Transverse target spin asymmetries at COMPASS

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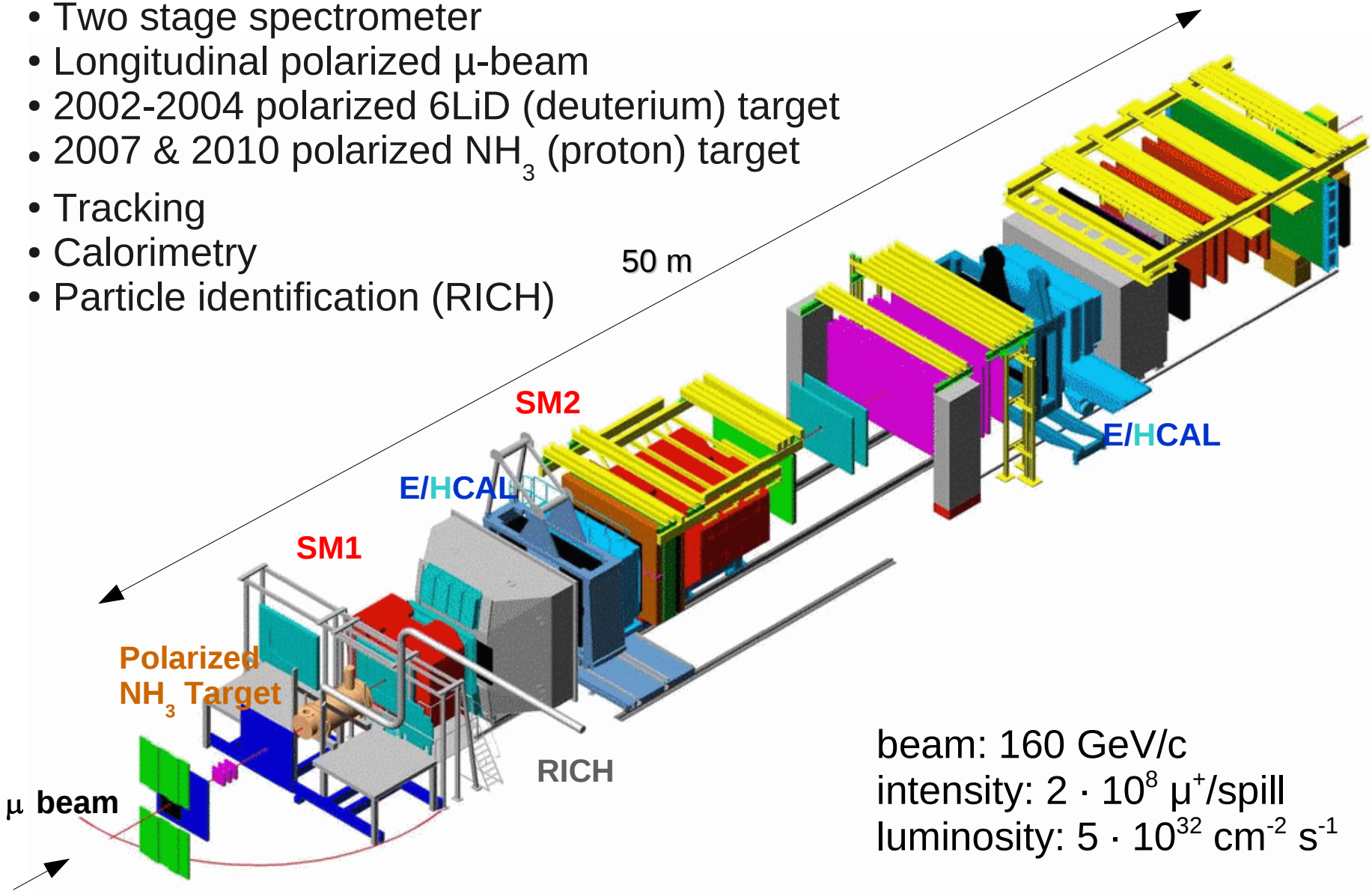
bmb+f - Förderschwerpunkt COMPASS Großgeräte der physikalischen Grundlagenforschung

The COMPASS experiment at CERN

The COMPASS spectrometer in 2007

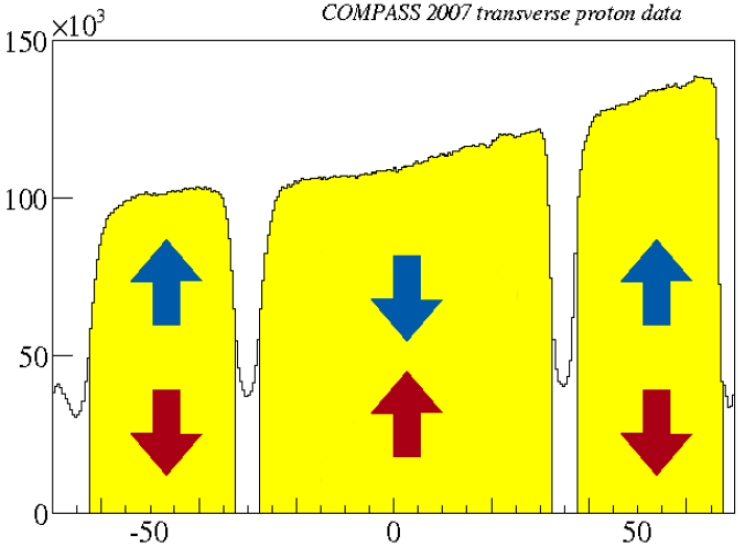
- Two stage spectrometer
- Longitudinal polarized μ-beam
- 2002-2004 polarized 6LiD (deuterium) target
- 2007 & 2010 polarized NH_3 (proton) target
- Tracking
- Calorimetry
- Particle identification (RICH)

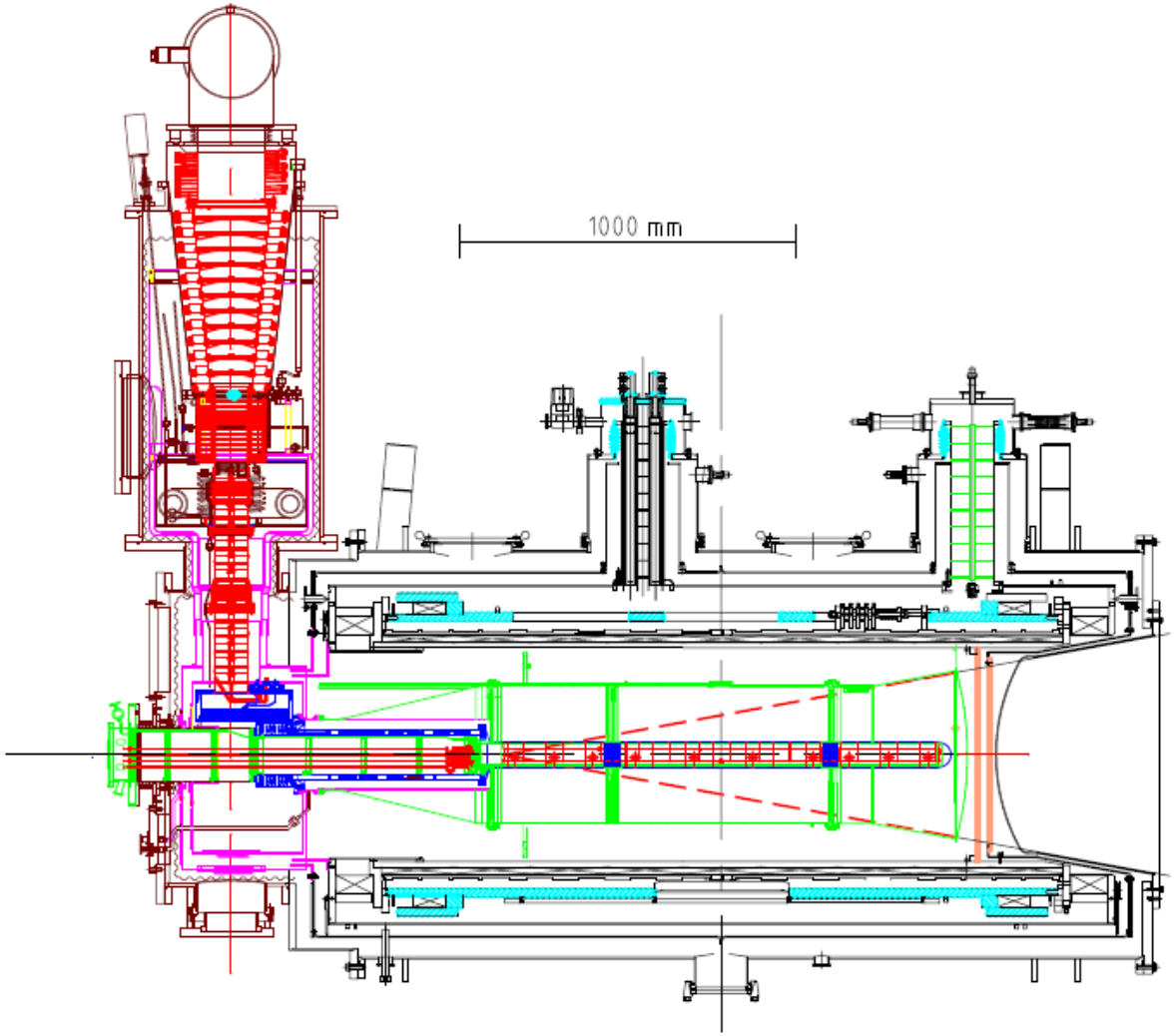


beam: 160 GeV/c
intensity: $2 \cdot 10^8$ μ^+/spill
luminosity: $5 \cdot 10^{32}$ cm^{-2} s^{-1}

The COMPASS target system

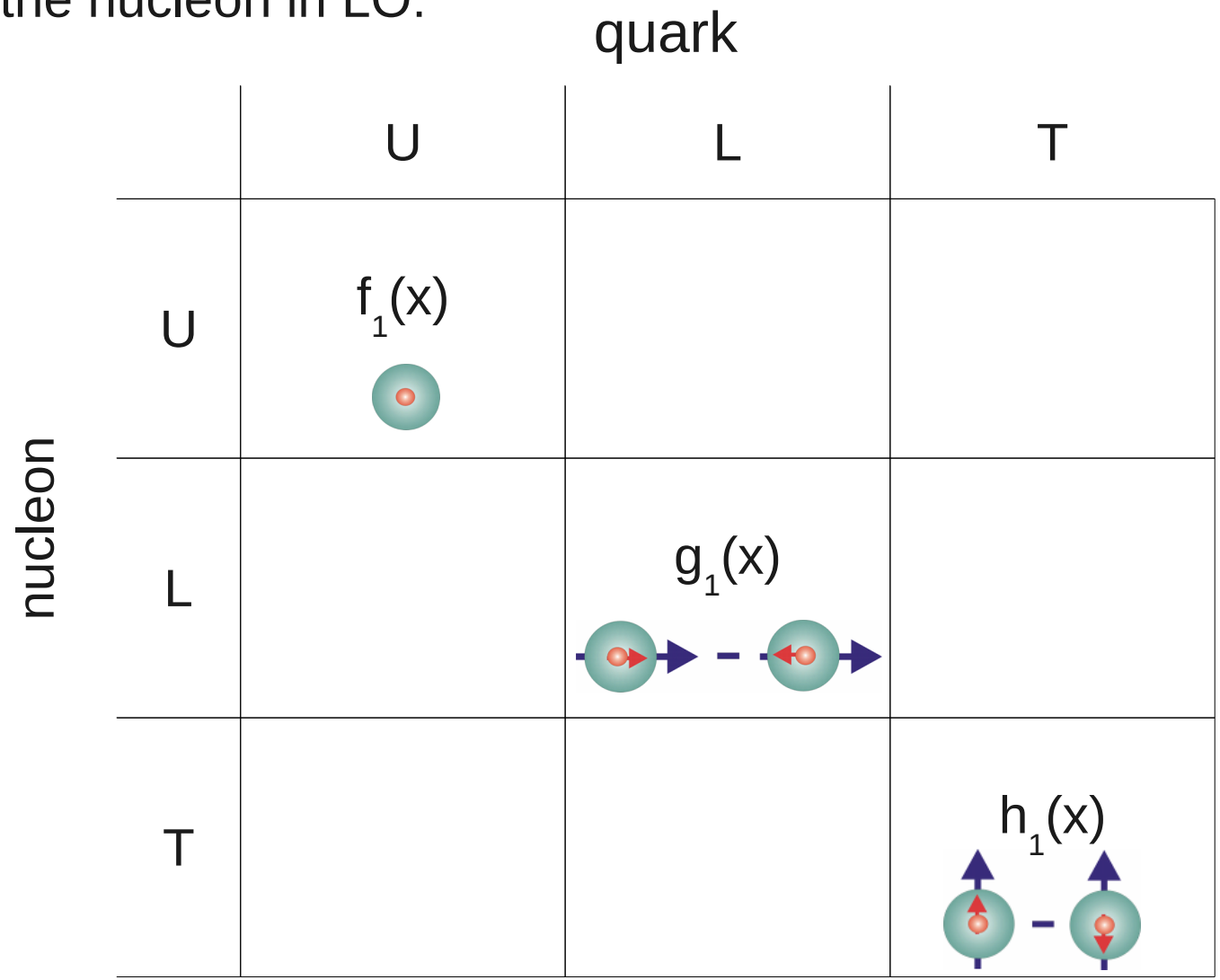
- Upgrade of target system in 2005
- Three cells with opposite polarisation (2002-04 two cells)
- 180mrad geometrical acceptance
- ^{6}LiD:
  - polarization: ~48%
  - dilution factor: ~0.38
- NH_3:
  - polarization: ~90%
  - dilution factor: ~0.15
- Transverse polarization reversed every week via microwave





Spin structure ⟶ Transversity

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



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

helicity distribution
$\Delta q(x) = q^+(x) - q^-(x)$

Transversity distribution
$\Delta_T q(x) = q^\uparrow(x) - q^\downarrow(x)$

$l N^\uparrow \to l' h X$ *Collins FF*

$l N^\uparrow \to l' h h X$ *Interference FF*

$l N^\uparrow \to l' \Lambda X$ *FF of* $q^\uparrow \to \Lambda$

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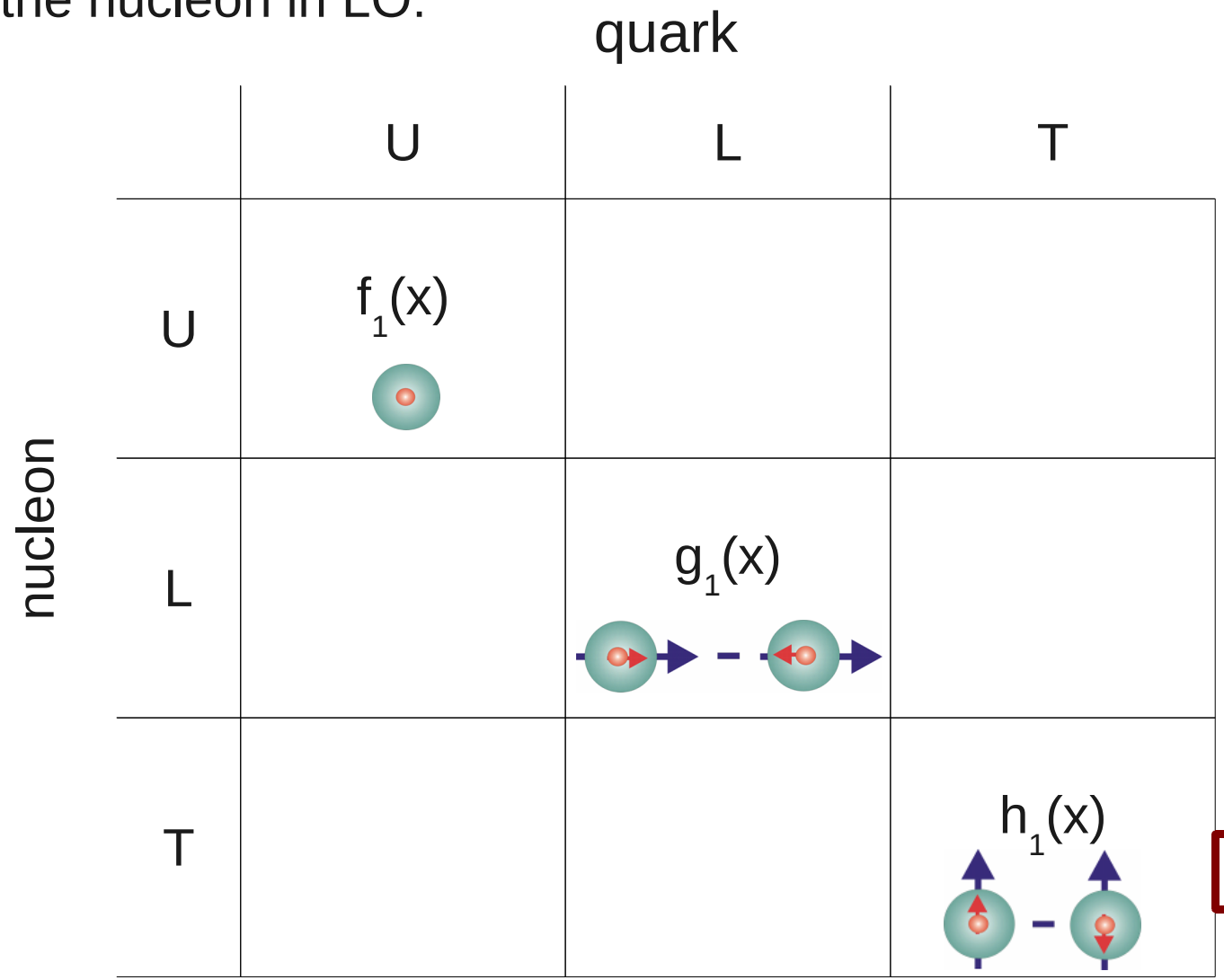

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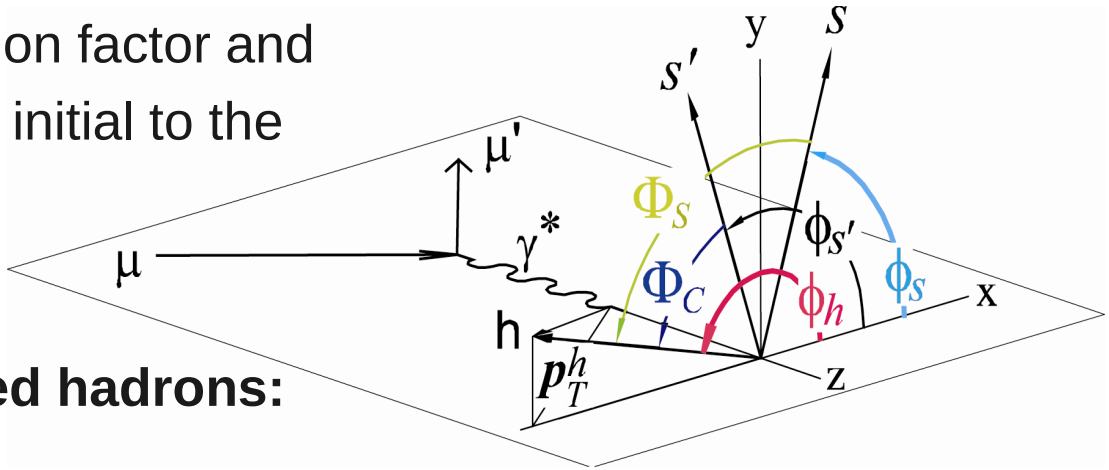
The Collins modulation

For measuring Transversity quark spin must flip:
→ $\Delta_T q(x)$ decouples from inclusive DIS

Product of $\Delta_T q(x)$ and another chiral-odd function needed: Collins FF $\Delta_T^0 D_q^h$
→ $\Delta_T q(x)$ can be extracted via SIDIS on a transversely polarized target.

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

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:

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

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

Hadron statistics

Deuteron data (2002-2004)

Charged hadrons

h^+ h^-	8.5M 7.0M

identified hadrons

π^+ π^-	5.2M 4.5M
K^+ K^-	0.9M 0.6M

Proton data (2007)

Charged hadrons

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

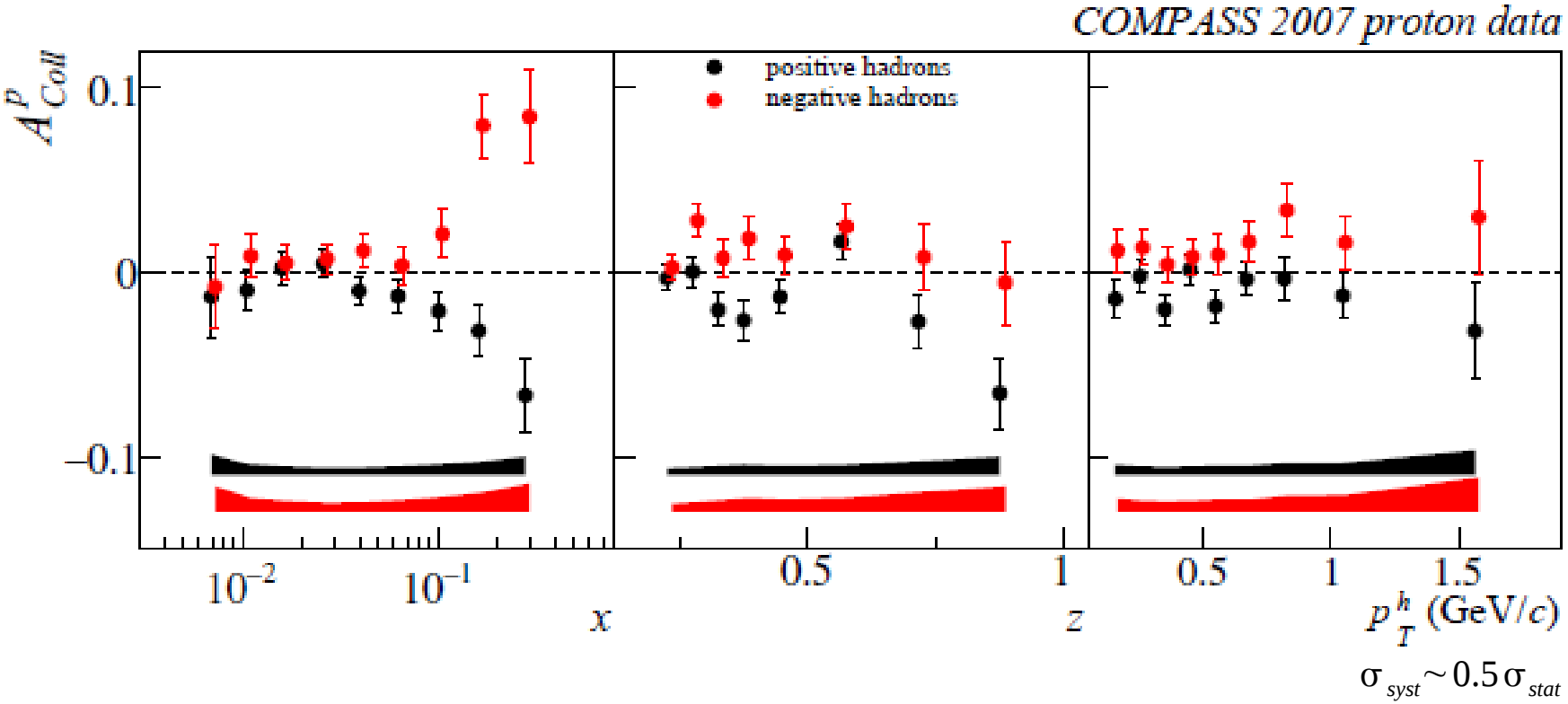
identified hadrons

	Collins	Sivers
π^+ π^-	9.6M 8.4M	6.6M 5.8M
K^+ K^-	1.7M 1.1M	1.2M 0.7M

The Collins modulation – 2007 data

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

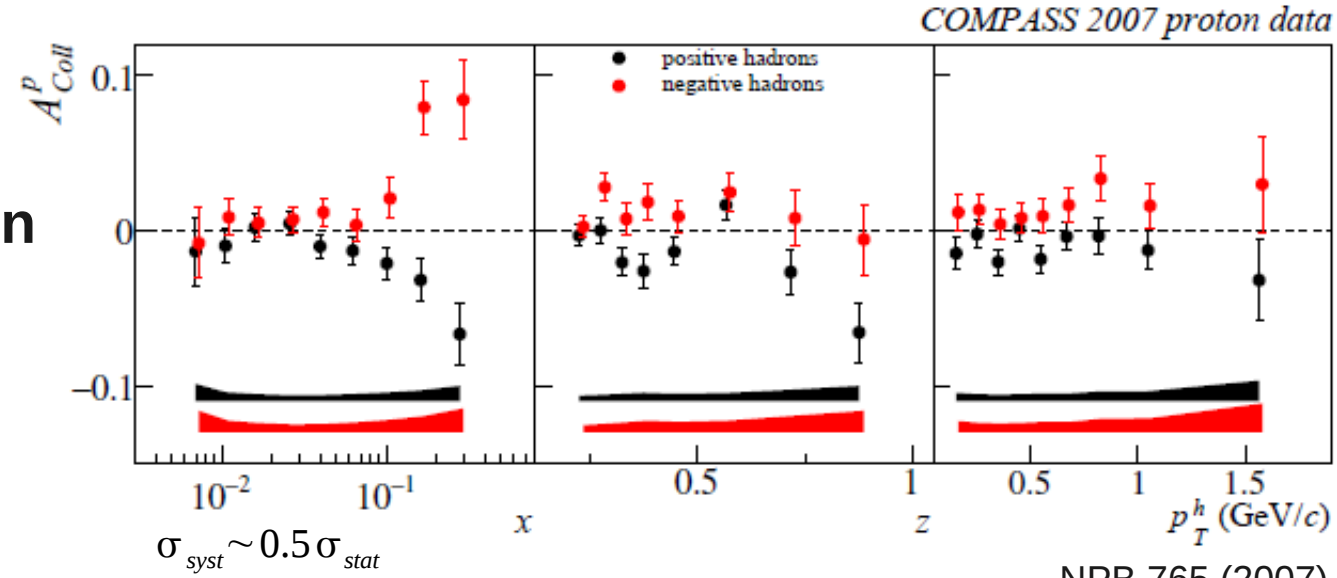
PLB 692 (2010)



The Collins modulation deuteron ↔ proton

proton

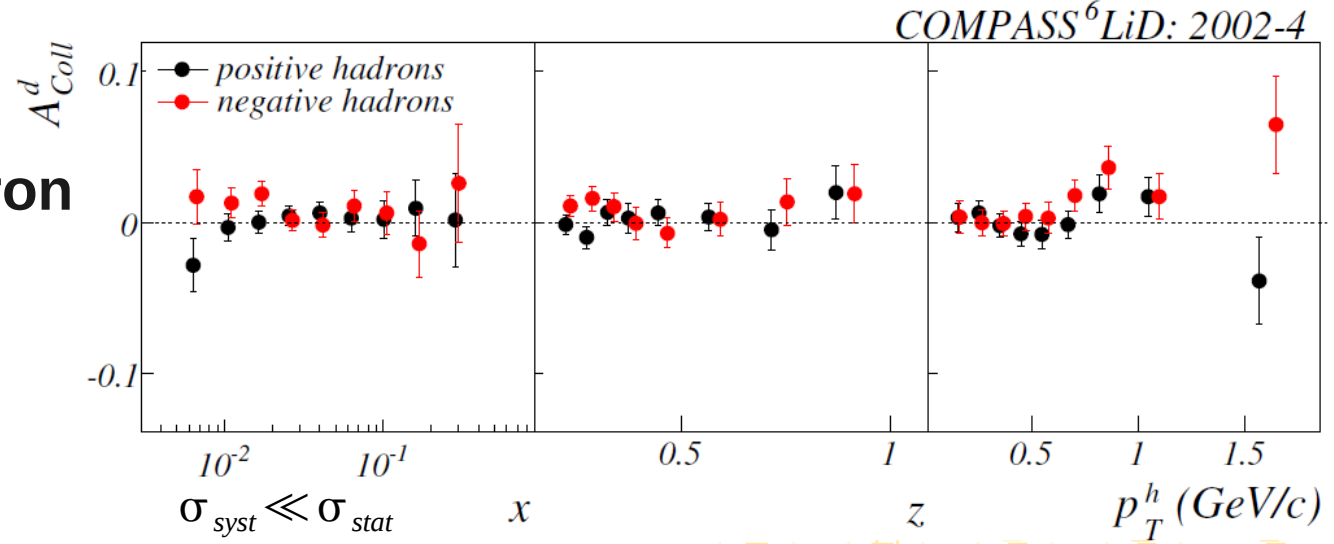
PLB 692



Large signal in the valence region

deuteron

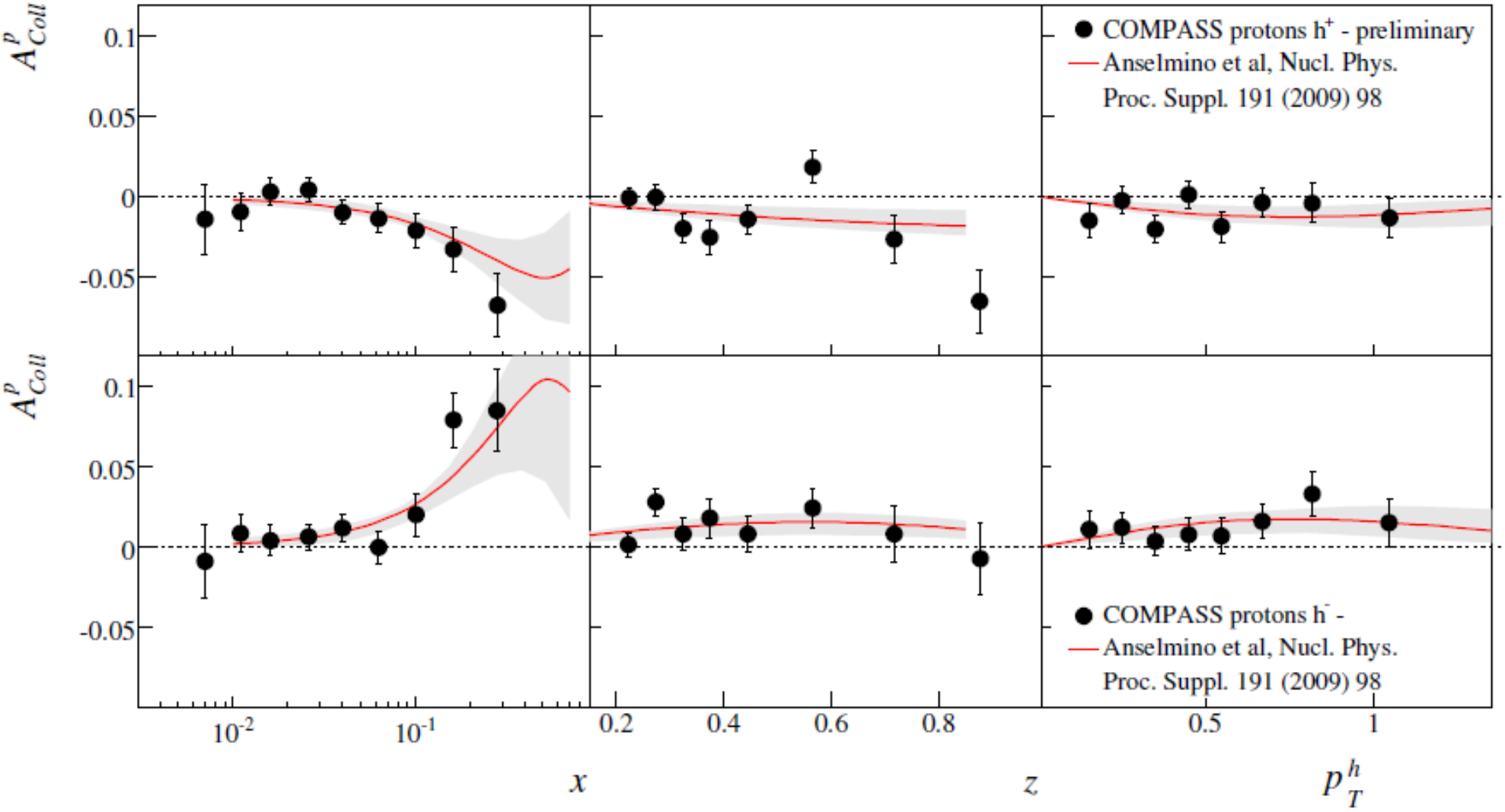
NPB 765 (2007)



Asymmetries compatible with zero for deuteron data → u-d cancellation

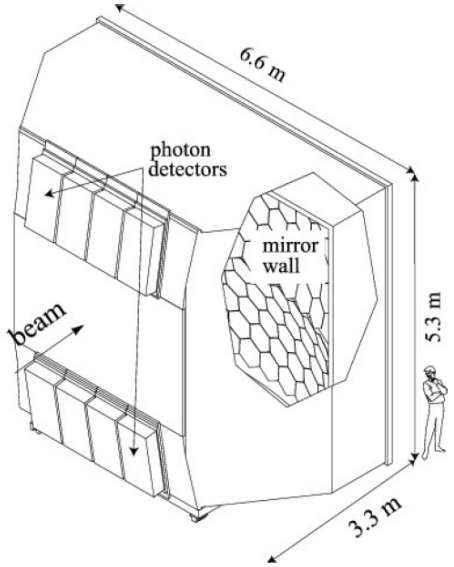
The Collins modulation
Comparison to model predictions

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

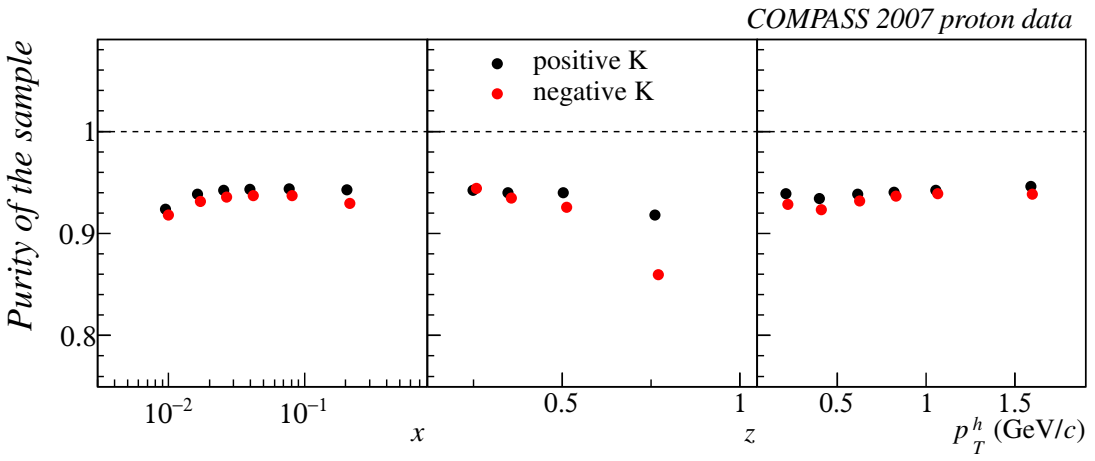


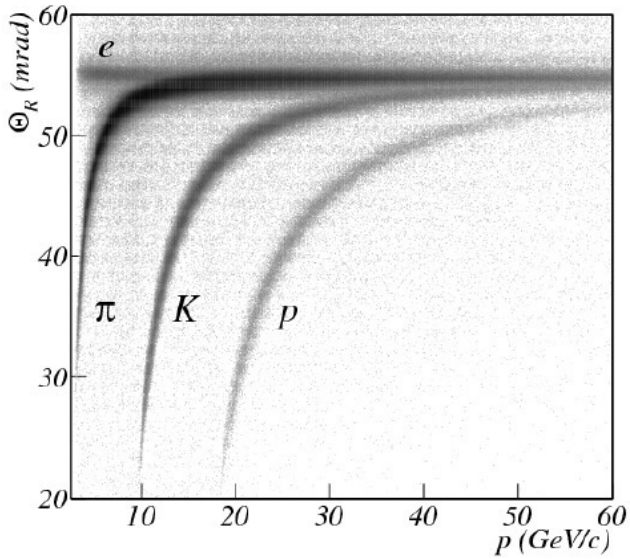
Hadron identification

RICH



- C_4F_{10} radiator gas
- likelihood-based algorithm
- purity of π sample > 99%





$p_{thr}^{\pi} \sim 3\,GeV/c$

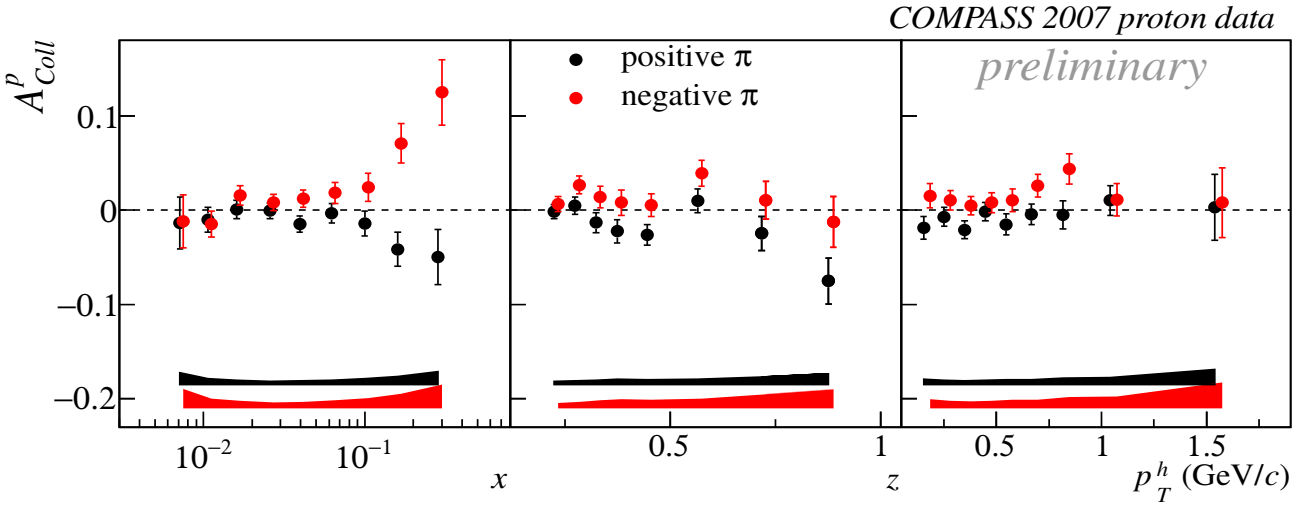
$p_{thr}^{K} \sim 9\,GeV/c$

$p_{thr}^{p} \sim 17\,GeV/c$

$p_{max}^{2007} \sim 50\,GeV/c$

The Collins modulation Identified hadrons 2007

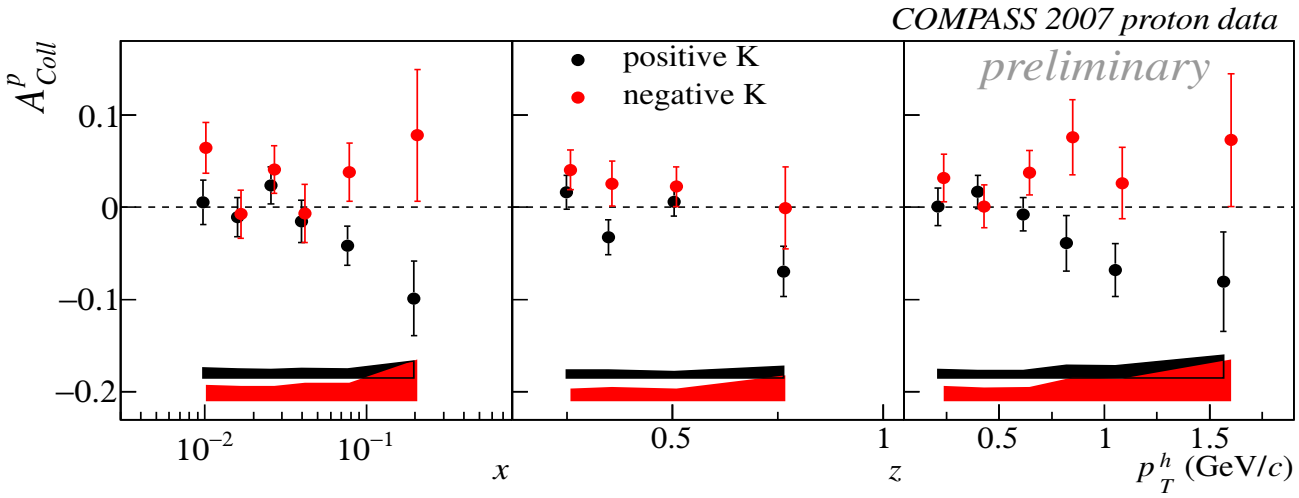
strong signal for π in the valence region



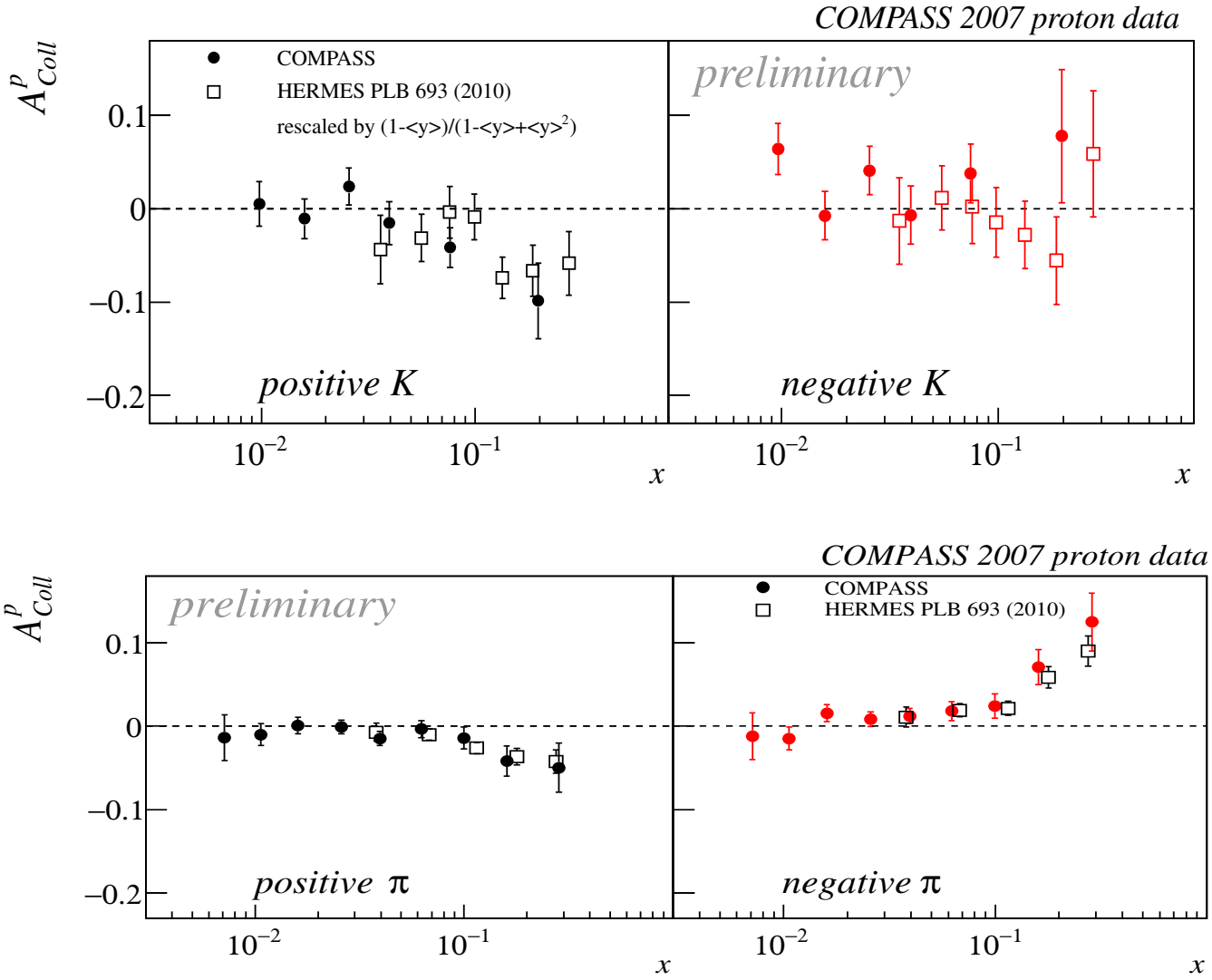
$K^+, \pi^+: \sigma_{syst} \sim 0.5\,\sigma_{stat}$; $K^-, \pi^-: \sigma_{syst} \sim 0.7\,\sigma_{stat}$

negative trend for K^+

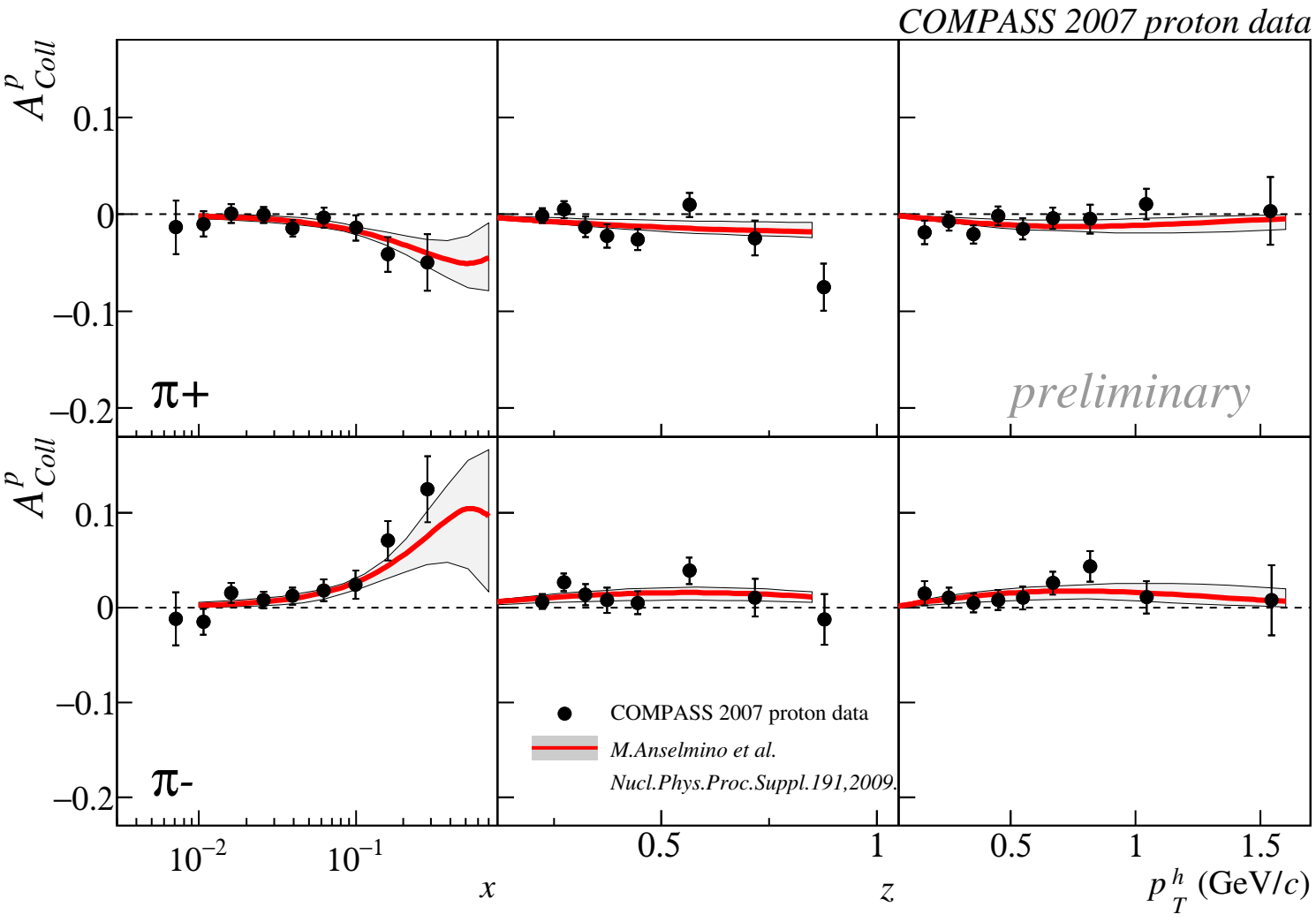
positive trend for K^-



The Collins modulation
Identified hadrons compared to Hermes

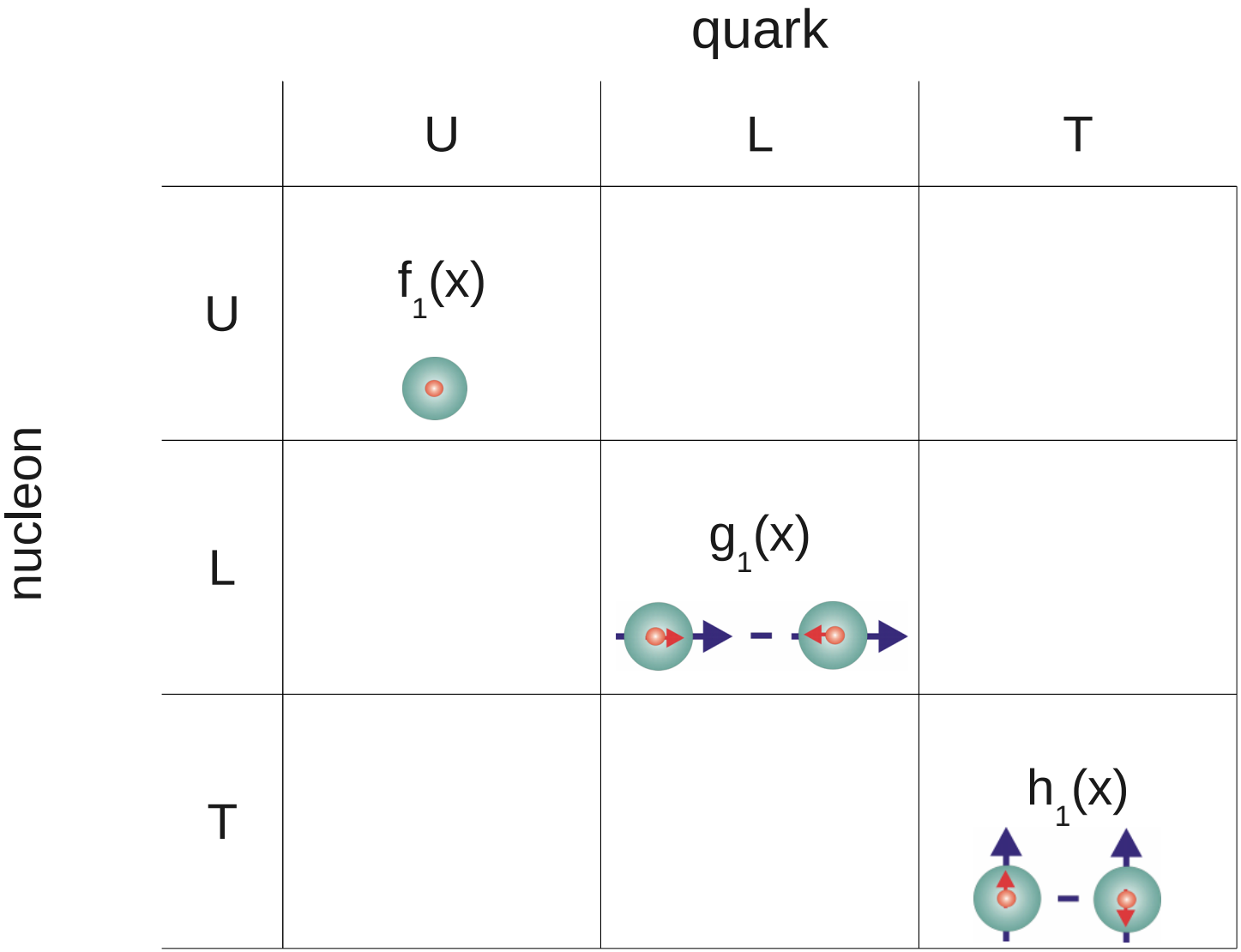


The Collins modulation Comparison to model predictions of identified pions



Transverse spin physics

Taking into account the transverse momentum k_T of the quarks:



Transverse spin physics: TMDs

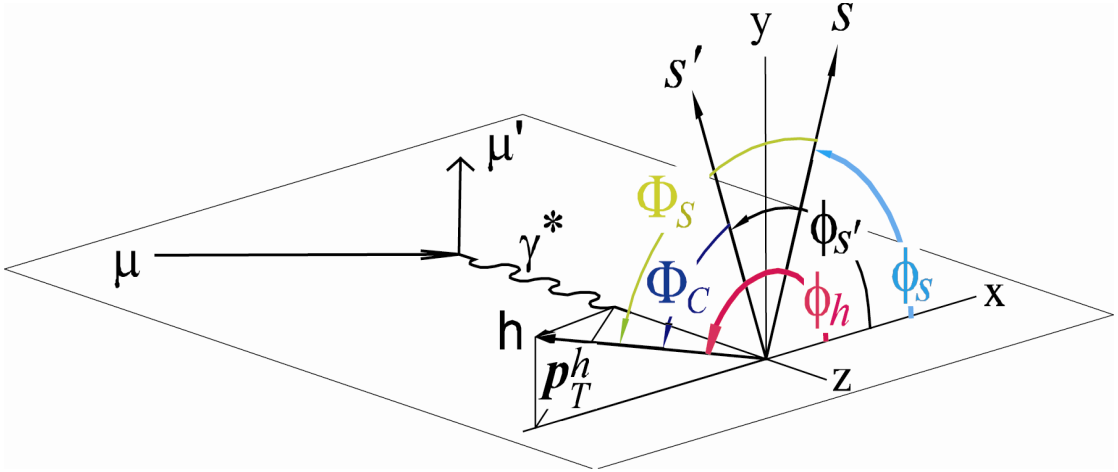
Taking into account the transverse momentum k_T of the quarks:

nucleon \ quark	U	L	T
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 $f_{1T}^{\perp}(x,k_T)$: Correlation between the transverse spin of a nucleon and the intrinsic transverse momentum of unpolarized quarks

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



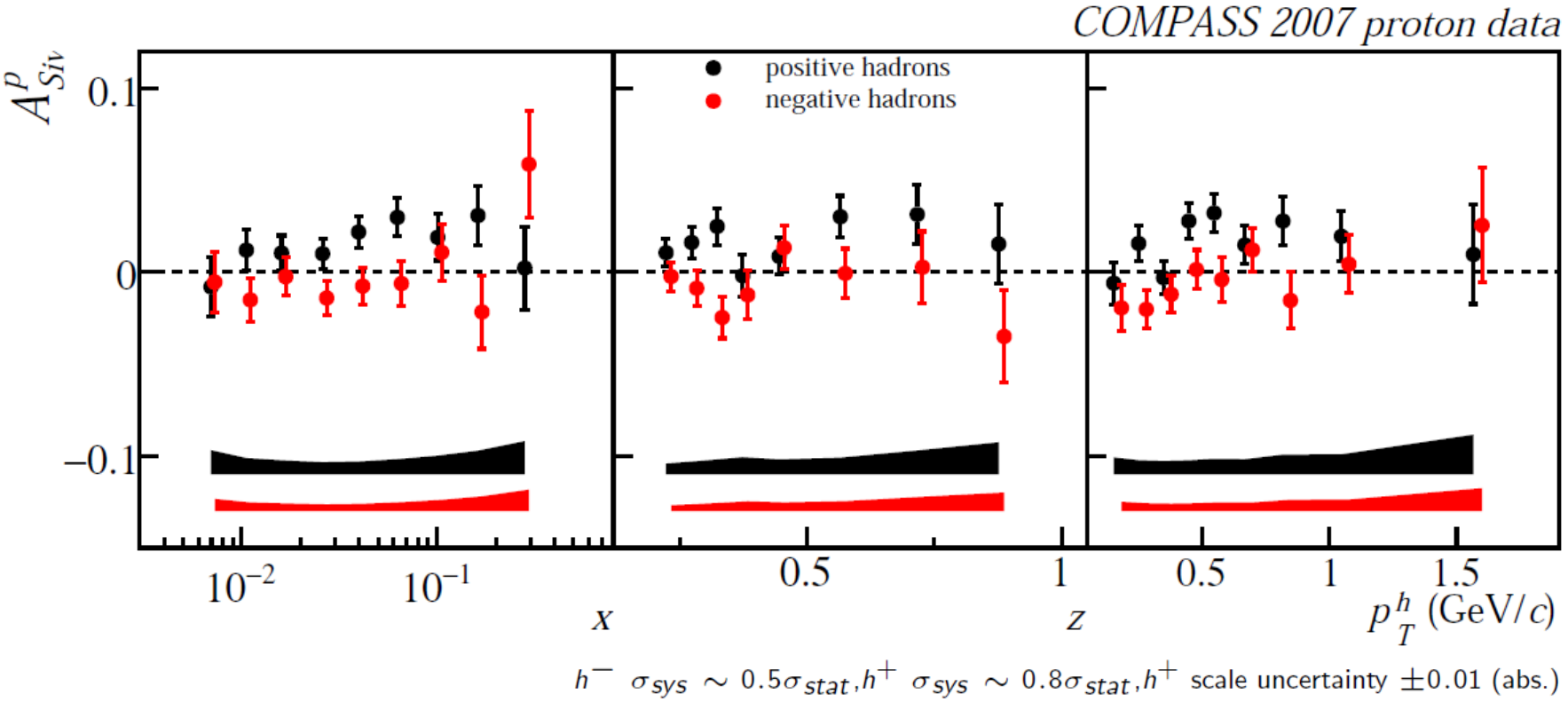
Azimuthal distribution of the produced hadrons:

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

With Sivers angle $\Phi_S = \phi_h - \phi_s$

The Sivers modulation - 2007 data

PLB 692 (2010)

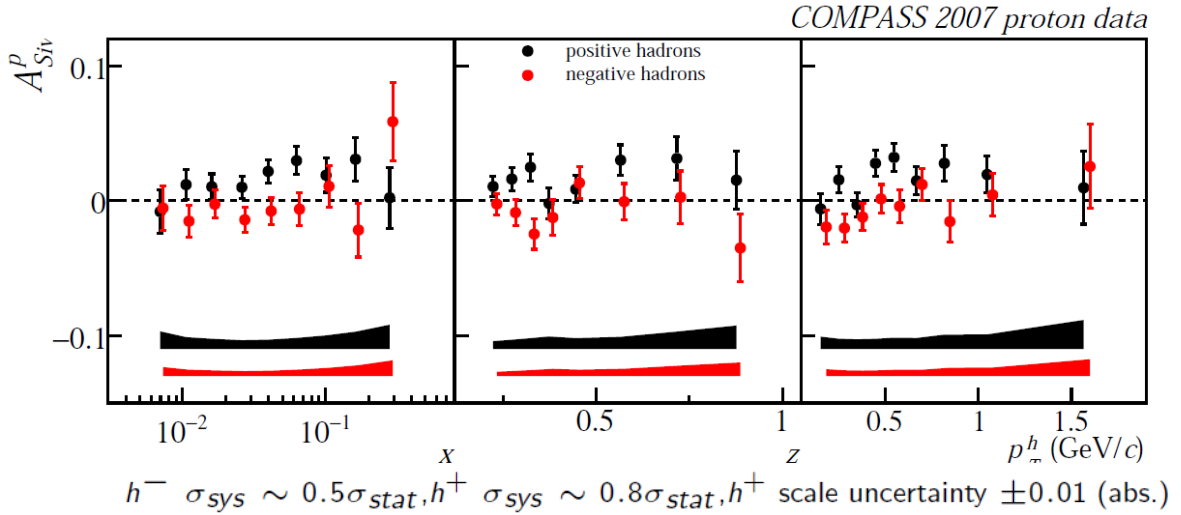


- positive signal for positive hadrons
- h^- asymmetry compatible with zero

The Sivers modulation deuteron ↔ proton

proton

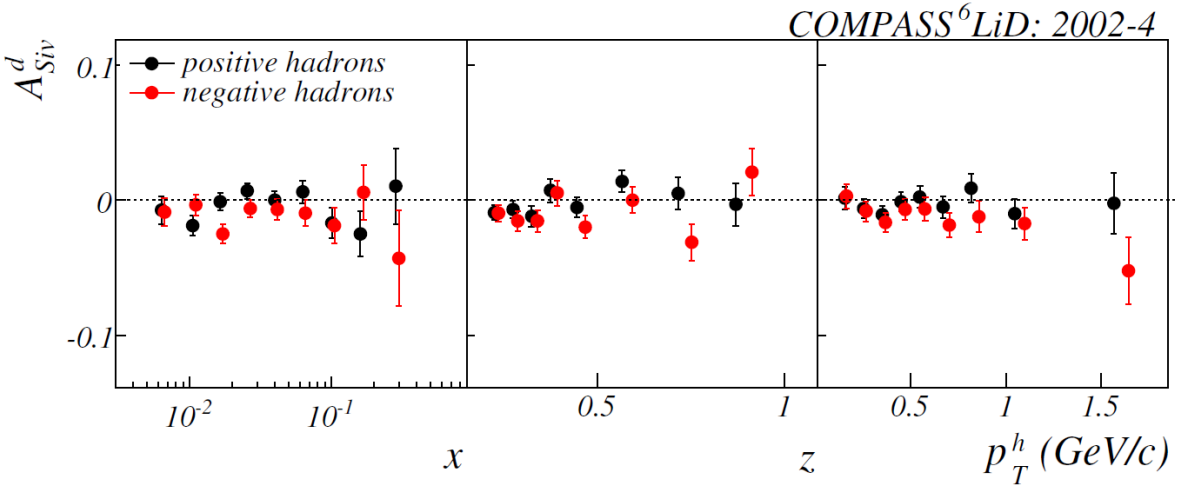
PLB 692 (2010)



positive signal for positive hadrons

deuteron

NP B765 (2007)

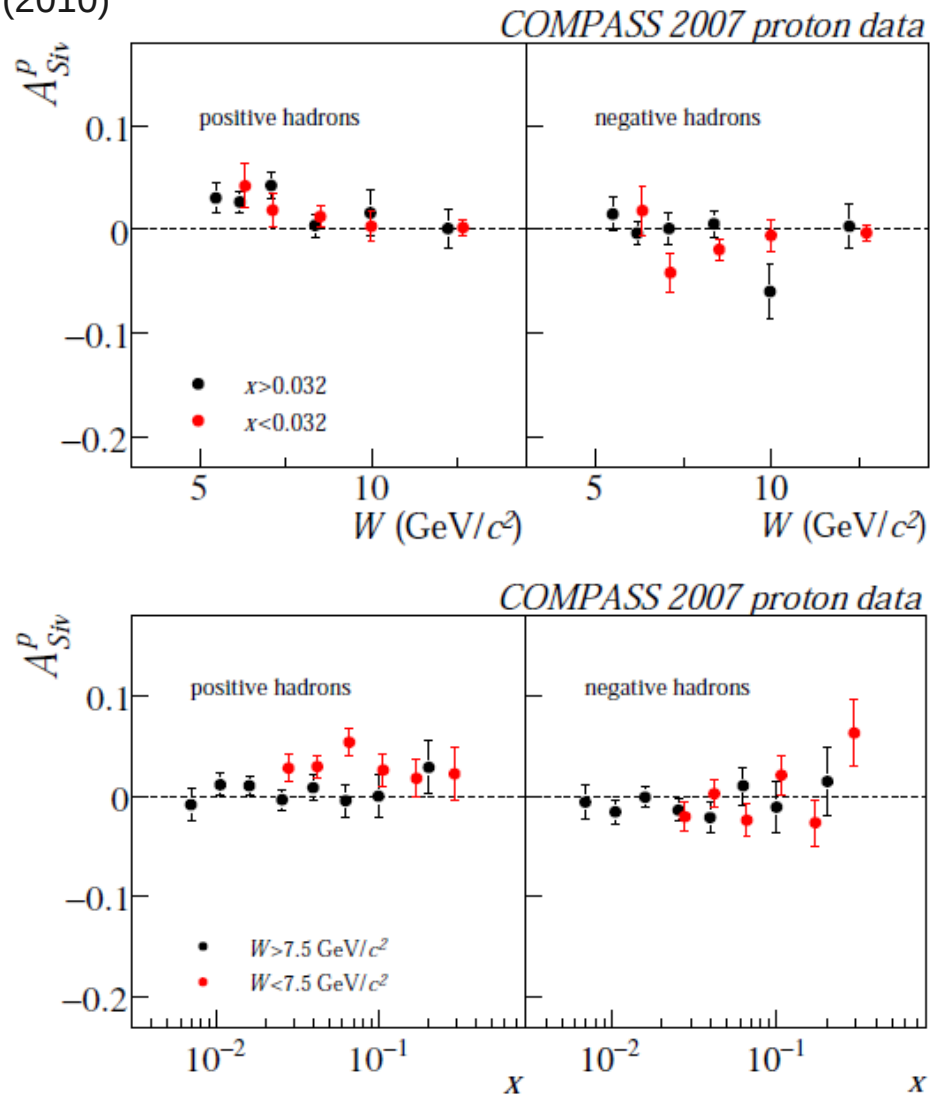


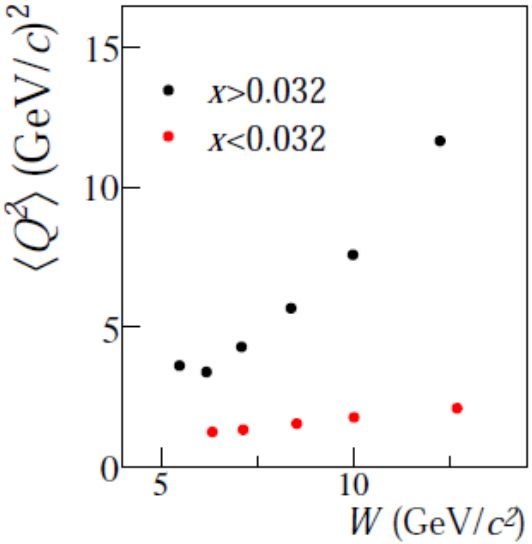
compatible with zero

The Sivers modulation W dependency?

Hints for a possible W dependence of the h^+ Sivers asymmetry

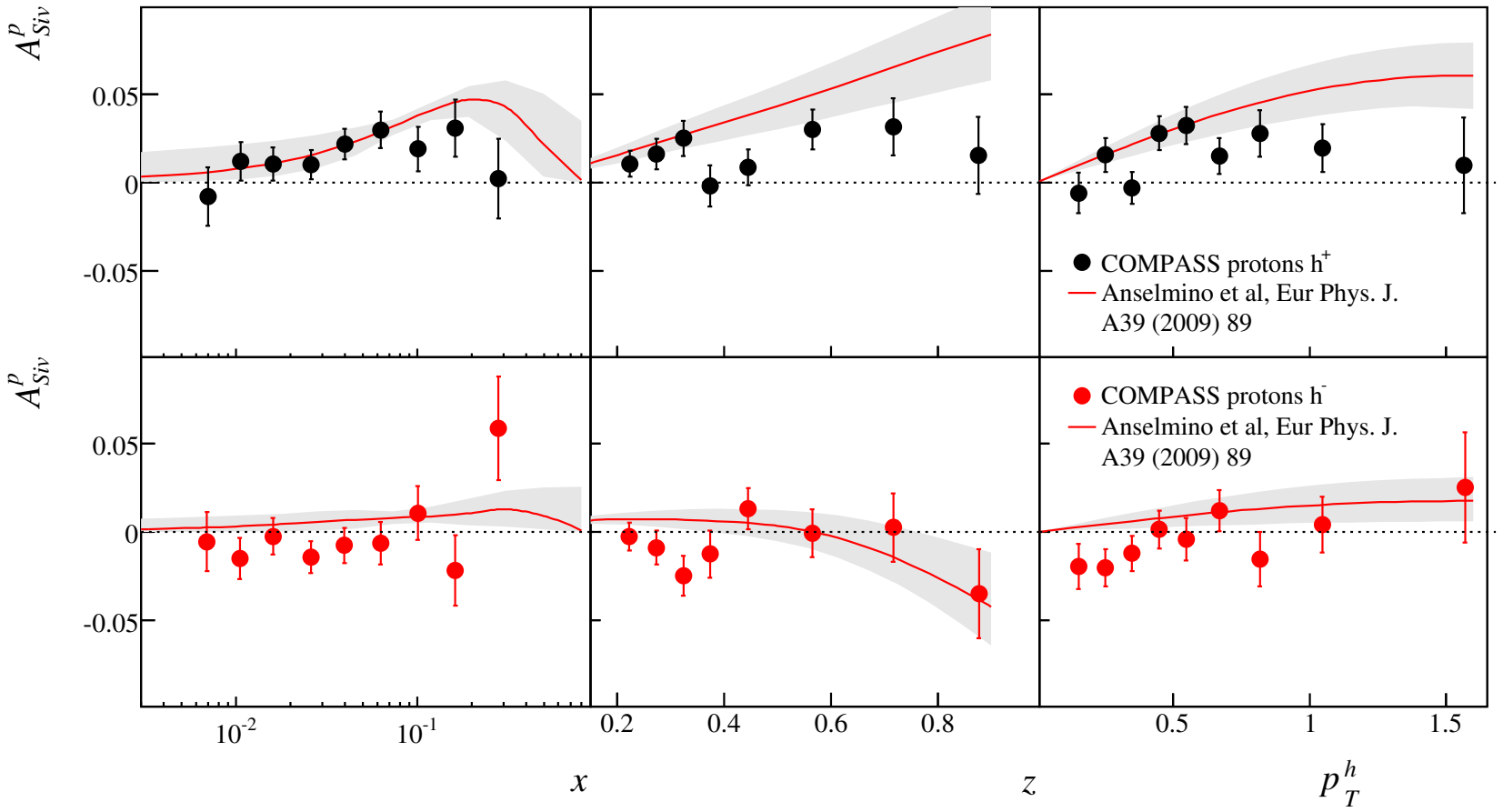
PLB 692 (2010)



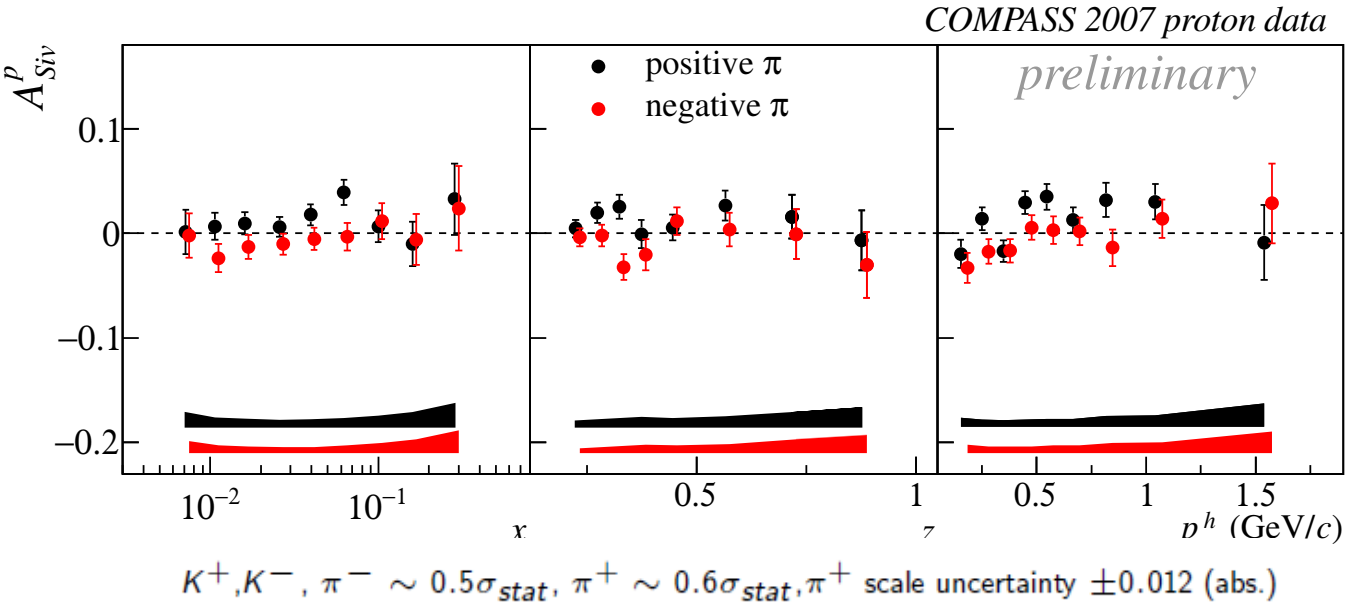


The Sivers modulation
Comparison to model predictions

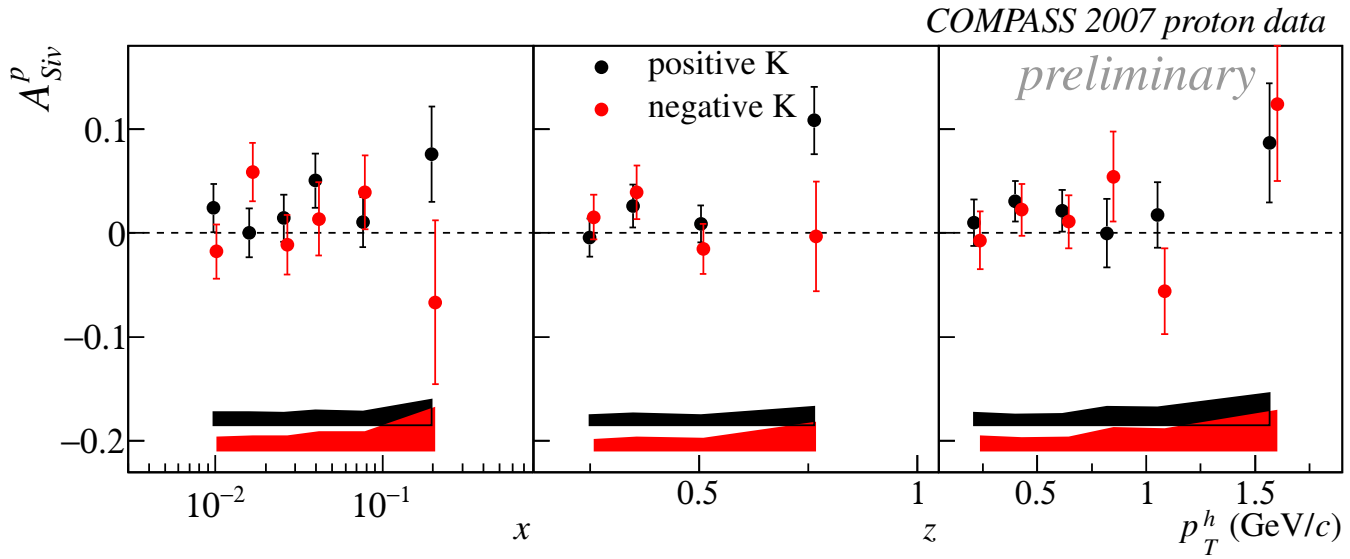
Comparison with the predictions from the fit to the COMPASS deuteron and HERMES proton data:



The Sivers modulation
Identified hadrons



$K^+, K^-, \pi^- \sim 0.5\sigma_{stat}$, $\pi^+ \sim 0.6\sigma_{stat}$, π^+ scale uncertainty ± 0.012 (abs.)



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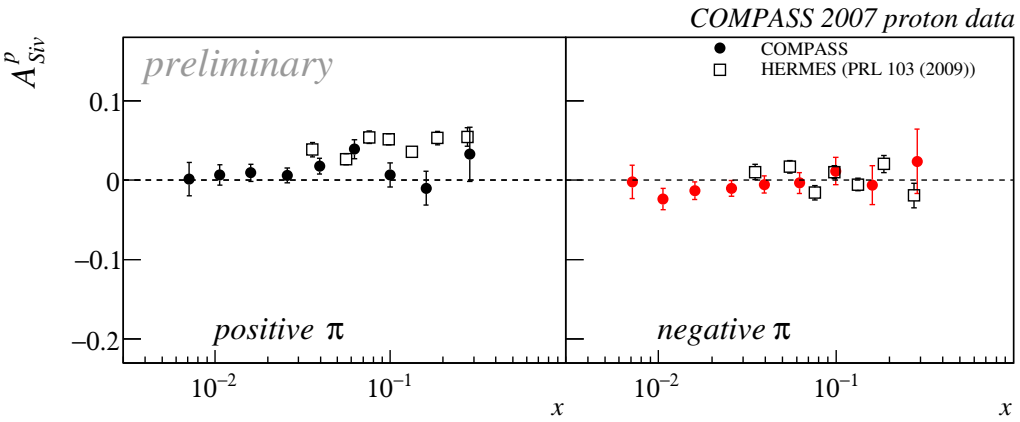
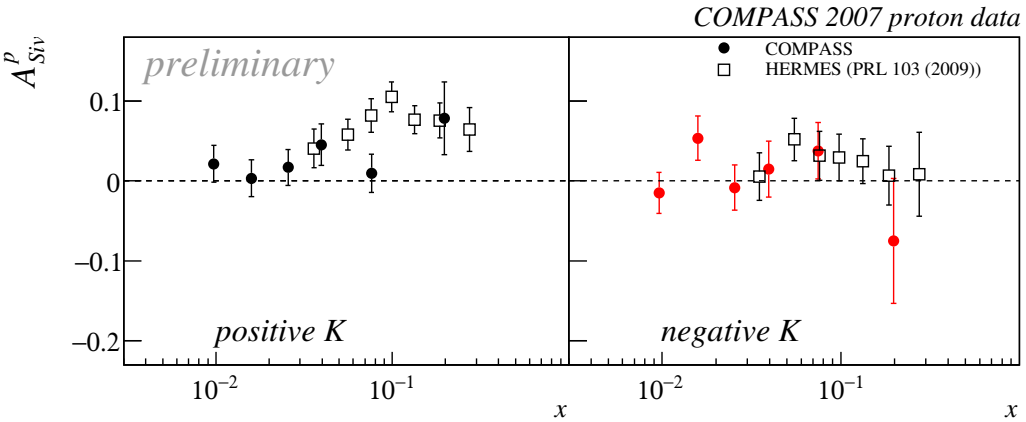
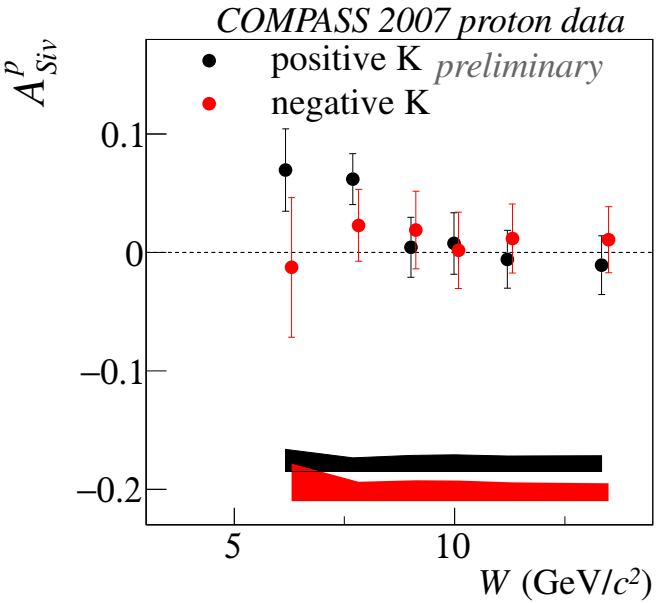
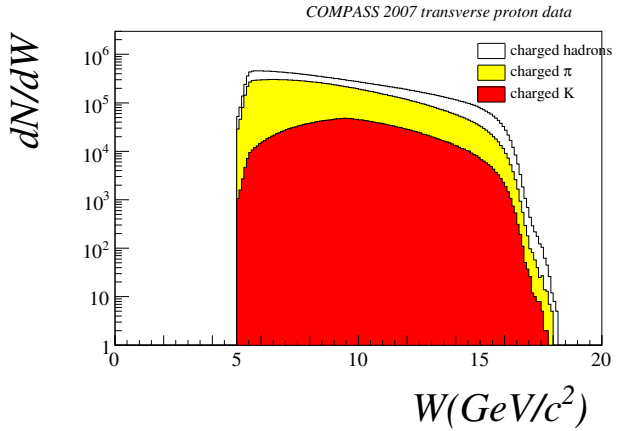








Clear signal for Sivers asymmetry at small values of W

Conclusions

2007 proton data fully analysed:

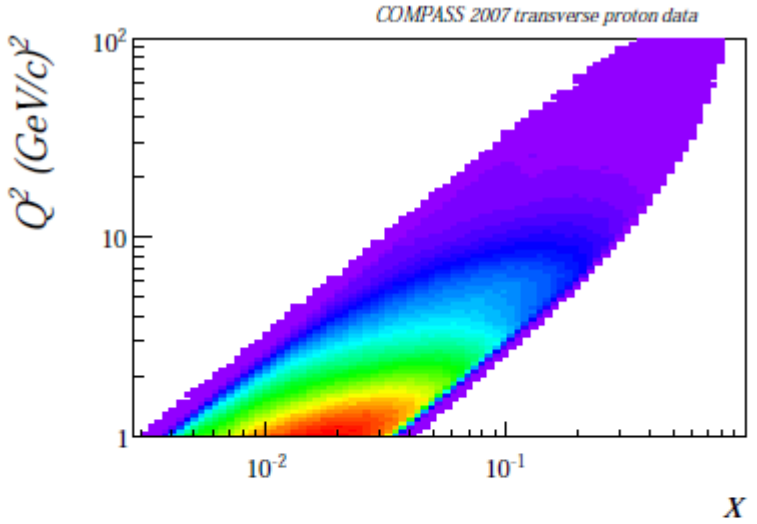
- large Collins asymmetry
- positive signal for Sivers asymmetry for positive hadrons
- possible W dependence of Sivers asymmetry
- Sivers asymmetry for K^+ larger than for all positive hadrons
- clear signal for Sivers asymmetry for K^+ at small values of W

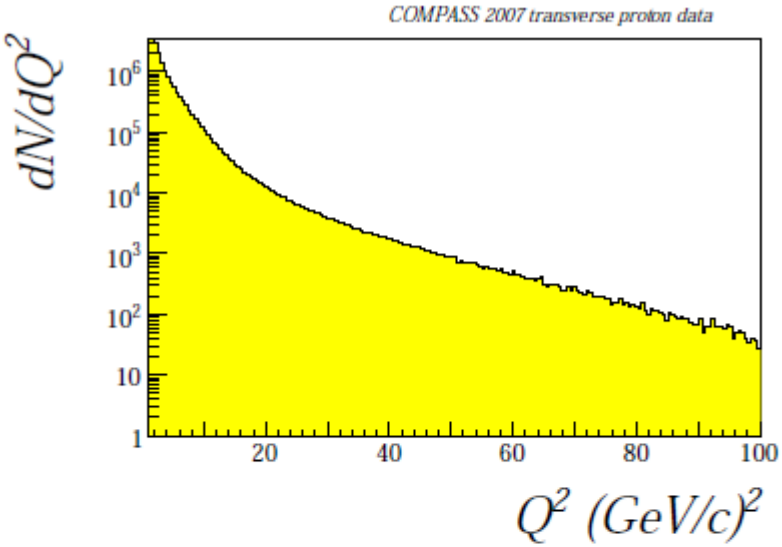
2010: one year of data taking on a transversely polarized proton target

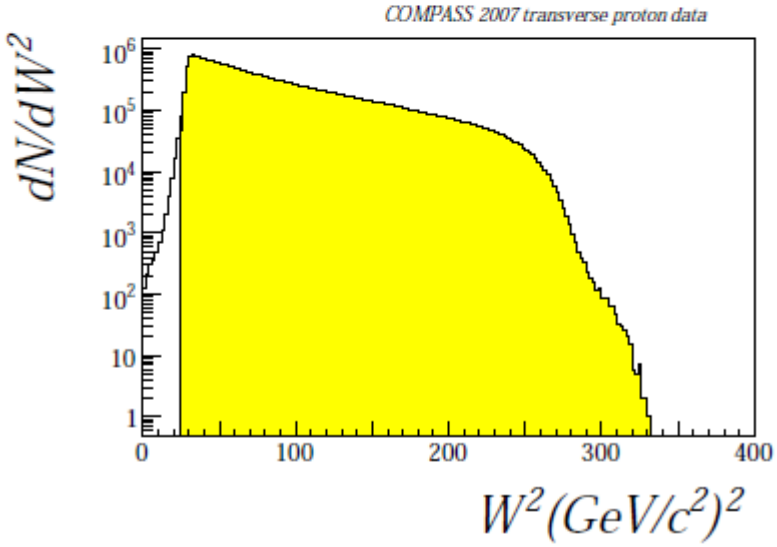
- higher statistics
- analysis ongoing

SPARES

Data selection
DIS cuts







$$Q^2 > 1\ (GeV/c)^2$$

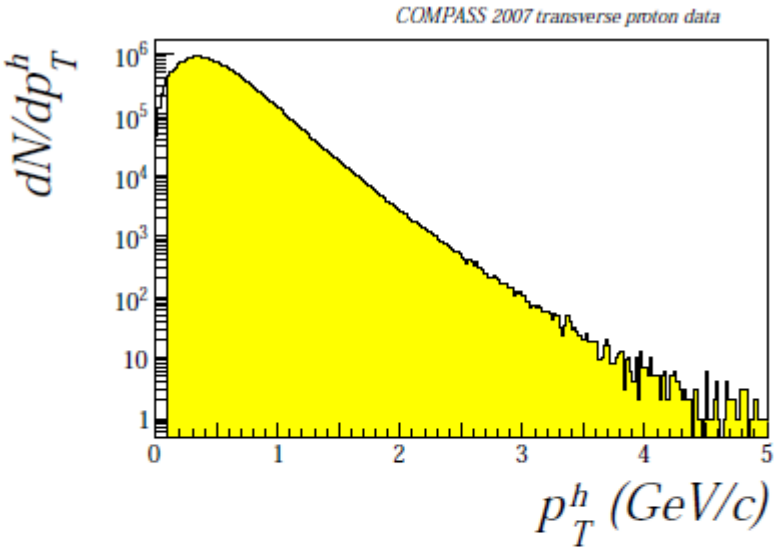
$$0.1 < y < 0.9$$

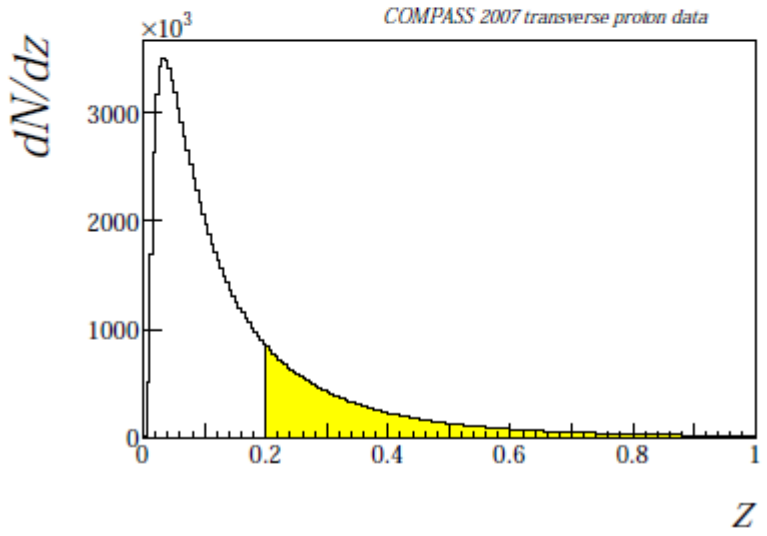
$$W > 5\ GeV/c^2$$

Data selection
Hadron cuts

$p_T > 0.1\ GeV/c$

$z > 0.2$





Identified hadrons kinematical values