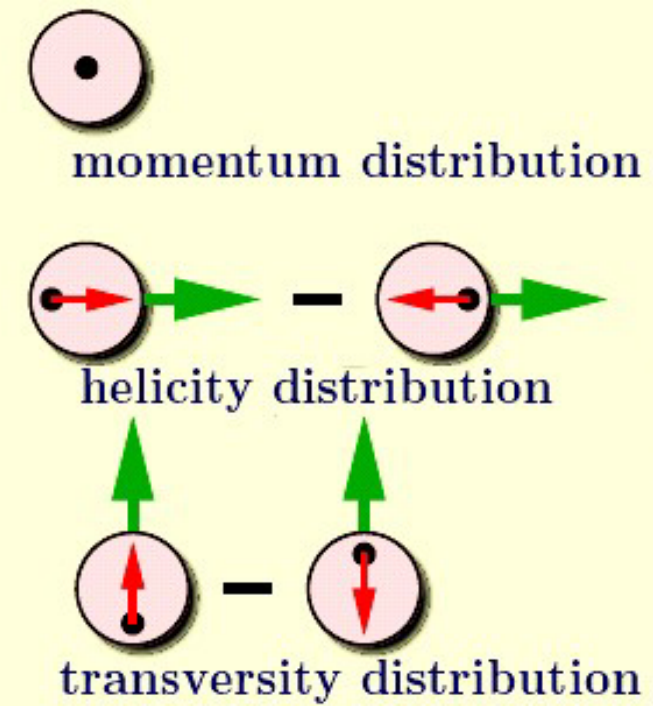
3 distribution functions are necessary to describe the spin structure of the nucleon at LO:

$q(x)$

$\Delta q(x)$

$\Delta_T q(x)$



All of equal importance!

Transversity

In the last ten years:

- great developments in the theory of transversity;
- remarkable importance of $\Delta_T q(x)$; the measurement of transversity clearifies many "open" points in the spin structure of the nucleon, notably complementary to those connected to helicity.

Key features of transversity:

- $\Delta_T q(x)$ doesn't mix with Gluons in evolution: valence like behavior at variance from $\Delta q(x)$;
- differences between $\Delta q(x)$ and $\Delta_T q(x)$ are evidence of relativistic effects in the nucleons state;
- Soffer inequality (95)

$$\Delta_T q(x) \leq \frac{1}{2}\left[q(x) + \Delta q(x)\right]$$

- tensor charge (91-92)

$$g_T = \int dx\left[\Delta_T q(x) - \Delta_T \bar{q}(x)\right]$$

axial charge $\rightarrow$

$$g_A = \int dx\left[\Delta q(x) + \Delta \bar{q}(x)\right]$$

- transverse spin sum rule (Leader 2004)

$$\frac{1}{2} = \frac{1}{2}\sum_{q,\bar{q}} \int \Delta_T q(x) dx + \sum_{q,\bar{q},g} < L_{S_T} >$$

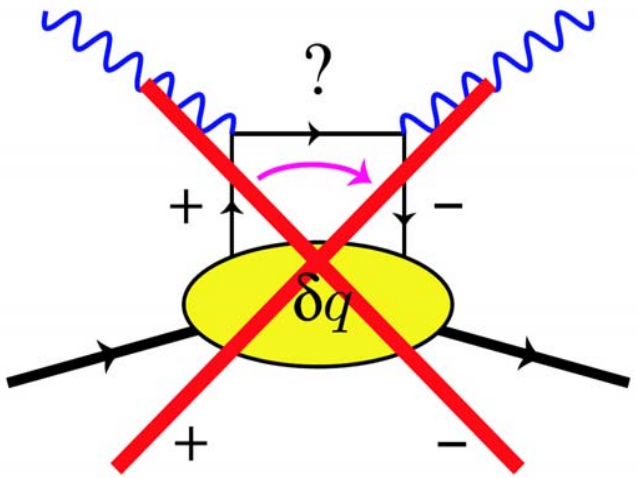
as for $\rightarrow$

$$S_z = \frac{1}{2}\Delta\Sigma + \Delta G + < L_z >$$

Measuring $\Delta_T q(x)$

$\Delta_T q(x)$ is chiral odd and decouples from inclusive DIS because helicity of quark must flip.

How to access it:



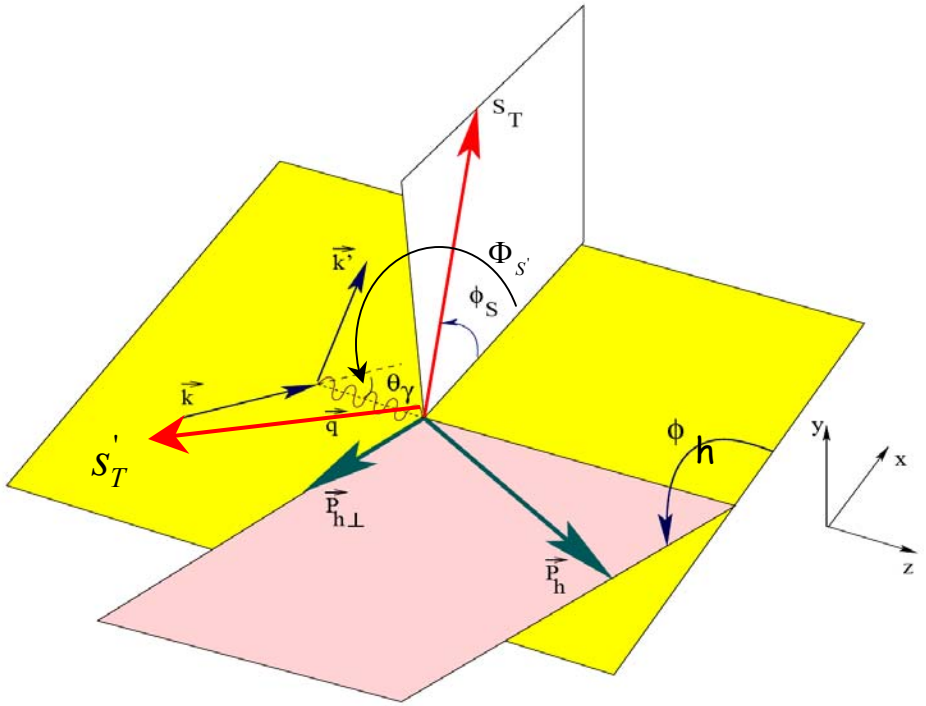
- SIDIS:
  - see next slide
- Hard scattering NN
  - Drell-Yan
  - Single Spin Asymmetries

SIDIS off trans. polarized target (1)

3 possible quark polarimeters suggested:

- Measure transverse polarization of Λ
- Azimuthal dependence of the plane containing leading & next to leading hadrons (see R. Joosten's talk)
- Collins effect of (leading) $h^{\pm}$

← Results!



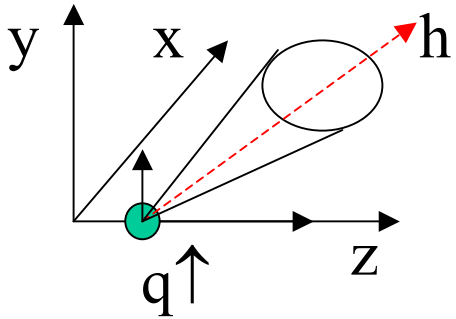
ϕ_S = azimuthal angle of spin vector of **fragmenting** quark (before scattering)

$\phi_{S'}$ = azimuthal angle of spin vector of **fragmenting** quark (after scattering)

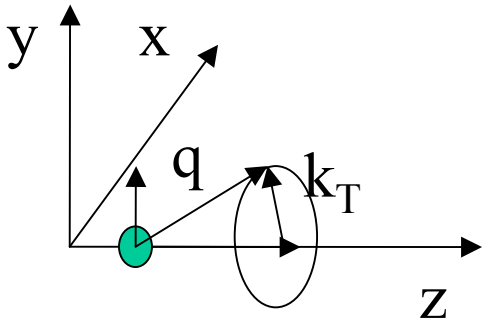
ϕ_h = azimuthal angle of hadron

SIDIS off trans. polarized target (2)

- Collins effect predicts an azimuthal asymmetry in the quark fragmentation



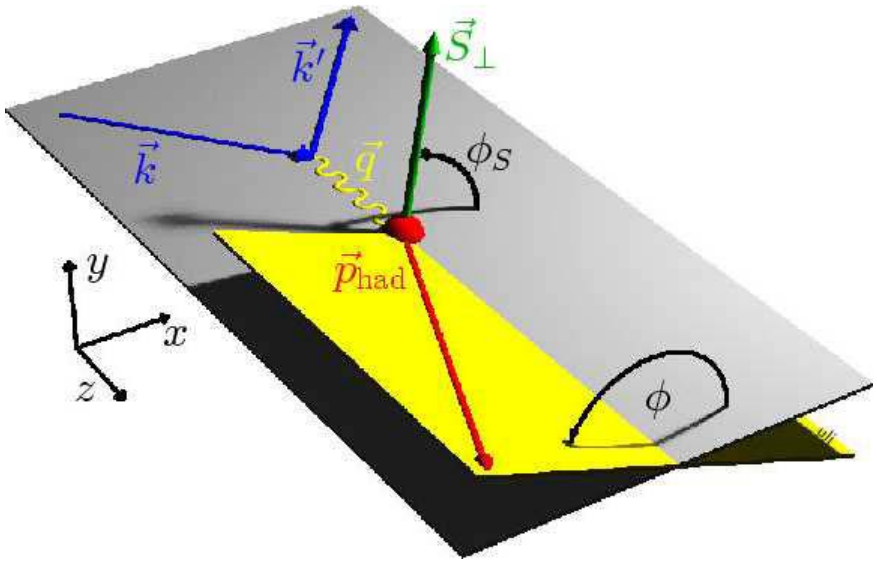
- The quark prefers to fragment in one direction;
- Look at leading hadron (it comes from the struck quark);
- The larger is "z" (fraction of the available energy carried by the hadron), the stronger is the signal ;
- But an azimuthal asymmetry can also come from the un-polarised quarks; namely from an azimuthal modulation of quark transverse momentum for a transversely polarized nucleon (Sivers effect)



SIDIS off trans. polarized target (3)

$$\phi_{Siv} = \phi_h - \phi_S$$

$$\phi_{Coll} = \phi_h - \phi_{S'} = \phi_h + \phi_S - \pi$$



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

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

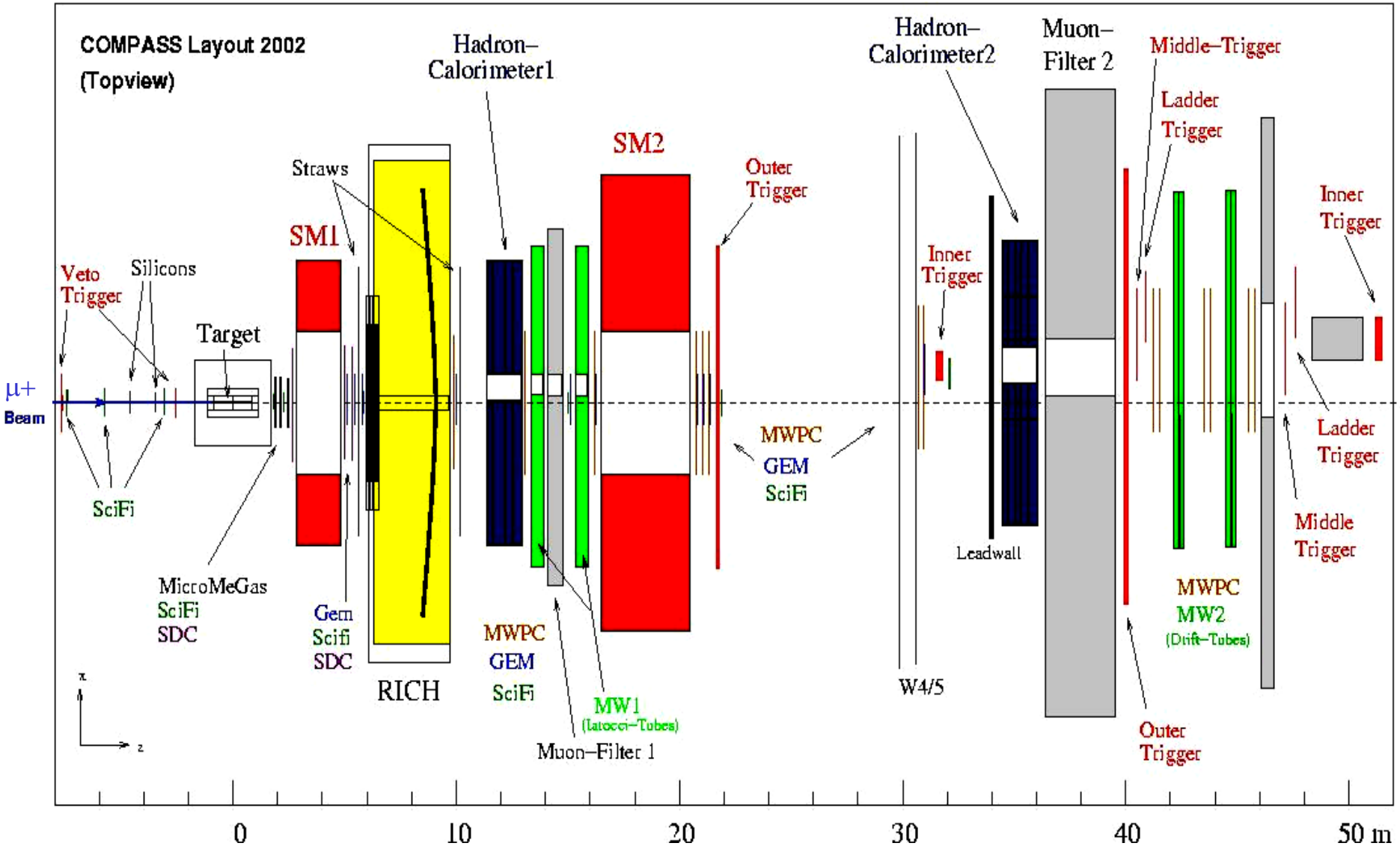
For transversely polarised target:

2 azimuthal angles,

Collins and Sivers effect distinguishable

$A_{UT}^{\sin(\phi - \phi_S')}$ $A_{UT}^{\sin(\phi - \phi_S)}$

The COMPASS Experiment in 2002



Data Sample

2002: 12+7 days of data taking (total) with transversely polarized ^{6}LiD target

(separate analysis for both periods of data taking)

- **$1.8 * 10^9$ events**
- **$(0.9\ h^+ + 0.7\ h^-) * 10^6$ events after all cuts**

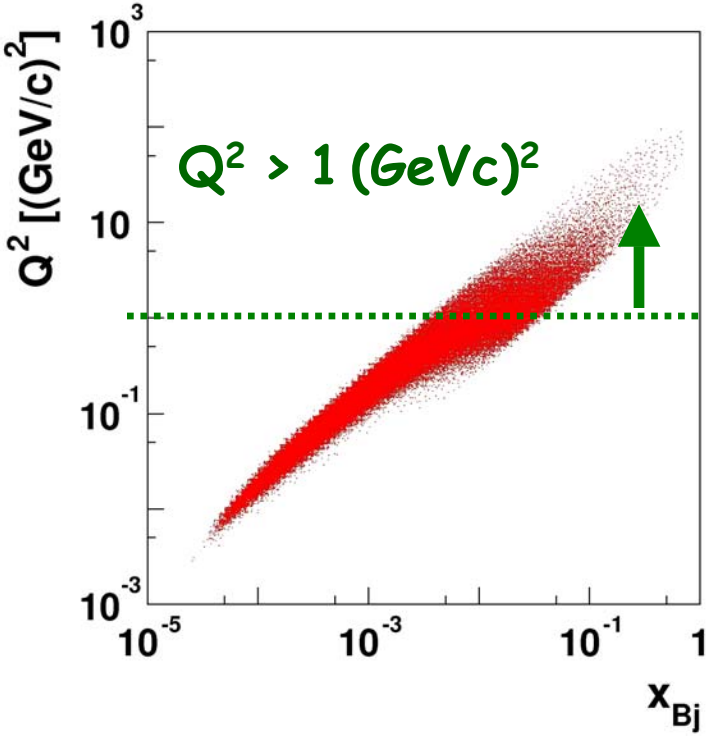
2003: 2002 doubled;

2004 expected: 2002+2003

+ 2003 trigger upgrade

to gain sensitivity

on large x_{Bj} & large Q^2 events!

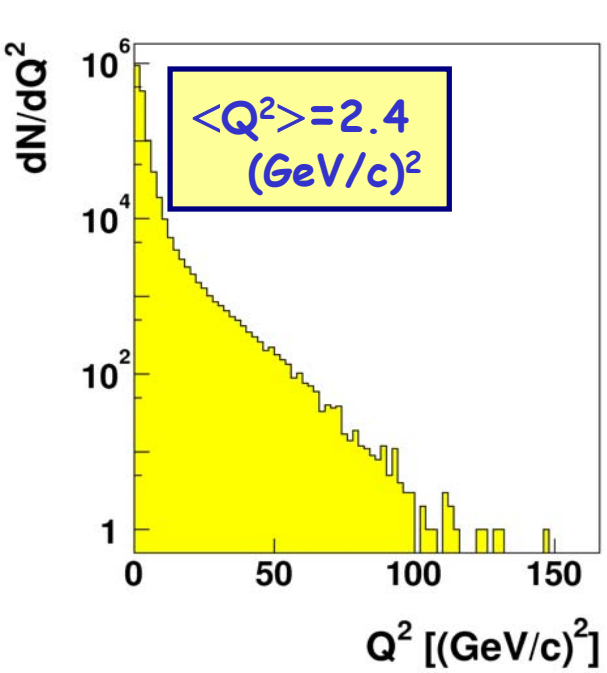


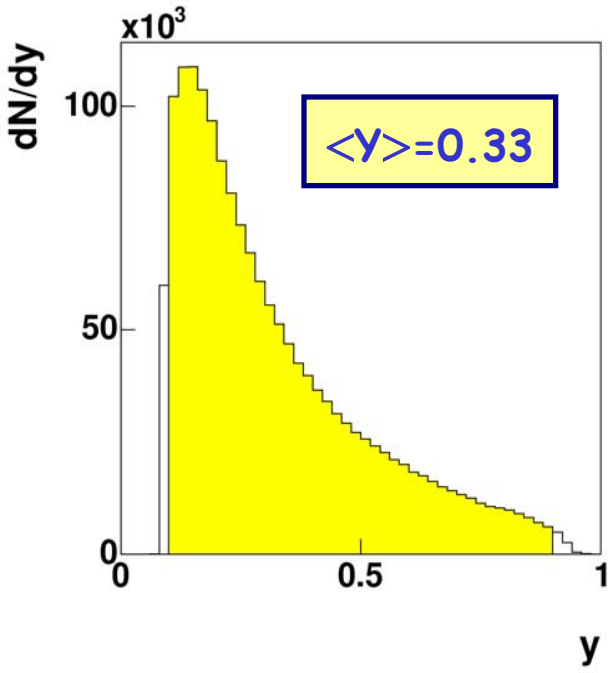
Event selection (1)

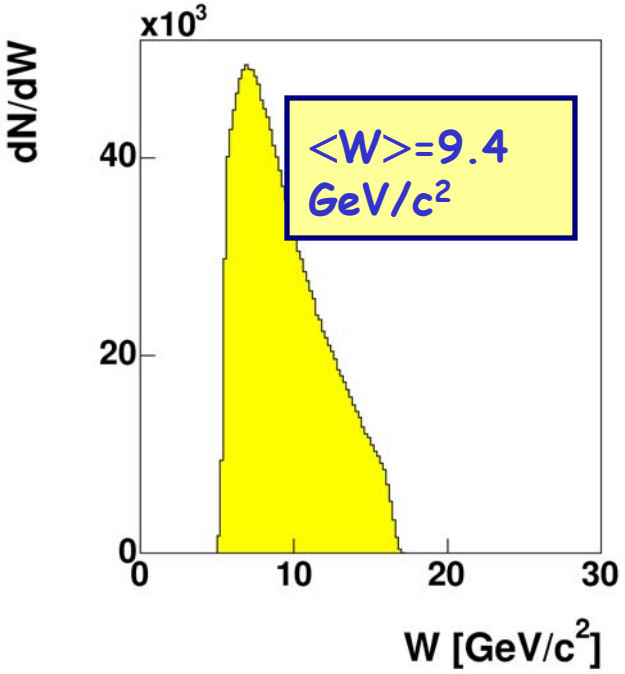
- Primary vertex with identified μ, μ' & hadrons

Kinematical cuts:

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



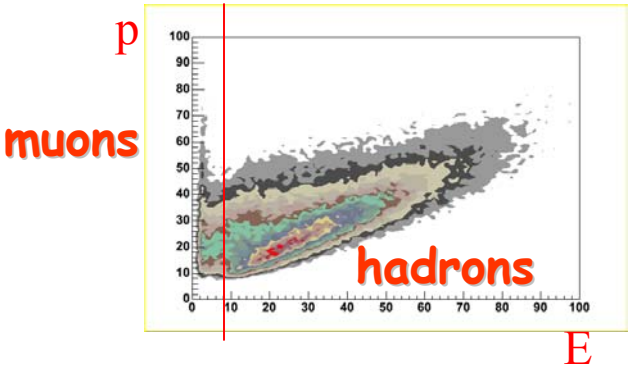




Event selection (2)

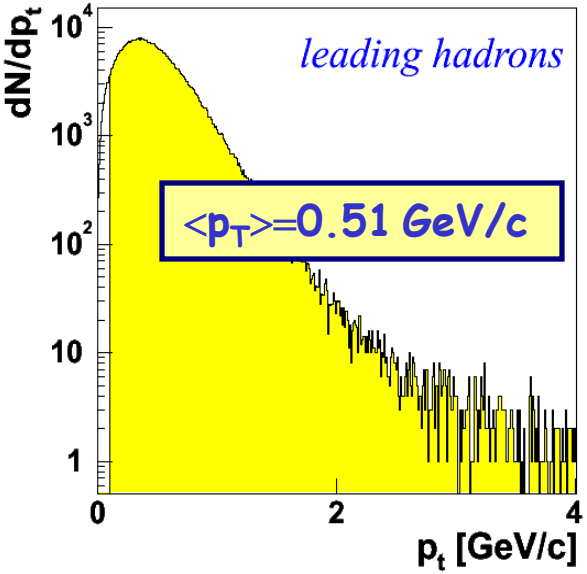
Hadron selection:

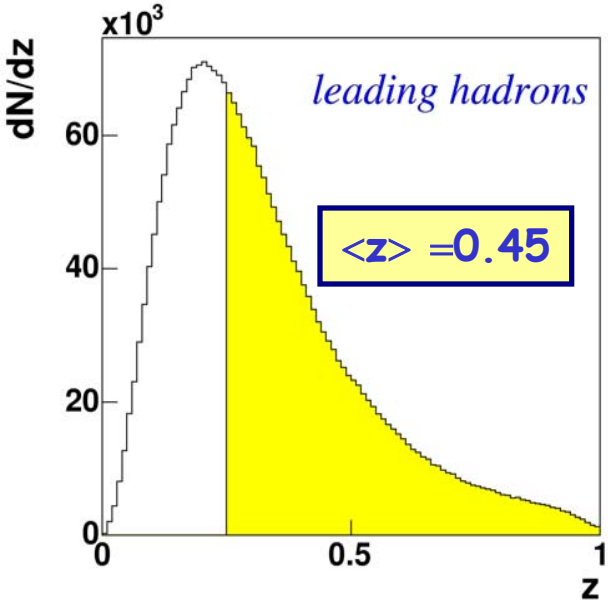
- energy deposit in hadron calorimeters
- Penetration < 10 X_0
- Presently no π / K / p separation by RICH

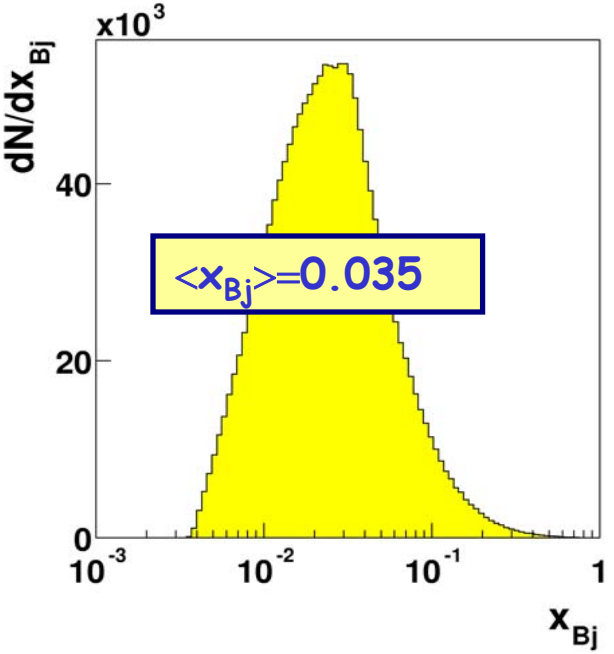


Cuts on hadrons based on kinematics:

- $p_T > 0.1$ GeV/c; $z_{lh} > 0.25$; $z_{lh} > 1 - \Delta z_i$ (leading hadron analysis)
- $p_T > 0.1$ GeV/c; $z_{ah} > 0.20$ (all hadrons analysis)



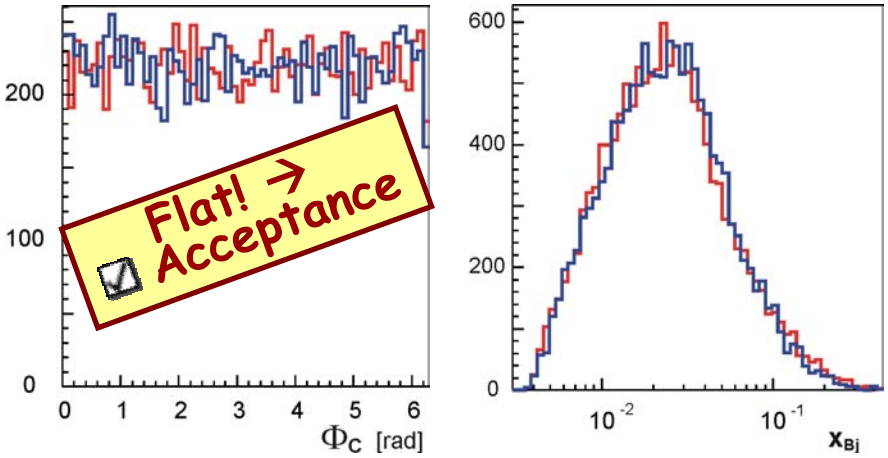




Monte Carlo studies

- MC events generated with Lepto 6.5.1

Data
MC



- ☑ Trigger geometry
- ☑ Mean tracking efficiencies

☑ **Overall good agreement between MC and RD**

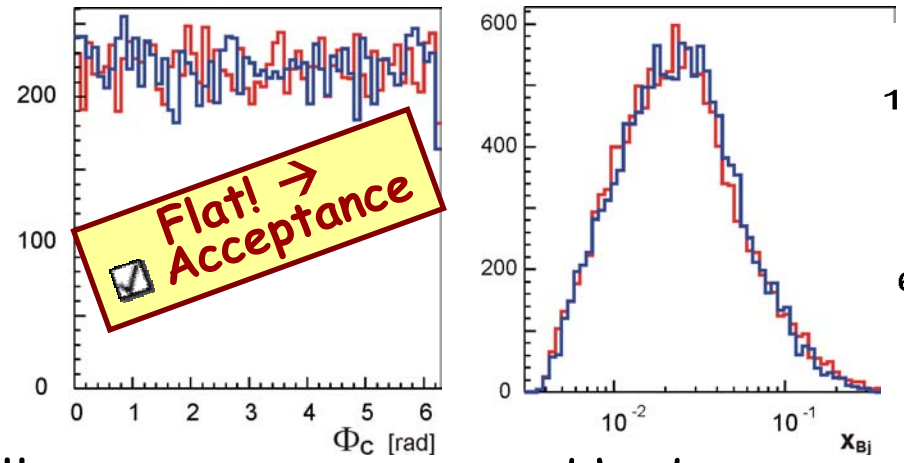
Monte Carlo studies

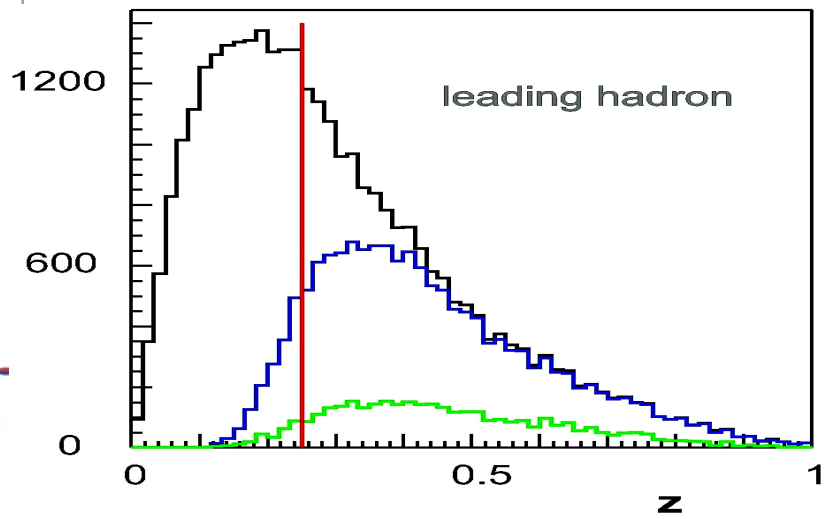
- MC events generated with Lepto 6.5.1

☑ Trigger geometry

☑ Mean tracking efficiencies

Data
MC





— all reconstructed hadrons

— correctly reconstructed leading hadrons

— correctly reconstructed leading hadron, but leading hadron is not a π

~20% of the final sample, mainly K and p

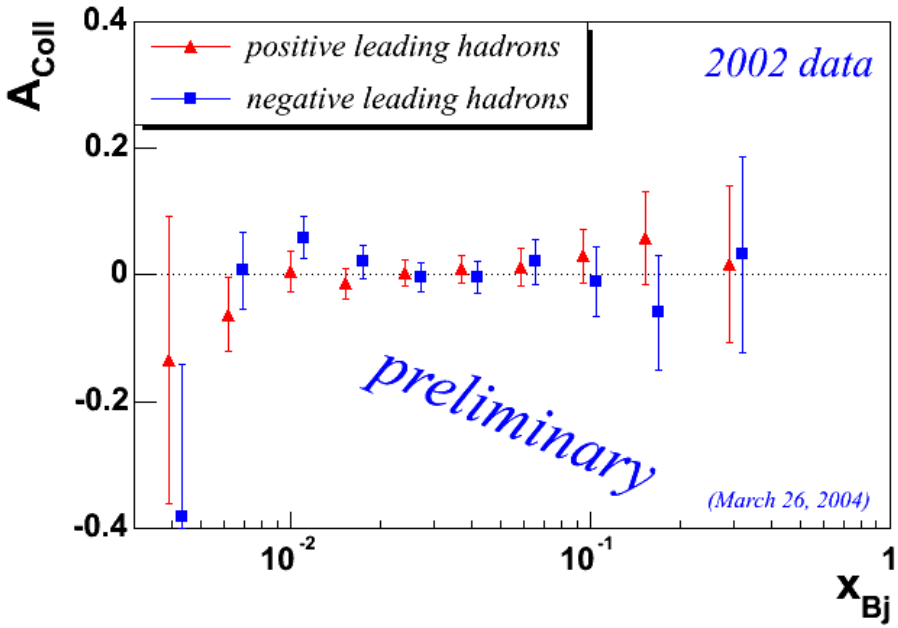
(RICH analysis not applied to data presented today)

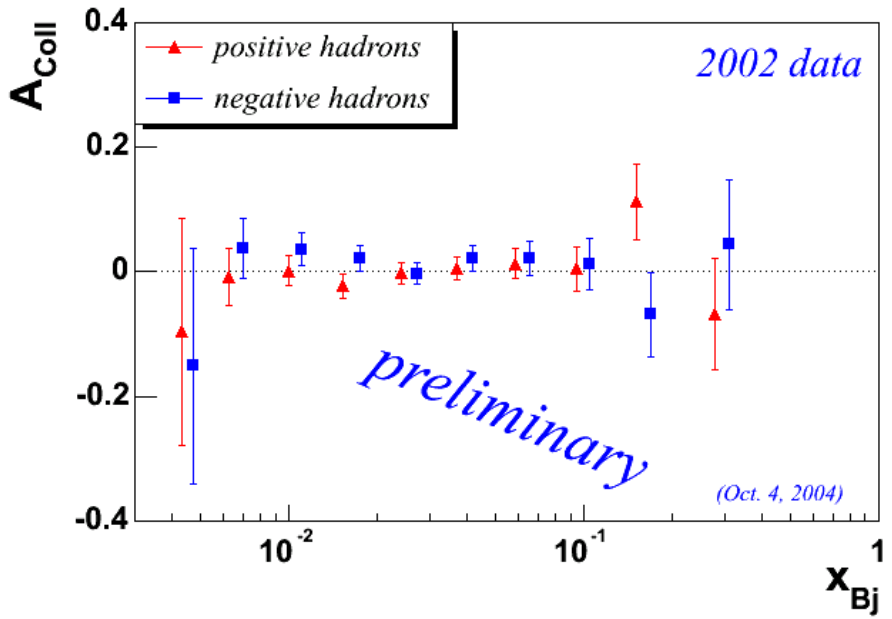
The reconstructed leading hadron is not the true leading hadron

~20% of the final sample (probably smaller in the data because cuts on HCAL & $z_{lh} > 1-\Delta z_i$ not applied to MC events)

Collins asymmetries (1)

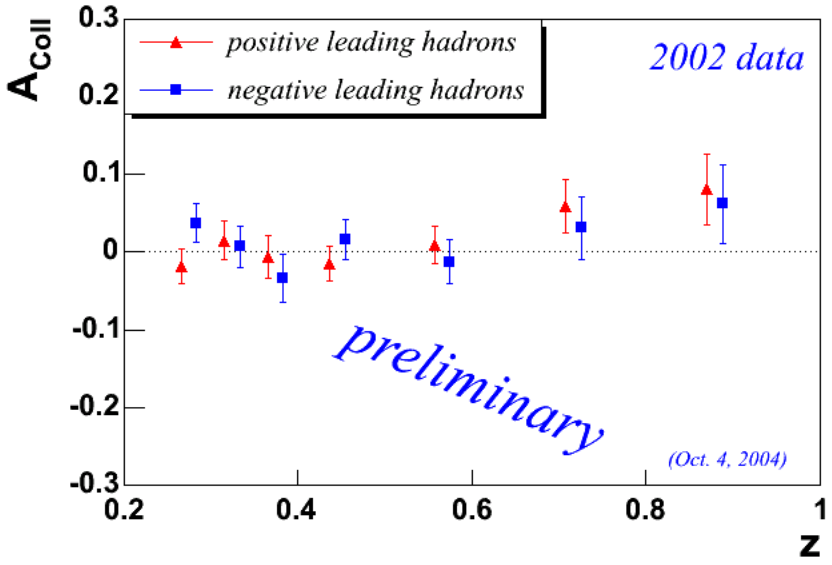
- Collins asymmetries for leading hadrons versus x_{Bj}
- Collins asymmetries for all hadrons versus x_{Bj}



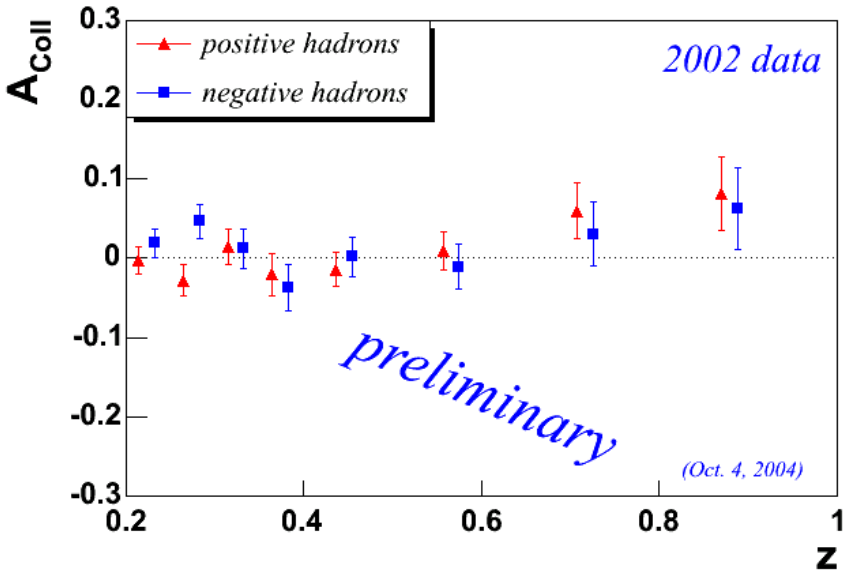


Collins asymmetries (2)

- Collins asymmetries for leading hadrons versus z

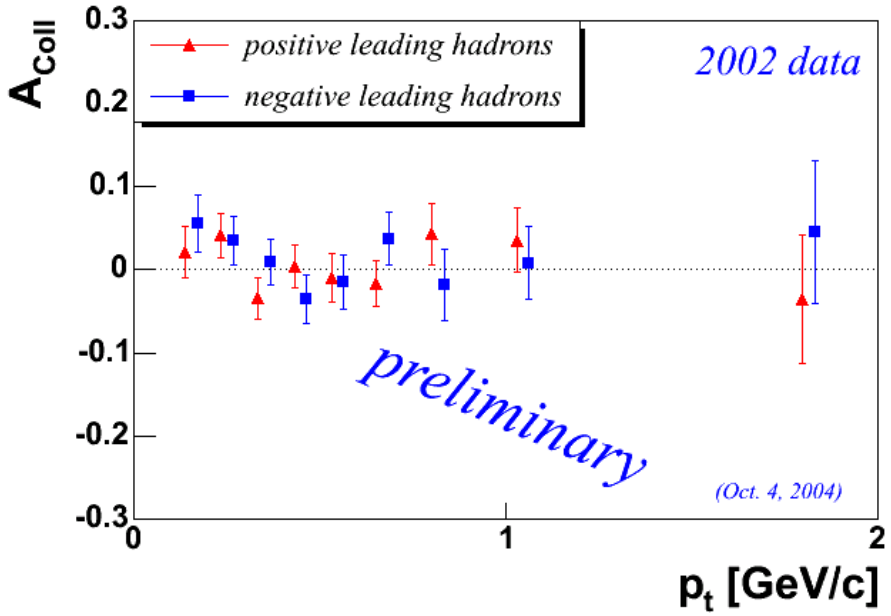


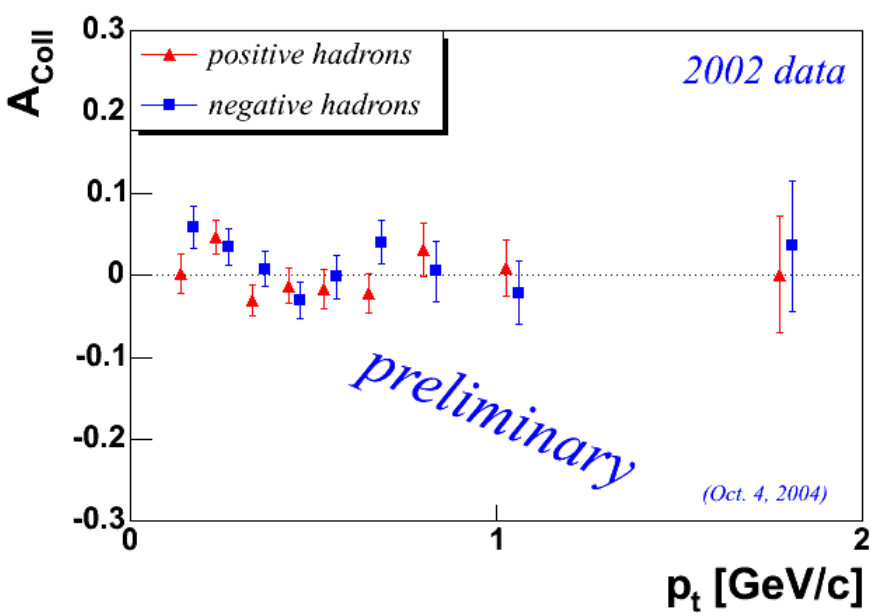
- Collins asymmetries for all hadrons versus z



Collins asymmetries (3)

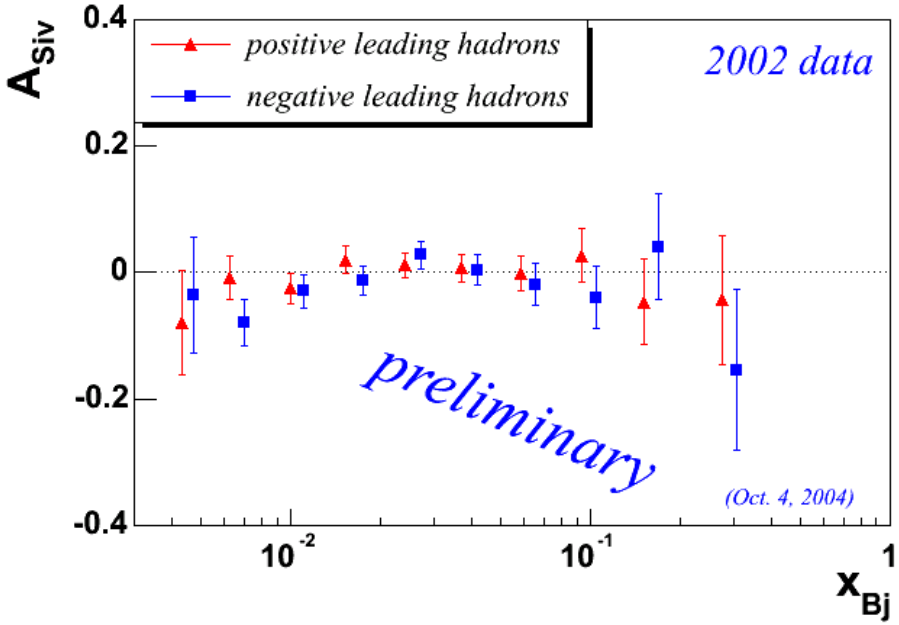
- Collins asymmetries for leading hadrons versus p_{hT}
- Collins asymmetries for all hadrons versus p_{hT}

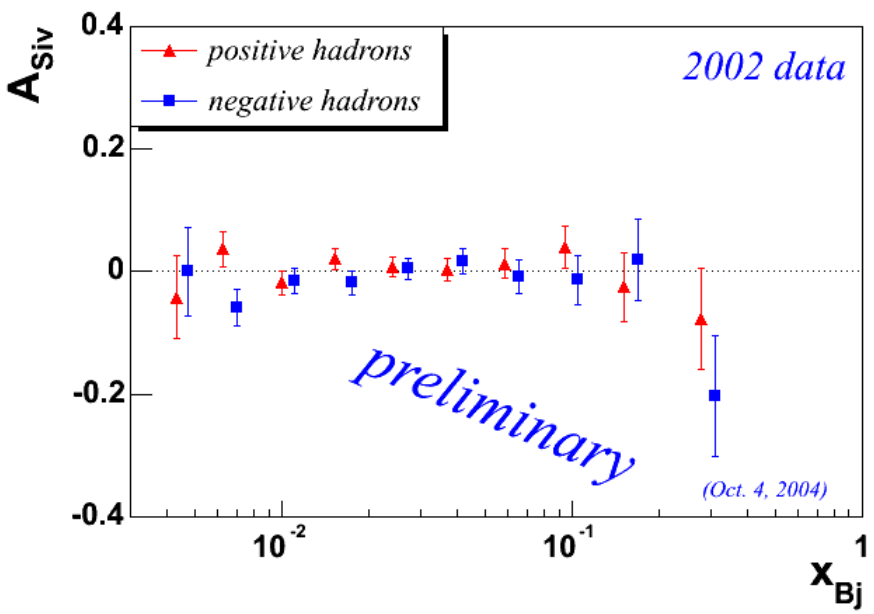




Sivers asymmetries (1)

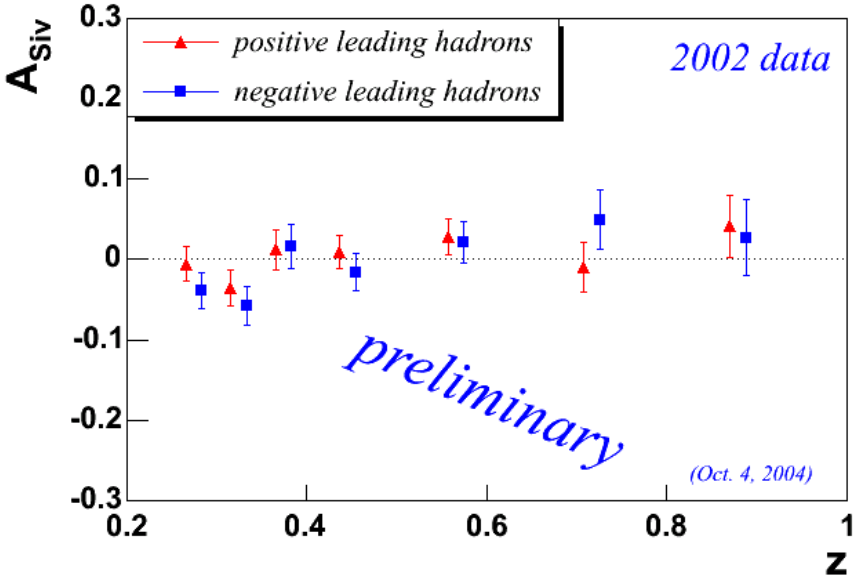
- Sivers asymmetries for leading hadrons versus x_{Bj}
- Sivers asymmetries for all hadrons versus x_{Bj}



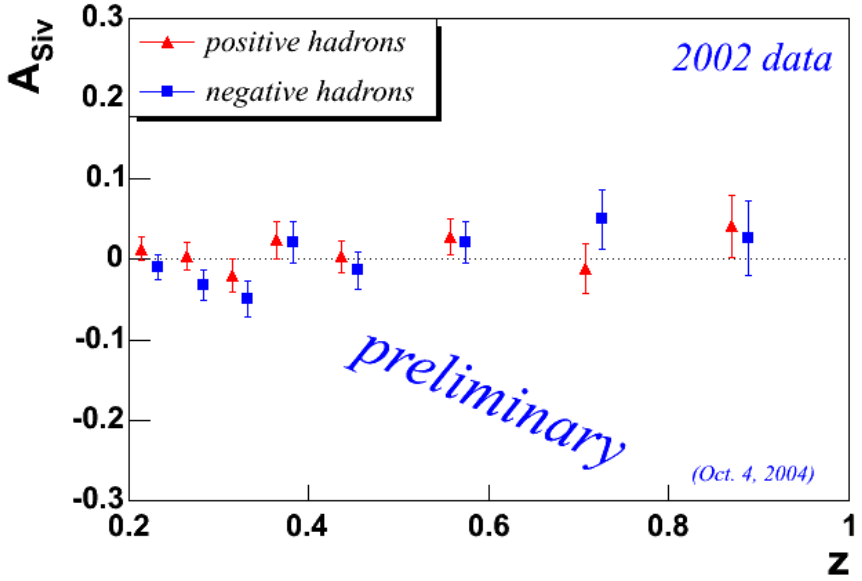


Sivers asymmetries (2)

- Sivers asymmetries for leading hadrons versus z

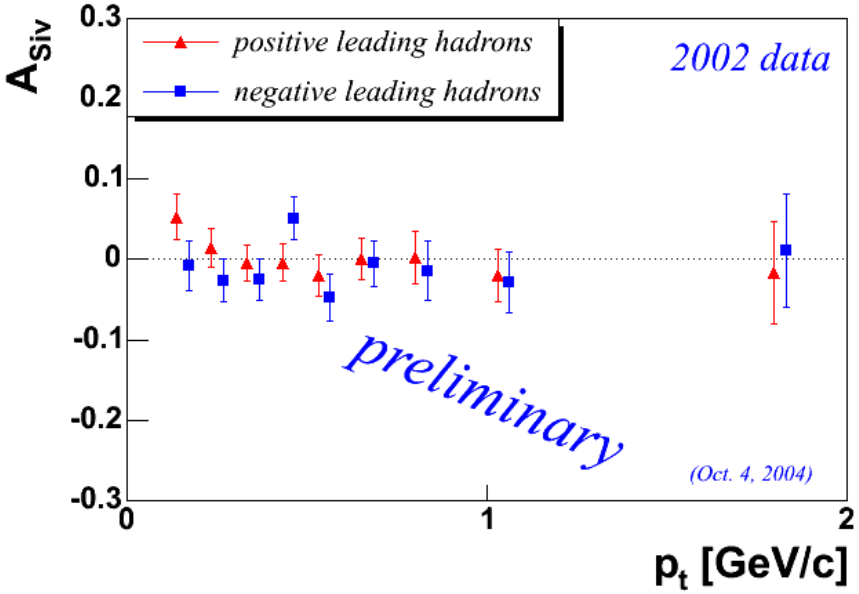


- Sivers asymmetries for all hadrons versus z

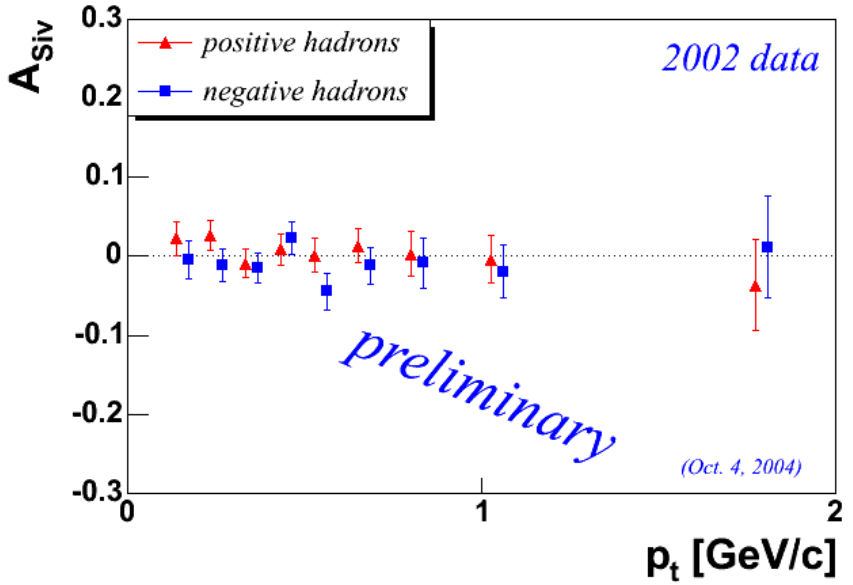


Sivers asymmetries (3)

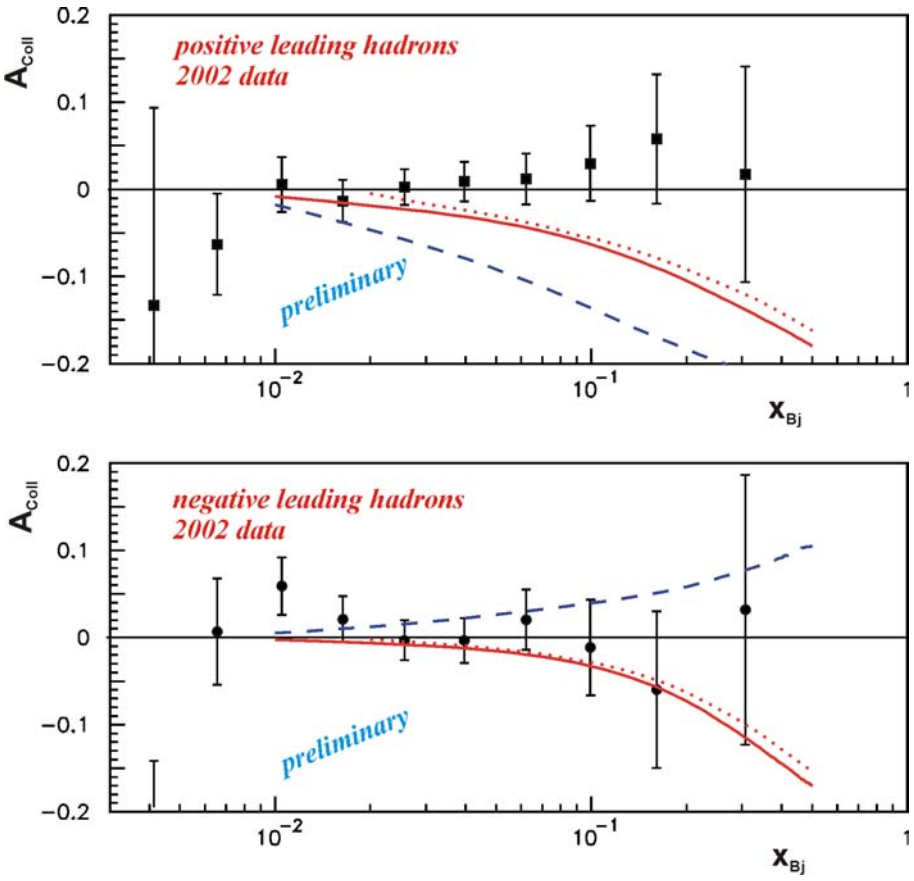
- **Sivers asymmetries for leading hadrons versus p_{hT}**



- **Sivers asymmetries for all hadrons versus p_{hT}**



Comparison w/ phen. calculation



Small signals are predicted for A_{UT} on a deuterium target;

COMPASS measurements are still compatible with Efremov et al. (Eur.Phys.J.C32:337-346,2003) predictions.

Conclusion & Outlook

- COMPASS has measured the Collins asymmetries from a deuteron target. The expected asymmetries are predicted to be small and within statistics are compatible with our measurements of 2002;

- A possible hint of negative asymmetries for the neutron in case of h^- combining COMPASS and HERMES results;

- No evidence for Sivers asymmetries from 2002 data;

- Including 2003 & 2004 data
  → sensitivity improvement by factor > 2 expected;

- All the tests we made are consistent with the fact that systematic effects, if present, are smaller than statistical errors.