

1-Hadron transverse target spin asymmetries at COMPASS

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on behalf of the COMPASS collaboration



Friedrich-Alexander-Universität
Erlangen-Nürnberg



bmb+f - Förderschwerpunkt

COMPASS

Großgeräte der physikalischen
Grundlagenforschung

Outline

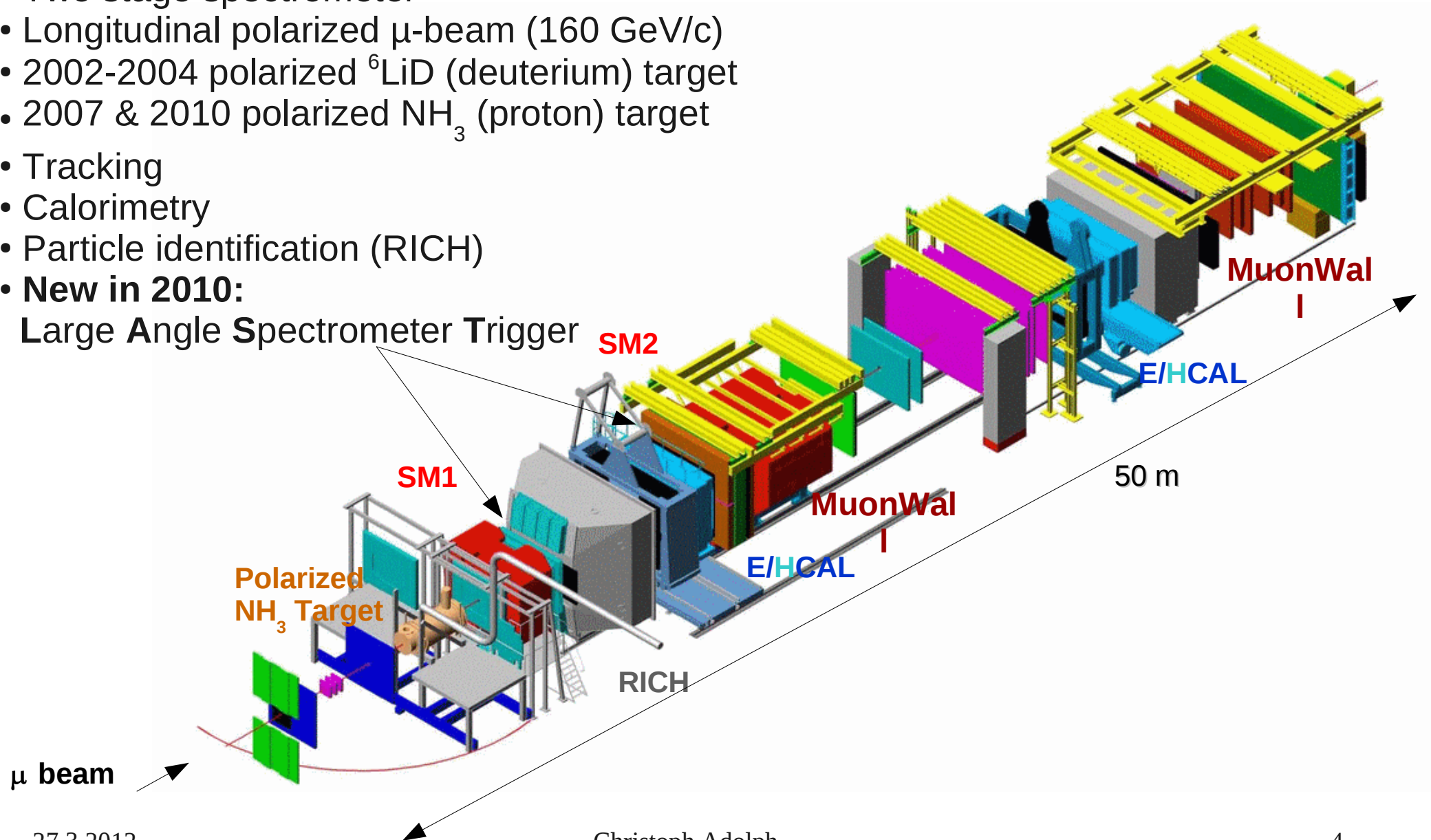
- The COMPASS experiment
- Collins and Sivers asymmetries from 2010 run
- Asymmetries at low z and low y
- Summary and Outlook

The COMPASS experiment at CERN



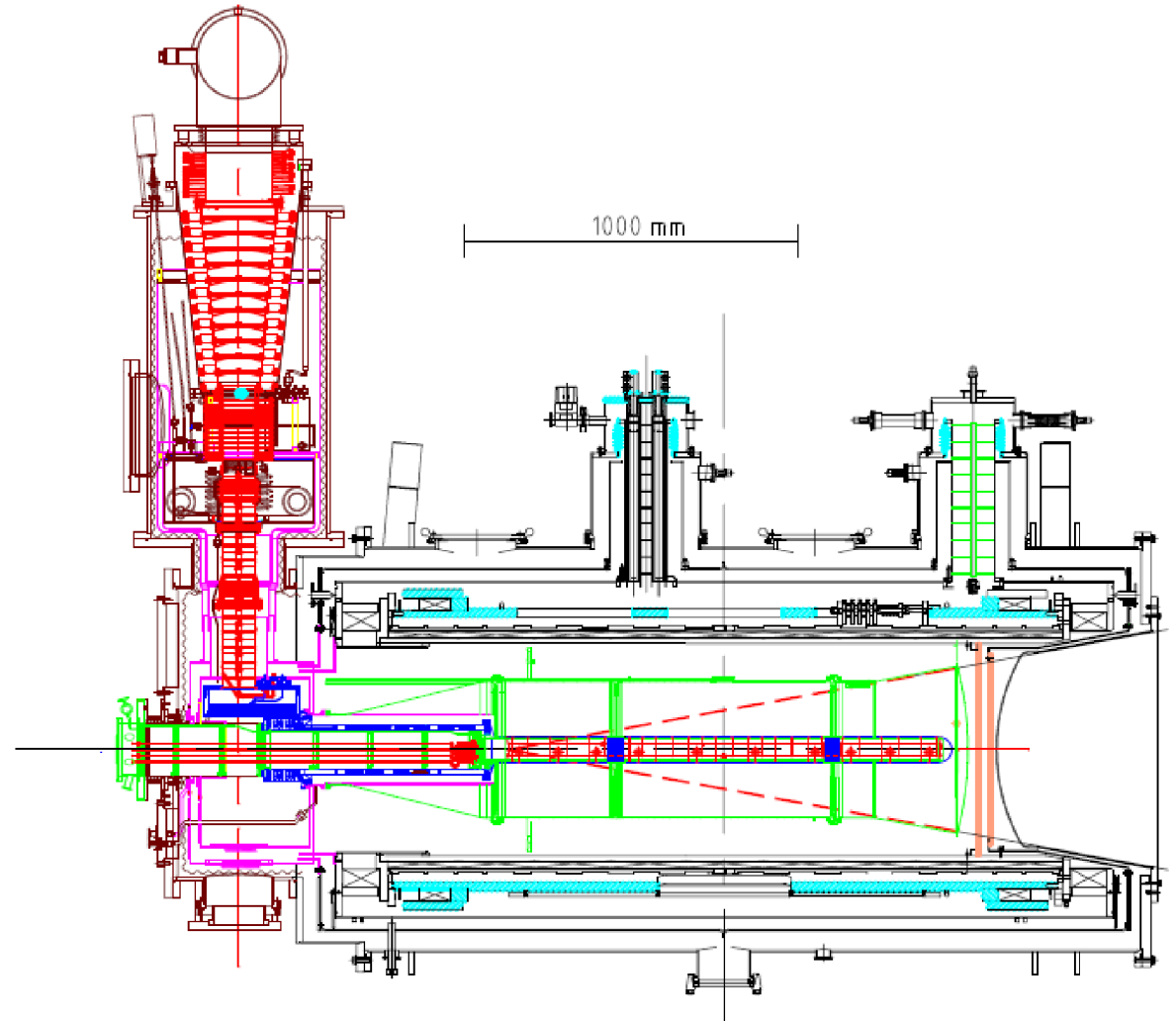
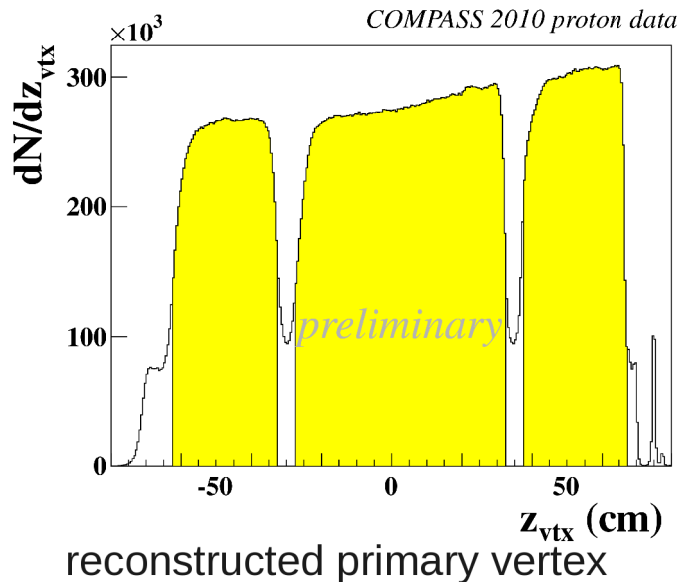
The COMPASS spectrometer in 2010

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



The COMPASS polarized target system



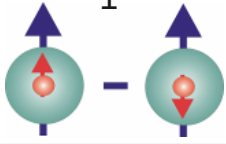
- Upgrade of target system in 2005
- Three cells with opposite polarisation (2002-04 two cells)
- $\pm 180\text{mrad}$ geometrical acceptance
- ${}^6\text{LiD}$:
 - polarization: $\sim 50\%$
 - dilution factor: ~ 0.40
- NH_3 :
 - polarization: $\sim 90\%$
 - dilution factor: ~ 0.15
- Transverse polarization reversed every week via microwave



Spin structure → Transversity

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



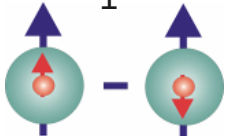
quark

		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:

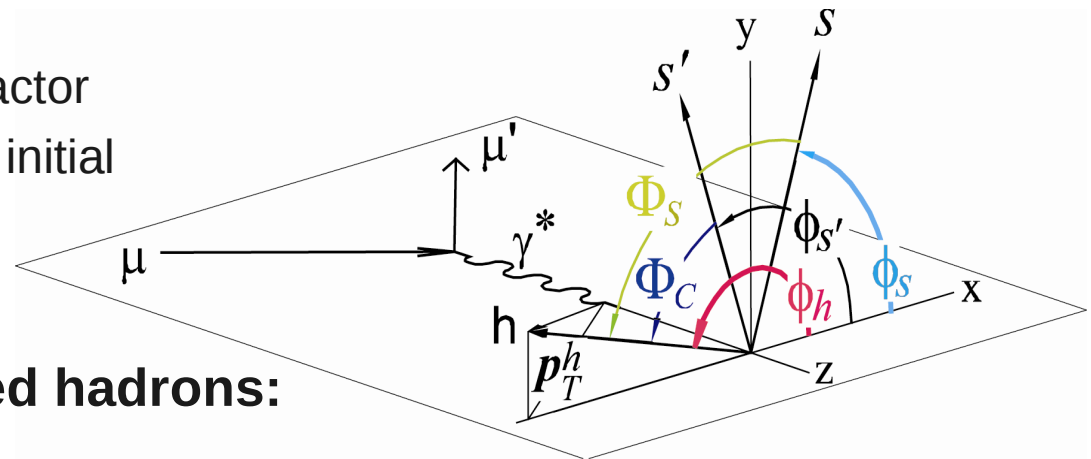
—► $h_1(x)$ decouples from inclusive DIS

Product of $h_1(x)$ and another chiral-odd function needed: Collins FF H_{1q}^h

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

$$A_{Coll} = \frac{A_C^h}{f \cdot P_T \cdot D_{nn}} = \frac{\sum_q e_q^2 \cdot h_1 \cdot H_{1q}^h}{\sum_q e_q^2 \cdot f_1 \cdot D_q^h}$$

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:

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

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

SIDIS event selection

Standard cuts like in 2007:

DIS cuts: $Q^2 > 1 \text{ (GeV/c)}^2$

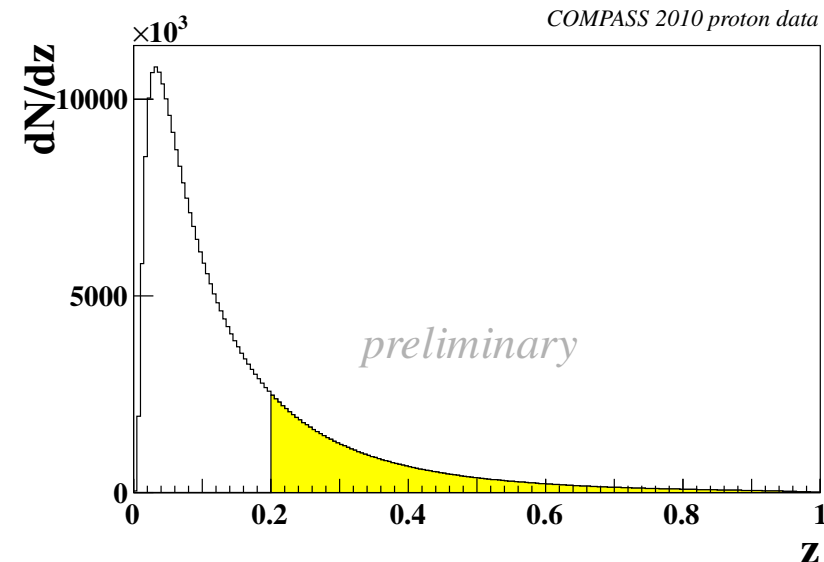
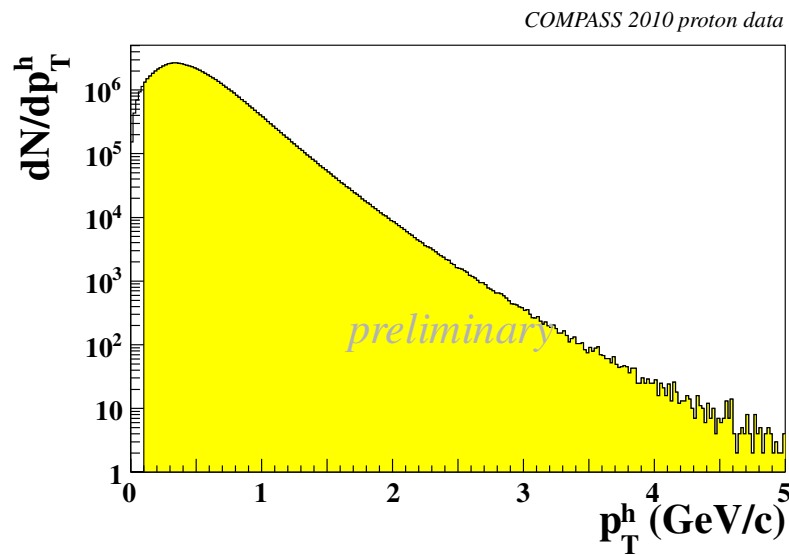
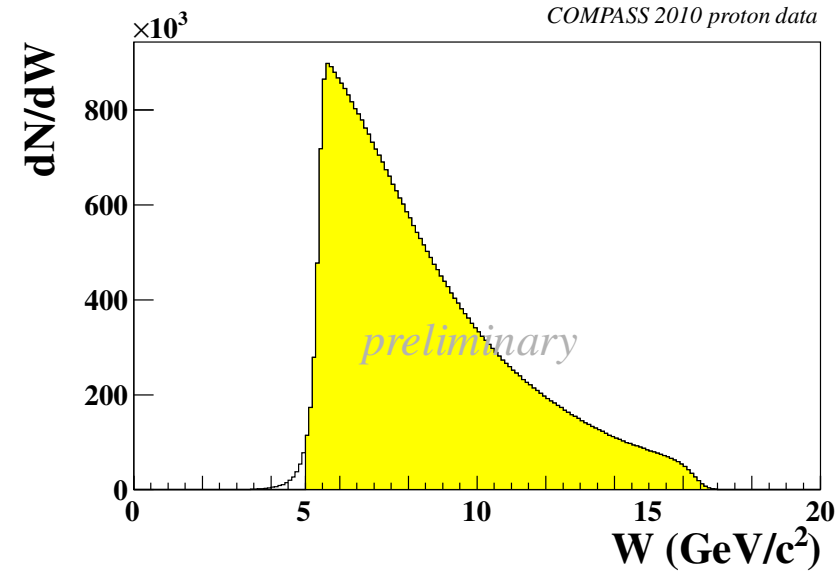
$0.1 < y < 0.9$

$W > 5 \text{ GeV/c}^2$

Hadron selection:

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

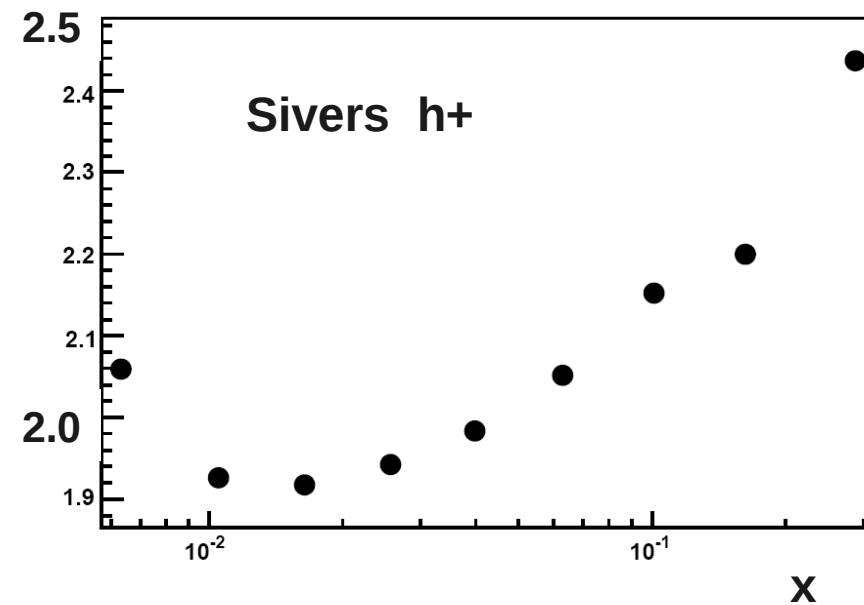
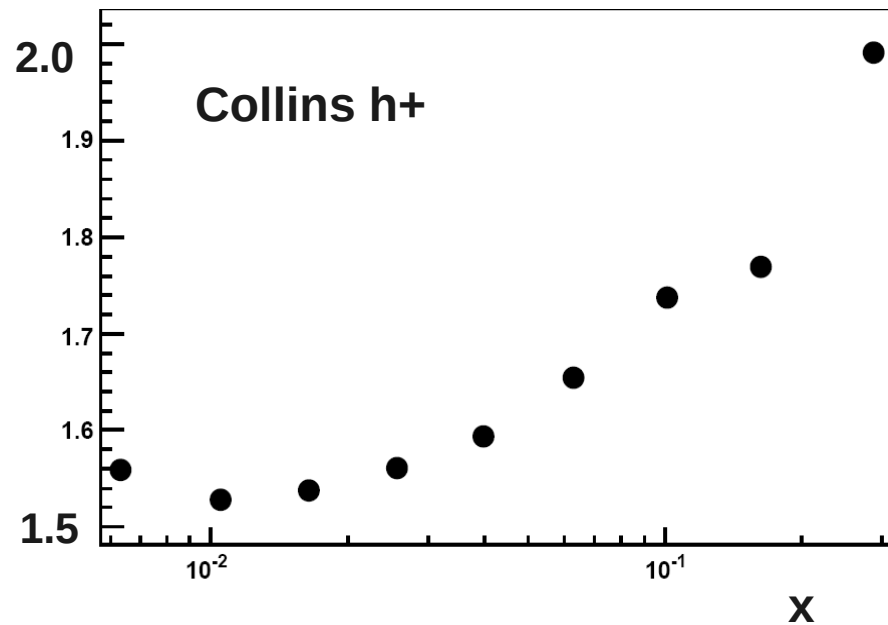
$z > 0.2$



2010 Hadron statistics

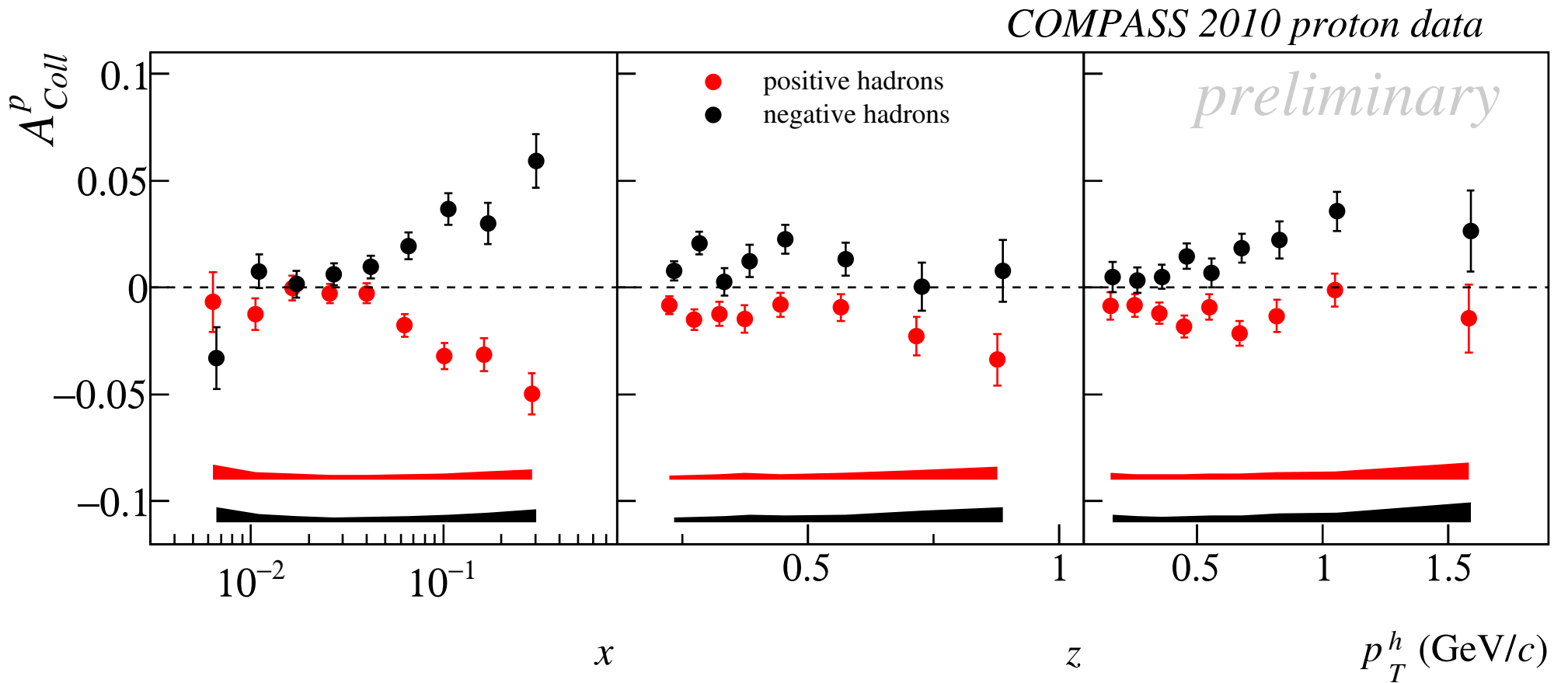
positive hadrons: $43 \cdot 10^6$
negative hadrons: $34 \cdot 10^6$

ratio of statistical errors: 2007 / 2010



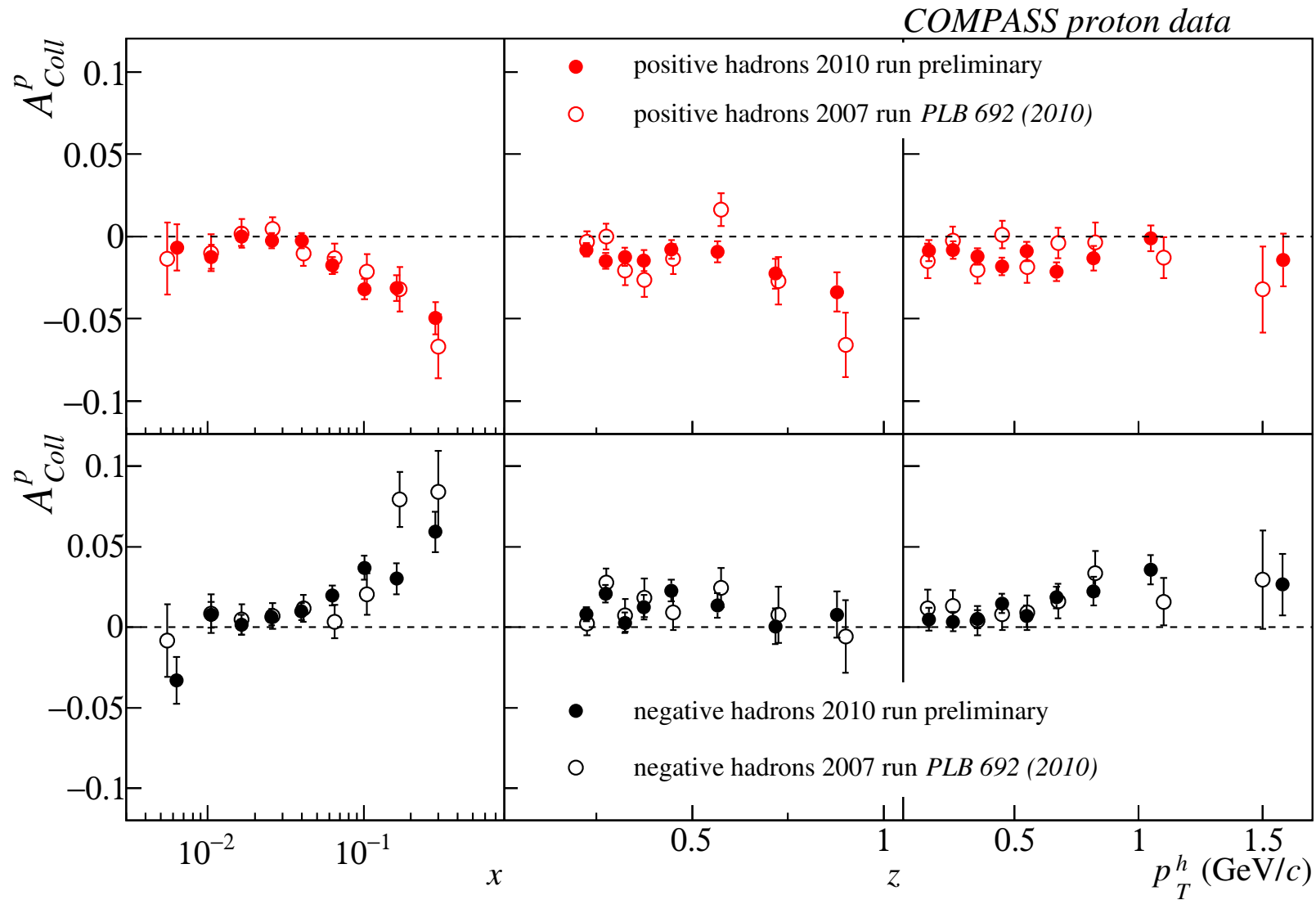
The Collins modulation – 2010 data

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



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

The Collins modulation 2010 ↔ 2007

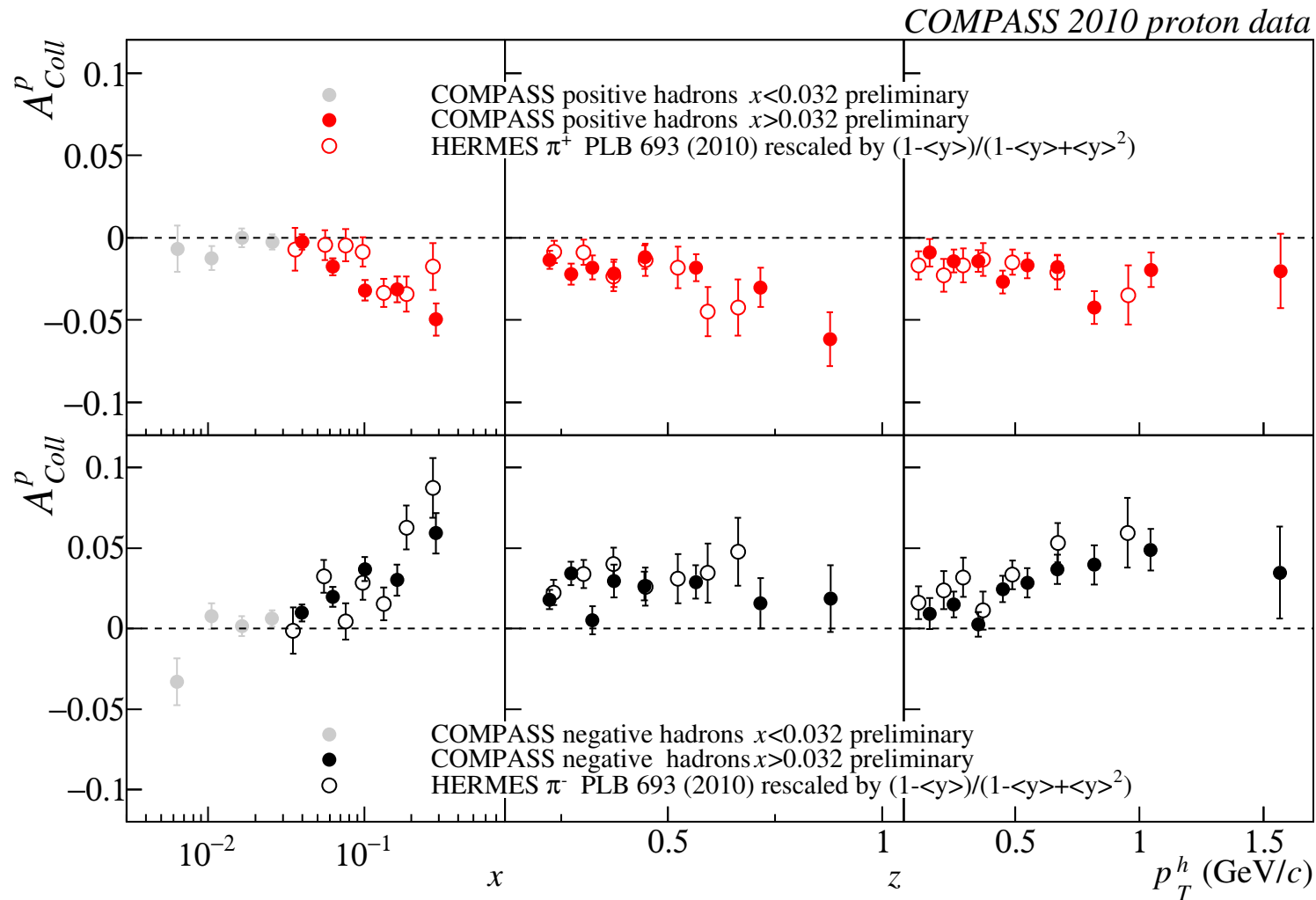


confirmation of 2007 results with increased statistics

The Collins modulation

Comparison to HERMES data

for $x > 0.032$

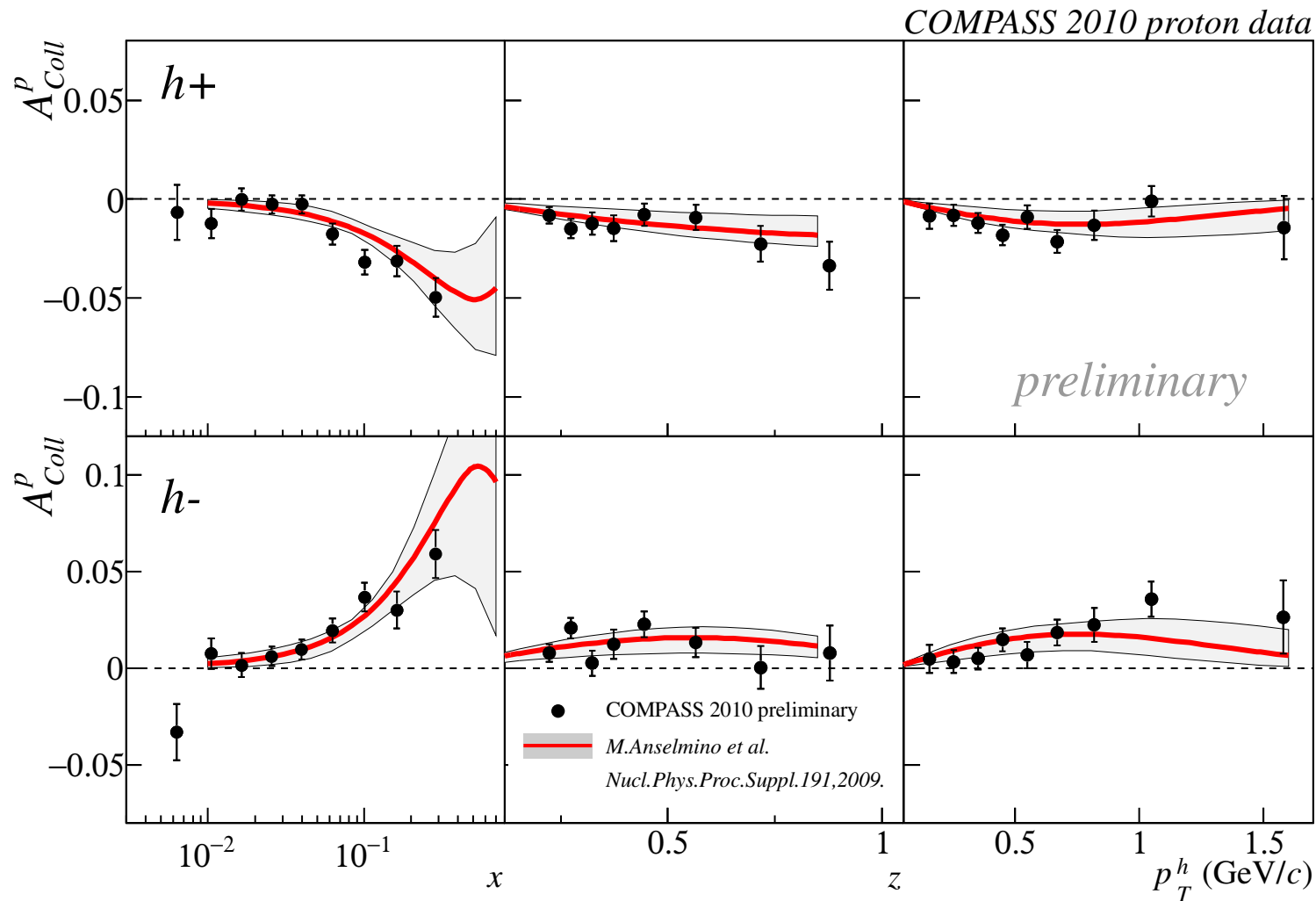


nice agreement between COMPASS and HERMES

The Collins modulation



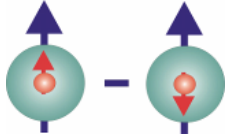
Comparison to model predictions

Comparison with the predictions from the fit to the COMPASS deuteron data, HERMES proton SIDIS data and BELLE e^+e^- data (Anselmino et al.):



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

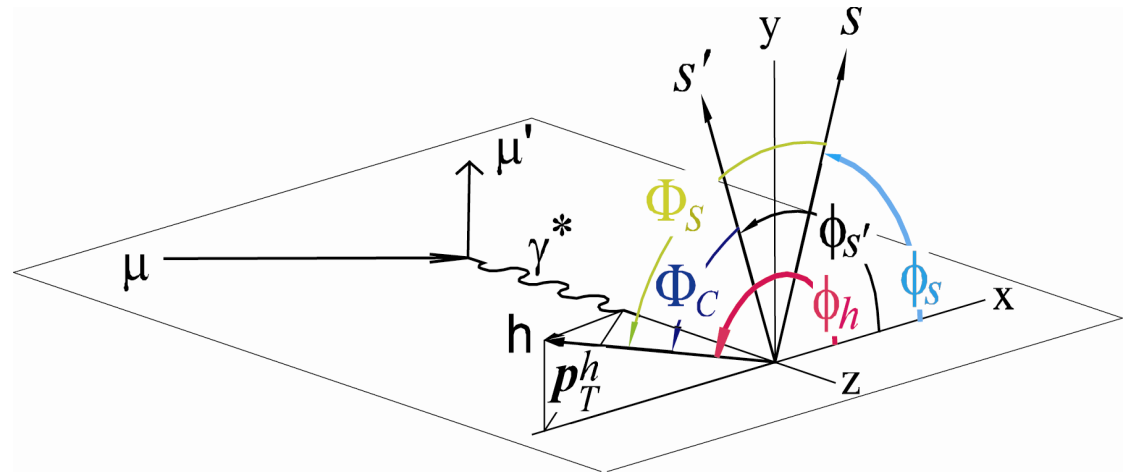
Taking into account the transverse momentum k_T of the quarks:

		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

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

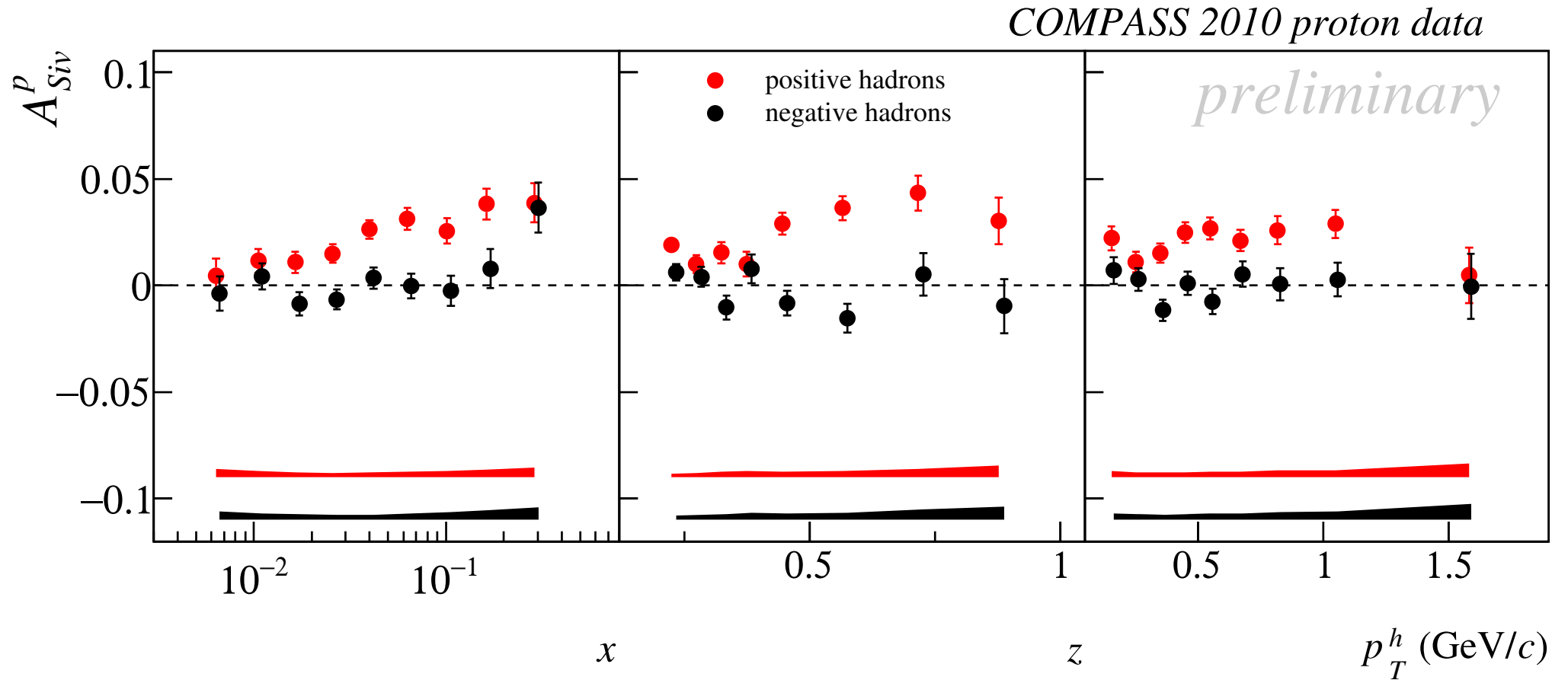


Azimuthal distribution of the produced hadrons:

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

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

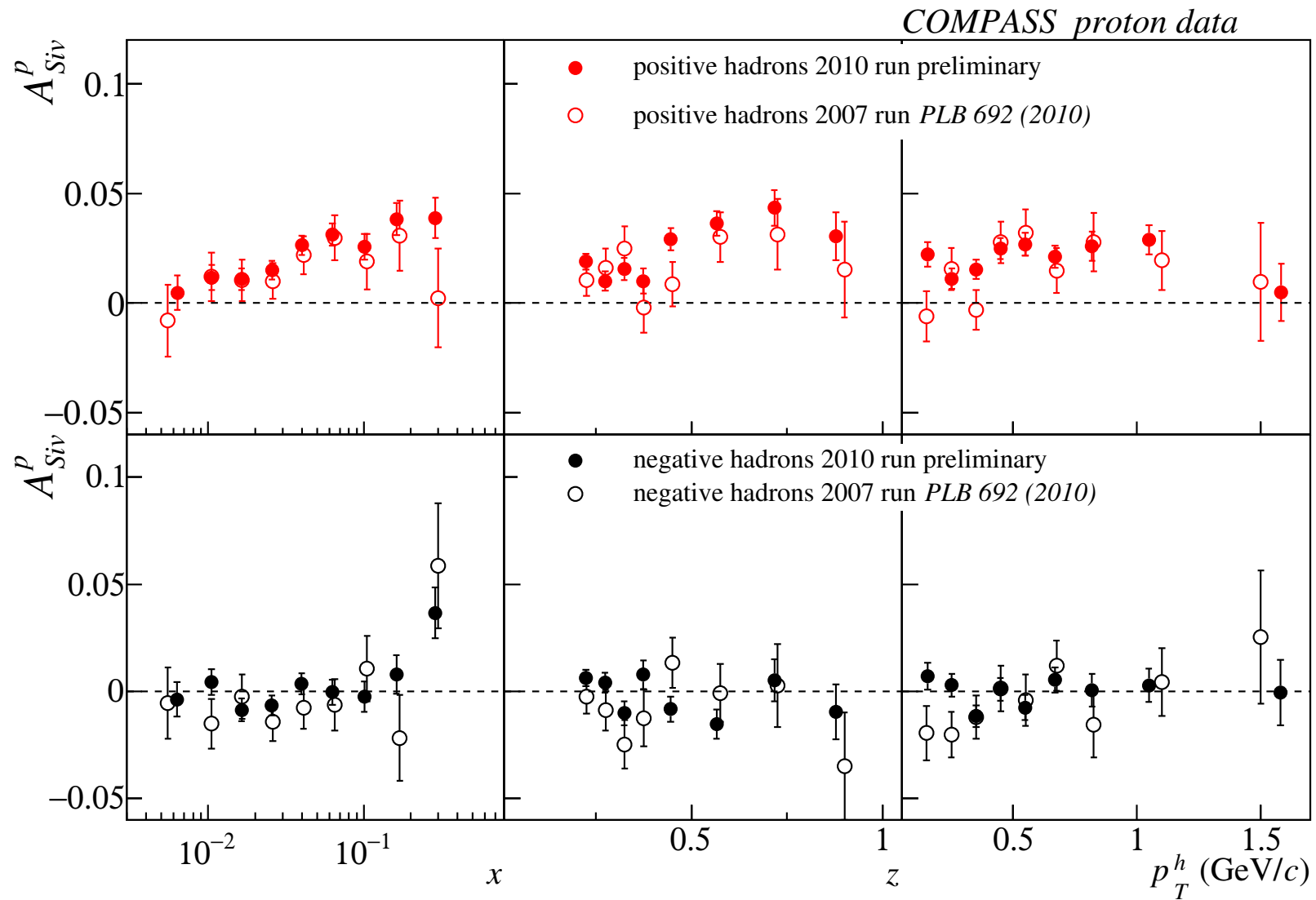
The Sivers modulation – 2010 data



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

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

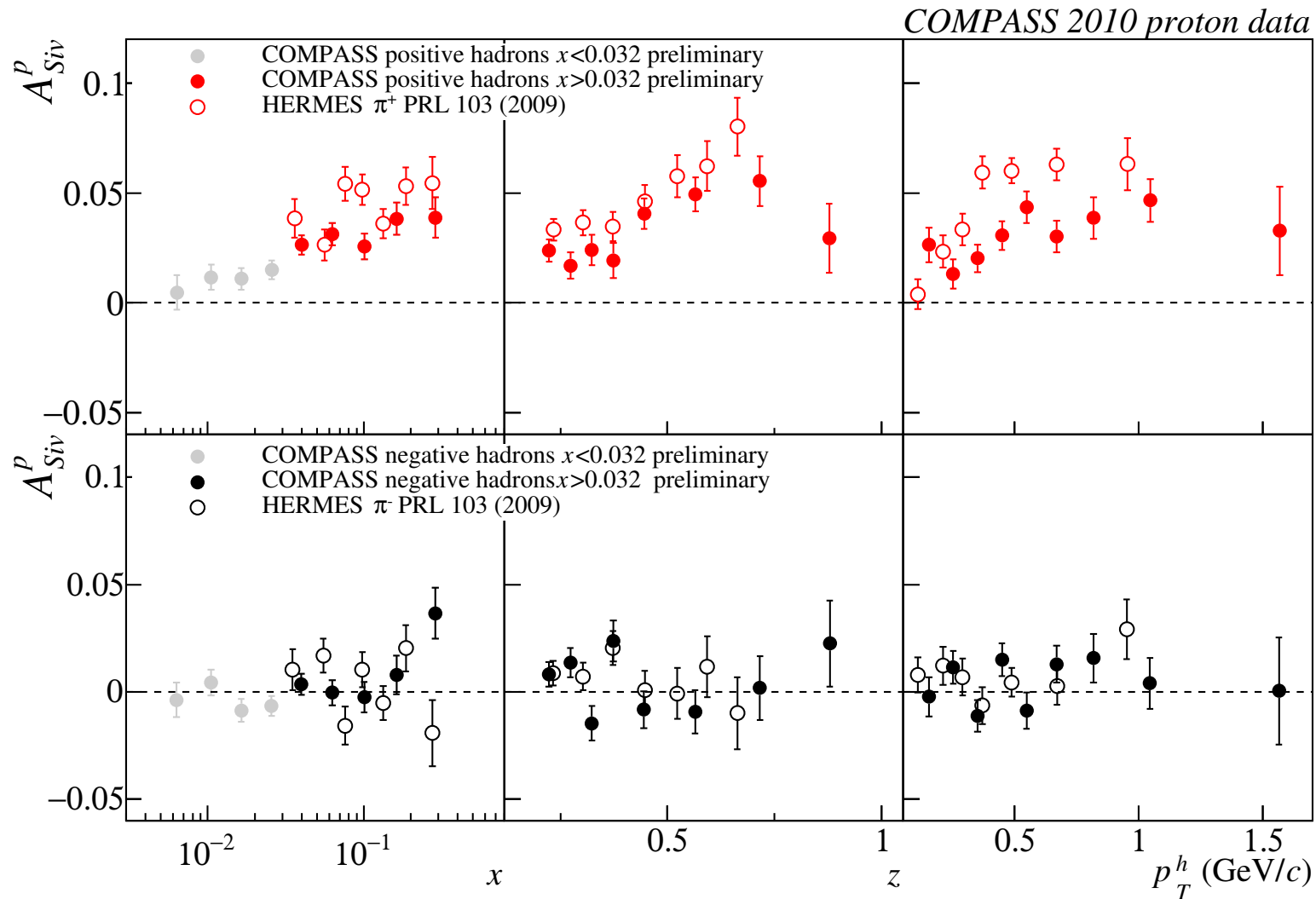
The Sivers modulation 2010 ↔ 2007



good agreement with 2007 published results, but with smaller errors

The Siverts modulation

Comparison to Hermes data for $x > 0.032$

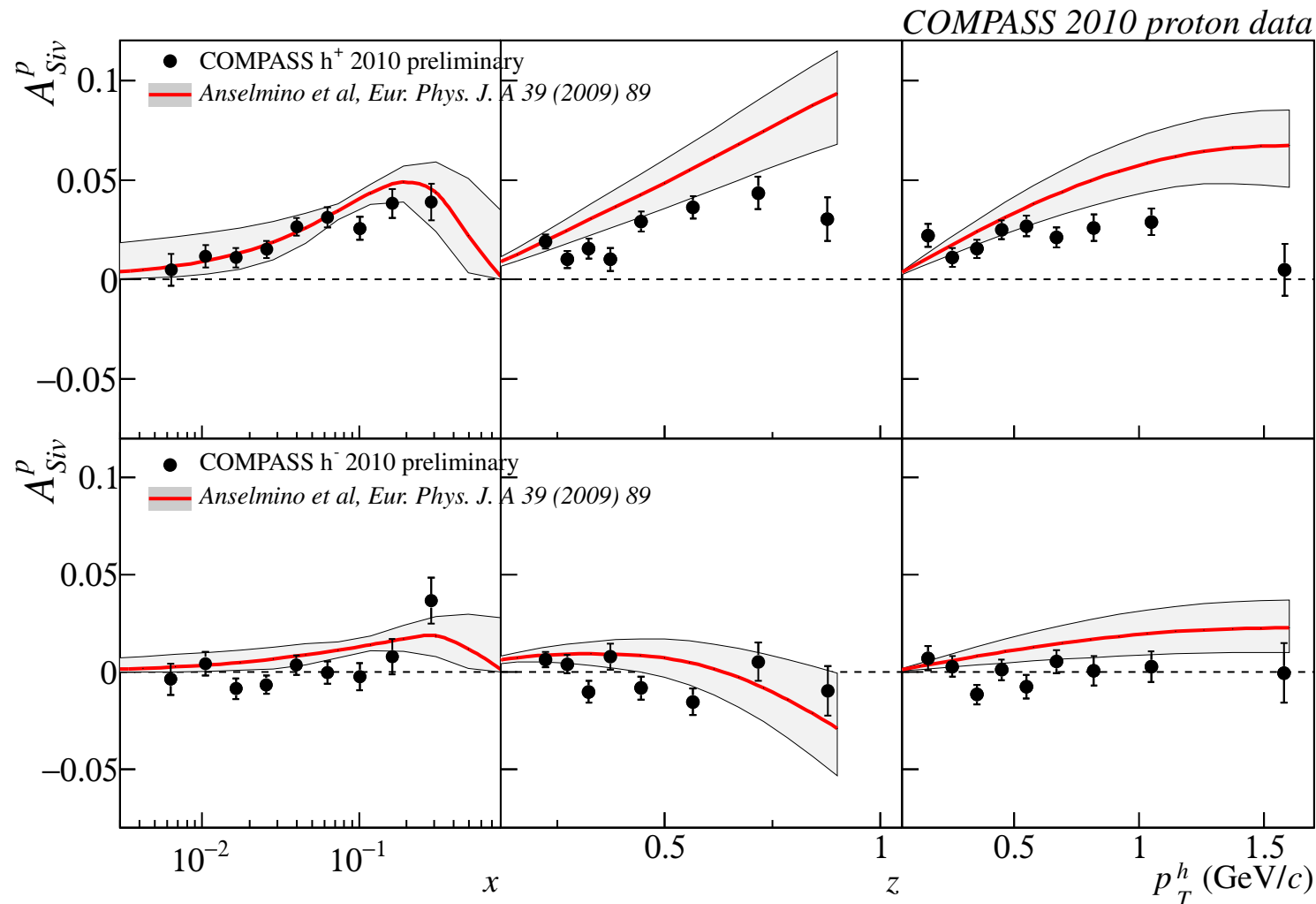


difference between COMPASS and HERMES results, but same trend

The Siverts modulation

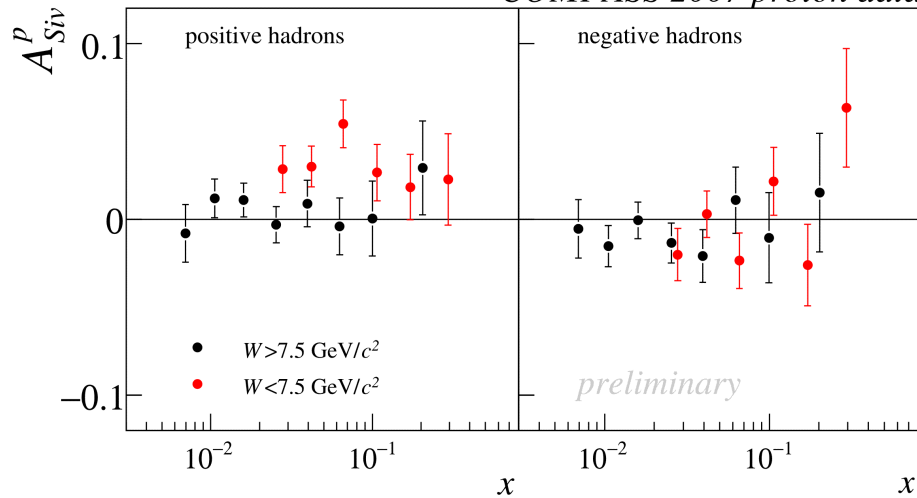
Comparison to model predictions

Comparison with the predictions from the fit to the COMPASS deuteron and HERMES proton SIDIS data (Anselmino et al.):



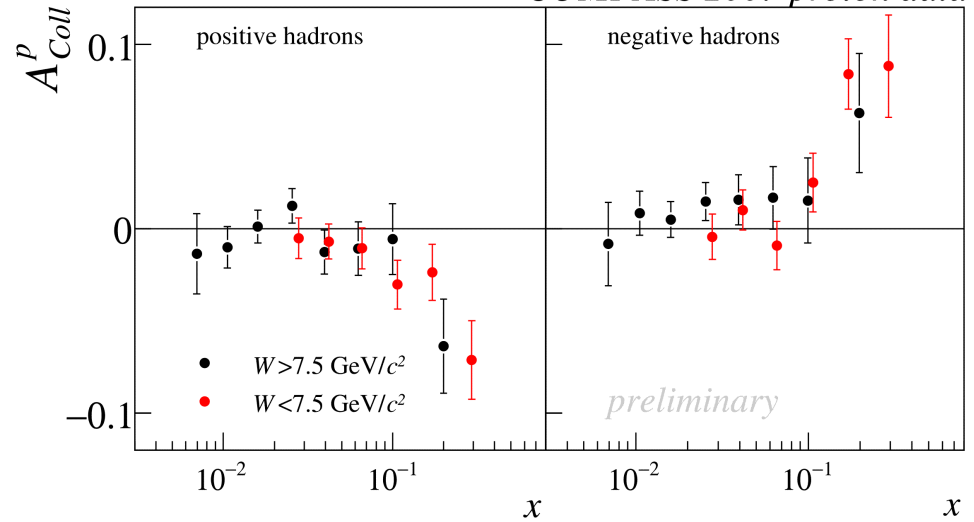
W dependence

COMPASS 2007 proton data

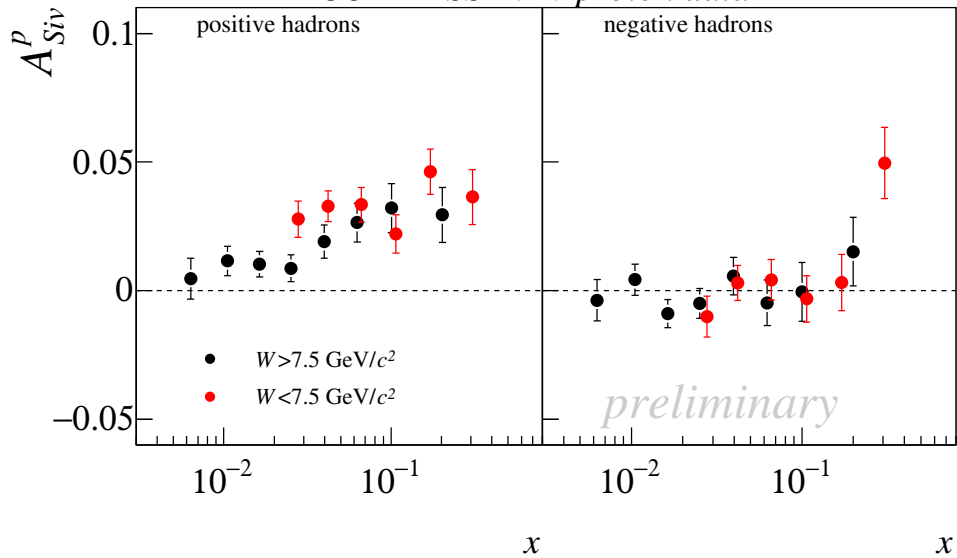


2007: hint for possible W dependence

COMPASS 2007 proton data

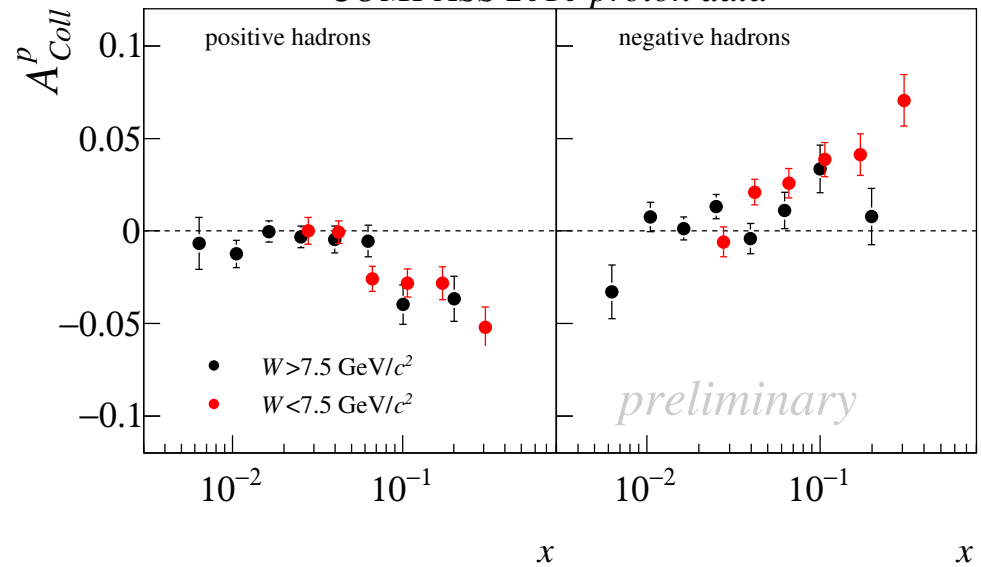


COMPASS 2010 proton data



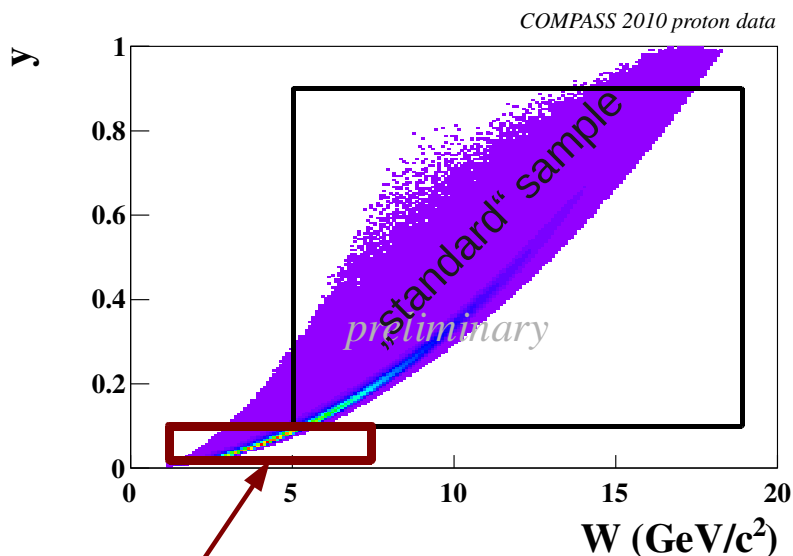
2010: absolute difference smaller

COMPASS 2010 proton data

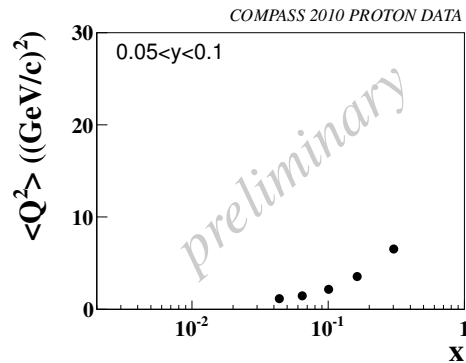
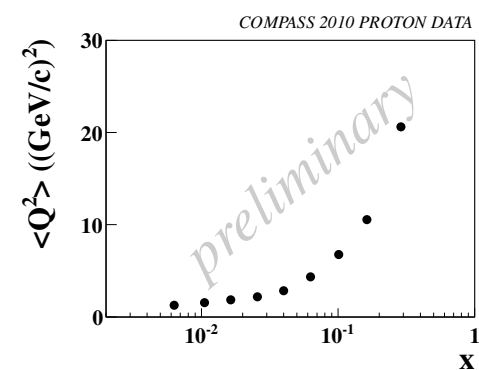
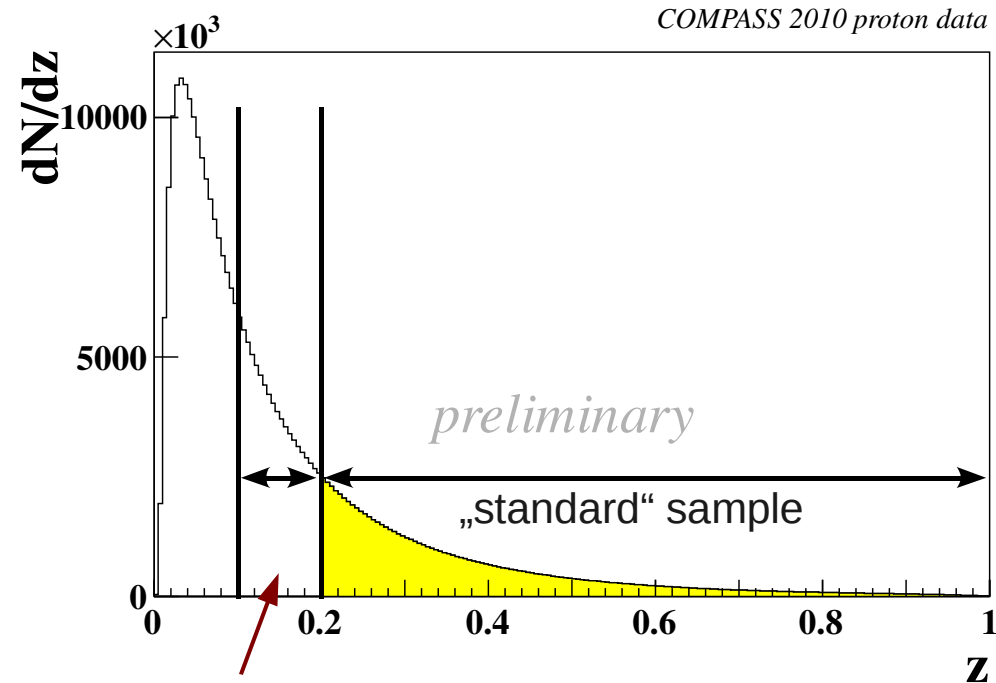


Exploration of different kinematic regions

low y : $0.05 < y < 0.1$

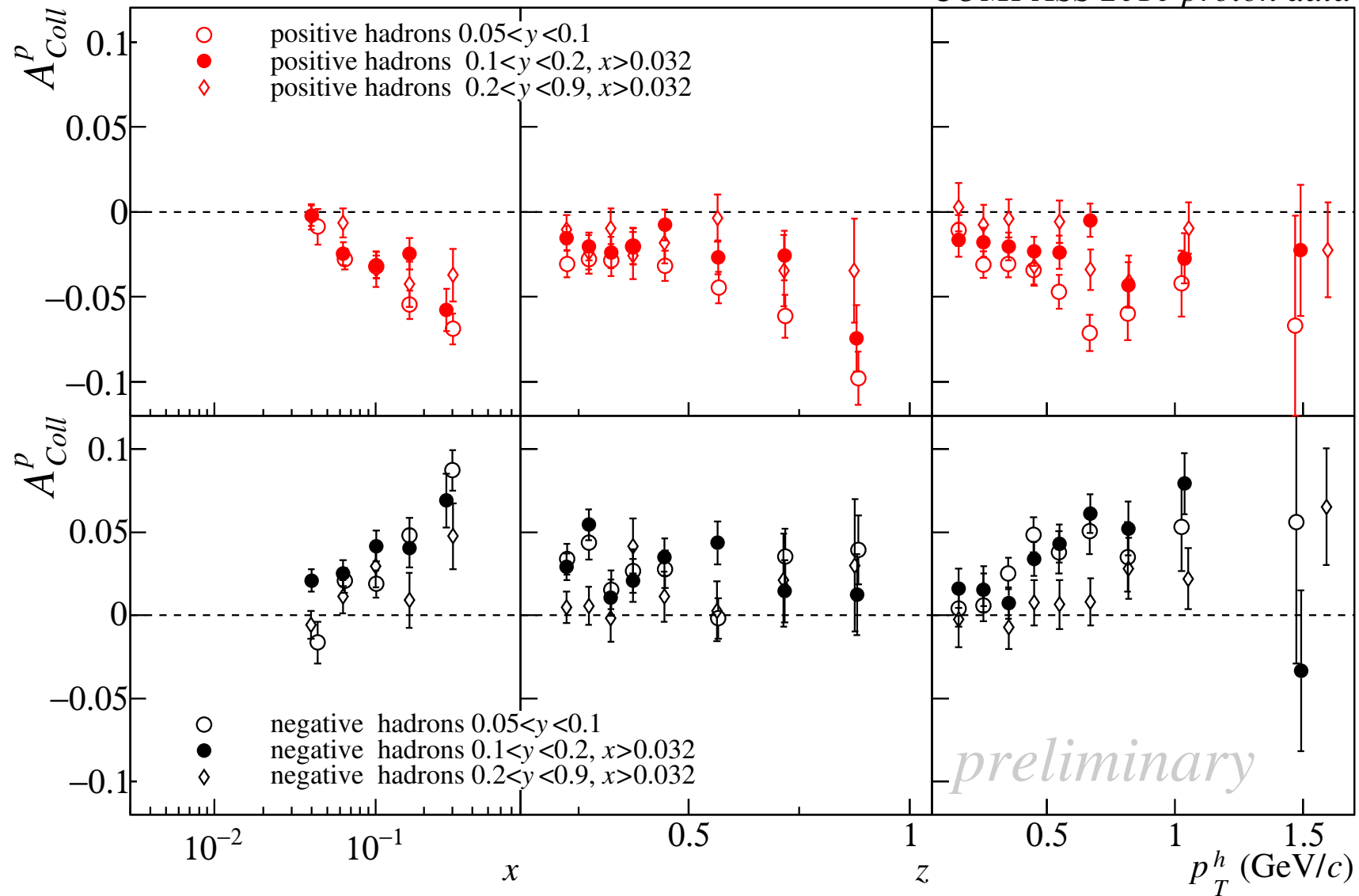


low z : $0.1 < z < 0.2$



3 y ranges – Collins asymmetry

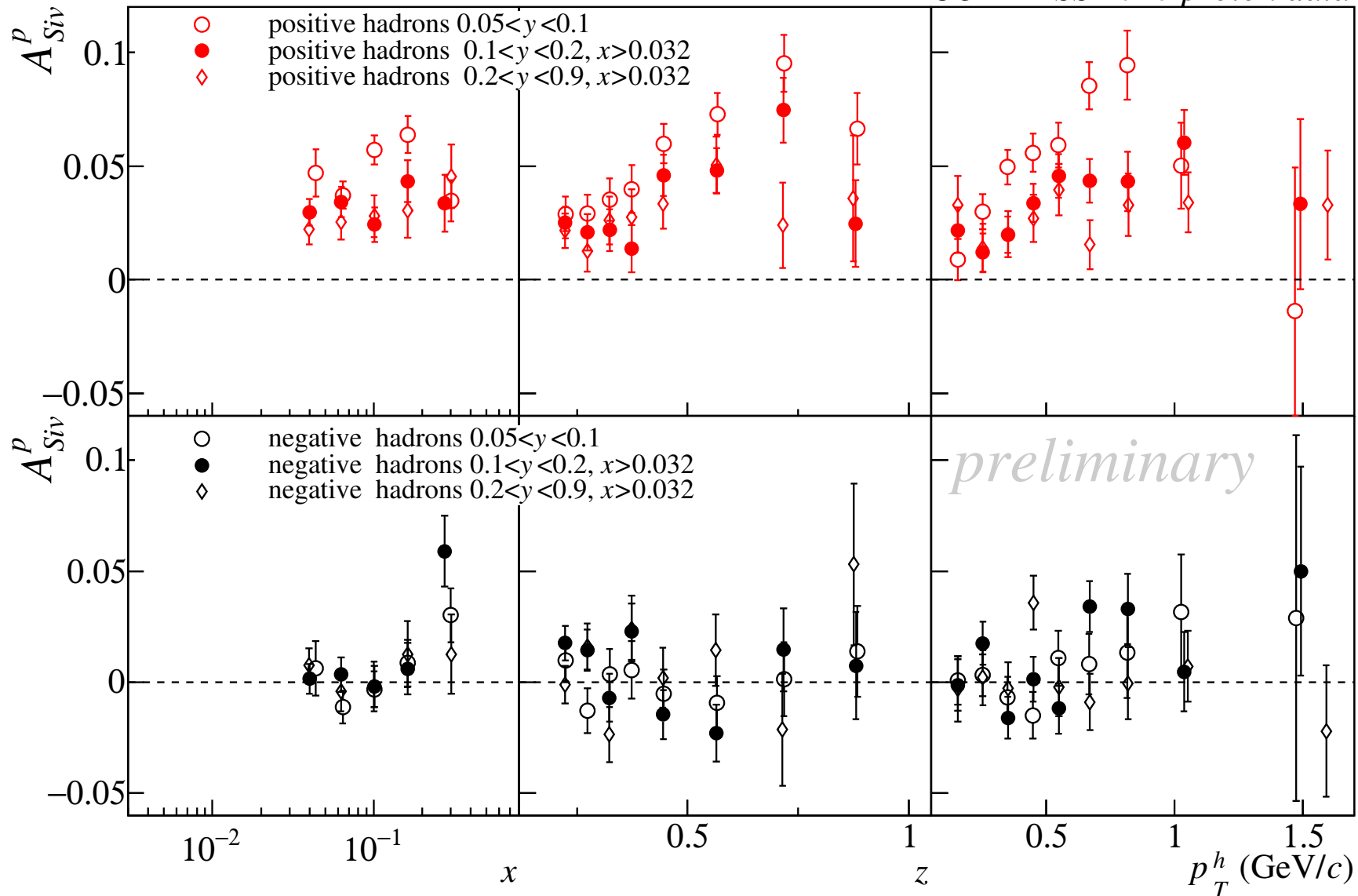
COMPASS 2010 proton data



small effect for positive hadrons

3 y ranges – Sivers asymmetry

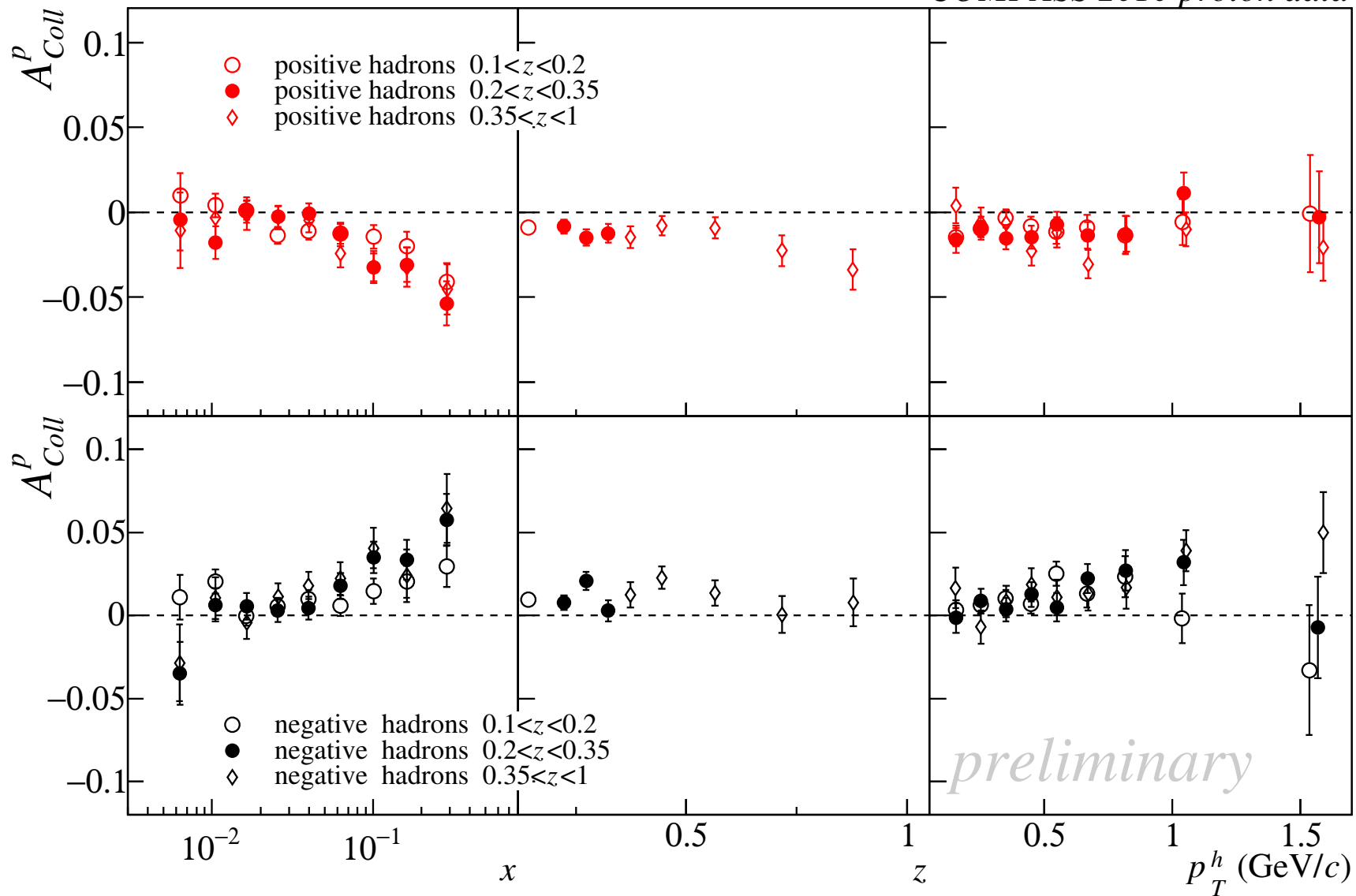
COMPASS 2010 proton data



clear increase of Sivers asymmetries for positive hadrons at low y

z in 3 ranges – Collins asymmetry

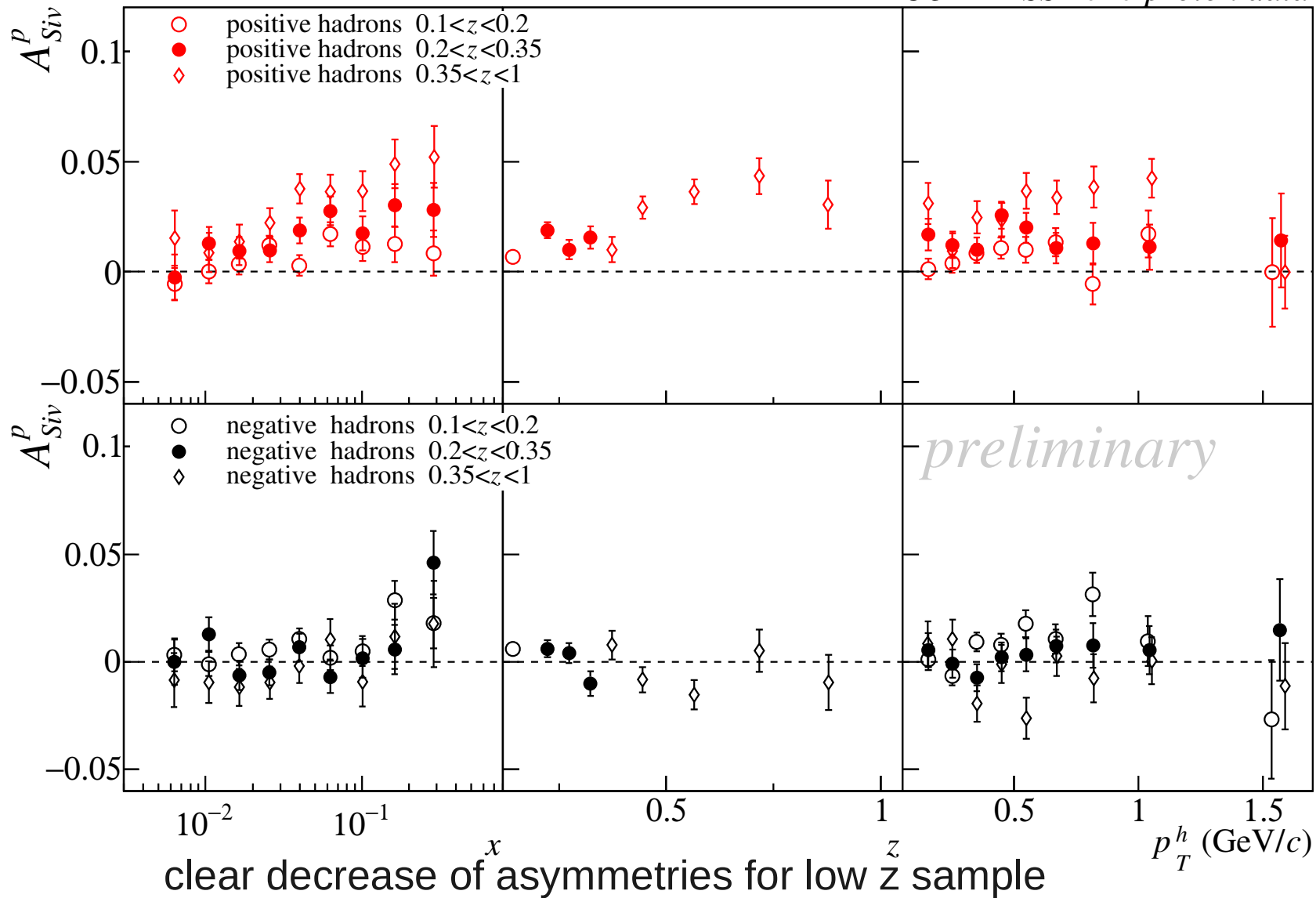
COMPASS 2010 proton data



small decrease of asymmetries for low z sample

z in 3 ranges – Sivers asymmetry

COMPASS 2010 proton data



Conclusions

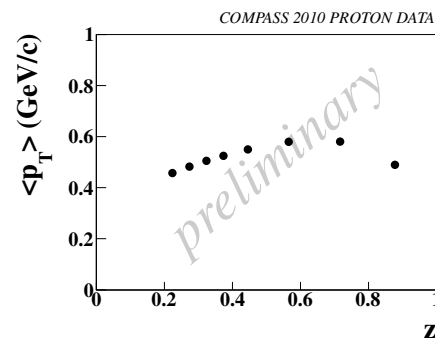
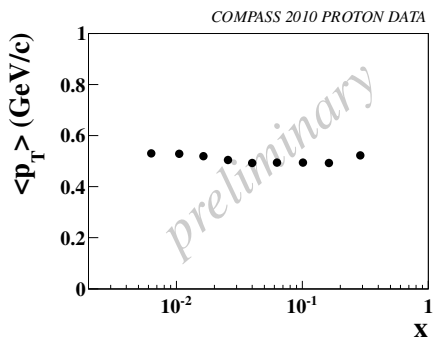
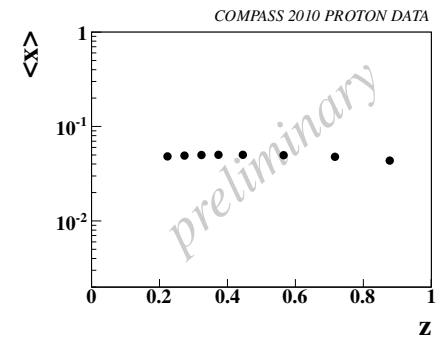
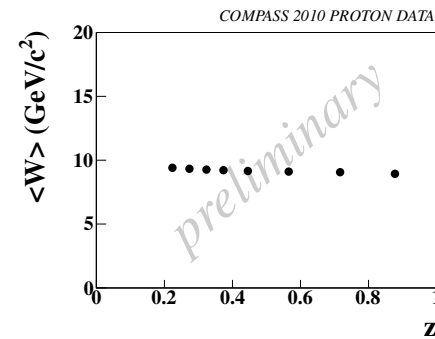
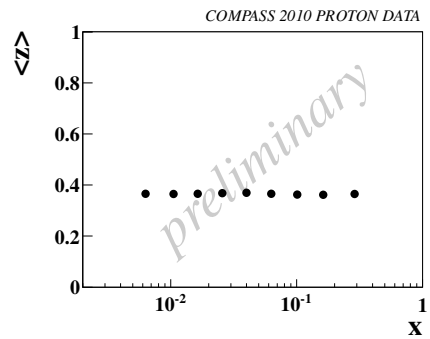
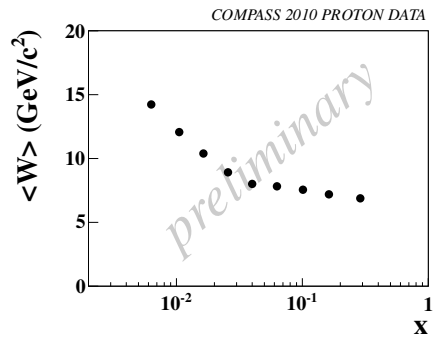
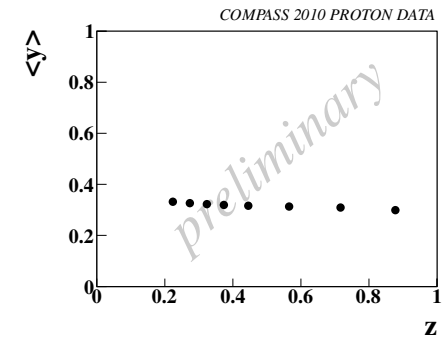
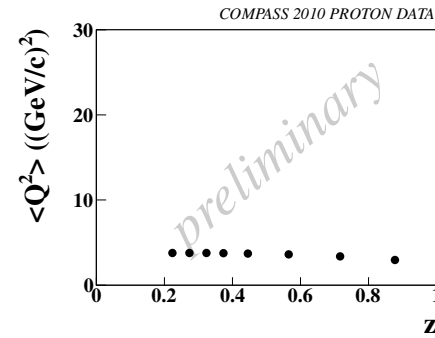
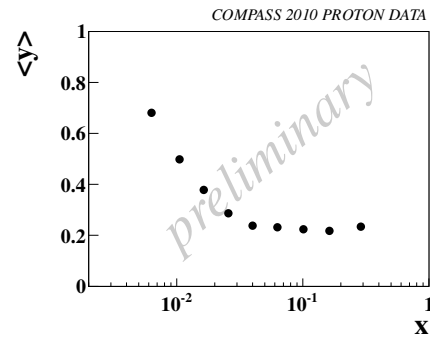
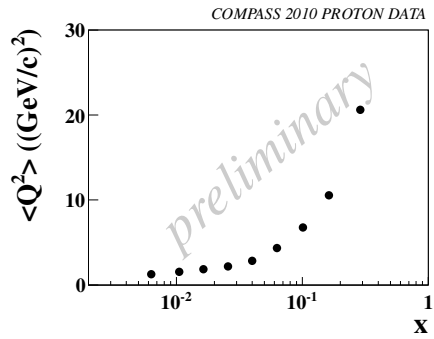
2010: one year of data taking on a transversely polarized proton target

- 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

