Single Spin Asymmetries with Transverse Target at COMPASS

C. Schill (Universität Freiburg)

on behalf of the COMPASS collaboration

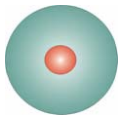
- **Transversity:**
  - **single hadrons, hadron pairs**
- **TMDs:**
  - **measured with transversely polarized nucleons**

DIS 2011, April 12th 2011, Newport News, USA

Transverse spin physics

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

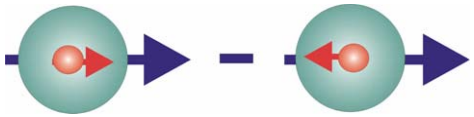
$q(x)$



quark distribution

in unpolarized DIS
$l\ N \rightarrow l'\ X$

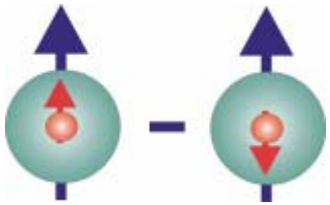
$\Delta q(x)$



helicity distribution

in polarized DIS
$\vec{l}\ \vec{N} \rightarrow l'\ X$

$\Delta_T q(x) = q^{\uparrow\uparrow}(x) - q^{\uparrow\downarrow}(x)$



transversity distribution

in polarized SIDIS

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

Transversity $\Delta_T q$

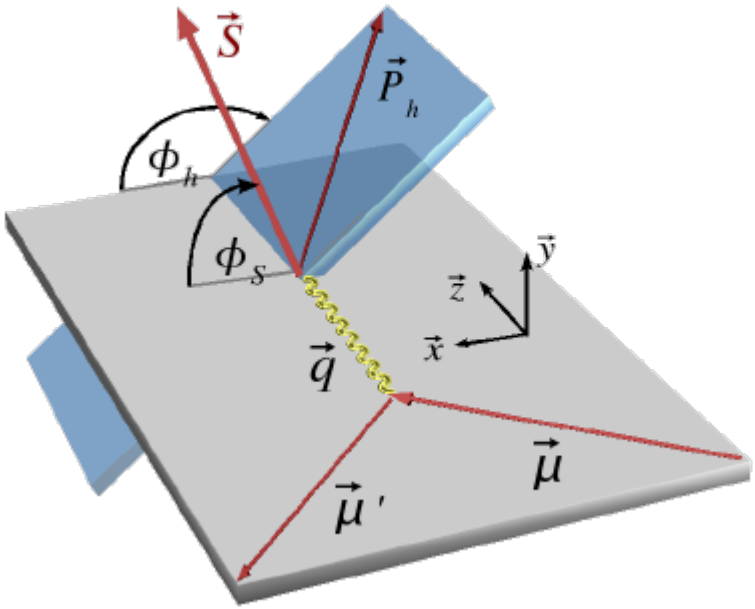
- Couple $\Delta_T q$ to chiral odd Collins FF $\Delta_T^0 D_q^h$

$$A_{Coll} = \frac{\sum_q e_q^2 \Delta_T q(x) \Delta_T^0 D_q^h(z, p_T^h)}{\sum_q e_q^2 q(x) D_q^h(z, p_T^h)}$$

Azimuthal cross-section asymmetry:

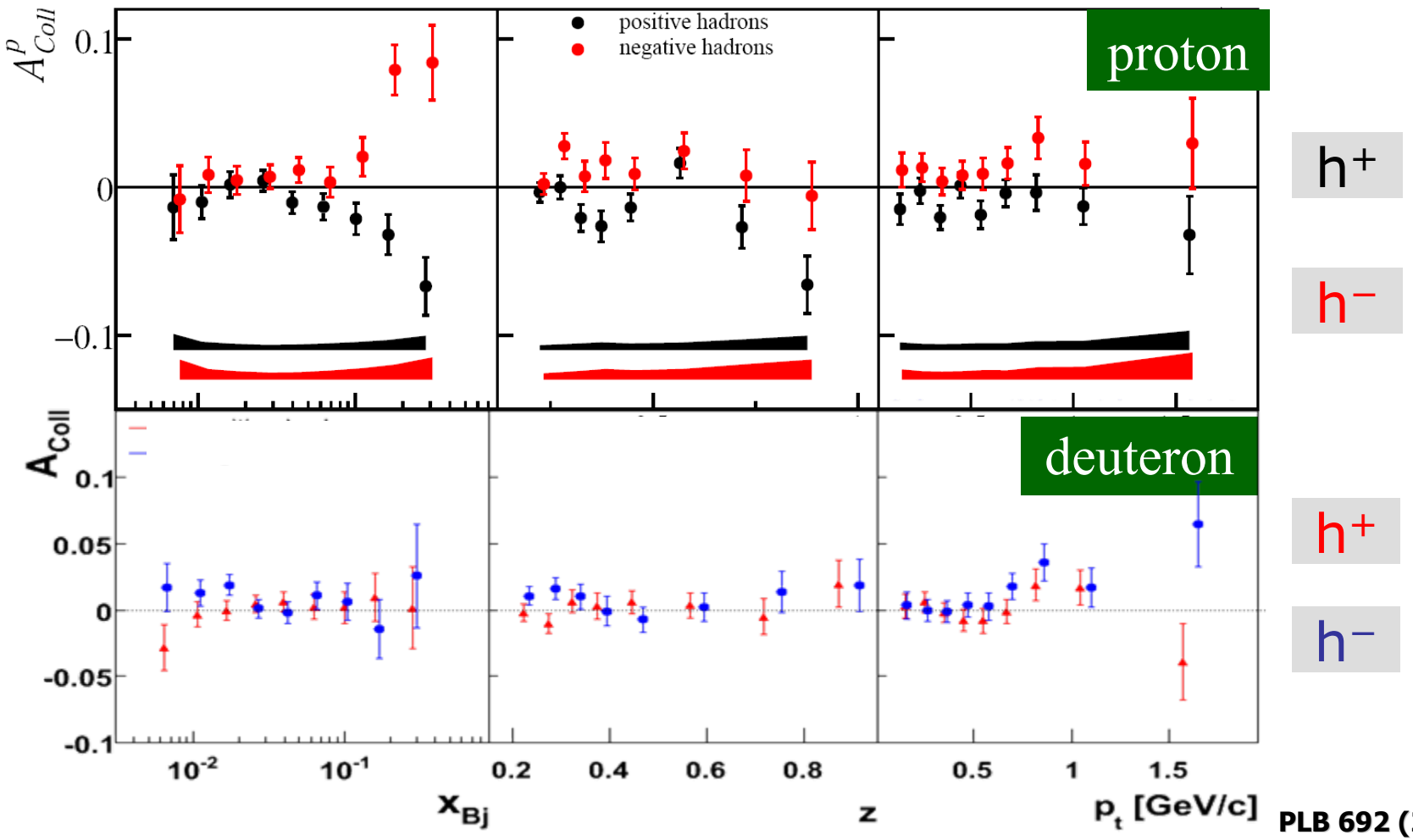
$$\frac{\Delta\sigma}{\sigma} \propto A_{Coll} \sin\phi_{Coll}$$

$$\phi_{Coll} = \phi_h - \phi_s - \pi$$



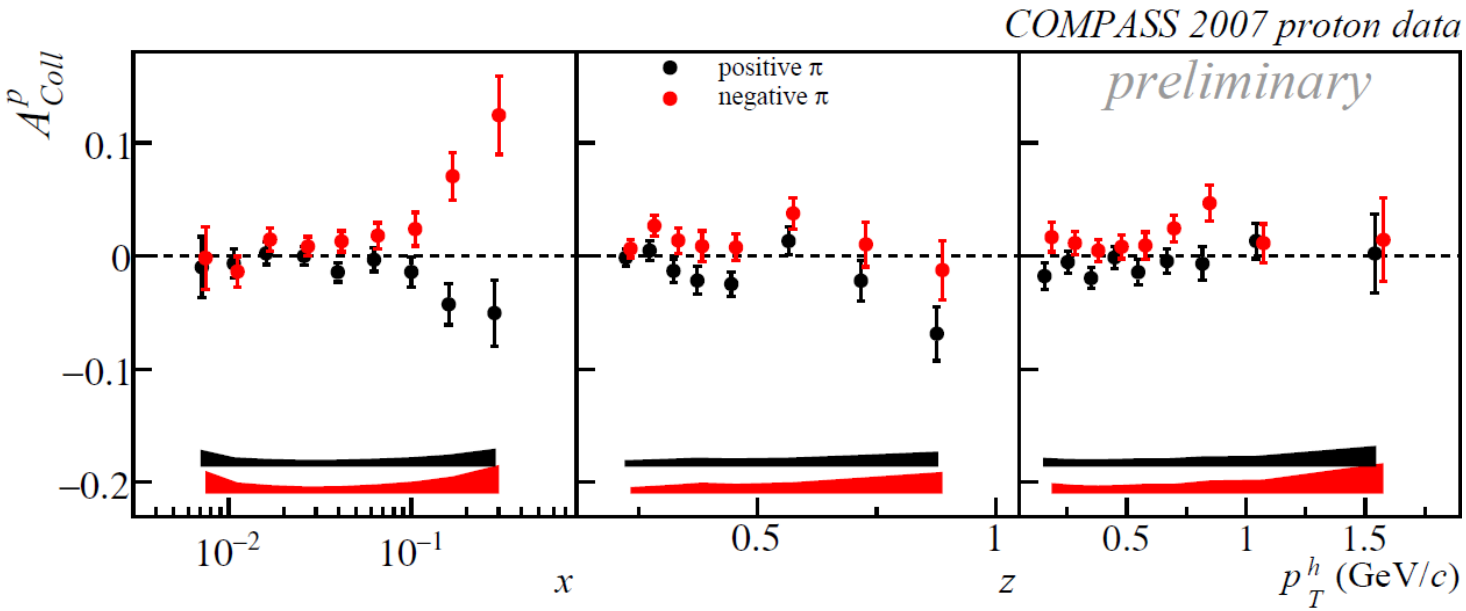
Transversity: Collins asymmetries

- large asymmetry when scattering on a proton ~10%
- deuteron result ⇒ opposite sign of $\Delta_T u$ and $\Delta_T d$

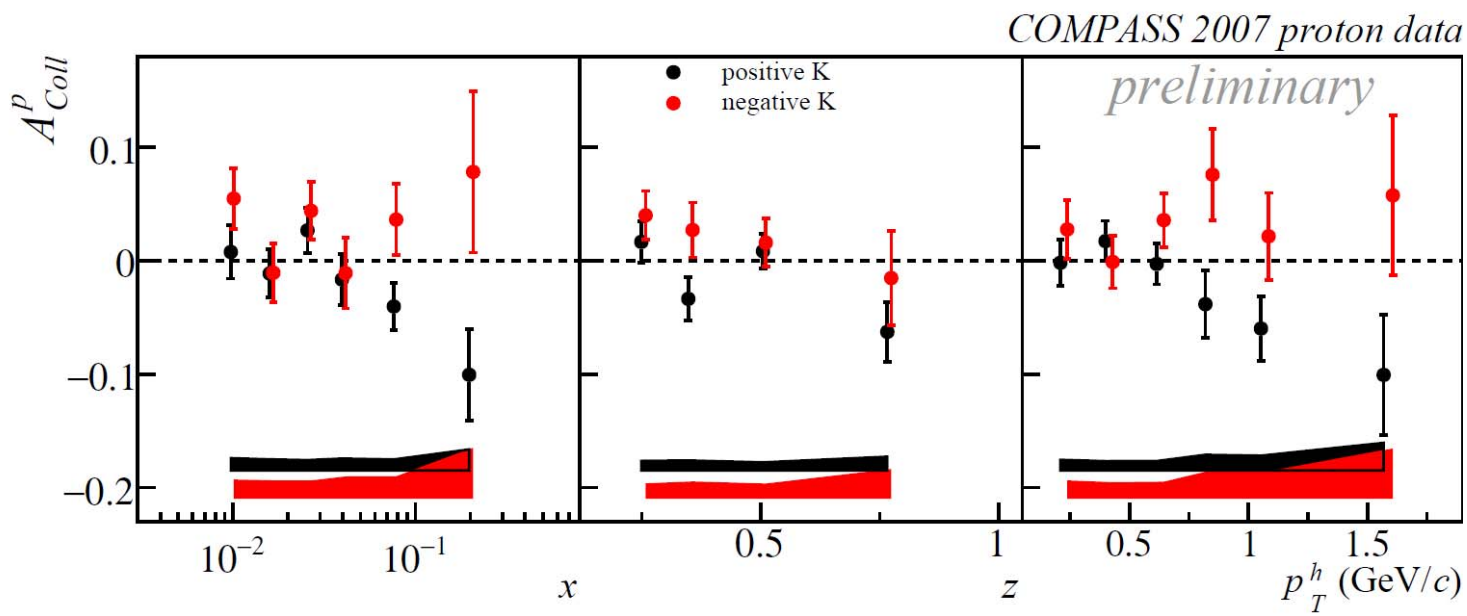


PLB 692 (2010), 240
PLB 673 (2009), 127

New results for identified hadrons



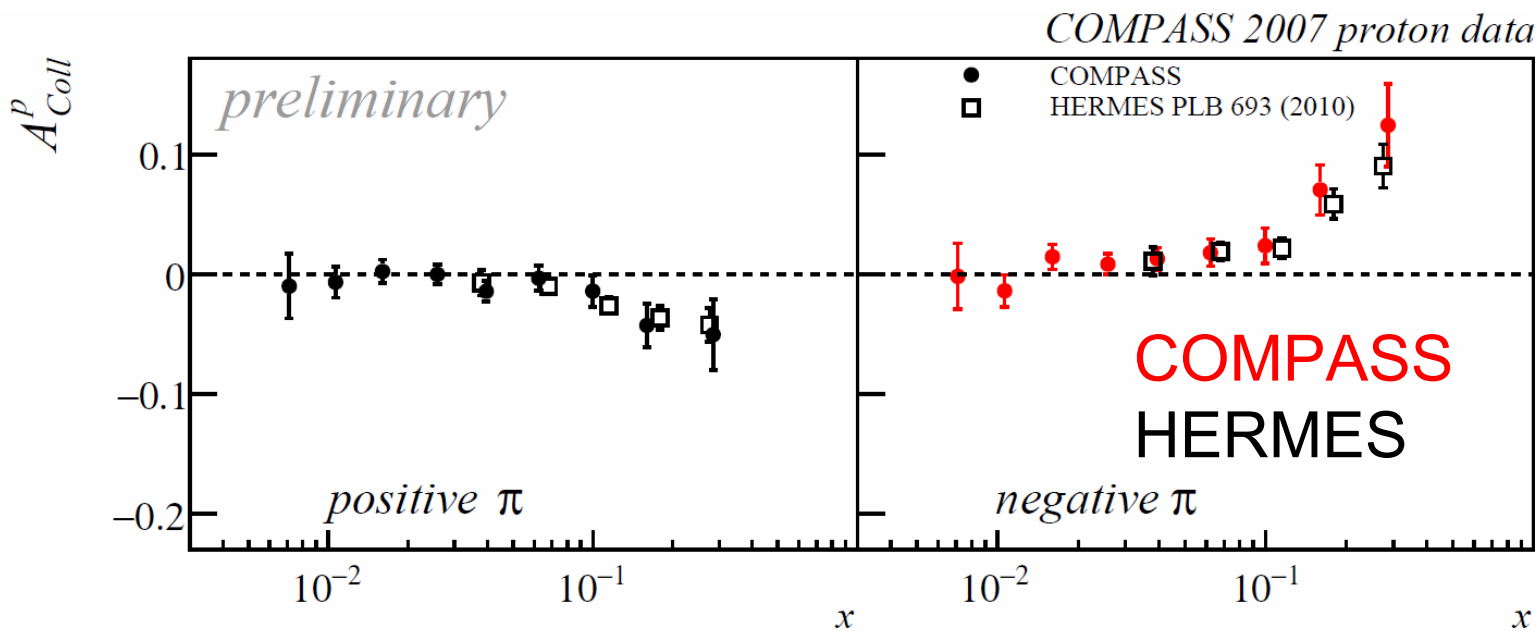
π^{+-}



K^{+-}

Comparison COMPASS-HERMES

Proton

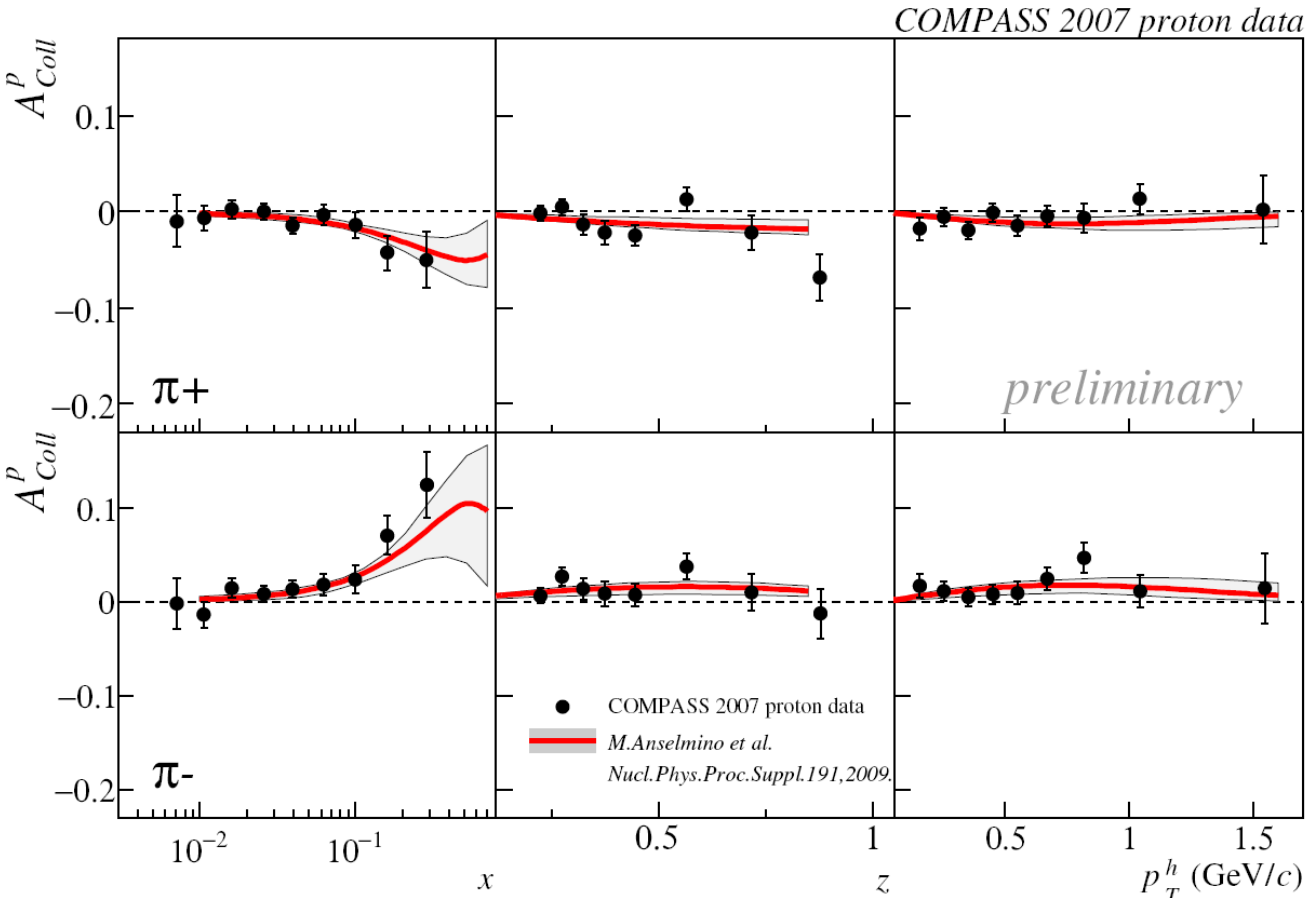


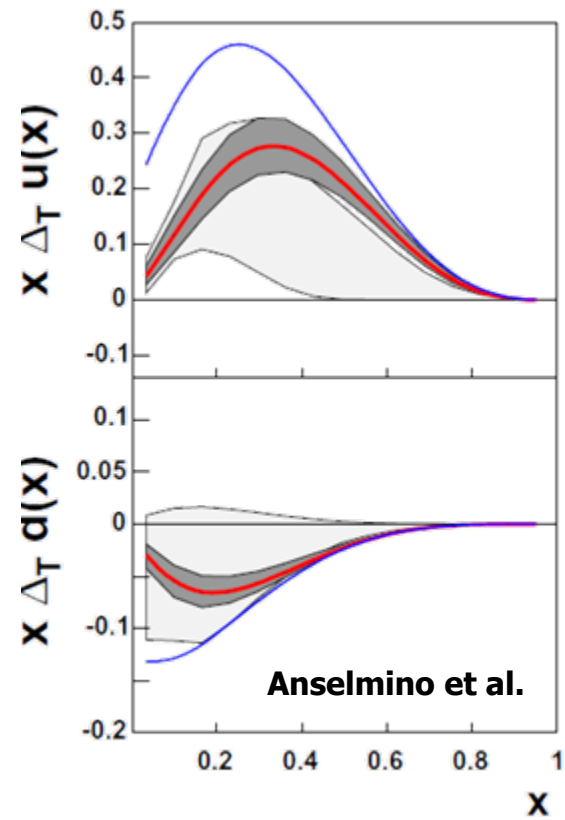
π^{+-}

- good agreement in common x-range

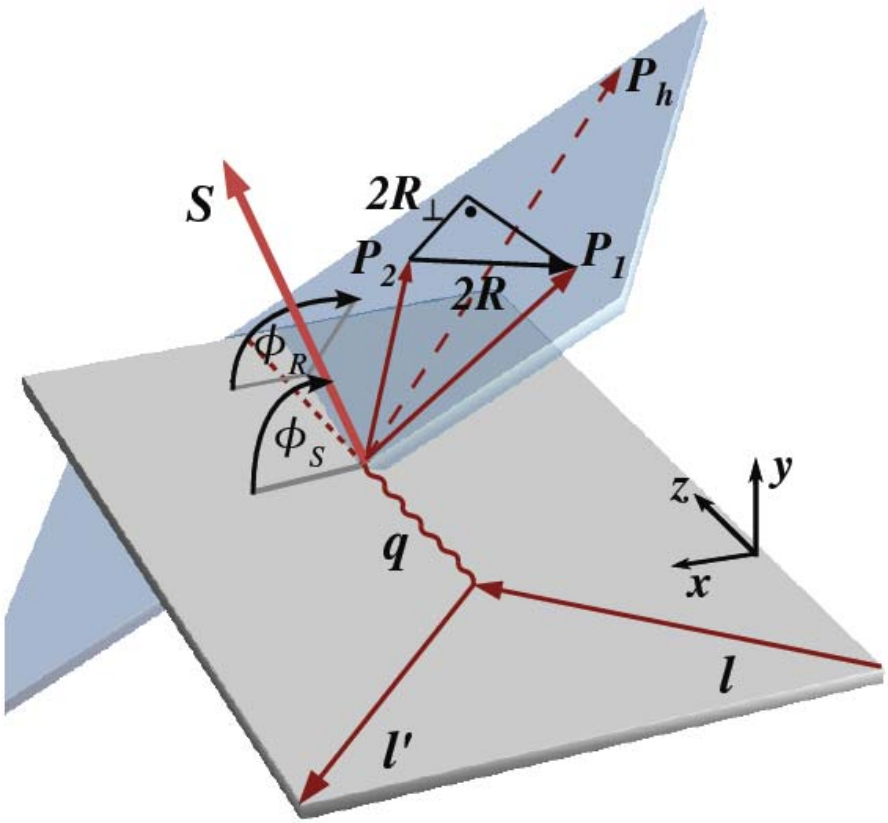
Transversity: global fit

- Fit to $A_d^{Coll}(x)$ from COMPASS and $A_p^{Coll}(x)$ from HERMES and Collins fragmentation function from BELLE (e^+e^- scattering)
- in good agreement with new proton data





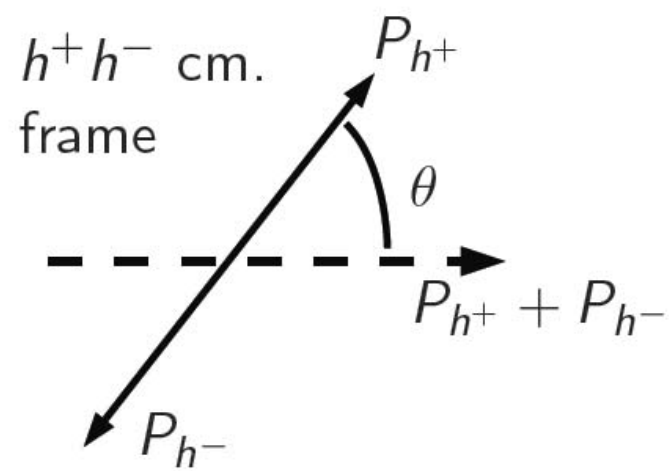
Transversity: dihadron-interference



$\rightsquigarrow$ azimuthal asymmetry:

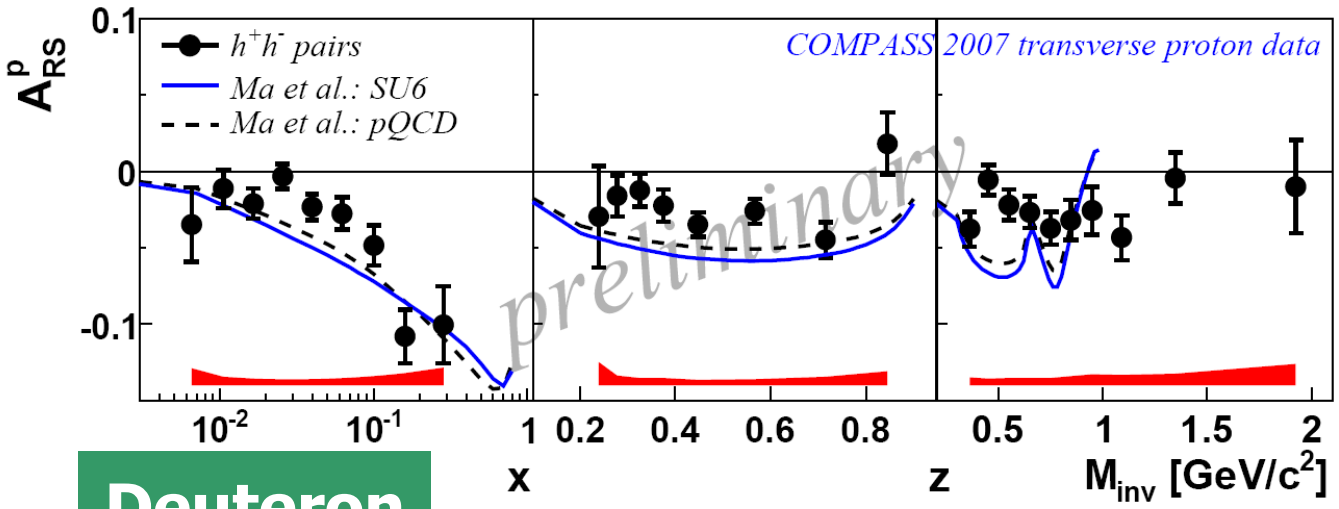
$$N_{h^+h^-} \propto 1 \pm A \cdot \sin\phi_{RS} \cdot \sin\theta$$

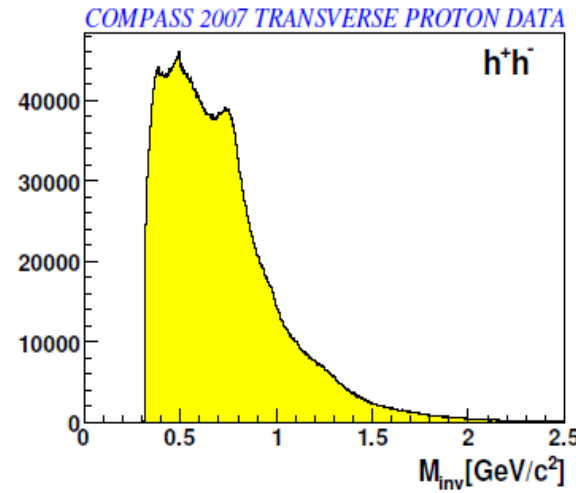
$$\boxed{\phi_{RS} = \phi_R + \phi_S - \pi}$$



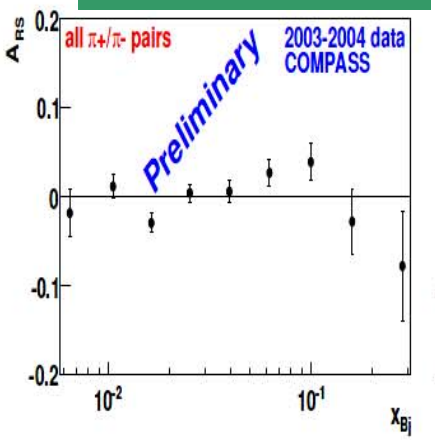
Transversity: dihadron interference

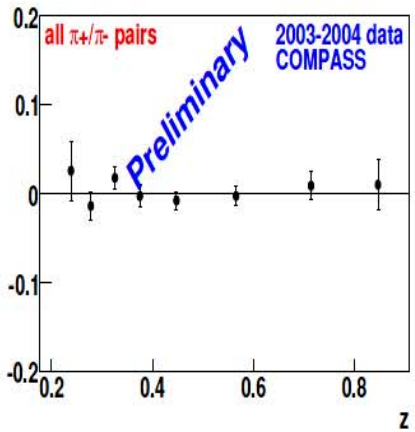
Proton

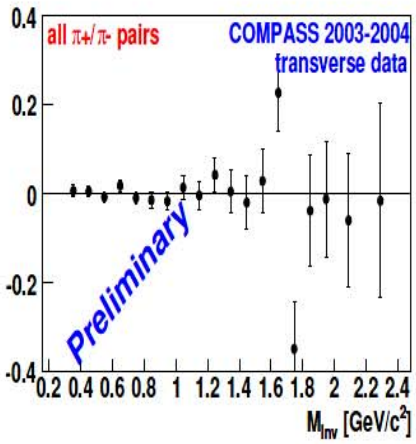


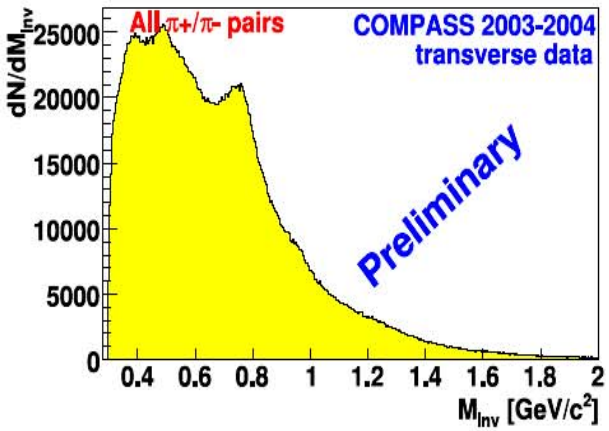


Deuteron



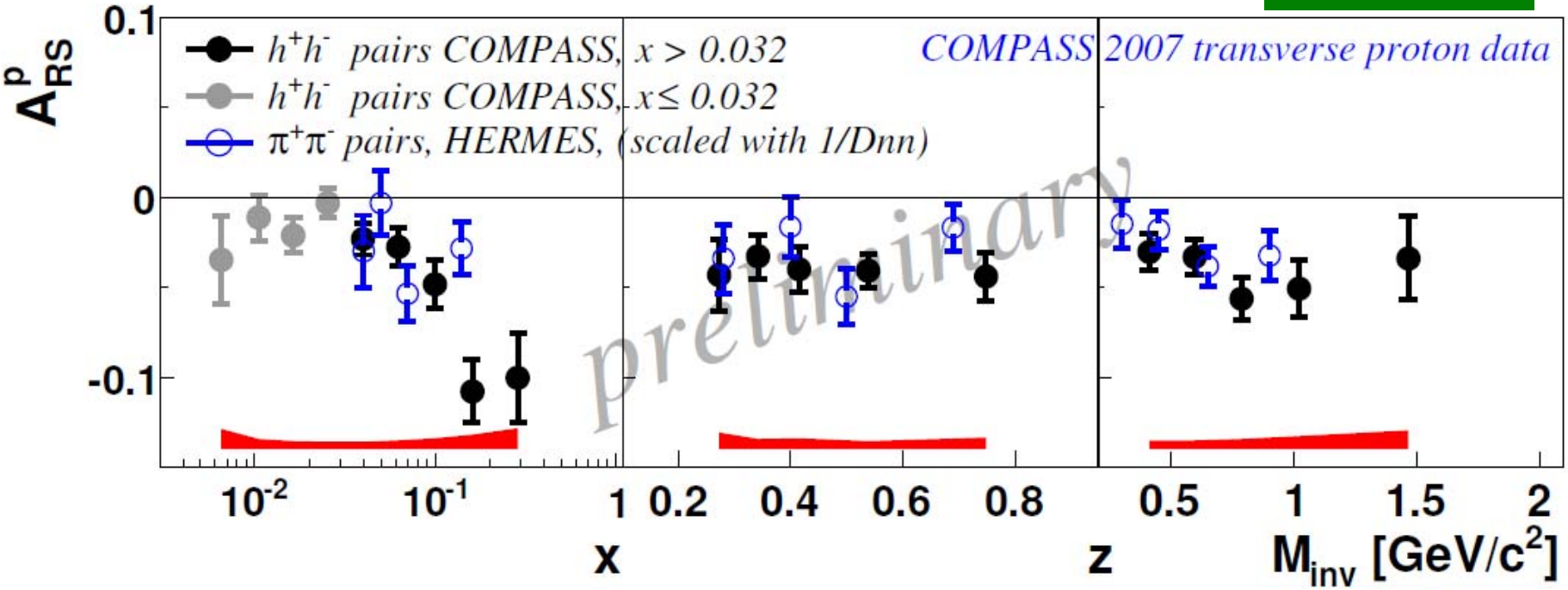






Comparison COMPASS-HERMES

Proton

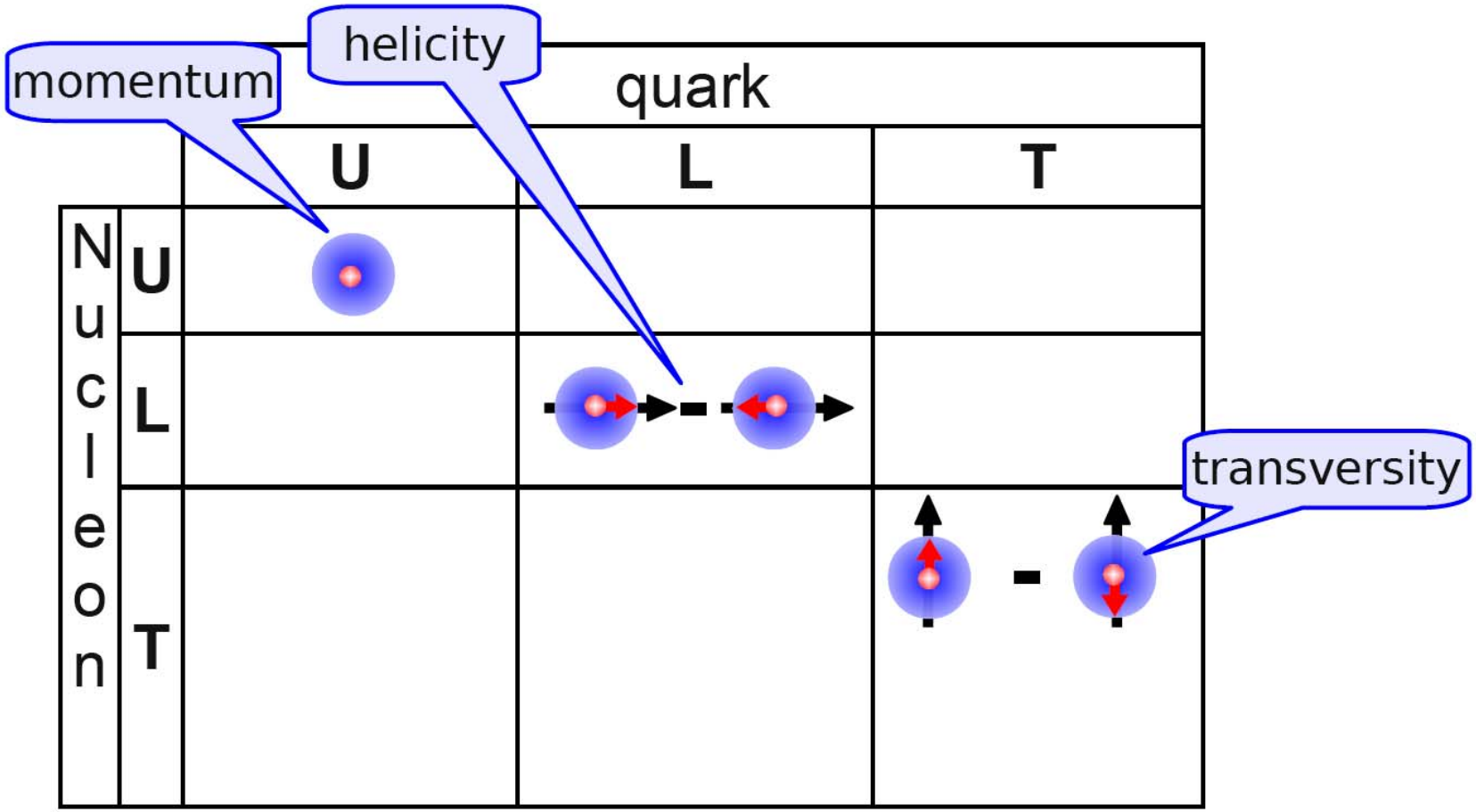


HERMES values scaled with $1/D_{nn}$

Global fit possible when interference fragmentation function measured (BELLE)

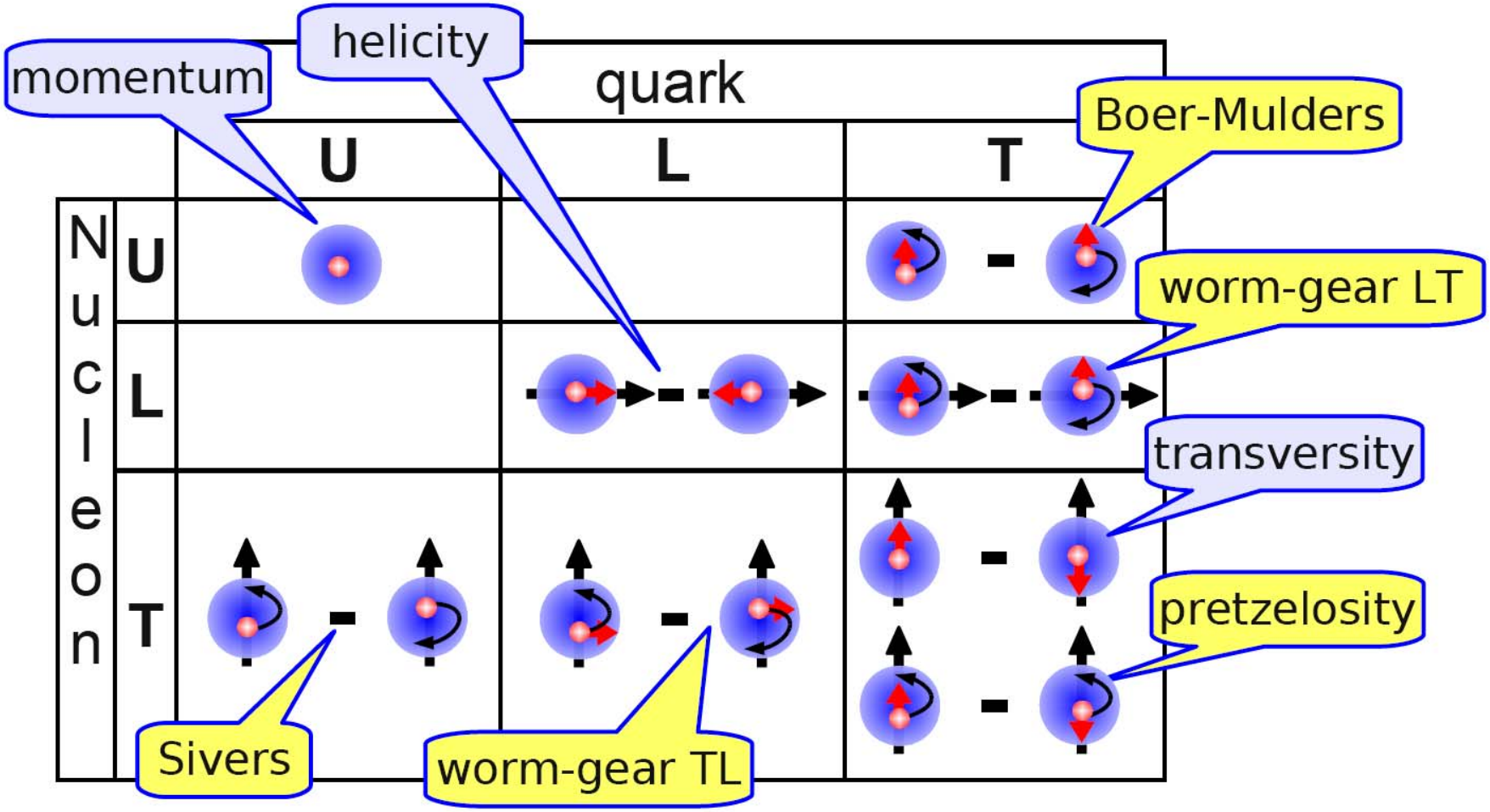
TMDs

Three parton distribution functions when integrating over $k_\perp$



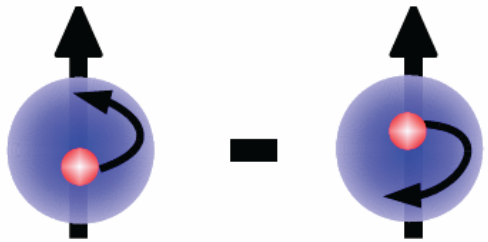
TMDs

Eight parton distribution functions when taking into account $k_\perp$

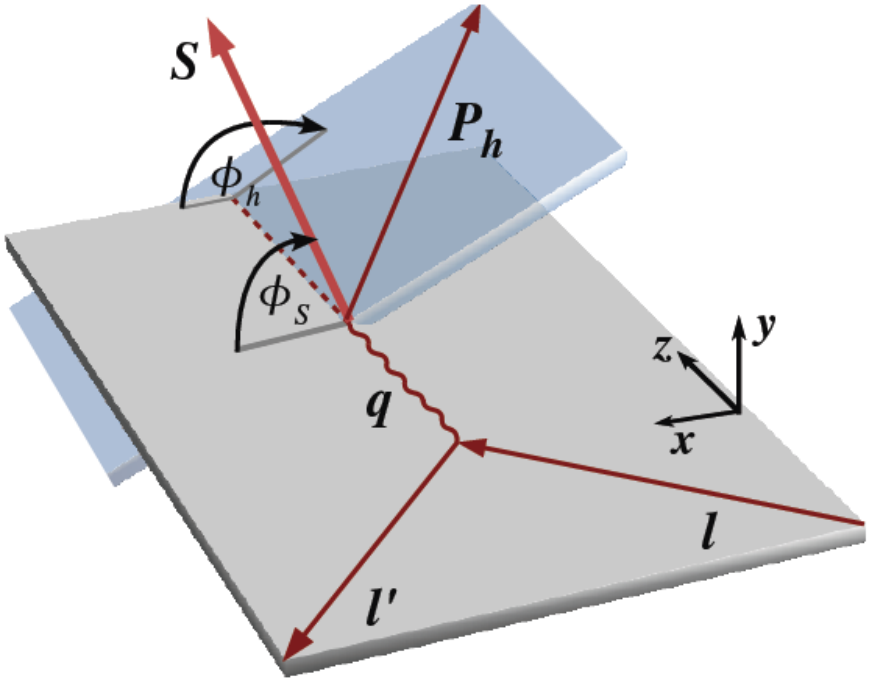


Sivers effect

Sivers PDF $\Delta_0^T q$:



correlation between intrinsic transverse momentum
of the quarks and the transverse polarization of the nucleon



$\rightsquigarrow$ azimuthal asymmetry:

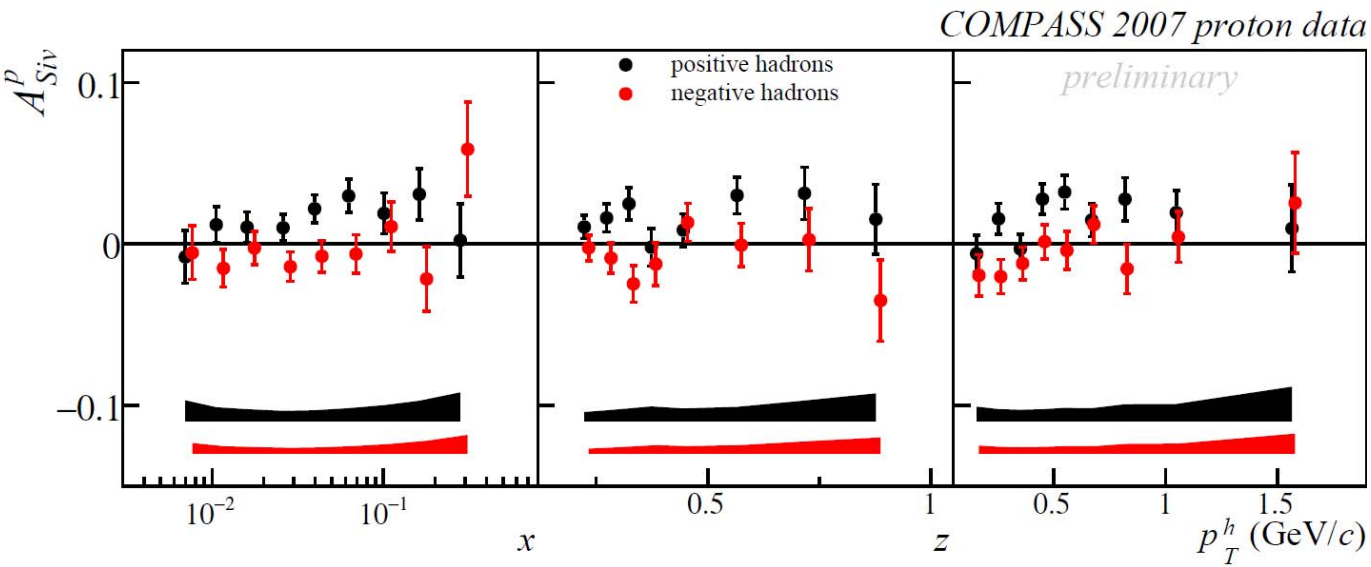
$$N_h \propto 1 \pm A \cdot \sin(\phi_h - \phi_S)$$

ϕ_h: azimuthal angle of hadron

ϕ_S: azimuthal angle of spin of initial quark

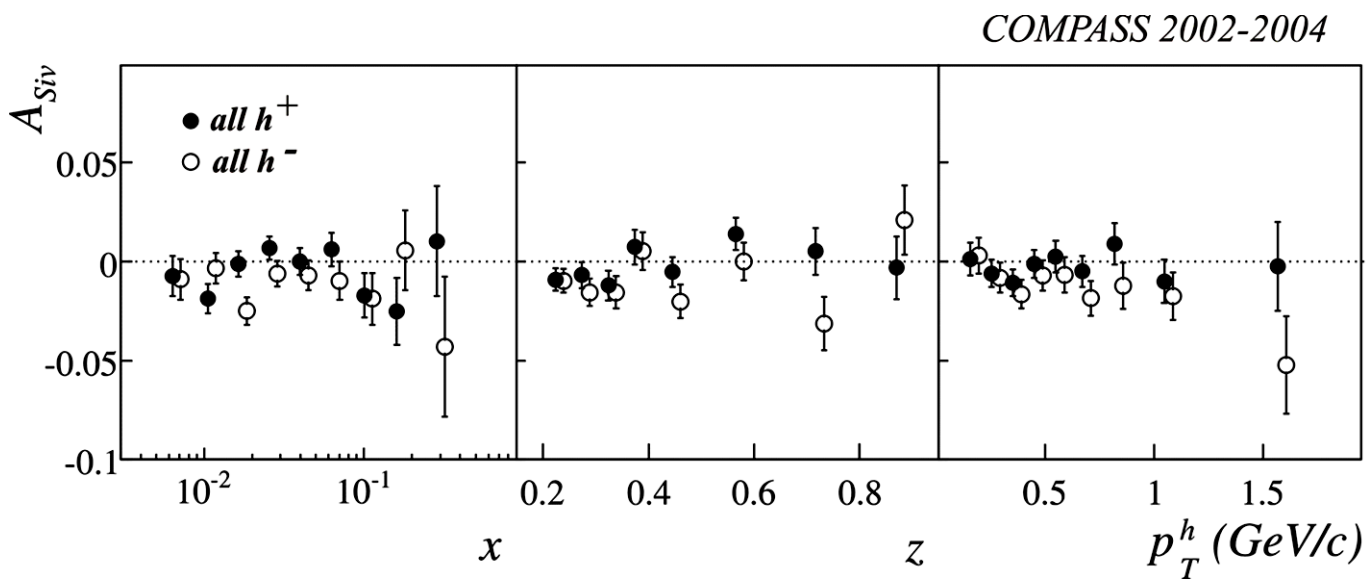
$$A_{Siv} = \frac{A}{f\ P_T} \propto \sum_q e_q^2 \cdot \Delta_0^T q \otimes D_q^h$$

Sivers asymmetries



Proton

pos. asymmetry for pos. hadrons

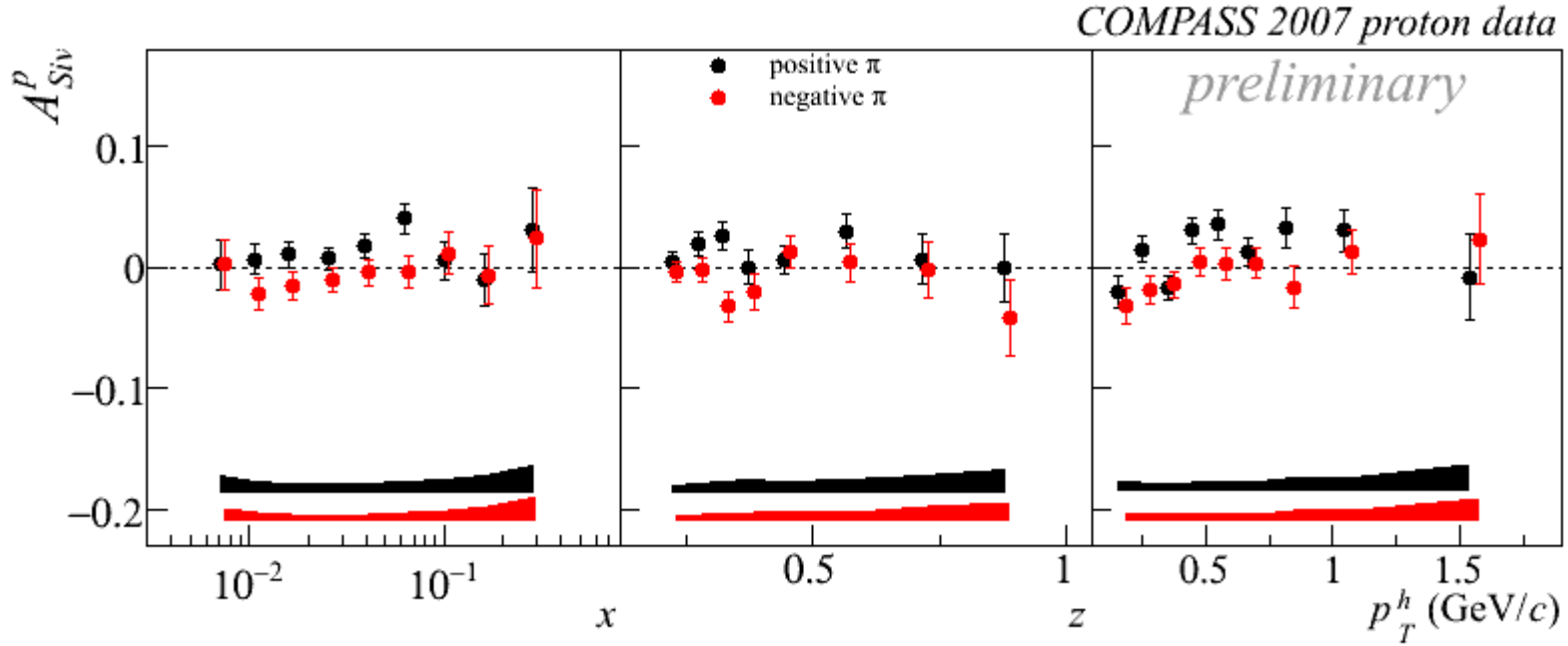


Deuteron

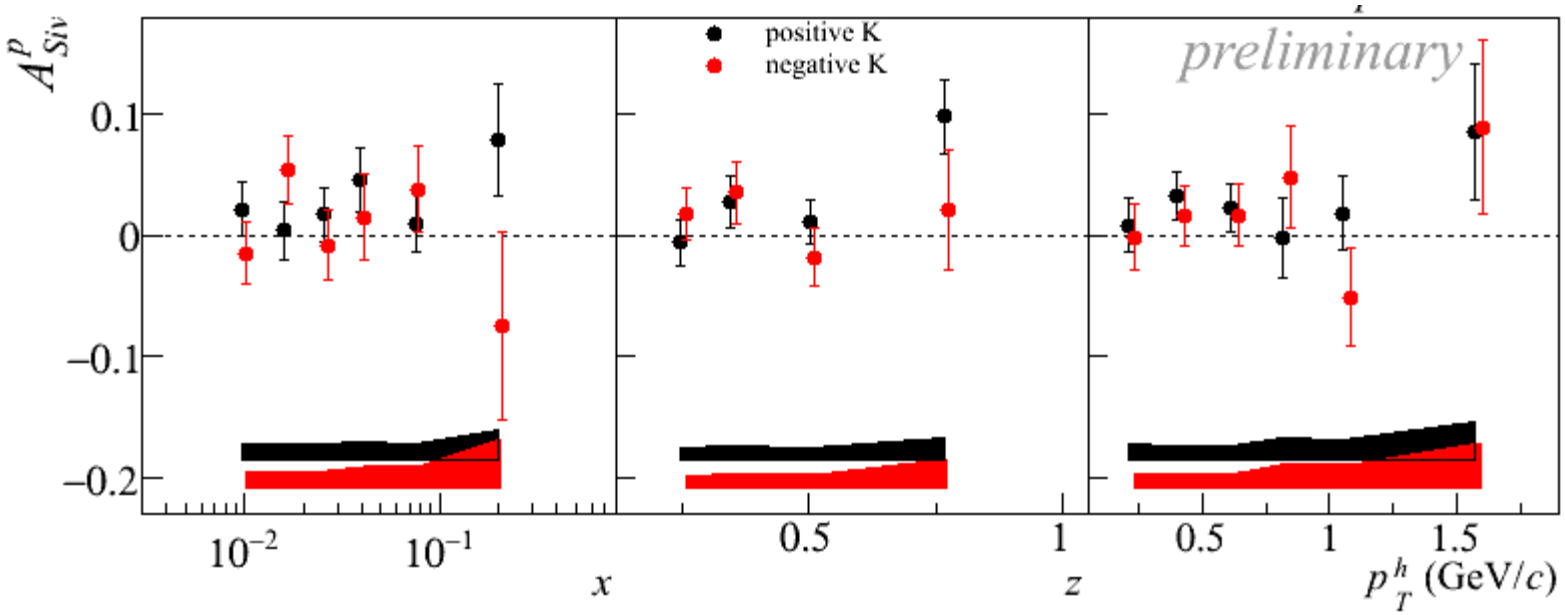
compatible with zero

PLB 692 (2010), 240
PLB 673 (2009), 127

New results for identified hadrons

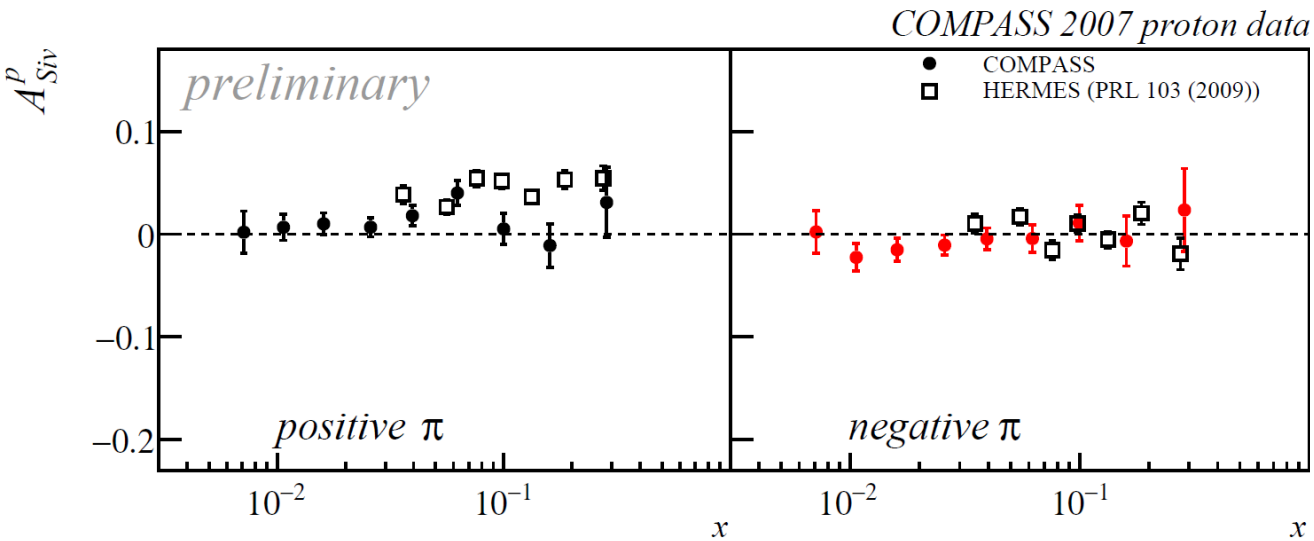


π^{+-}

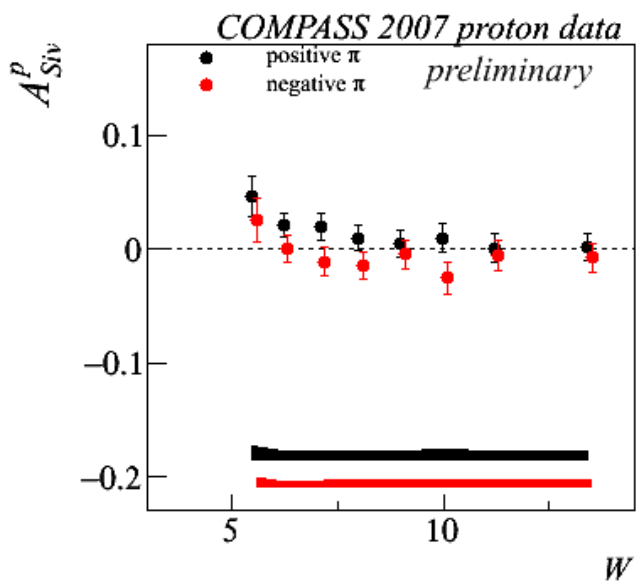


K^{+-}

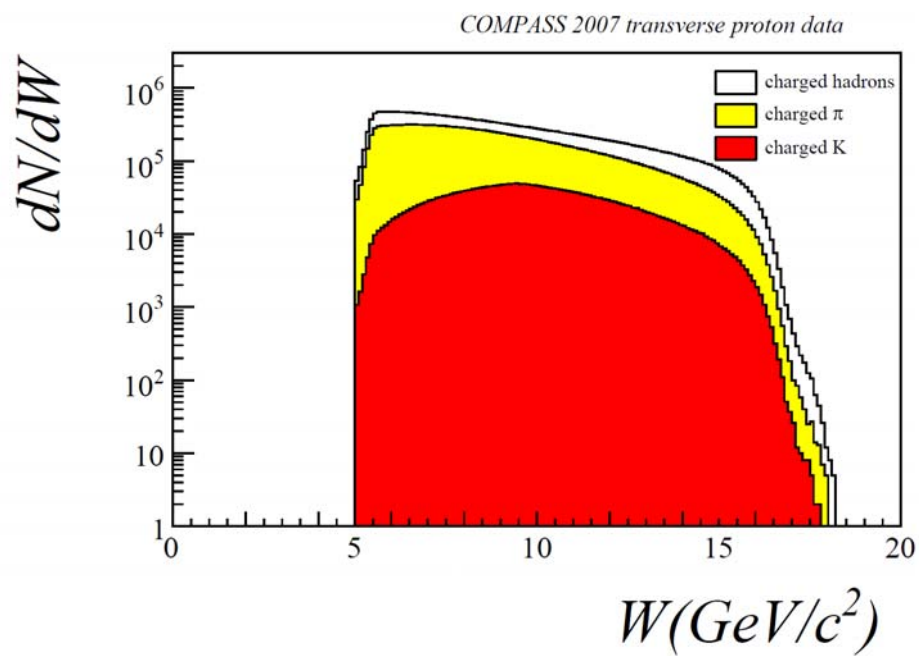
Sivers: Comparison with HERMES



π^+

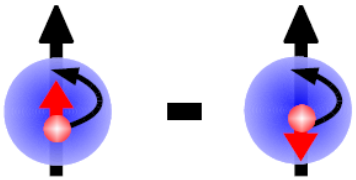


possible W dependence

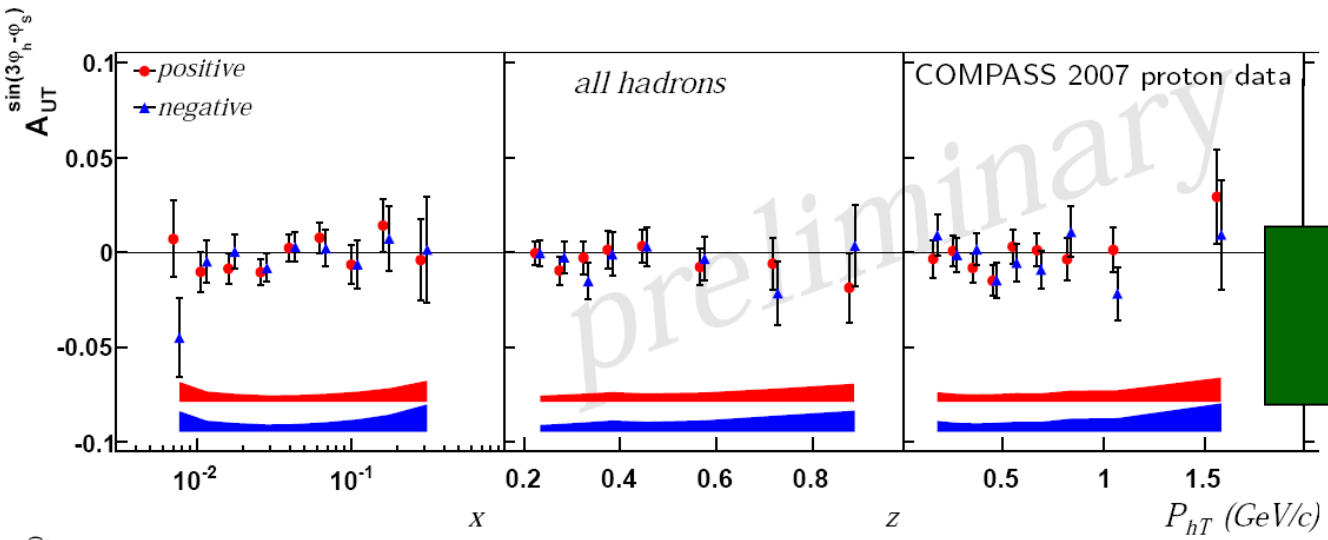


Pretzelosity

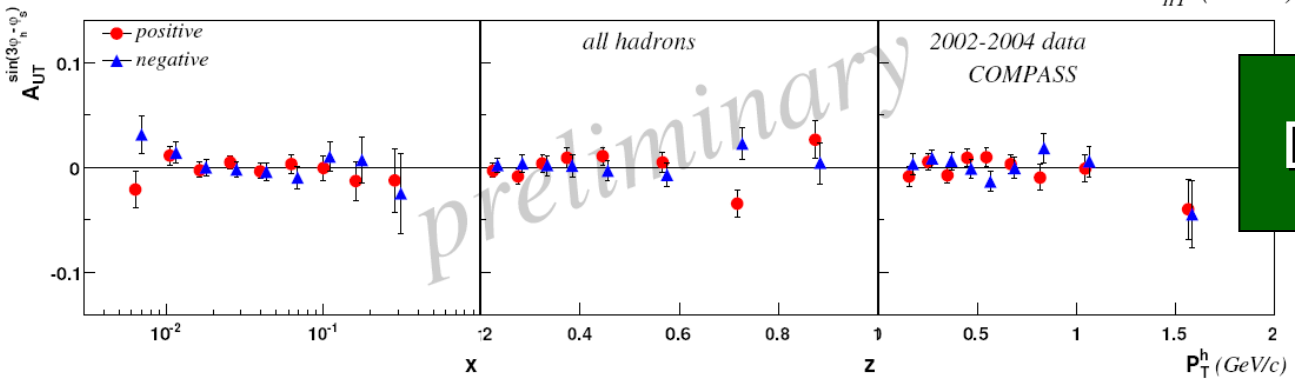
$F_{UT}^{\sin(3\phi_h-\phi_S)} \propto h_{1T}^{\perp,q} \otimes \Delta_T^0 D_q^h$, Pretzelosity PDF $h_{1T}^{\perp,q}$:



correlation of parton transv. momentum and transv. polarization in a transversely polarized nucleon



Proton

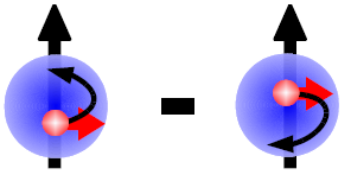


Deuteron

Worm-Gear

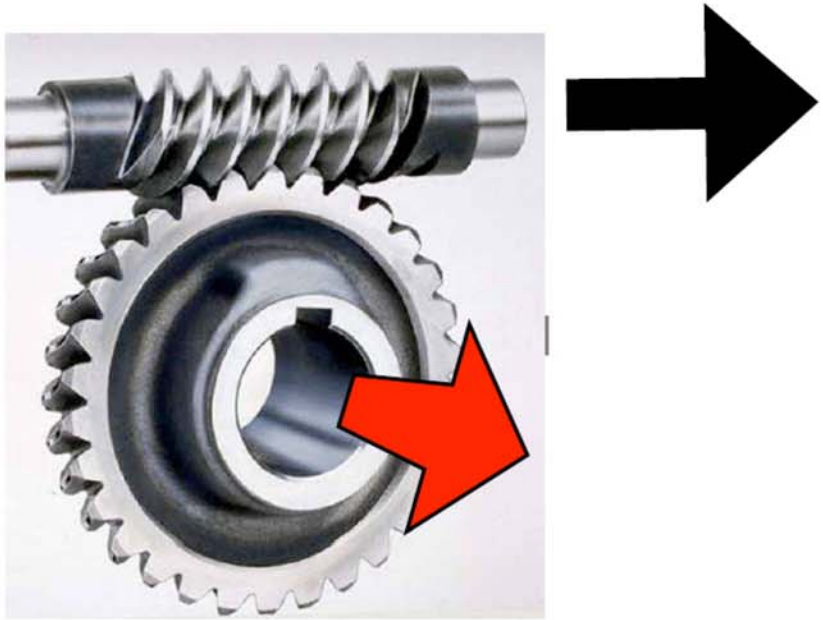
$F_{LT}^{\cos(\phi_h-\phi_S)} \propto g_{1T}^q \otimes D_q^h$,

worm-gear PDF g_{1T}^q:



correlation of parton transv. momentum and long. polarization in a transversely polarized nucleon

A worm gear

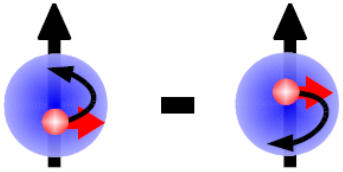


A. Bacchetta

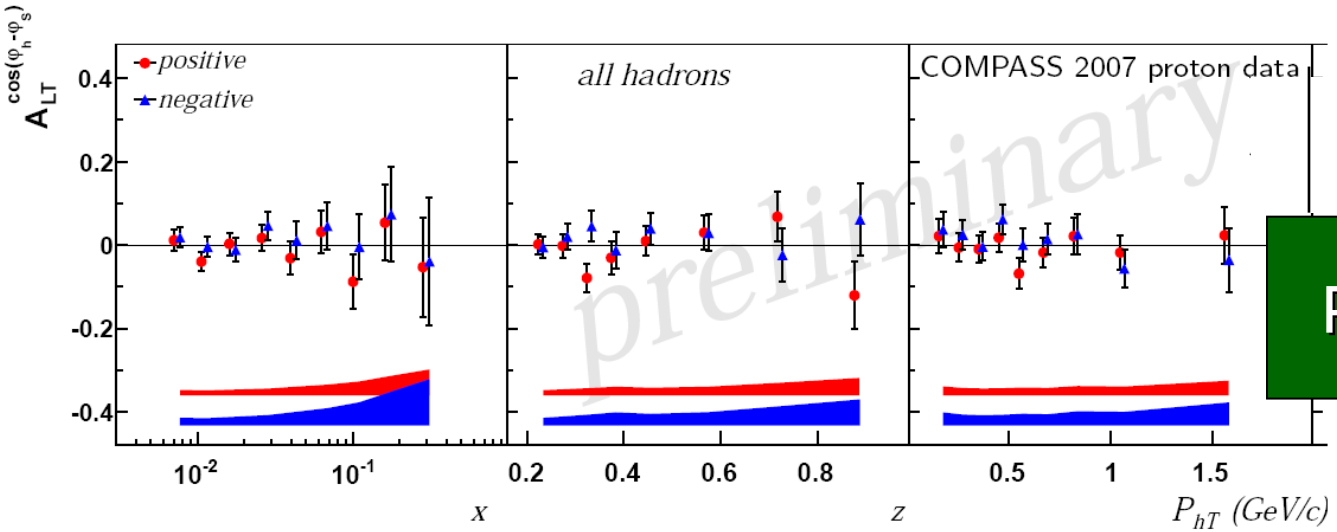
Worm-Gear

$F_{LT}^{\cos(\phi_h-\phi_S)} \propto g_{1T}^q \otimes D_q^h$,

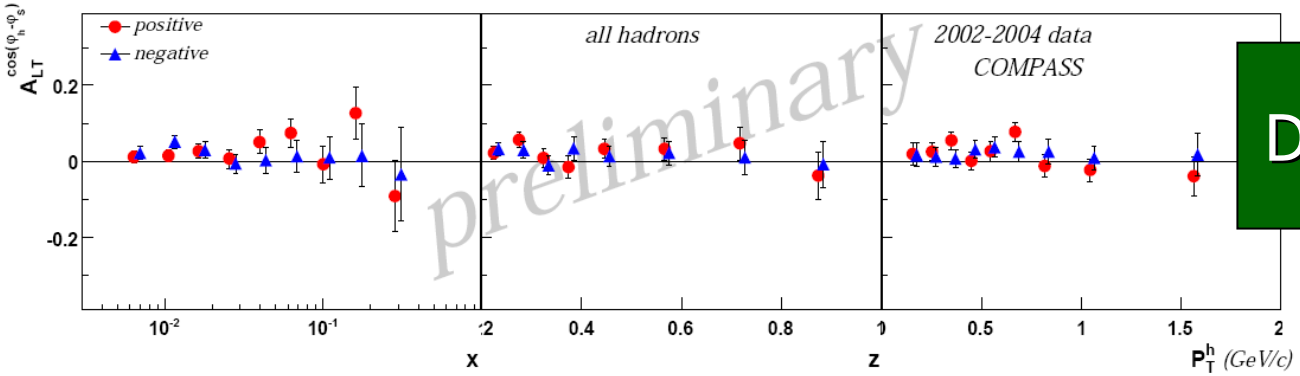
worm-gear PDF g_{1T}^q:



correlation of parton transv. momentum and long. polarization in a transversely polarized nucleon



Proton



Deuteron

Summary

COMPASS is a major player in transverse spin physics:

- PRESENT
  - Collins and Sivers asymmetries for π and K
  - two hadron interference asymmetries
  - 8 transverse momentum dependent TMDs

- NEAR FUTURE

  Improved statistics on proton target (2010 data)

- FUTURE (2012+)

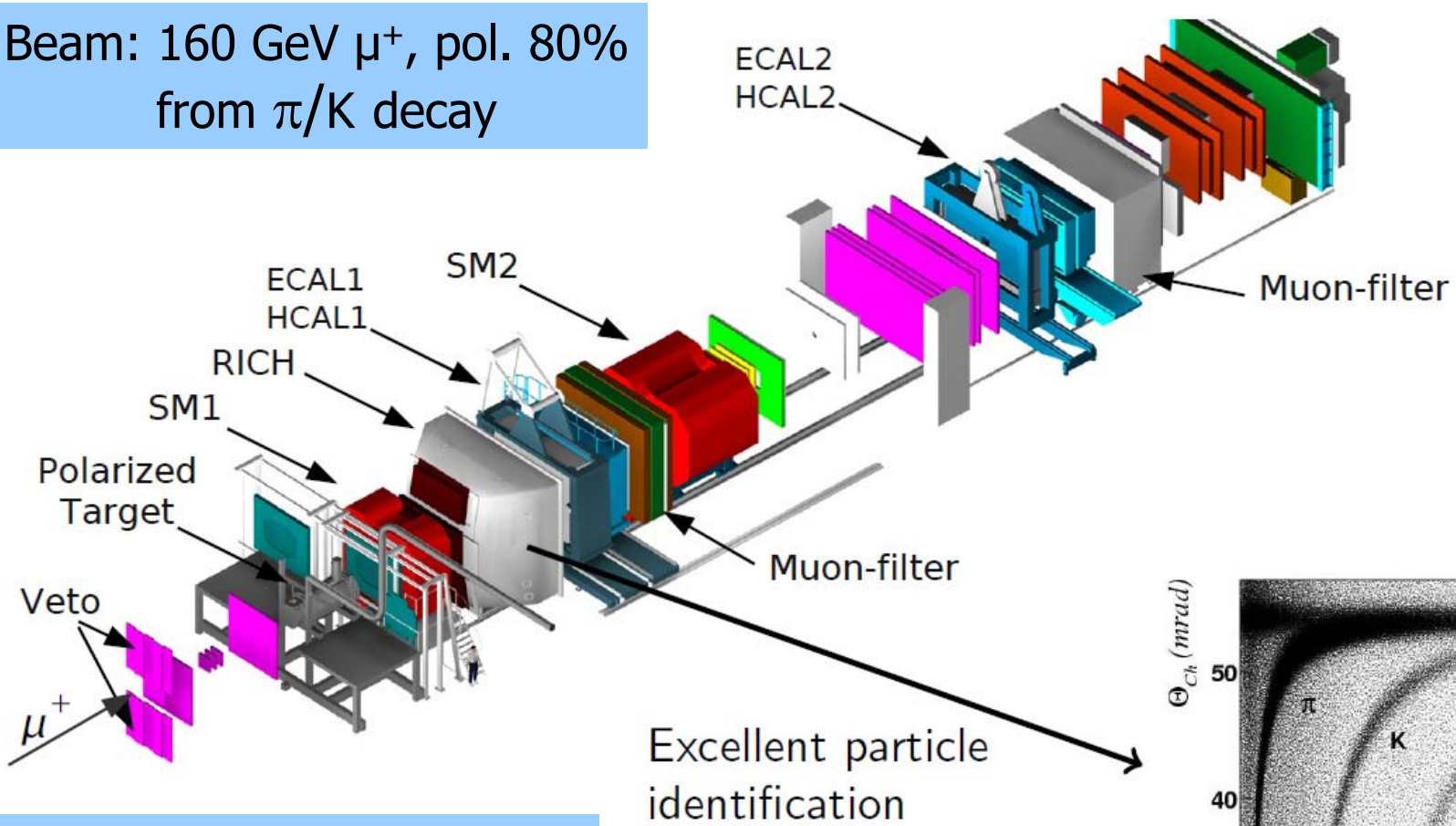
  COMPASS II: DRELL-YAN and GPD measurements

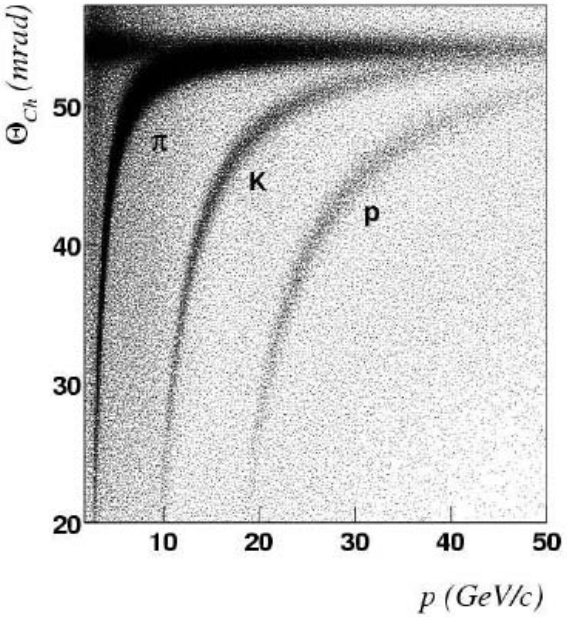
→ talks of Catarina Quintans:
today, 16.30 + tomorrow, 10.00

Spares

COMPASS

Beam: 160 GeV μ^+, pol. 80% from π/K decay





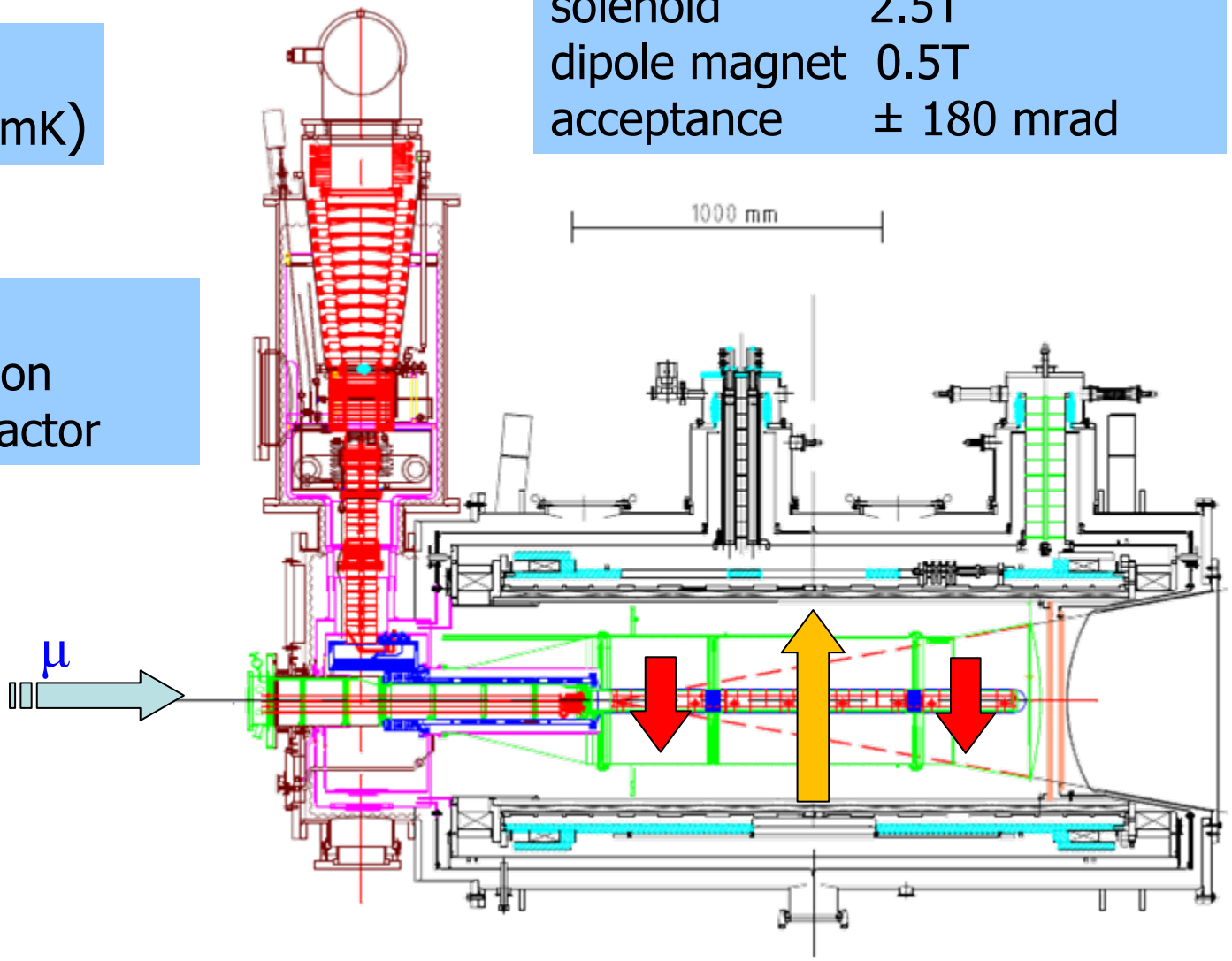
longitudinally or transversely polarized fixed target

COMPASS target system

^{3}He – ^{4}He dilution refrigerator (T~50mK)

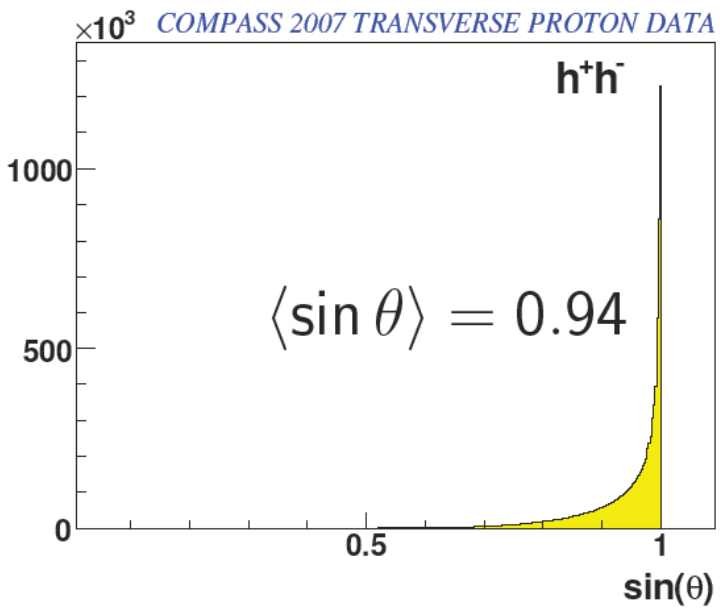
^{6}LiD or NH_3
50/90% polarization
40/16% dilution factor

solenoid	2.5T
dipole magnet	0.5T
acceptance	± 180 mrad



Dihadron-interference

Measuring transversity with Dihadron-Interference-FF $H_1^{\sphericalangle}$:



$\rightsquigarrow$ azimuthal asymmetry:

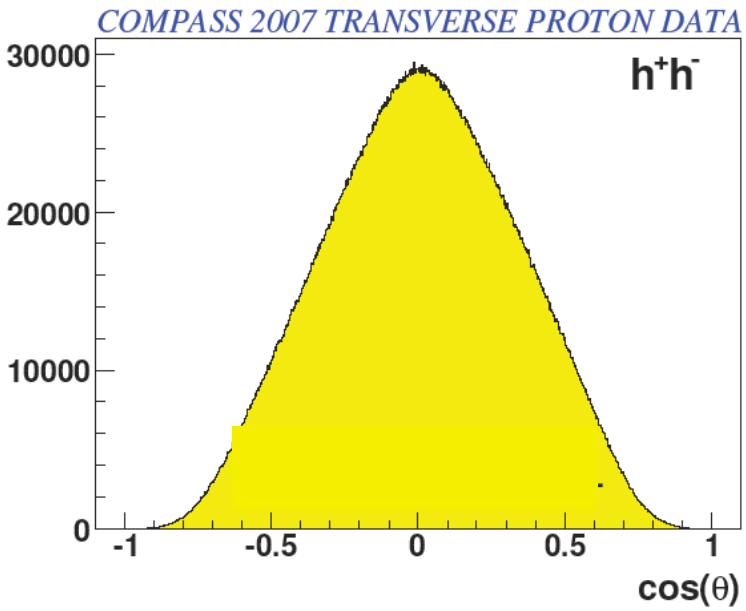
$$N_{h^+h^-} \propto 1 \pm A \cdot \sin\phi_{RS} \cdot \sin\theta$$

$$\phi_{RS} = \phi_R + \phi_S - \pi$$

For this analysis:
$\sin\theta$ can be neglected

Dihadron-interference

Measuring transversity with Dihadron-Interference-FF $H_1^{\sphericalangle}$:



$\rightsquigarrow$ azimuthal asymmetry:

$$N_{h^+h^-} \propto 1 \pm A \cdot \sin\phi_{RS} \cdot \sin\theta$$

$$\phi_{RS} = \phi_R + \phi_S - \pi$$

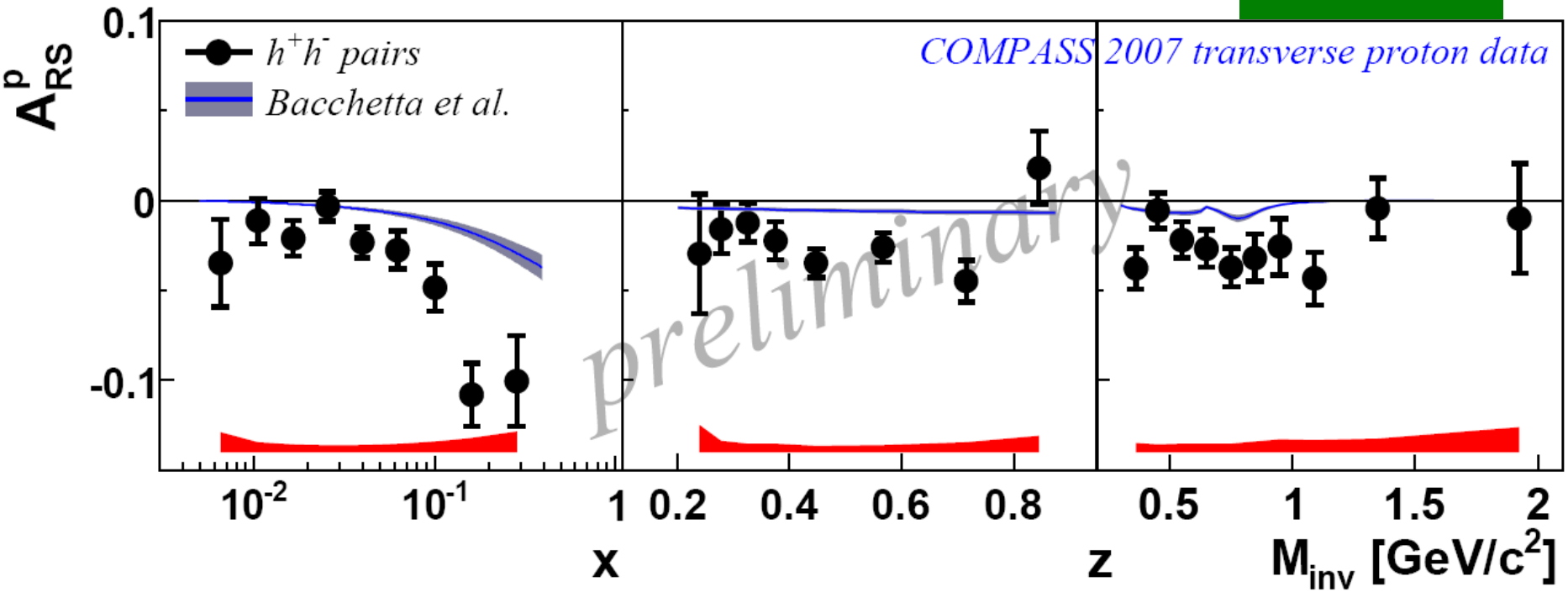
$$A_{RS} = \frac{A}{f\ P_T D_{nn}} \propto \sum_q e_q^2 \cdot \Delta_T q \cdot H_1^{\sphericalangle}$$

$$H_1^{\sphericalangle} = H_1^{\sphericalangle,sp} + \cos\theta\, H_1^{\sphericalangle,pp}$$

$\rightsquigarrow$ only sensitive to $H_1^{\sphericalangle,sp}$

Dihadron-interference

Proton

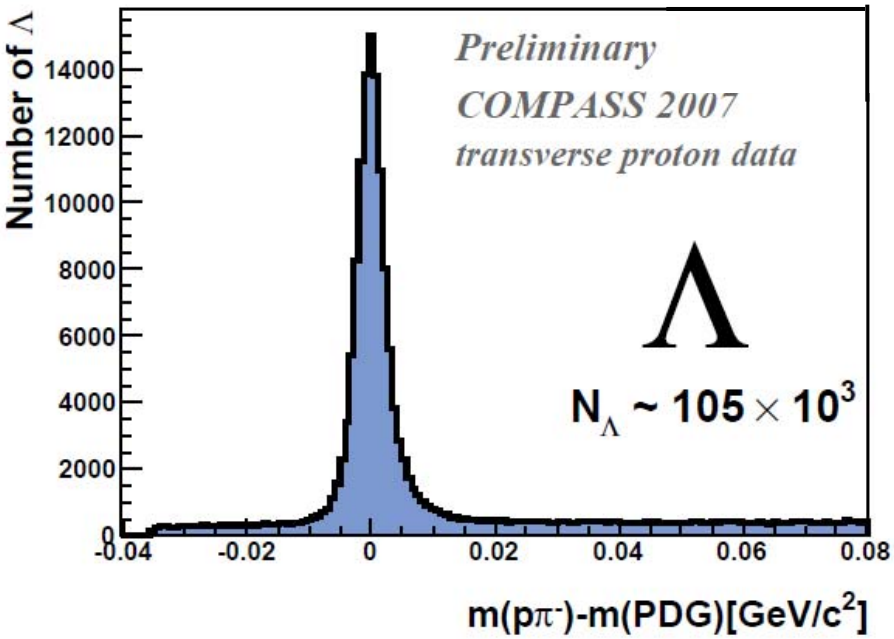


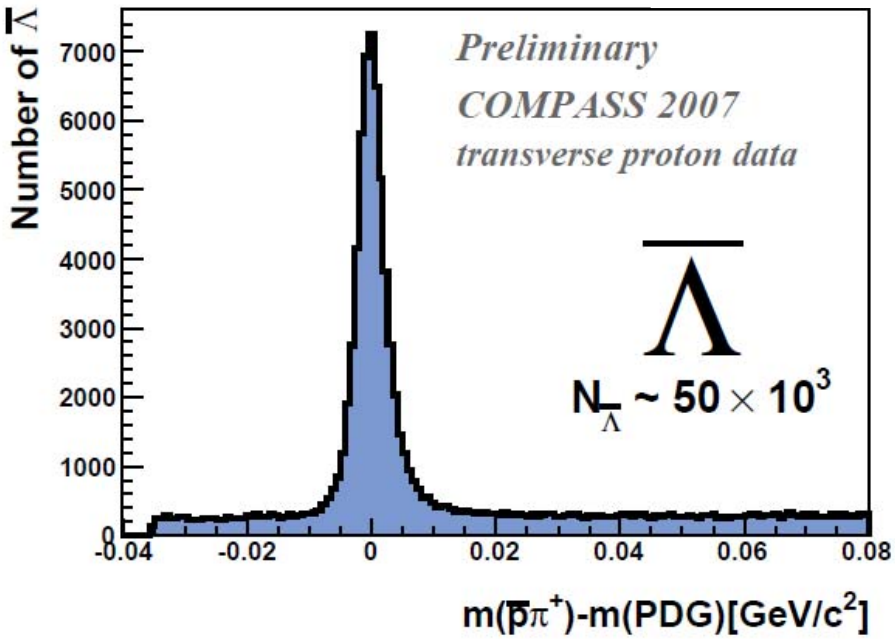
Prediction by Bacchetta, Radici, hep-ph/0608037
(Interference Fragmentation function scaled down to fit HERMES data)

Transverse Λ polarization

Λ-Polarization: $P_\Lambda \propto f\, P_T D_{nn} \sum_q e_q^2 \cdot \Delta_T q \cdot \Delta_T D_q^\Lambda$

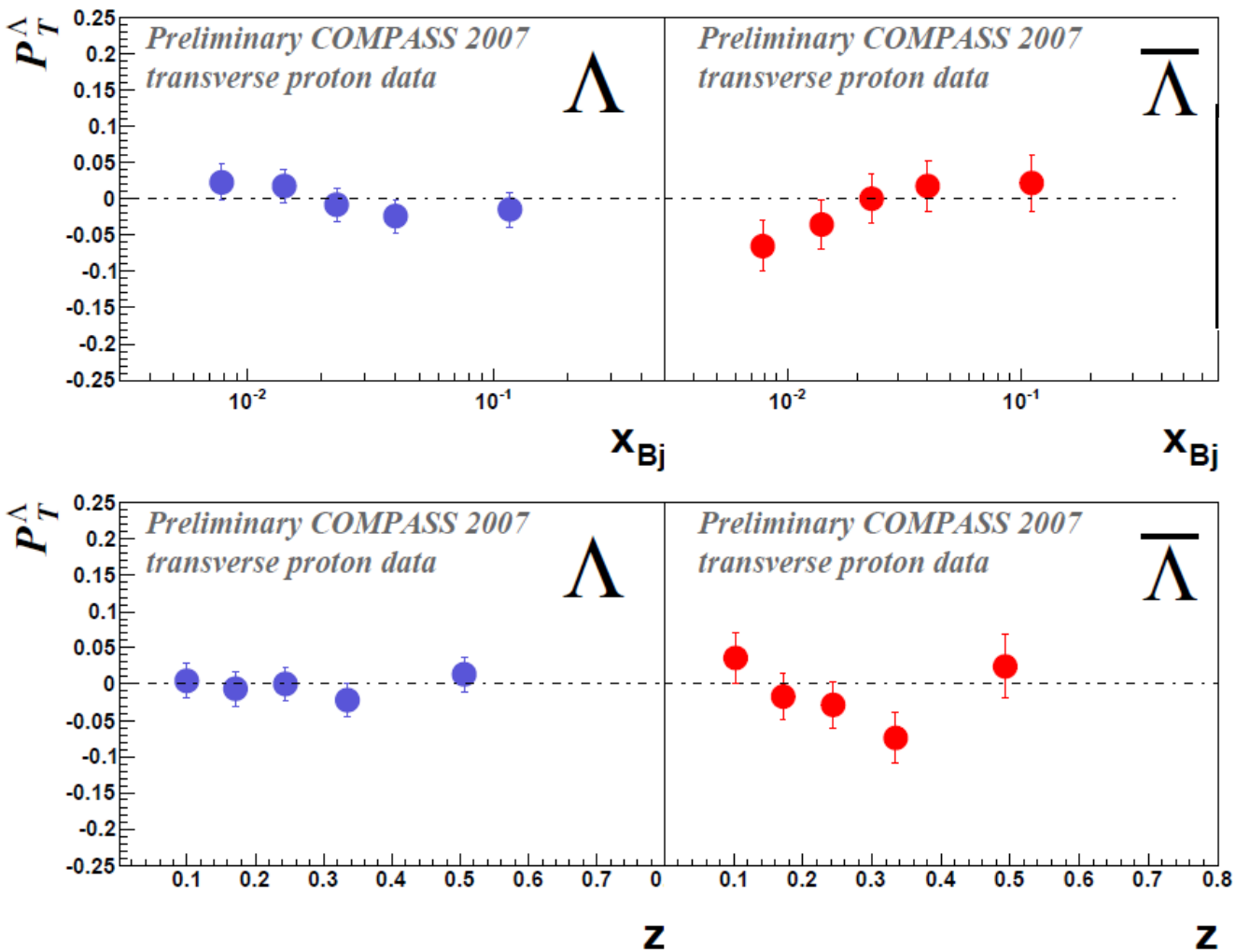
measured via parity violating decay





Transverse Λ polarization

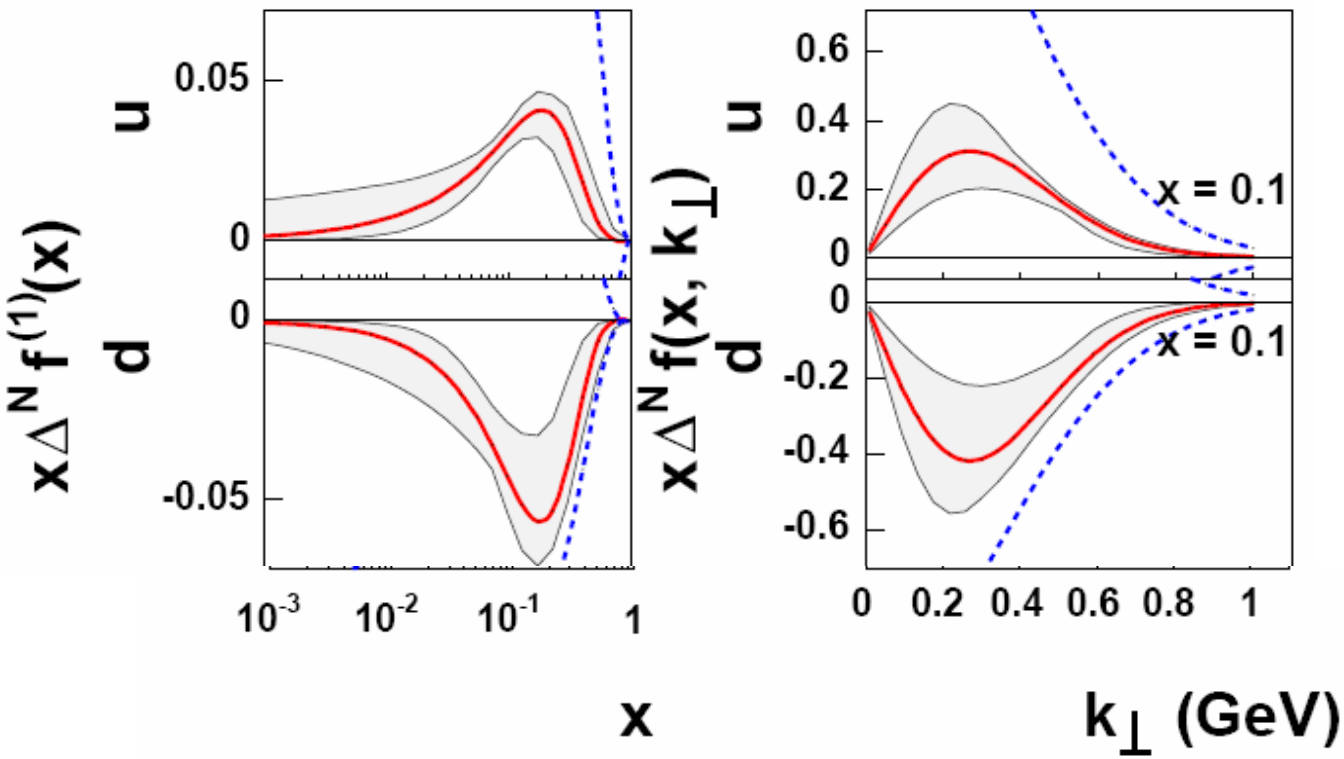
Proton



P_T^Λ, $P_T^{\bar{\Lambda}}$ small, compatible with zero $\rightsquigarrow$ small analyzing power of $\Delta_T D_q^\Lambda$

Sivers distribution function

Global fit using $A_d^{Siv}(\pi^{\pm})$ and $A_d^{Siv}(K^{\pm})$ from COMPASS and $A_p^{Siv}(\pi^{\pm})$ and $A_p^{Siv}(K^{\pm})$ from HERMES:



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