

1-Hadron transverse target spin asymmetries at COMPASS

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bmb+f - Förderschwerpunkt

COMPASS

Großgeräte der physikalischen
Grundlagenforschung

Outline

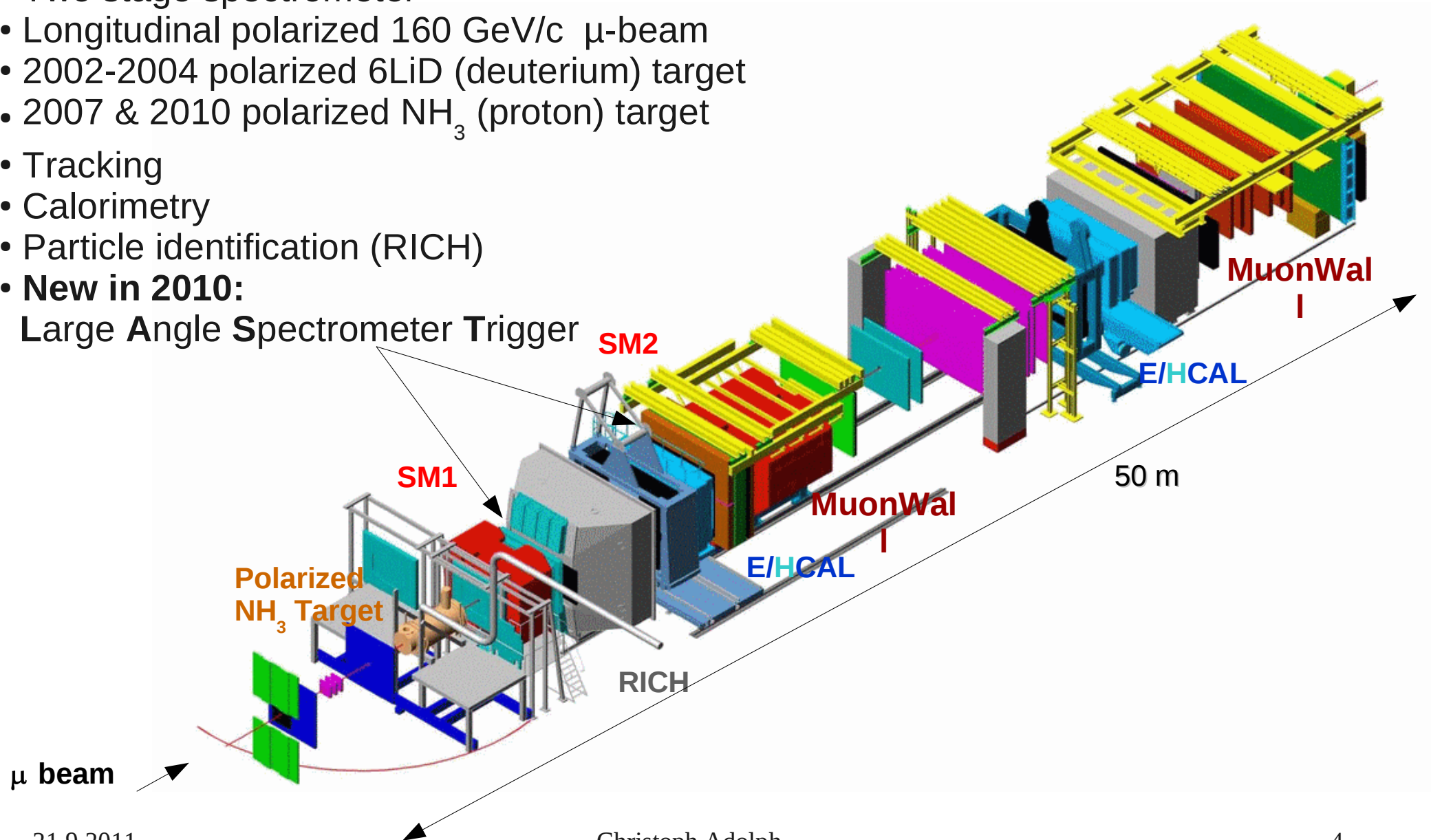
- The COMPASS experiment
- Collins and Sivers asymmetries from 2010 COMPASS run
- Outlook

The COMPASS experiment at CERN



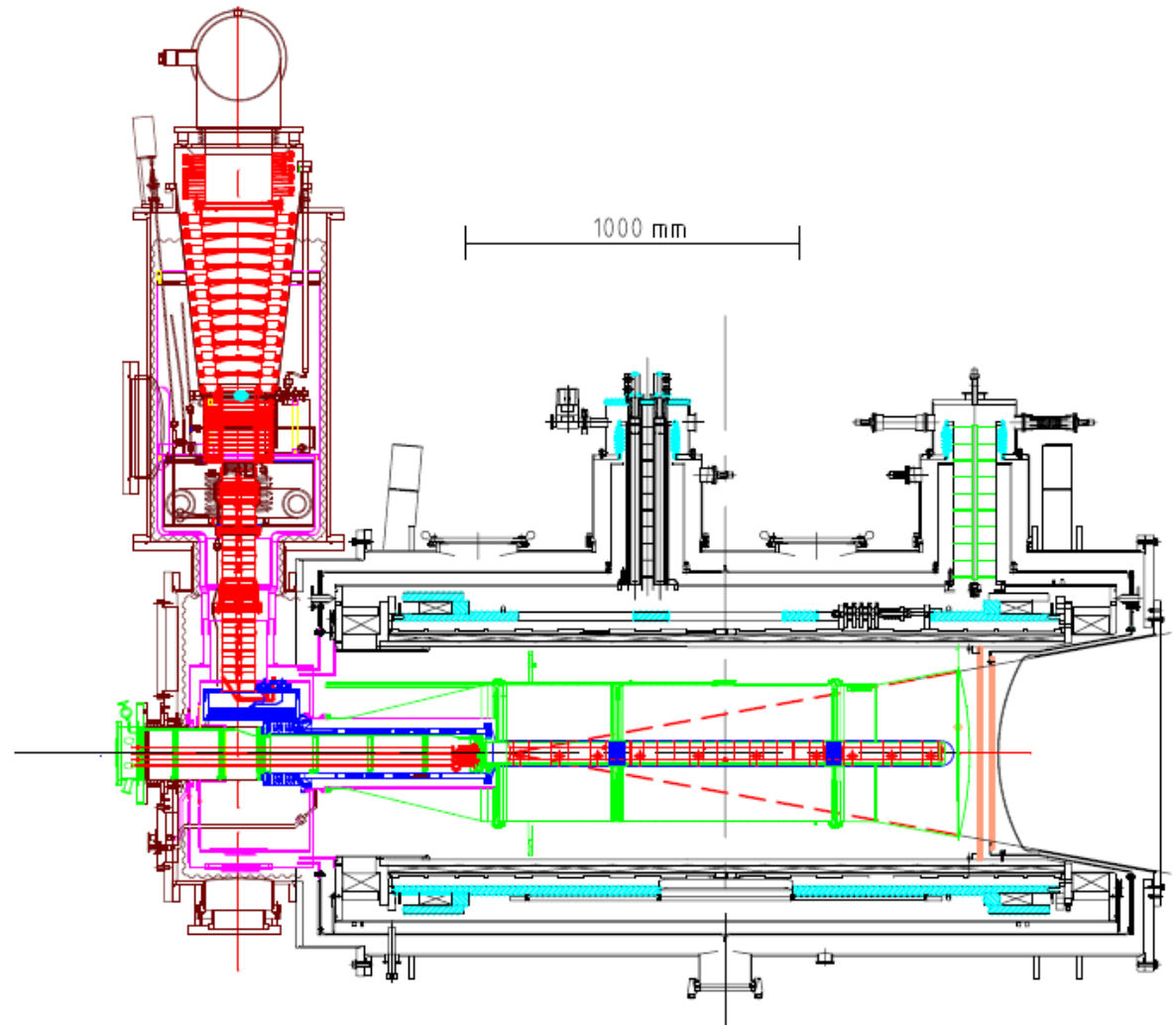
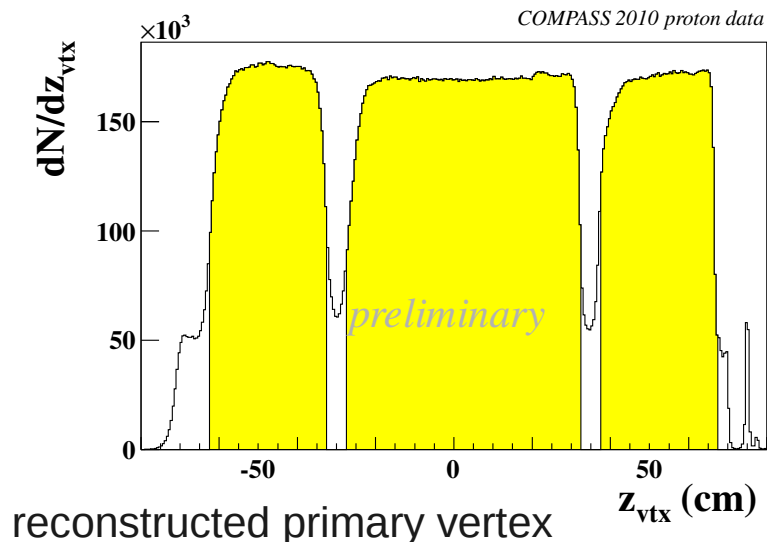
The COMPASS spectrometer in 2010

- Two stage spectrometer
- Longitudinal polarized 160 GeV/c μ -beam
- 2002-2004 polarized 6LiD (deuterium) target
- 2007 & 2010 polarized NH_3 (proton) target
- Tracking
- Calorimetry
- Particle identification (RICH)
- **New in 2010:**
Large Angle Spectrometer Trigger



The COMPASS target system

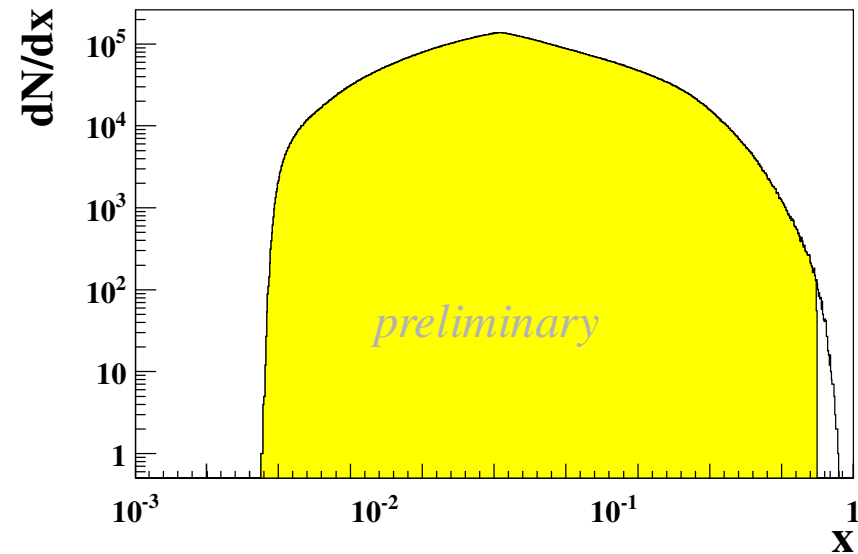
- Upgrade of target system in 2005
- Three cells with opposite polarisation (2002-04 two cells)
- 180mrad geometrical acceptance
- ${}^6\text{LiD}$:
 - polarization: $\sim 48\%$
 - dilution factor: ~ 0.38
- NH_3 :
 - polarization: $\sim 90\%$
 - dilution factor: ~ 0.15
- Transverse polarization reversed every week via microwave



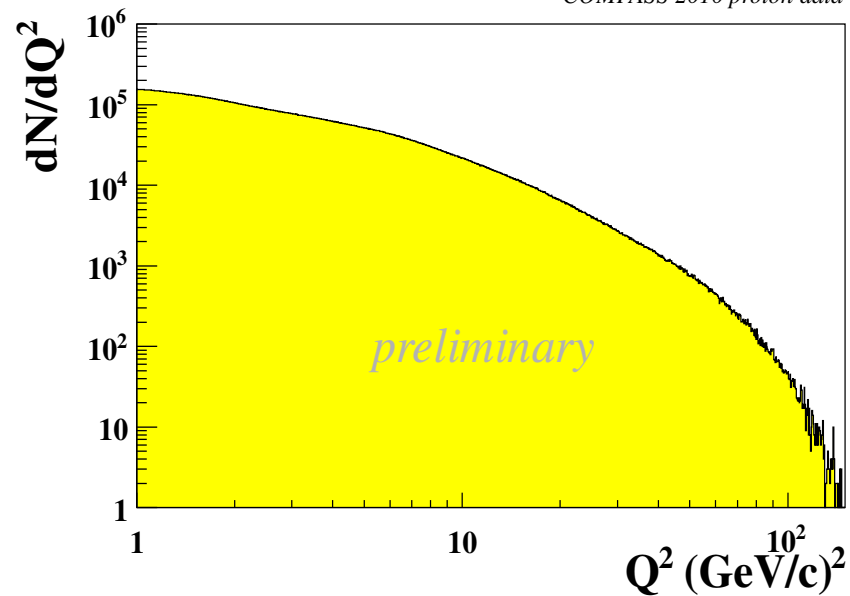
SIDIS event selection

DIS cuts: $Q^2 > 1 \text{ (GeV/c)}^2$
 $0.1 < y < 0.9$
 $W > 5 \text{ GeV/c}^2$

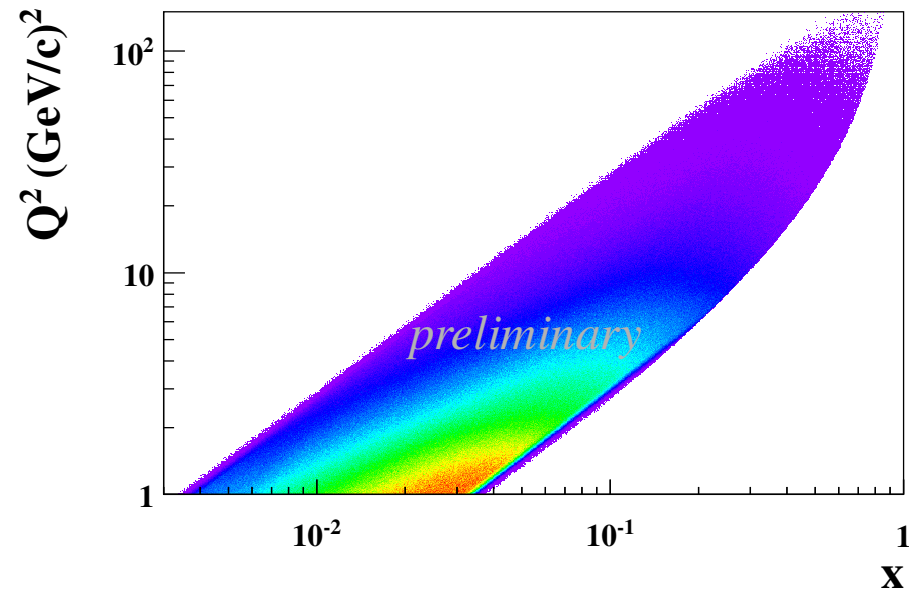
COMPASS 2010 proton data



COMPASS 2010 proton data



COMPASS 2010 proton data

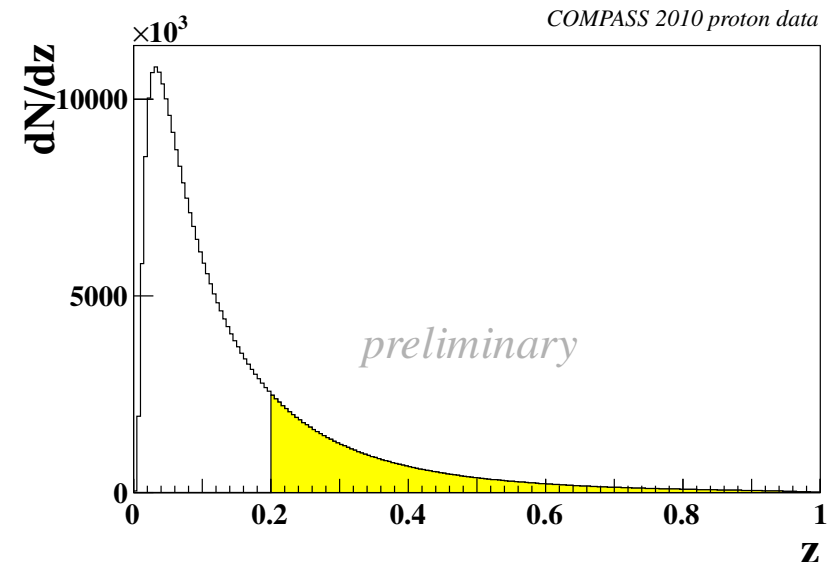
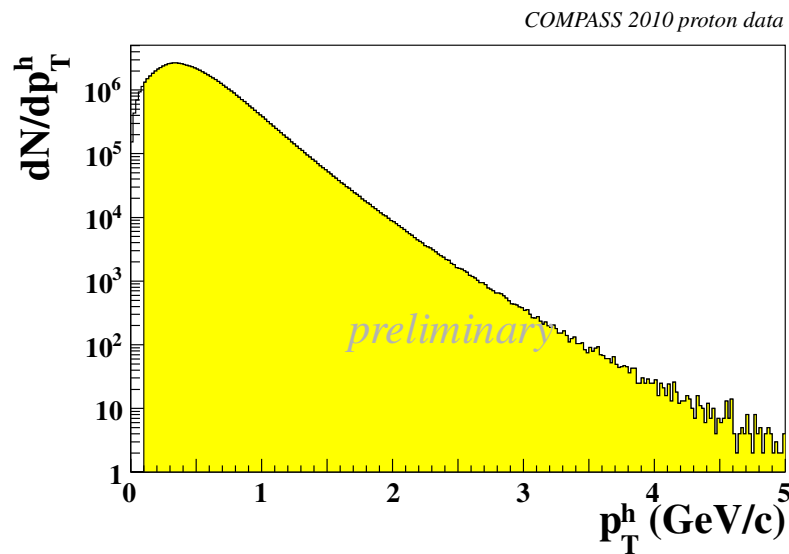
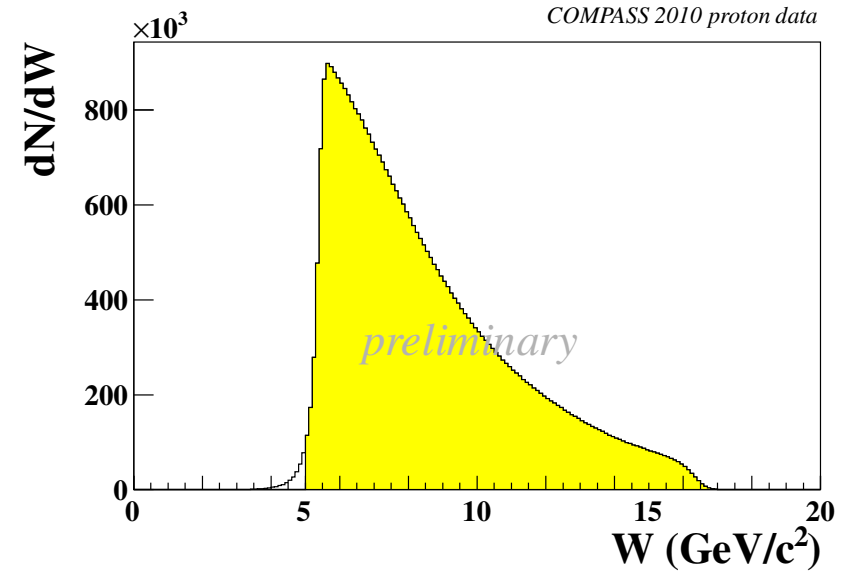


SIDIS event selection

DIS cuts: $Q^2 > 1 \text{ (GeV/c)}^2$
 $0.1 < y < 0.9$
 $W > 5 \text{ GeV/c}^2$

Hadron selection:

$P_t^h > 0.1 \text{ GeV/c}$
 $z > 0.2$



Hadron statistics

2007

Charged hadrons

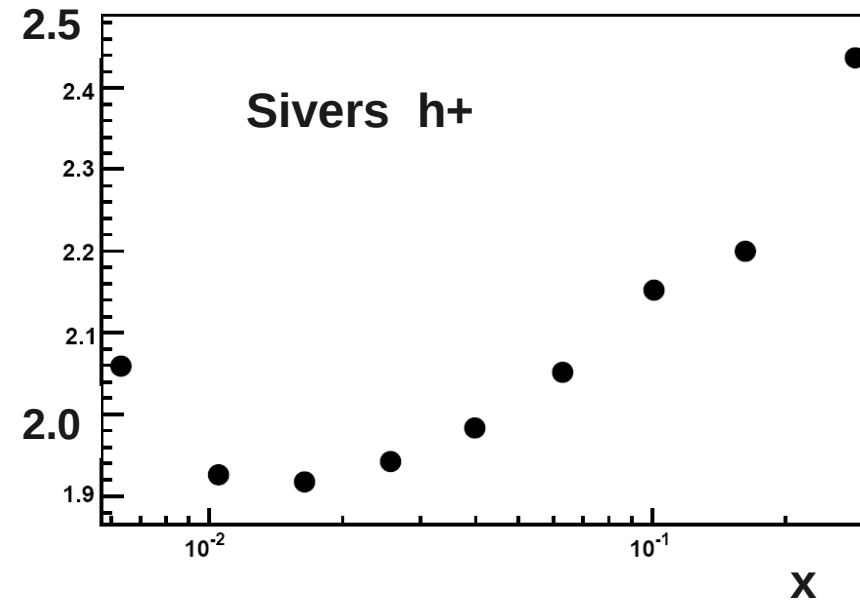
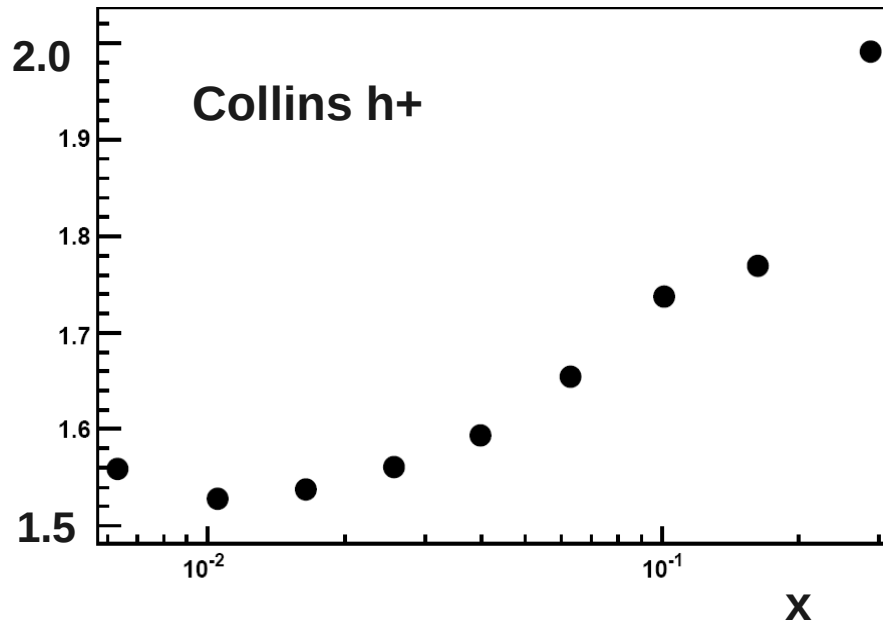
	h+	h-
Collins	15.1M	12.0M
Sivers	10.2M	8.1M

2010

Charged hadrons

h+	h-
43M	34M



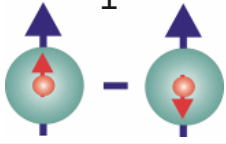
ratio of statistical errors: 2007 / 2010



Spin structure \longrightarrow Transversity

Three distribution functions are necessary to describe the spin structure of the nucleon in LO:



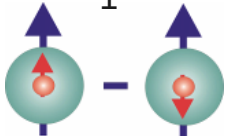
quark

		U	L	T	
nucleon	U	$f_1(x)$ 			Quark distribution $f_1(x) = q^+(x) + q^-(x)$
	L		$g_1(x)$ 		Helicity distribution $g_1(x) = q^+(x) - q^-(x)$
	T			$h_1(x)$ 	Transversity distribution $h_1(x) = q^{\uparrow\uparrow}(x) - q^{\uparrow\downarrow}(x)$ $lN^{\uparrow} \rightarrow l' hX$ Collins FF $lN^{\uparrow} \rightarrow l' hhX$ Interference FF $lN^{\uparrow} \rightarrow l' \Lambda X$ FF of $q^{\uparrow} \rightarrow \Lambda$

Spin structure → Transversity

Three distribution functions are necessary to describe the spin structure of the nucleon in LO:

quark

		quark		
		U	L	T
nucleon	U	$f_1(x)$ 		
	L		$g_1(x)$ 	
	T			$h_1(x)$ 

Quark distribution
 $f_1(x) = q^+(x) + q^-(x)$

Helicity distribution
 $g_1(x) = q^+(x) - q^-(x)$

Transversity distribution
 $h_1(x) = q^{\uparrow\uparrow}(x) - q^{\uparrow\downarrow}(x)$

- $l N^{\uparrow} \rightarrow l' h X$ Collins FF
- $l N^{\uparrow} \rightarrow l' h h X$ Interference FF
- $l N^{\uparrow} \rightarrow l' \Lambda X$ FF of $q^{\uparrow} \rightarrow \Lambda$

The Collins modulation

For measuring Transversity quark spin must flip:

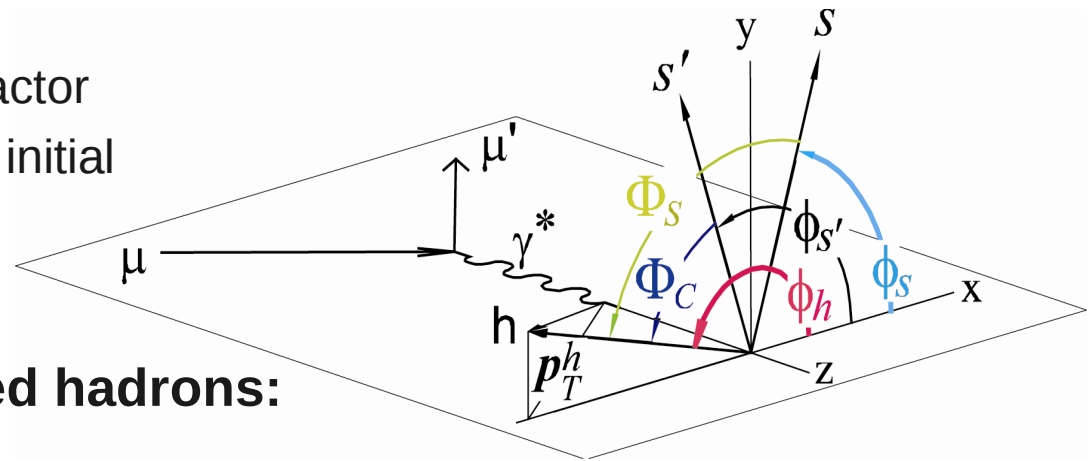
—► $h_1(x)$ decouples from inclusive DIS

Product of $h_1(x)$ and another chiral-odd function needed: Collins FF $\Delta_T^0 D_q^h$

—► $h_1(x)$ can be extracted via SIDIS on a transversely polarized target.

$$A_{Coll} = \frac{A_C^h}{f \cdot P_T \cdot D_{nn}} = \frac{\sum_q e_q^2 \cdot h_1 \cdot \Delta_T^0 D_q^h}{\sum_q e_q^2 \cdot q \cdot D_q^h}$$

with P_T the target polarization, f the dilution factor and D_{NN} the spin transfer coefficient from the initial to the struck quark



Azimuthal distribution of the produced hadrons:

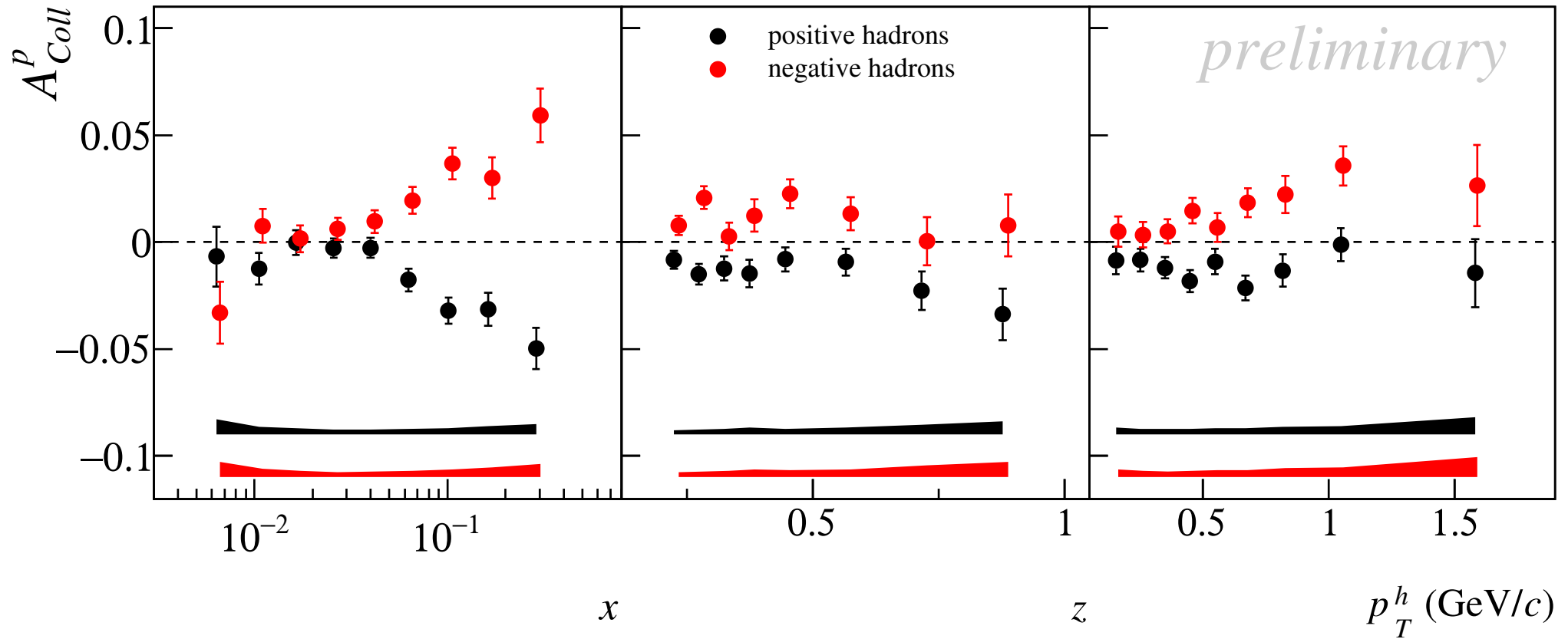
$$N_h^\pm(\Phi_C) = N_h^0(1 \pm A_C^h \sin(\Phi_C))$$

$$\text{with } \Phi_C = \phi_h - \phi_{s'} = \phi_h + \phi_S - \pi$$

The Collins modulation – 2010 data

- at small x asymmetries are compatible with zero
- Large signal in the valence region of opposite sign for positive and negative hadrons

COMPASS 2010 proton data

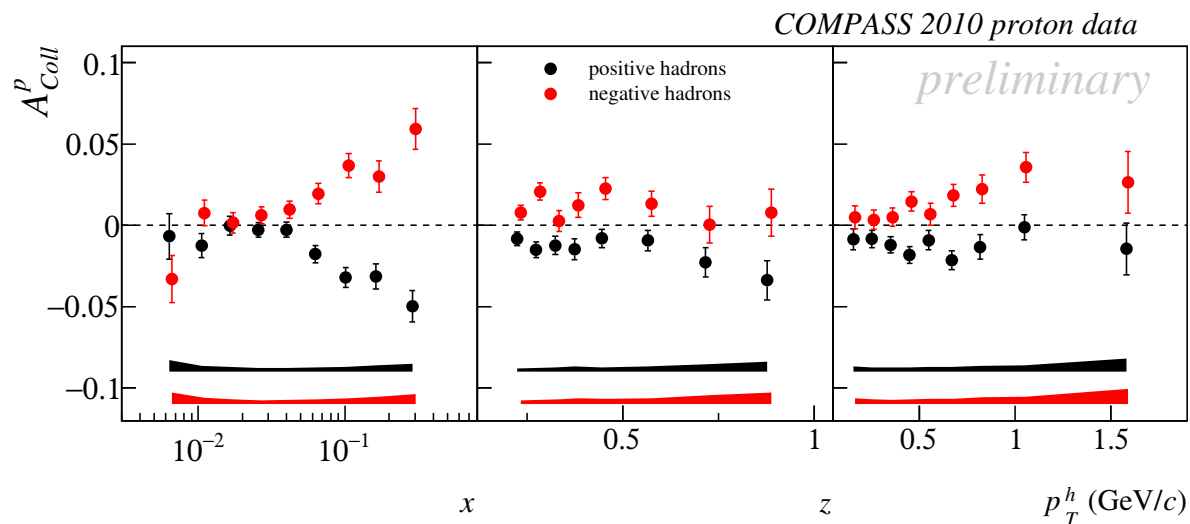


$$\sigma_{\text{syst}} \sim 0.5 \sigma_{\text{stat}}$$

The Collins modulation

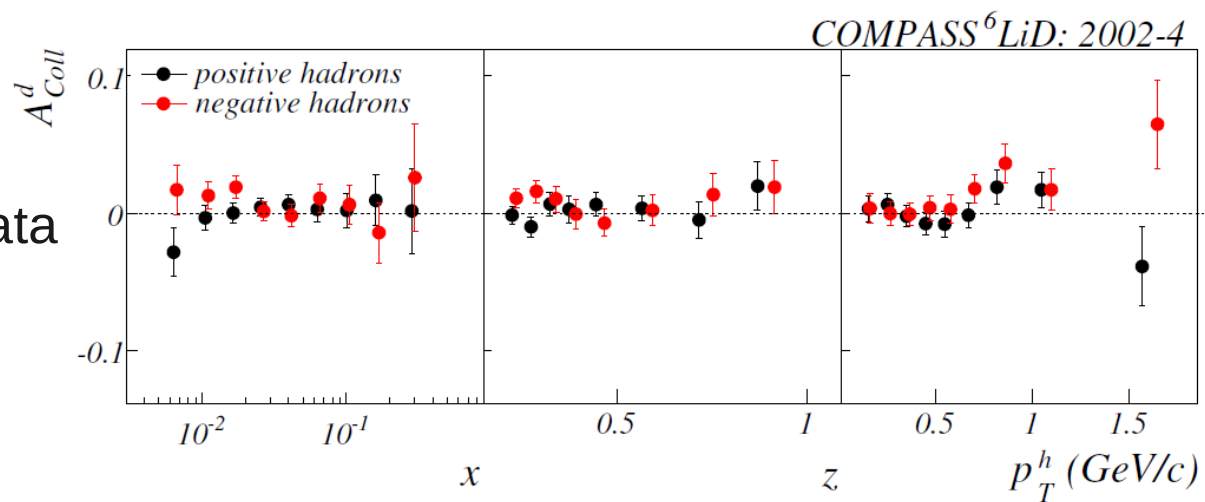
2010 proton ↔ deuteron

2010 proton data



large signal in the valence region

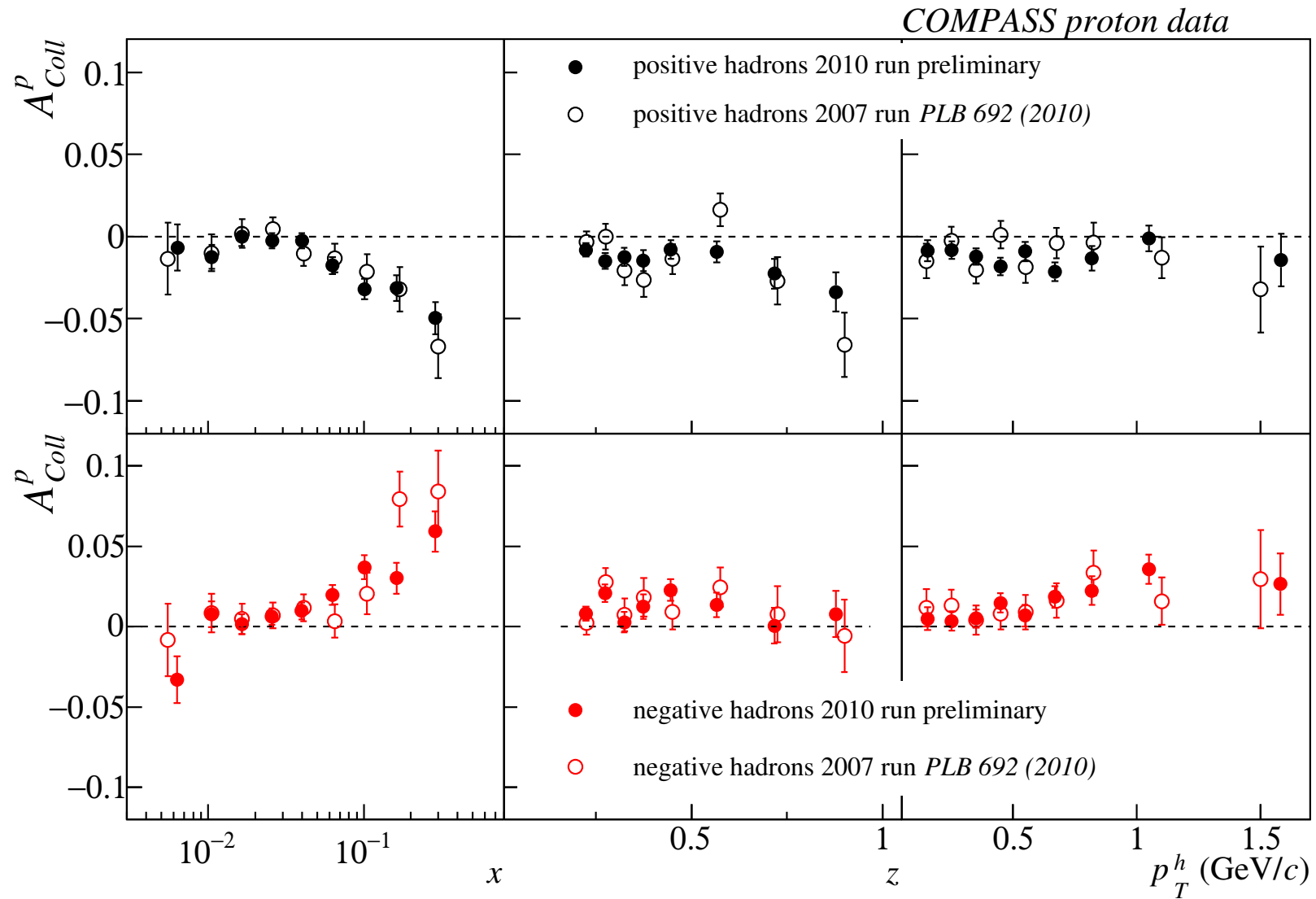
2002-04 deuteron data



Asymmetries compatible with zero

NPB 765 (2007)

The Collins modulation 2010 ↔ 2007

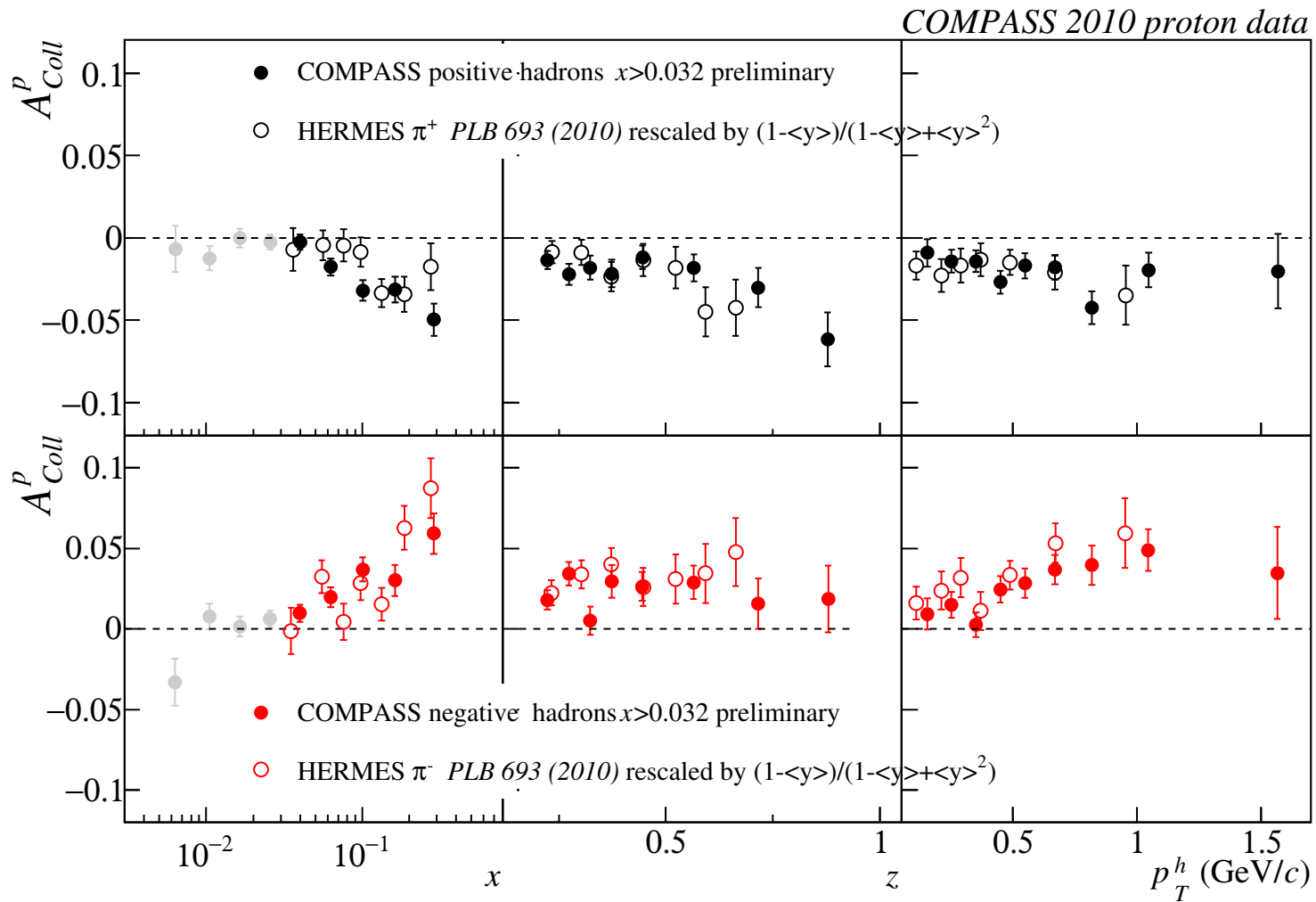


confirmation of 2007 results with increased statistics

The Collins modulation

Comparison to HERMES data



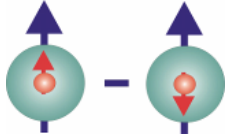
for $x > 0.032$



nice agreement between COMPASS and HERMES

Transverse spin physics

Taking into account the transverse momentum k_T of the quarks:

		quark		
		U	L	T
nucleon	U	$f_1(x)$ 		
	L		$g_1(x)$ 	
	T			$h_1(x)$ 

Transverse spin physics: TMDs

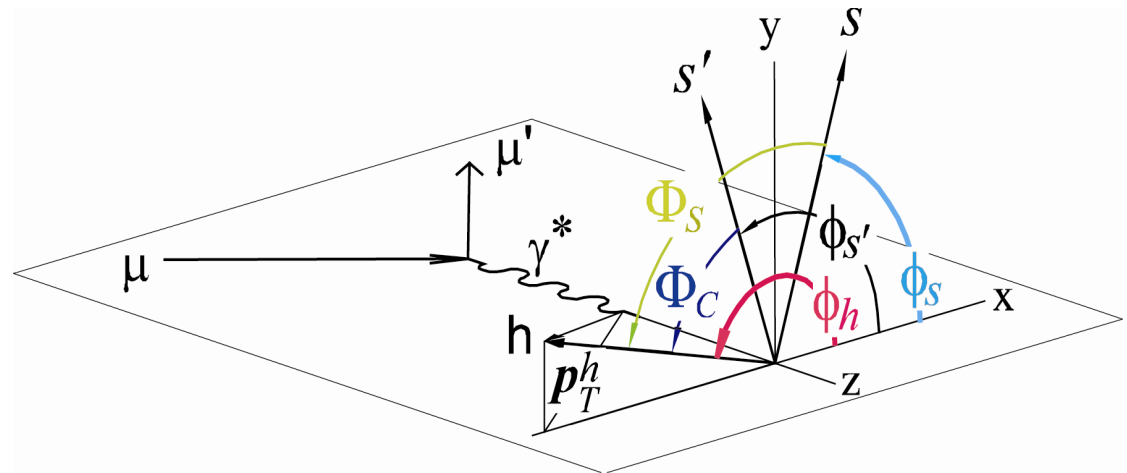
Taking into account the transverse momentum k_T of the quarks:

		quark		
		U	L	T
nucleon	U	$f_1(x, k_T)$		$h_1^\perp(x, k_T)$ Boer-Mulders
	L		$g_1(x, k_T)$	$h_{1L}(x, k_T)$ Worm-gear 1
	T	$f_{1T}^\perp(x, k_T)$ Sivers	$g_{1T}(x, k_T)$ Worm-gear 2	$h_{1T}(x, k_T)$ Transversity $h_{1T}^\perp(x, k_T)$ Pretzelosity

The Sivers modulation

Sivers function $f_{1T}^{\perp}(x, k_{\perp})$: Correlation between the transverse spin of a nucleon and the intrinsic transverse momentum of unpolarized quarks

$$A_{Siv} = \frac{A_S^h}{f \cdot P_T} = \frac{\sum_q e_q^2 \cdot f_{1Tq}^{\perp} D_q^h}{\sum_q e_q^2 \cdot f_{1q} \cdot D_q^h}$$



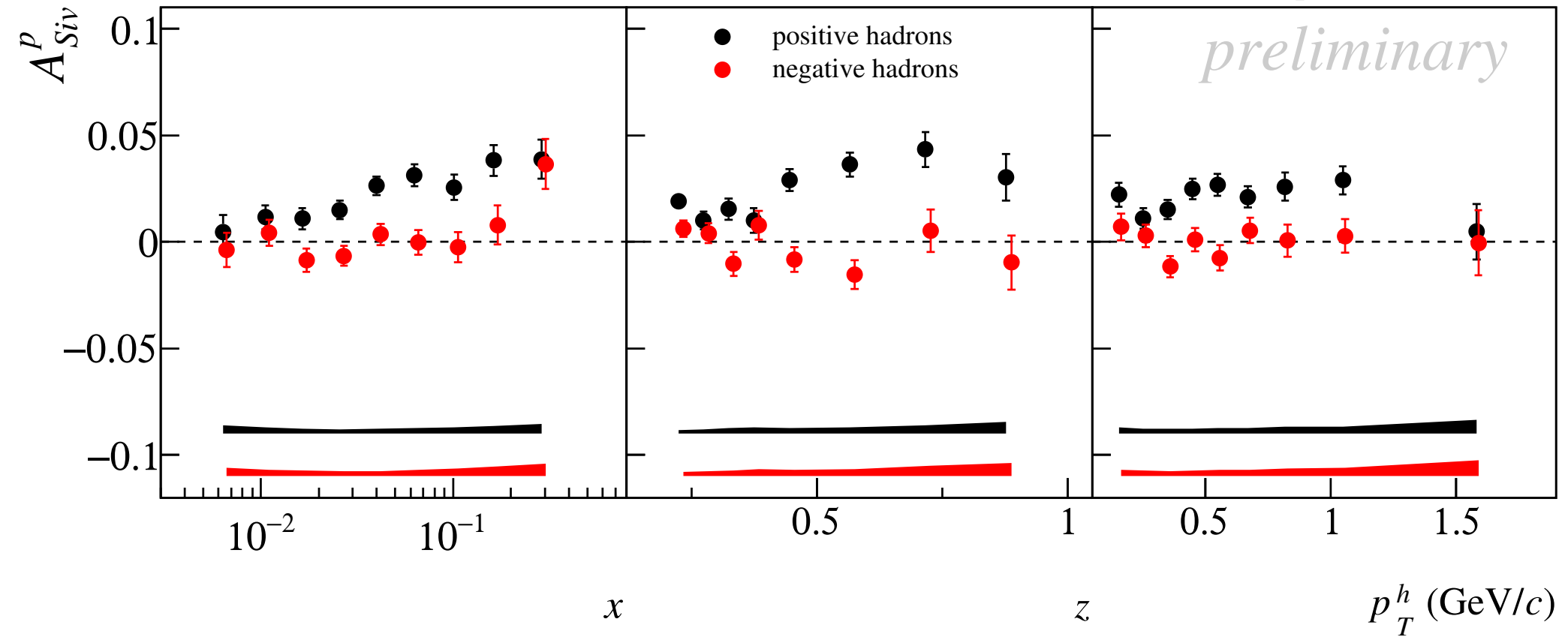
Azimuthal distribution of the produced hadrons:

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

$$\text{with } \Phi_S = \phi_h - \phi_s$$

The Sivers modulation – 2010 data

COMPASS 2010 proton data



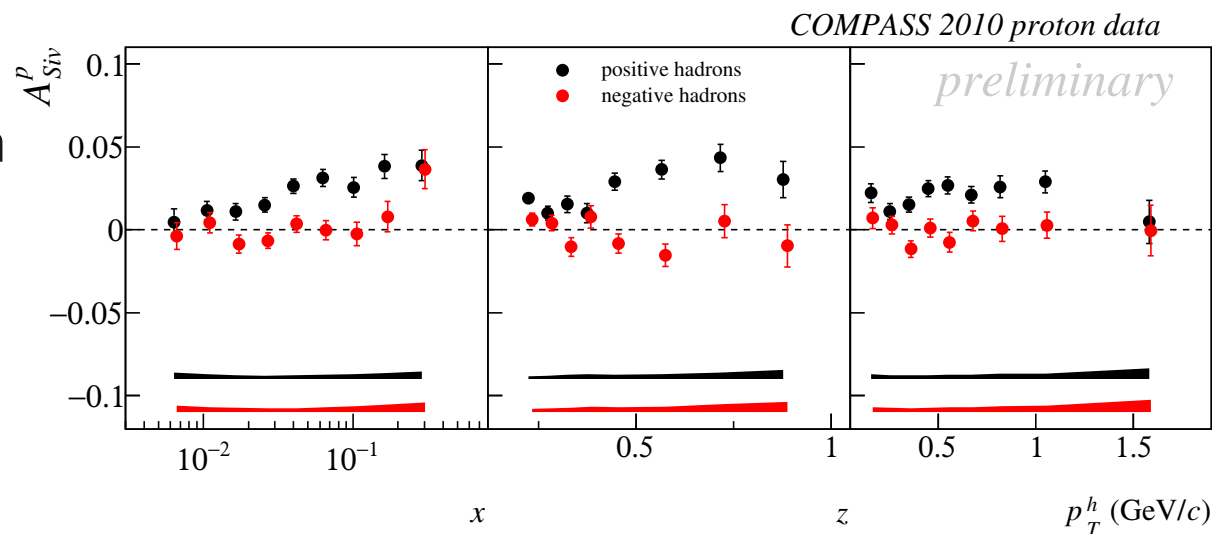
- positive signal for positive hadrons
- h^- asymmetry compatible with zero

$$\sigma_{\text{syst}} \sim 0.5 \sigma_{\text{stat}}$$

The Sivers modulation

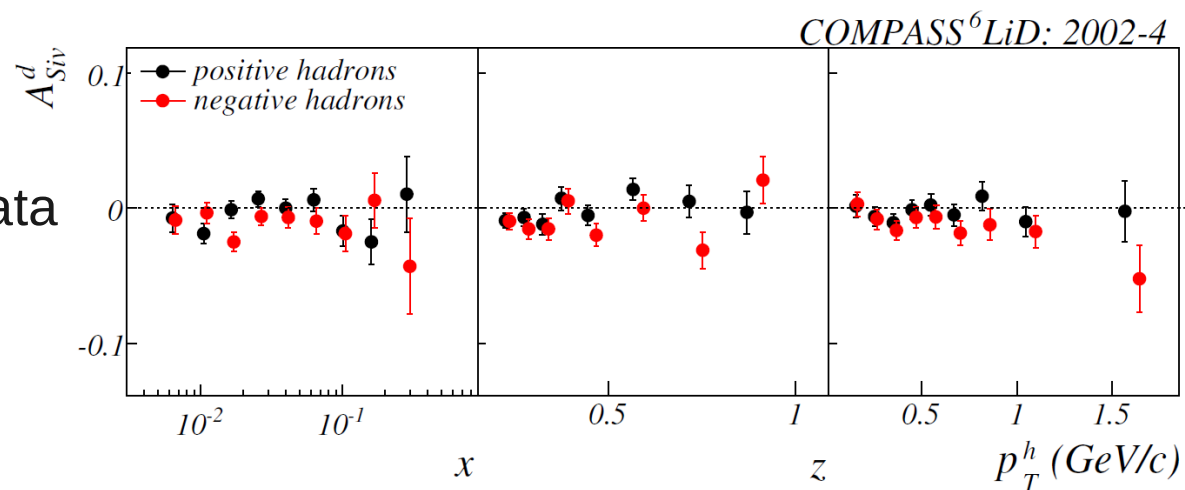
2010 proton ↔ deuteron

2010 proton
data



positive signal for
positive hadrons

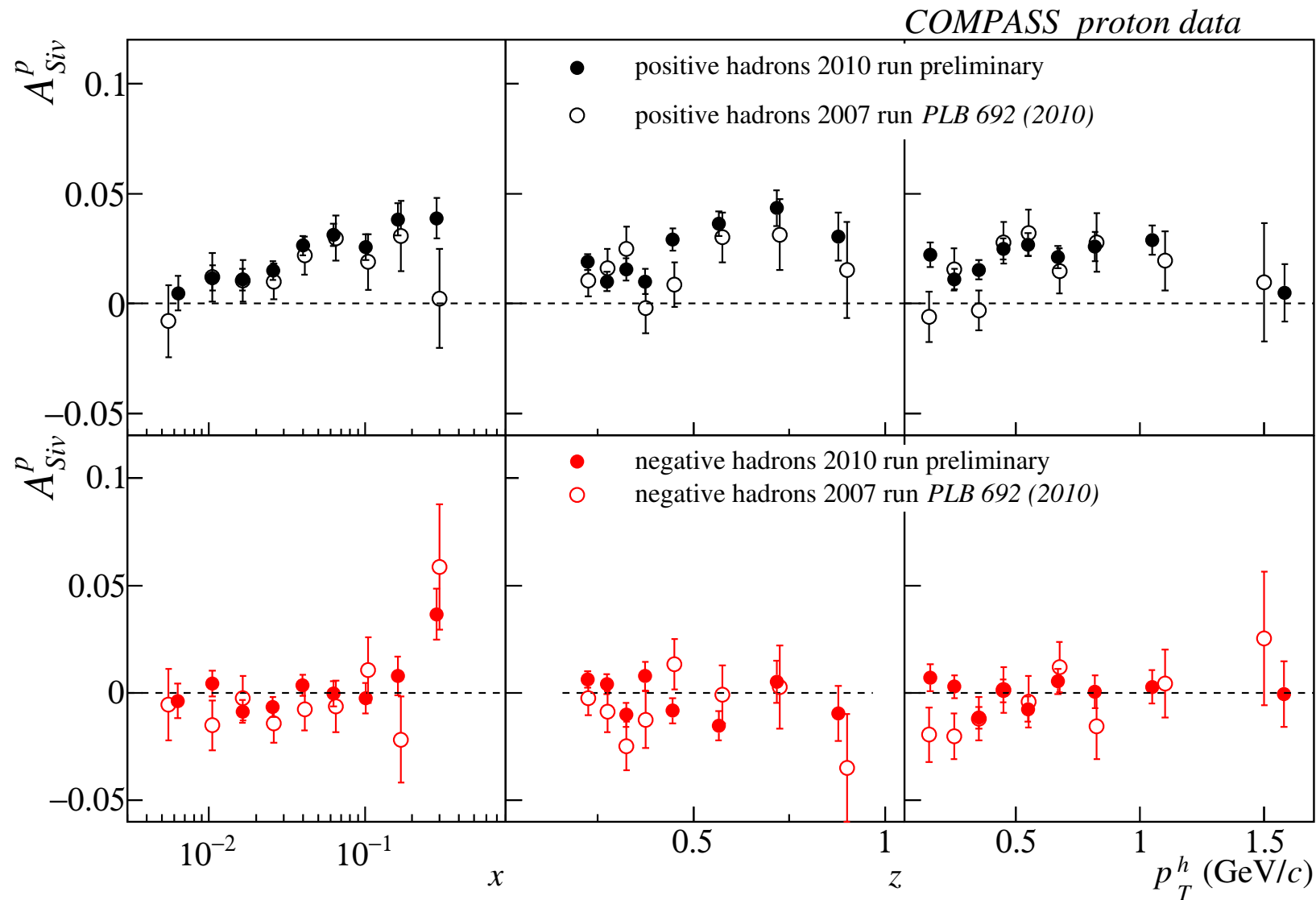
2002-04
deuteron data



Asymmetries
compatible with zero

NPB 765 (2007)

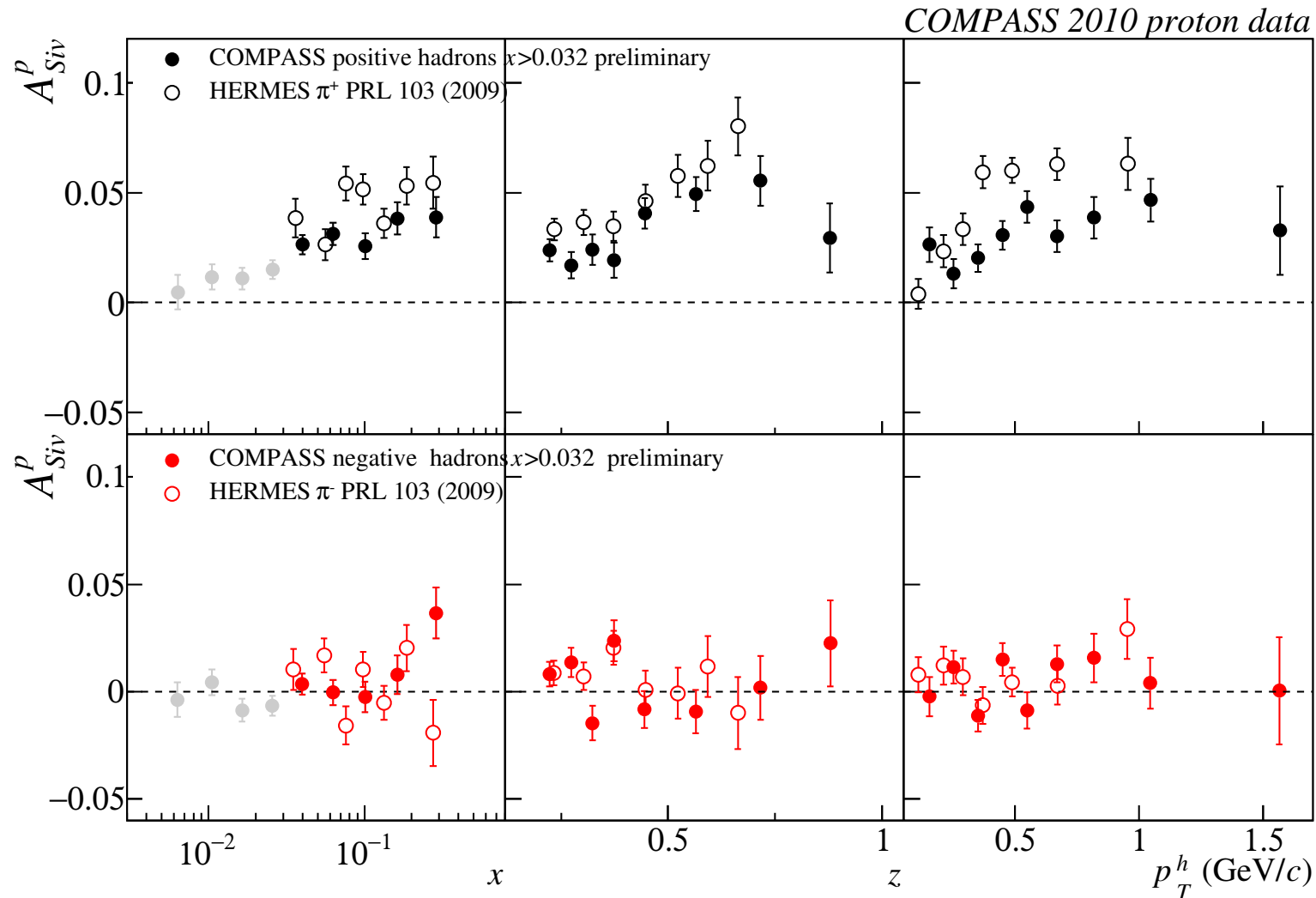
The Sivers modulation 2010 ↔ 2007



good agreement with 2007 published results, but with smaller errors

The Sivers modulation

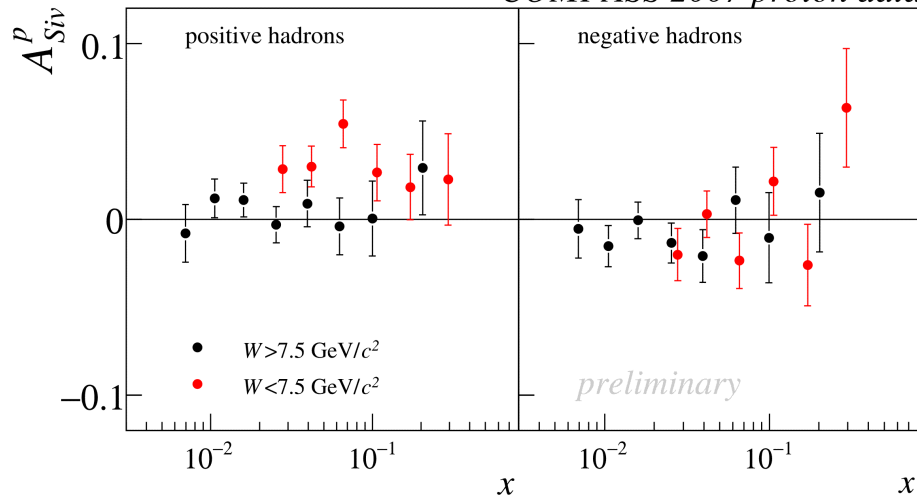
Comparison to Hermes data for $x > 0.032$



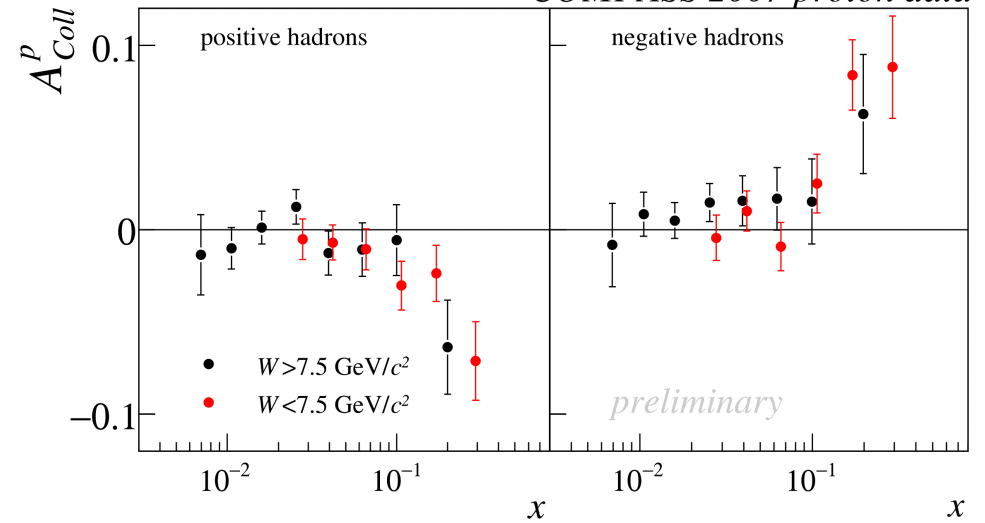
difference between COMPASS and HERMES results, but same trend

W dependence

COMPASS 2007 proton data

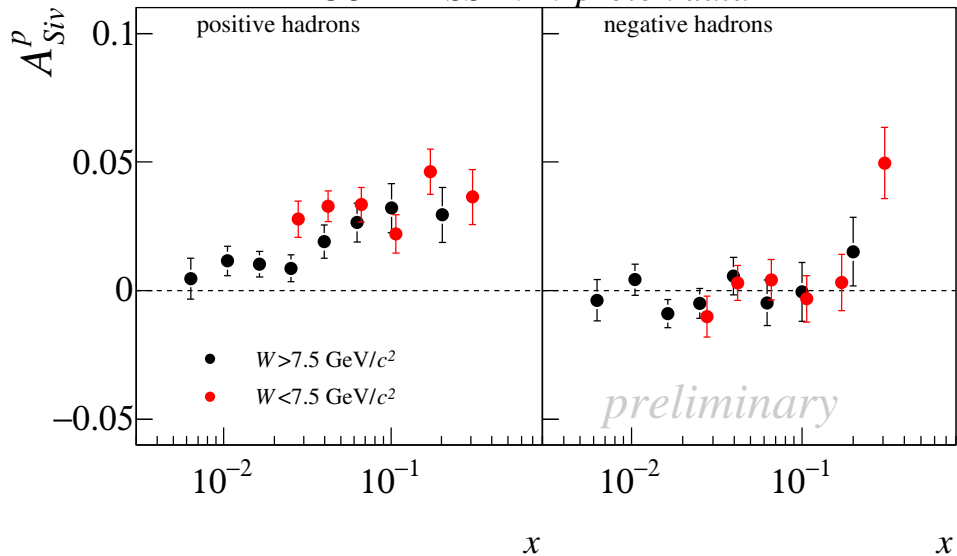


COMPASS 2007 proton data

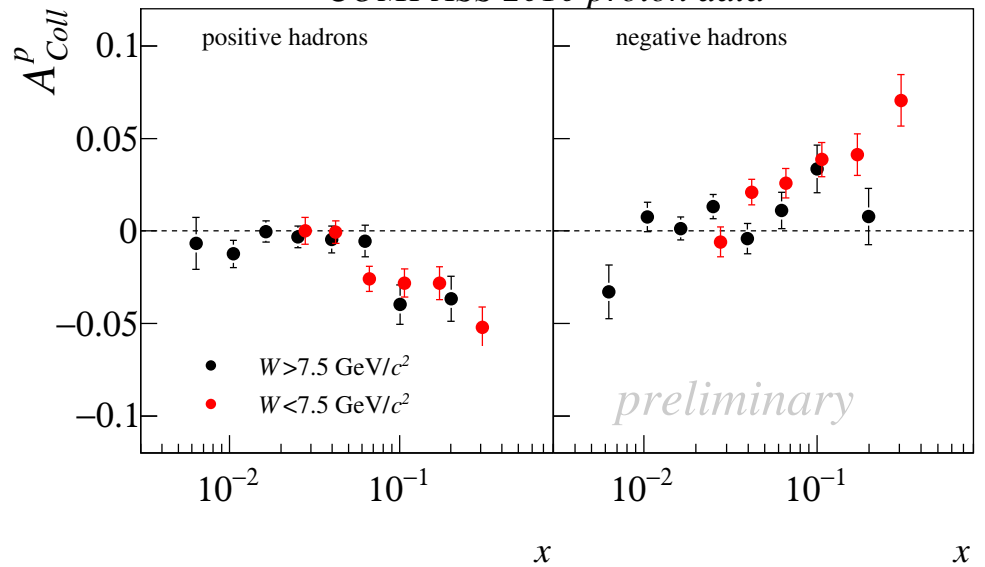


2007: hint for possible W dependence

COMPASS 2010 proton data



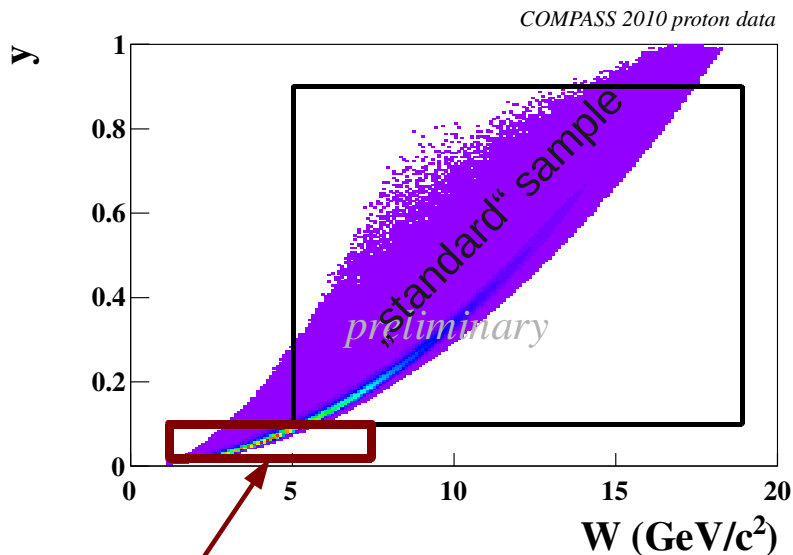
COMPASS 2010 proton data



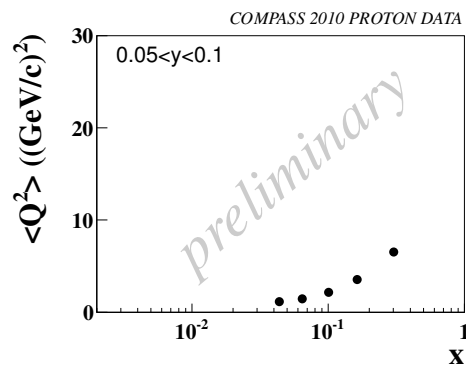
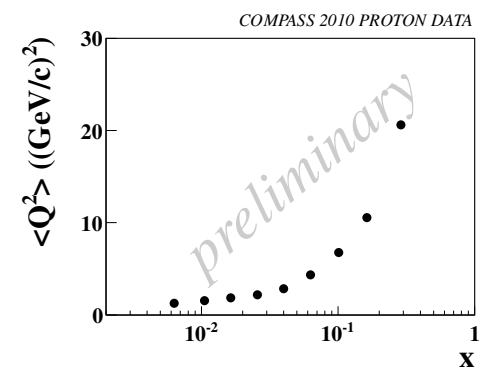
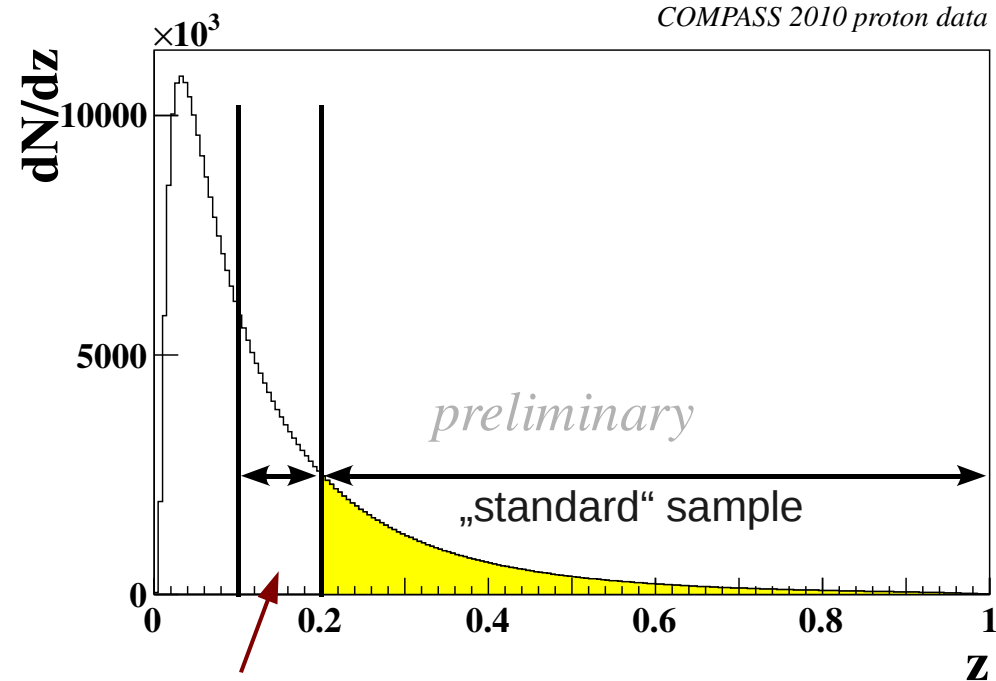
2010: absolute difference smaller

Exploration of different kinematic regions

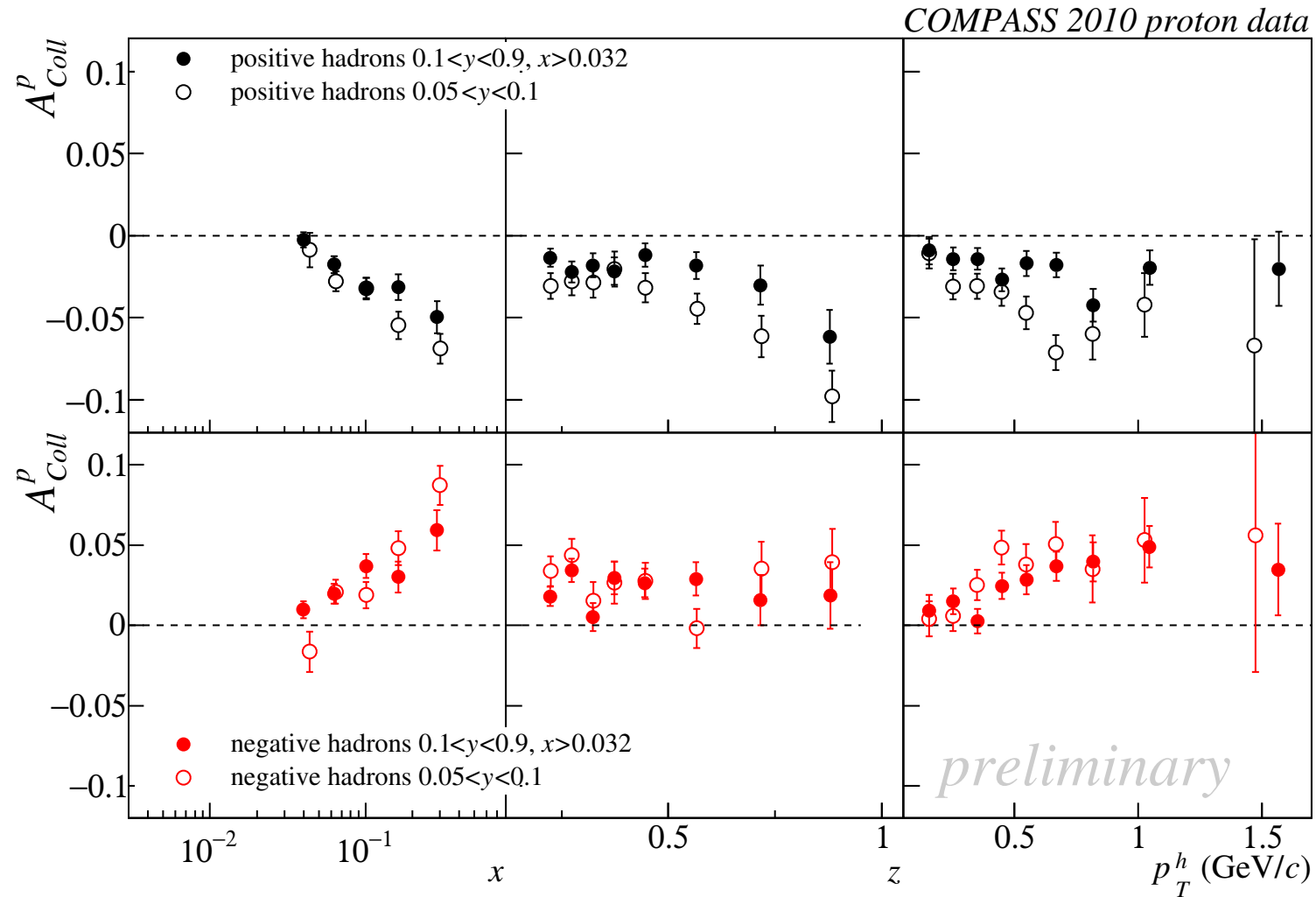
low y : $0.05 < y < 0.1$



low z : $0.1 < z < 0.2$



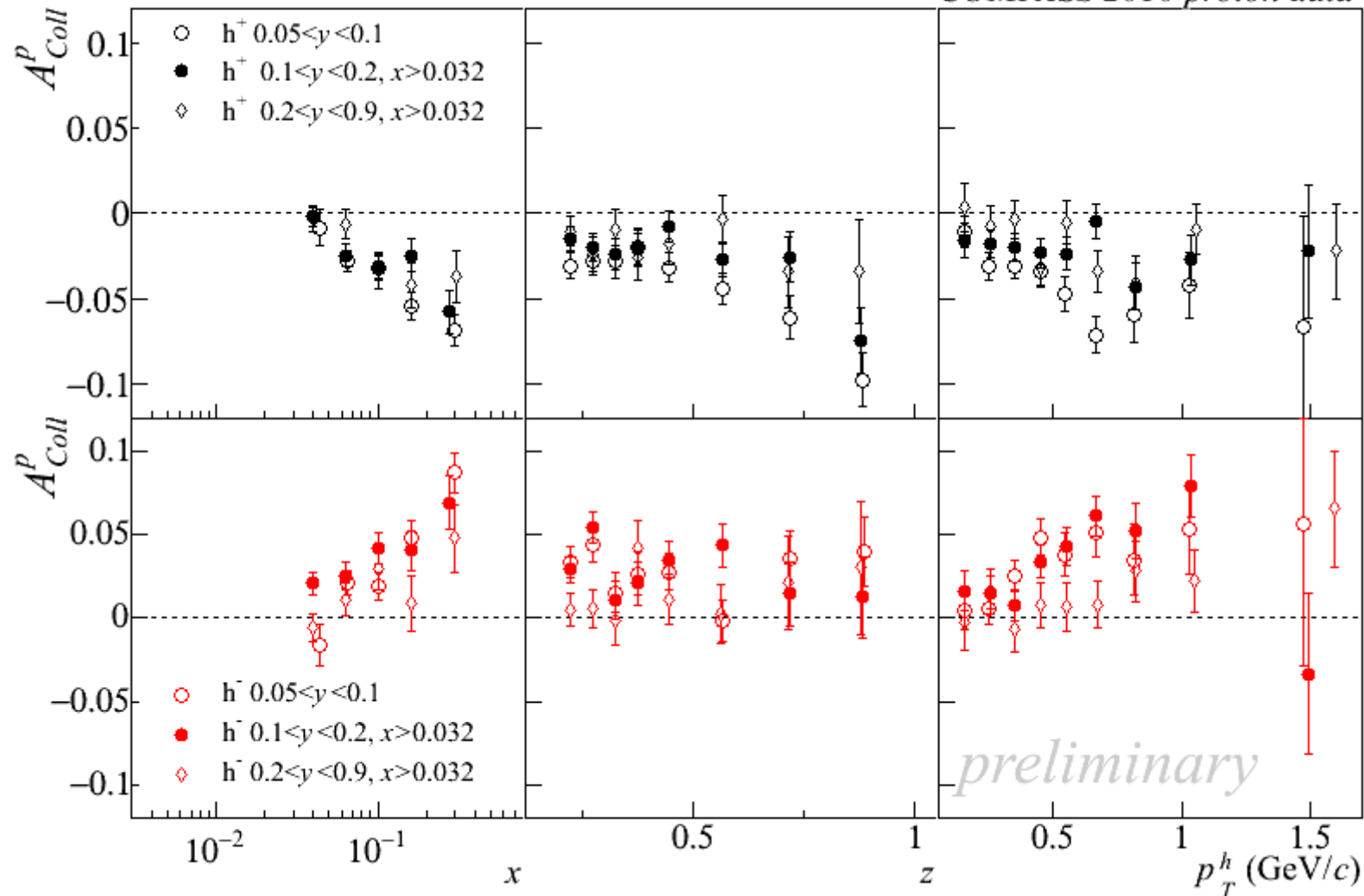
low y – Collins asymmetry



small effect visible for positive hadrons

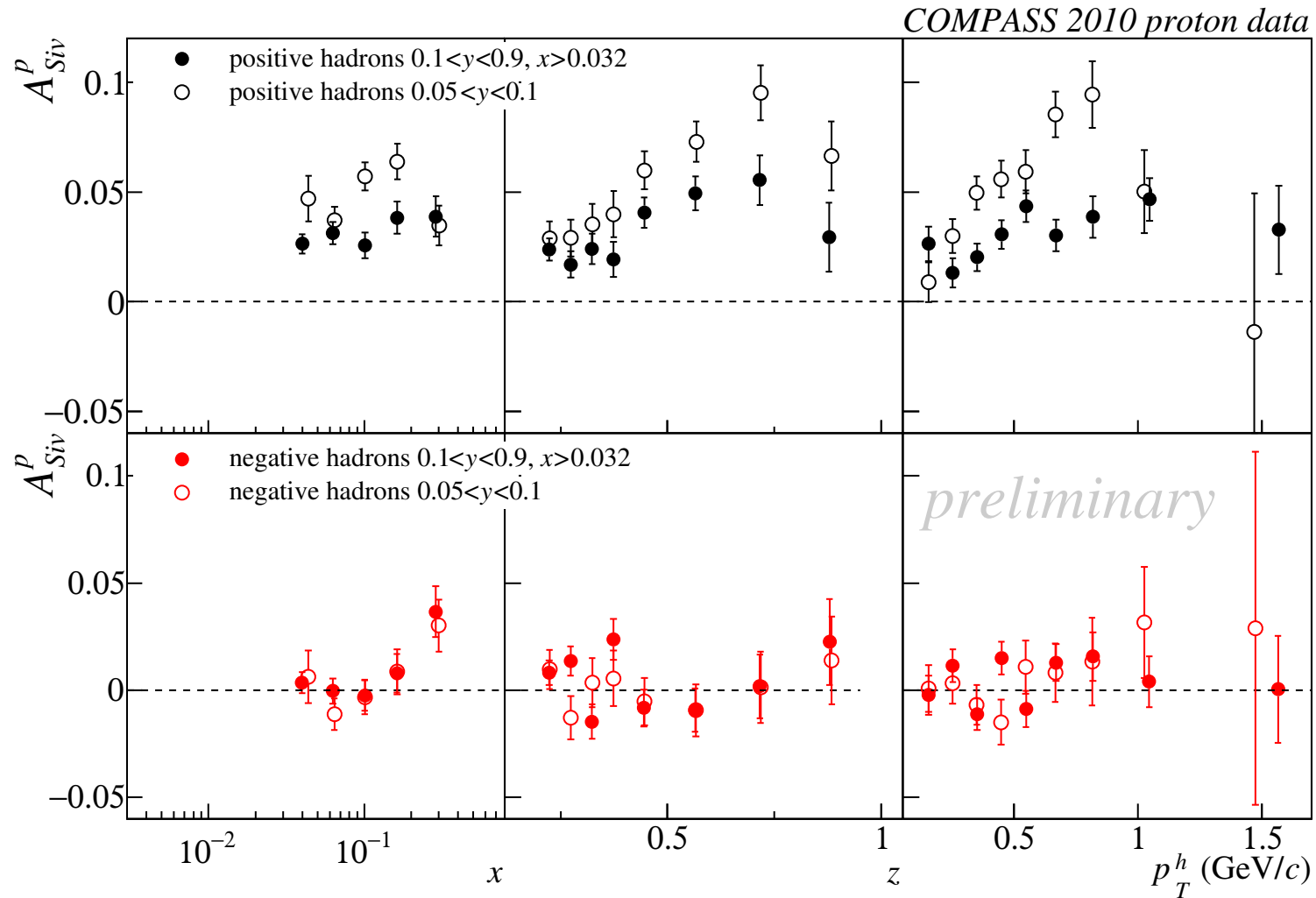
3 y ranges – Collins asymmetry

COMPASS 2010 proton data



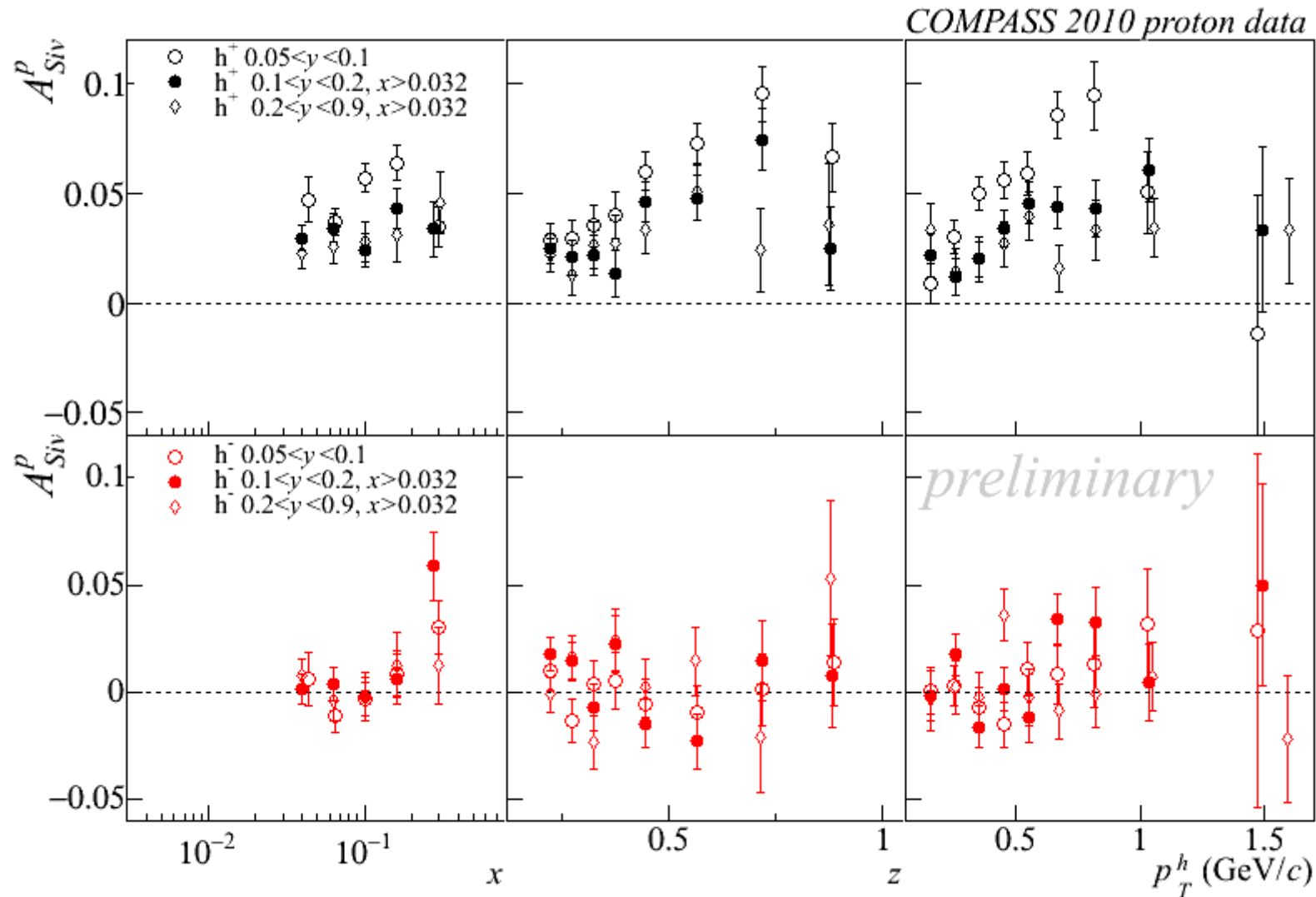
splitting the standard sample in two subsamples ($0.1 < y < 0.2$ and $0.2 < y < 0.9$)
has no effect

low y – Sivers asymmetry



larger asymmetries for positive hadrons at low y

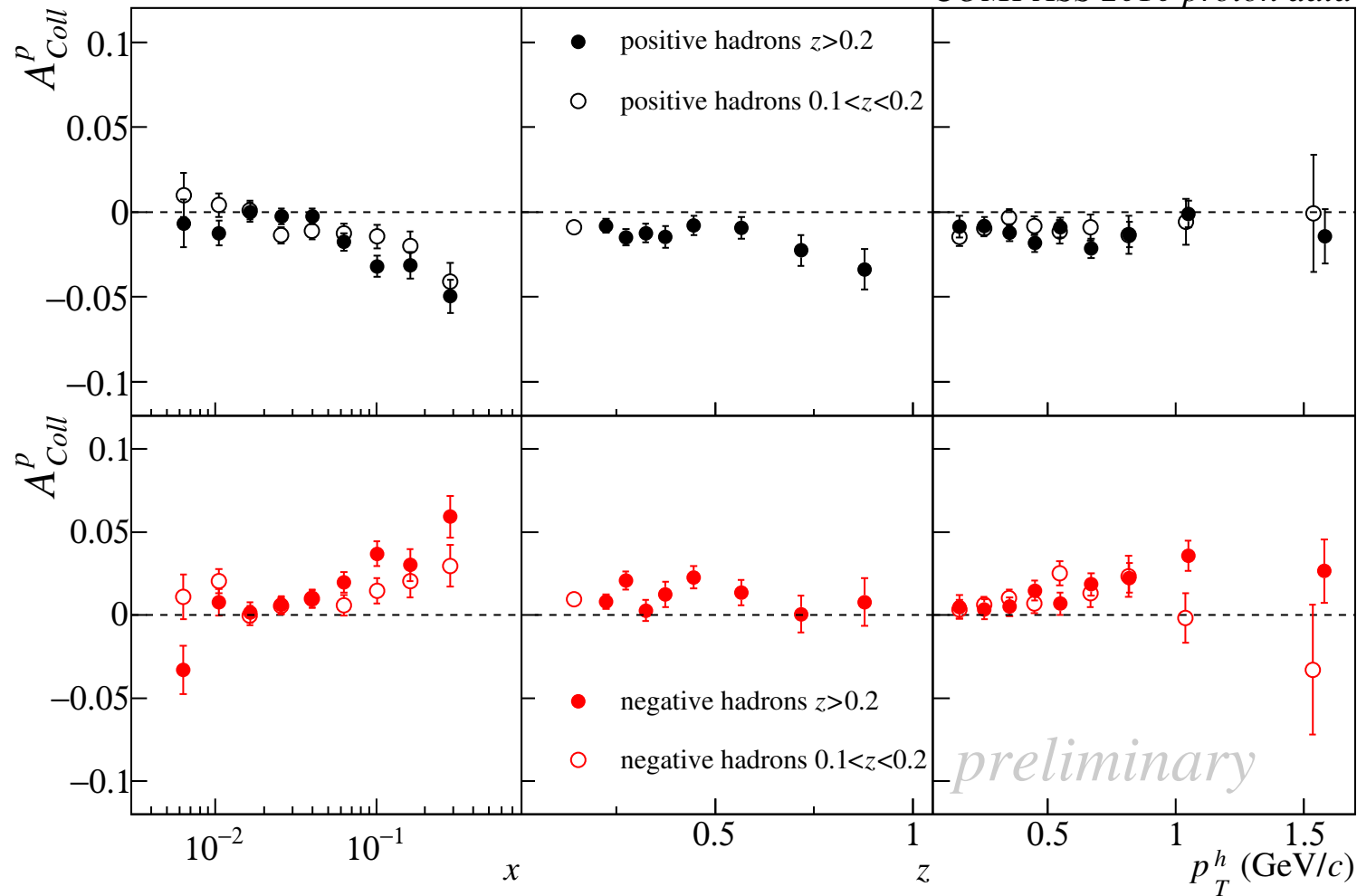
3 y ranges – Sivers asymmetry



splitting the standard sample in two subsamples ($0.1 < y < 0.2$ and $0.2 < y < 0.9$)
has no clear effect

low z – Collins asymmetry

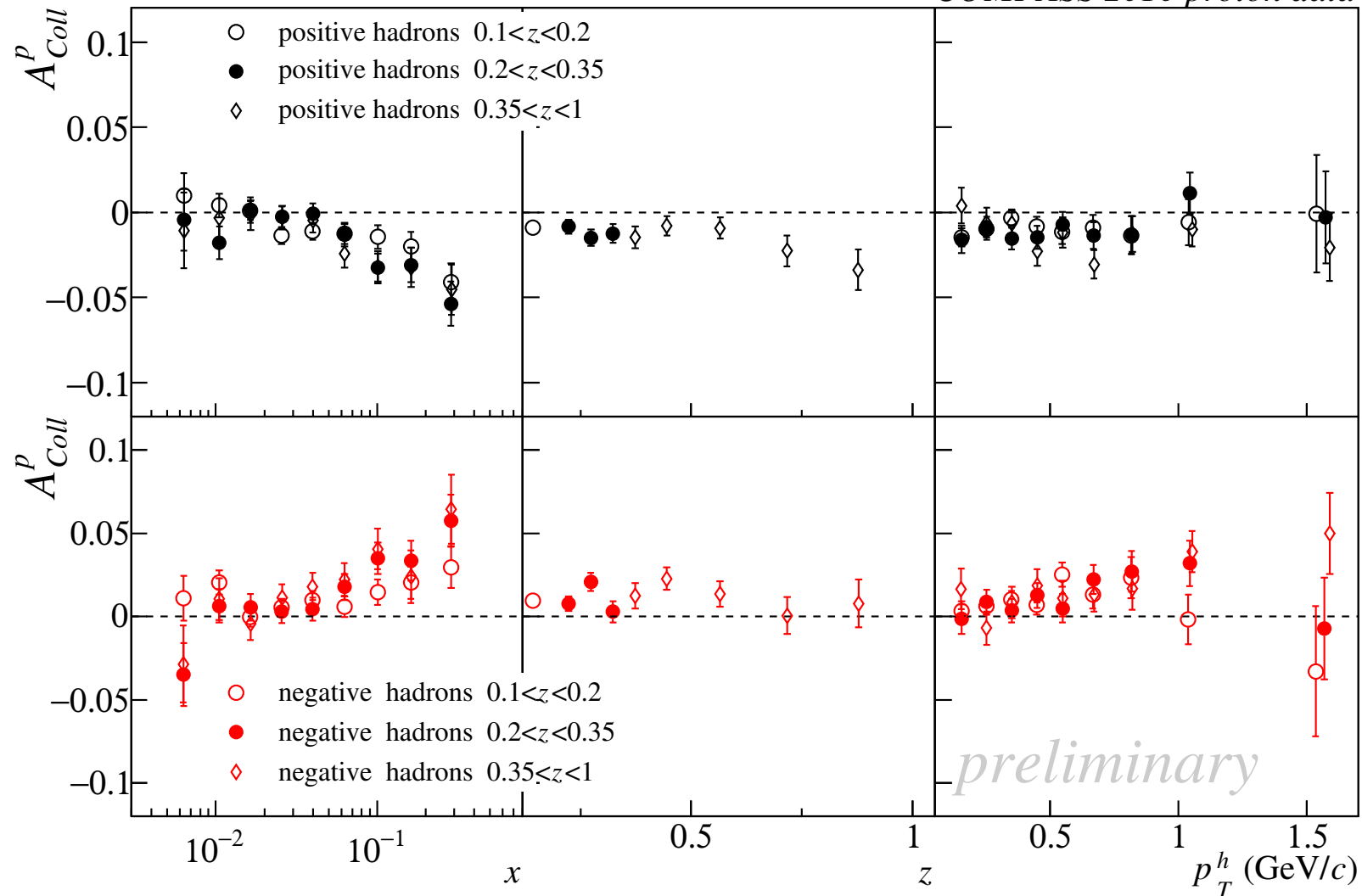
COMPASS 2010 proton data



small decrease of asymmetries for low z sample

z in 3 ranges – Collins asymmetry

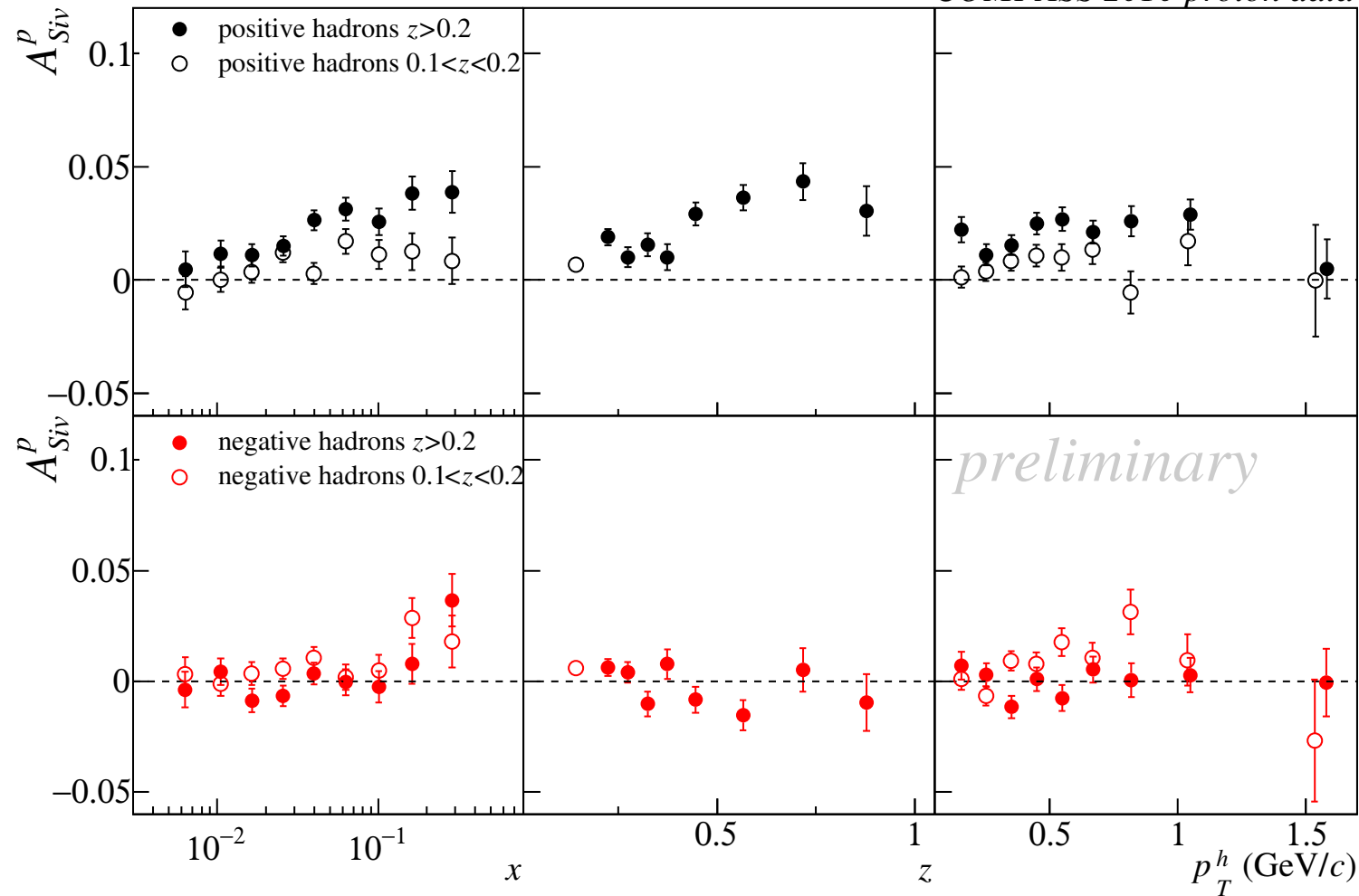
COMPASS 2010 proton data



small decrease of asymmetries for low z sample

low z – Sivers asymmetry

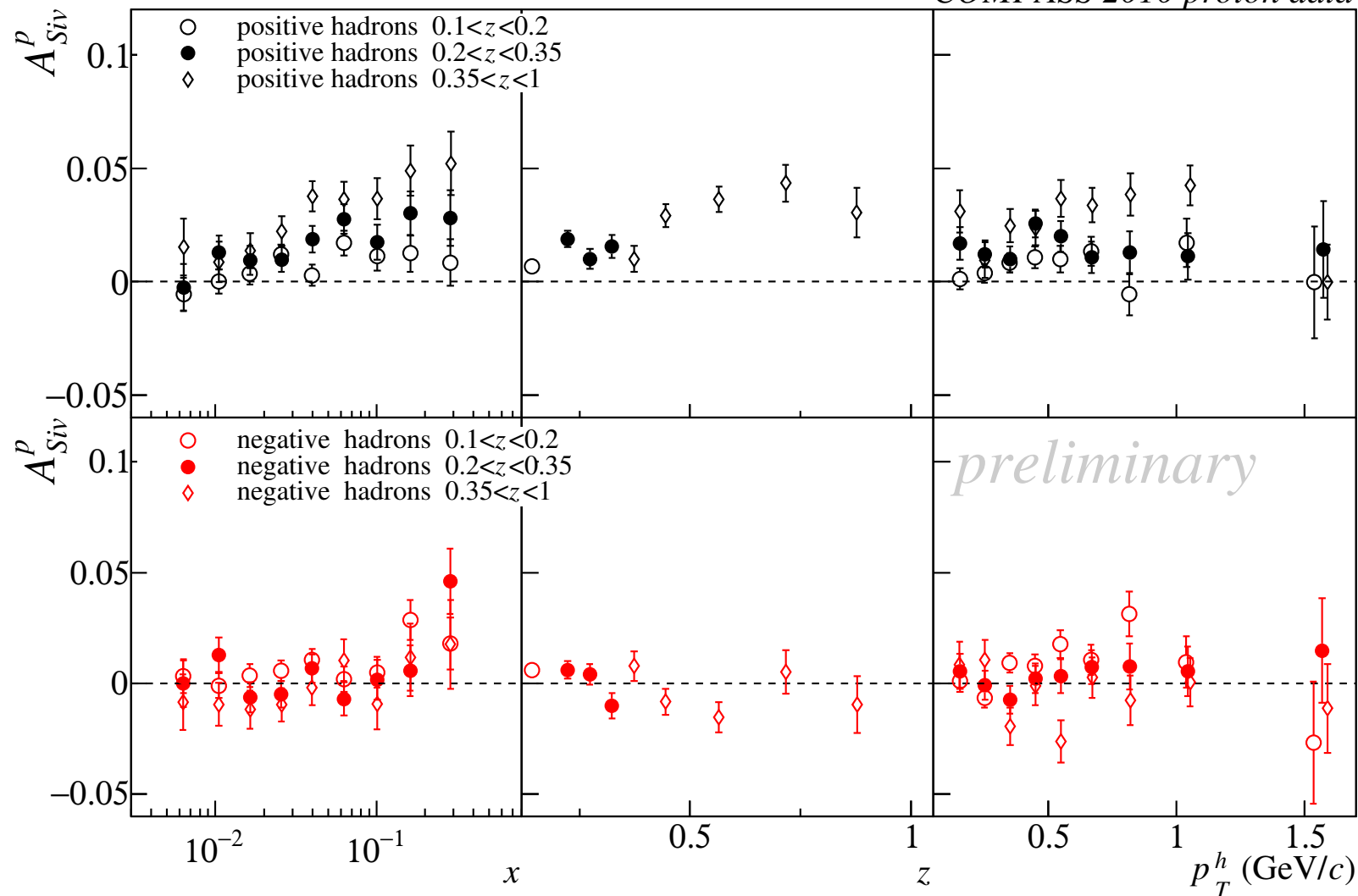
COMPASS 2010 proton data



clear decrease of asymmetries for low z sample

z in 3 ranges – Sivers asymmetry

COMPASS 2010 proton data



clear decrease of asymmetries for low z sample

Conclusions

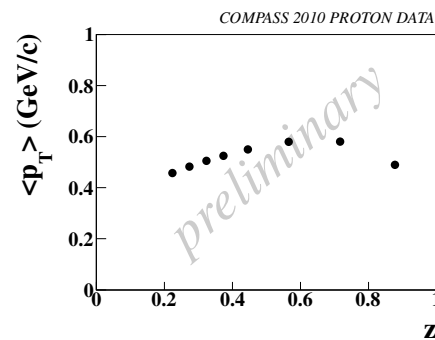
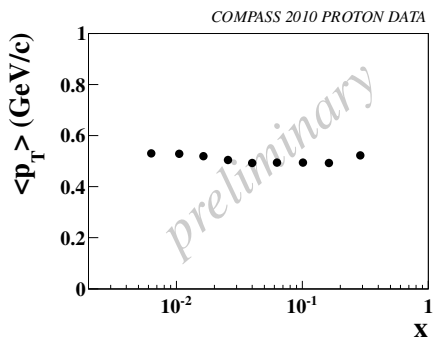
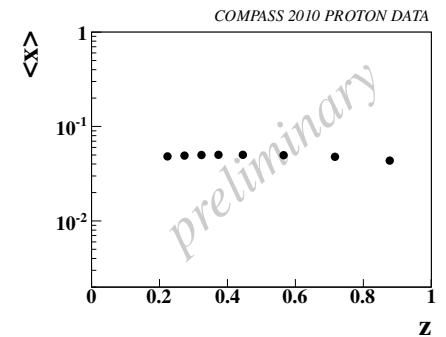
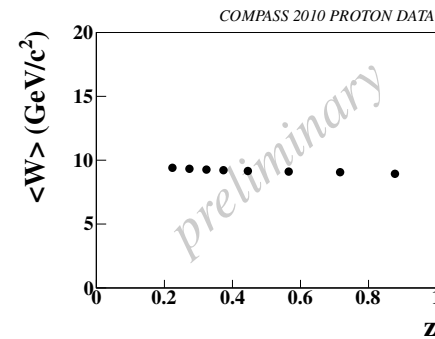
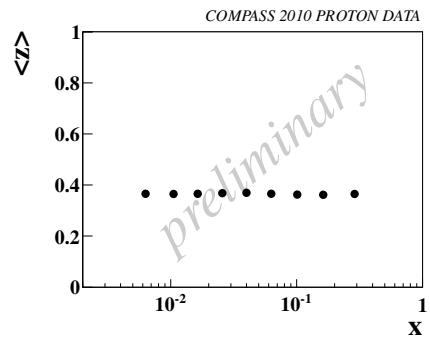
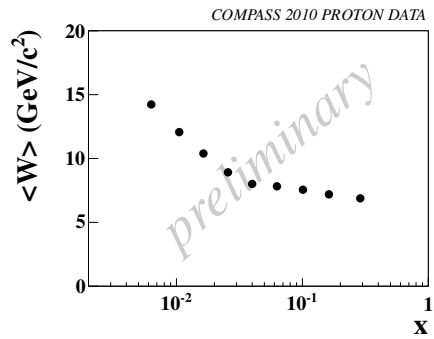
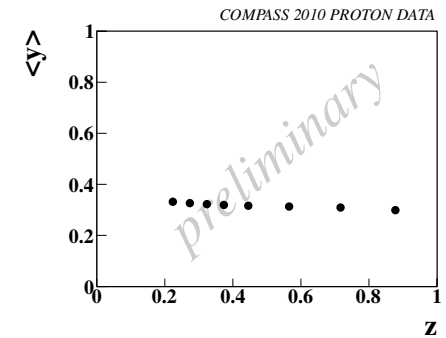
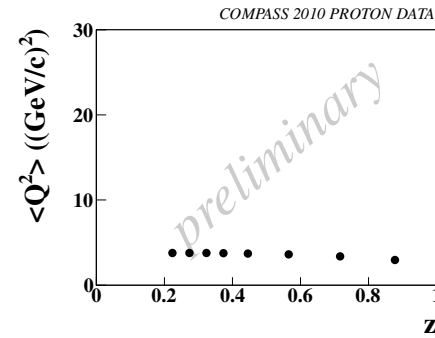
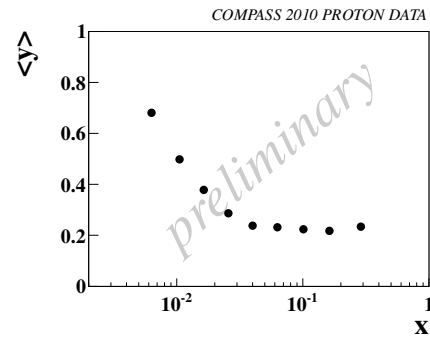
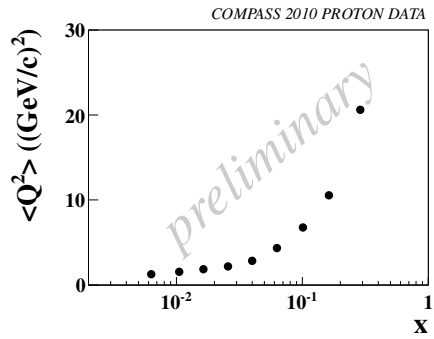
2010: one year of data taking on a transversely polarized proton target

- higher statistics and smaller systematical errors
- confirmation of 2007 results
- both Collins and Sivers asymmetries are different from zero
- new investigation of z and y dependence with interesting results

- next: asymmetries for identified hadrons (pions, kaons)
extraction of the other 6 asymmetries

SPARES

mean variables in different bins



mean variables in different bins

