Point-by-point extraction of parton distribution functions from SIDIS single transverse–spin asymmetries

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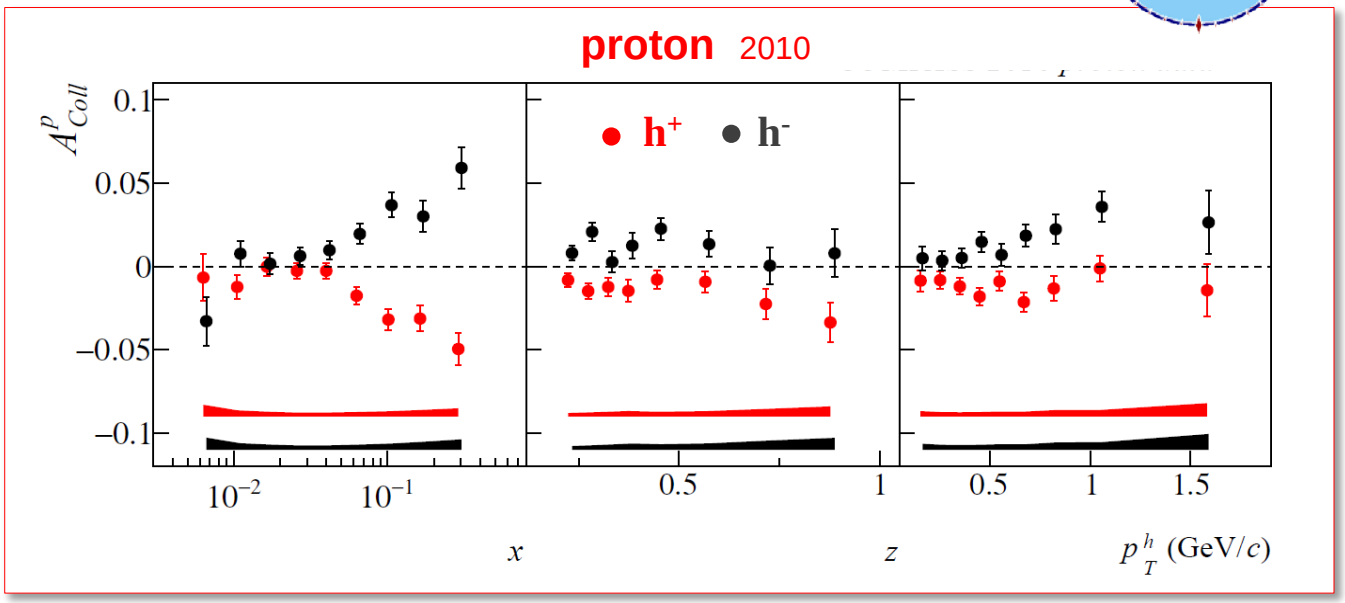
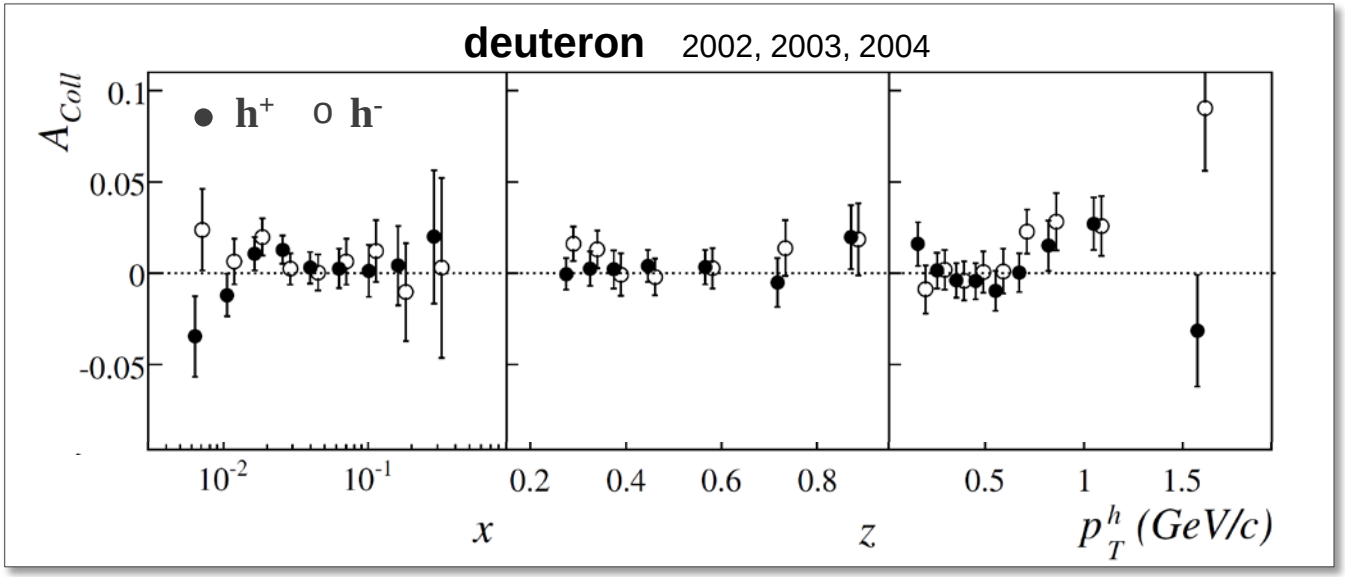
Trieste, 21 July 2017

COMPASS results on Collins asymmetry

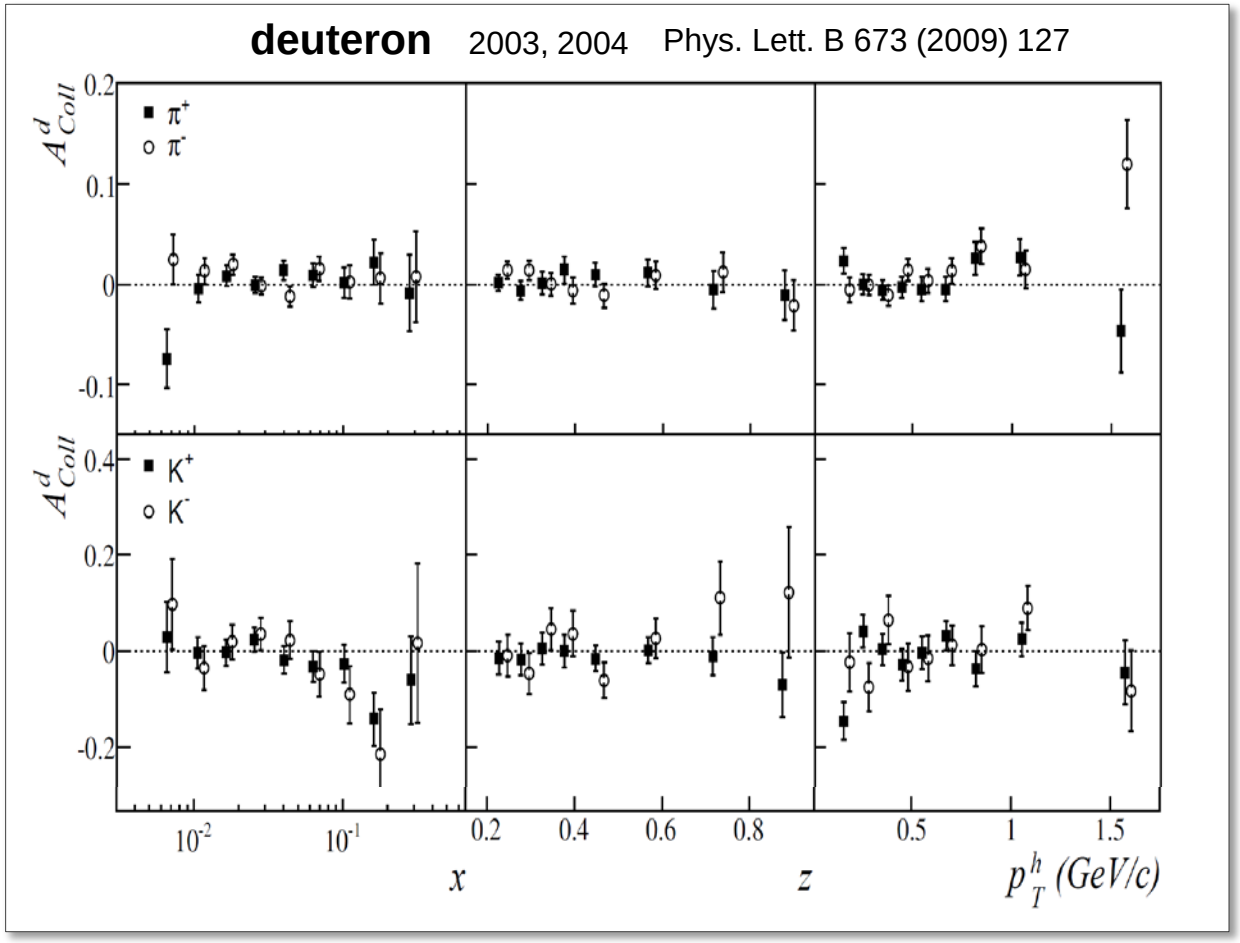
Phys. Lett. B 717 (2012) 376



Nucl. Phys. B765 (2007) 31

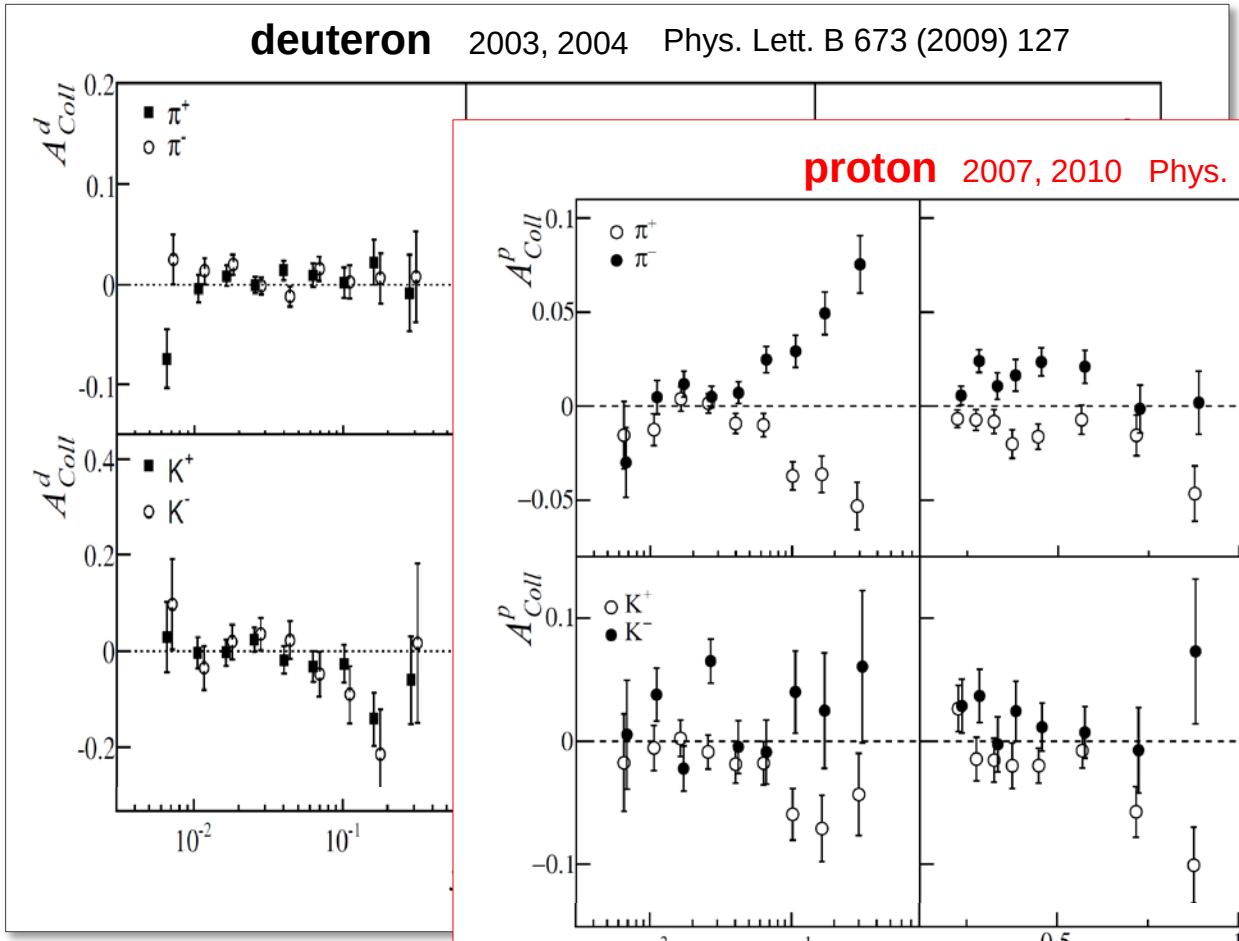


COMPASS results on Collins asymmetry



COMPASS results on Collins asymmetry

deuteron 2003, 2004 Phys. Lett. B 673 (2009) 127



proton 2007, 2010 Phys. Lett. B 744 (2015) 250

Phys. Lett. B 717 (2012)

Transversity from COMPASS p and d results

COMPASS results already used to extract the transversity PDFs

- **Collins asymmetry (COMPASS p and d, HERMES p, Belle)**
  Anselmino et al., Kang et al., …

- **Dihadron asymmetry (COMPASS p and d, HERMES p, Belle)**
  Bacchetta et al.

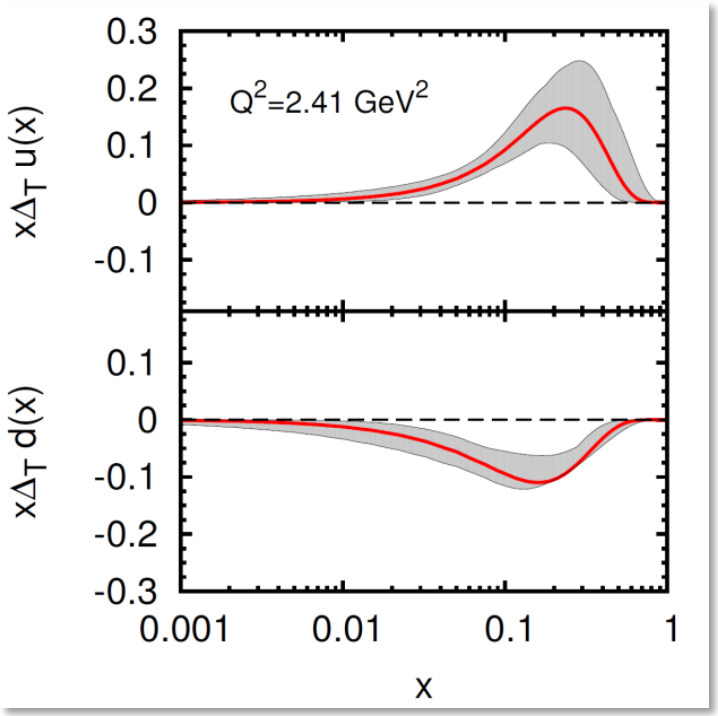
using parametrisations for transverity and spin-dependent FFs

Transversity from Collins asymmetries

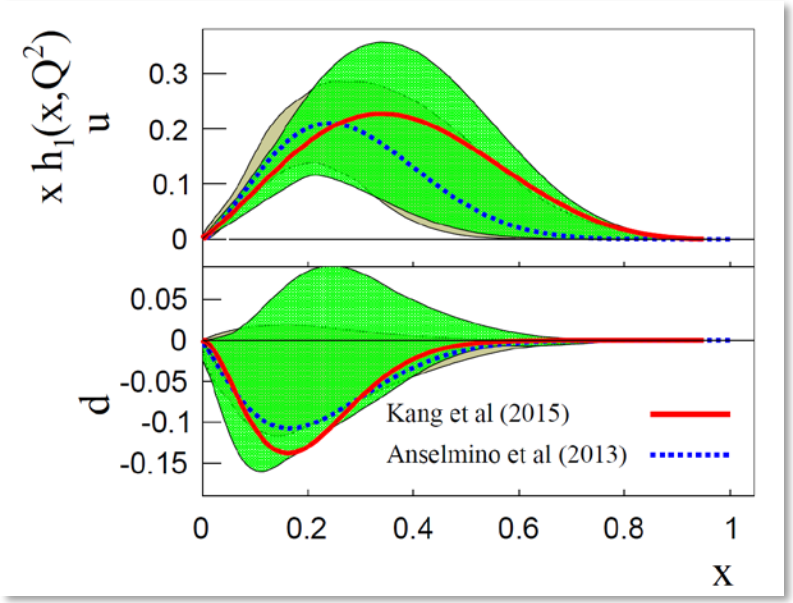
COMPASS results already used to extract the transversity PDFs

- **Collins asymmetry (COMPASS p and d, HERMES p, Belle)**

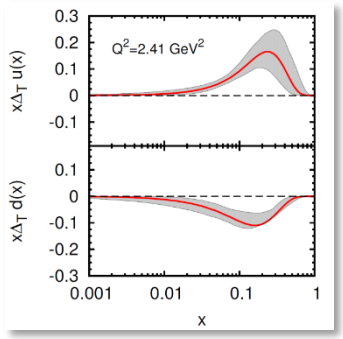
Anselmino et al. 2013

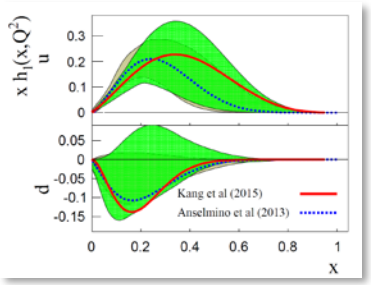


Kang et al. 2015



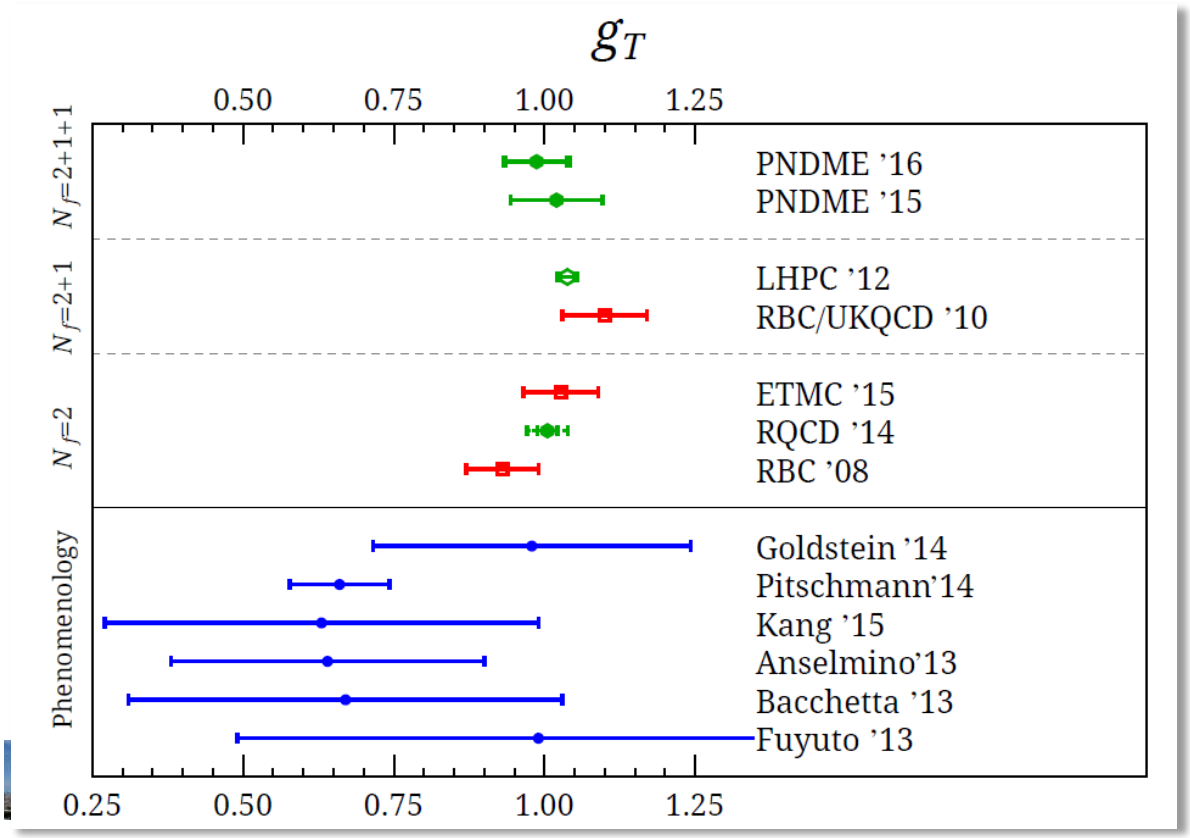
Transversity from Collins asymmetries





$$\int_0^1 dx[h_1^q(x) - \bar{h}_1^q(x)] = \delta q.$$

$$g_T = \delta u - \delta d$$



T. Bhattacharya et al.,
Phys. Rev. D 94 (2016) 054508

Transversity from COMPASS and Belle data

POINT - BY - POINT EXTRACTION:

results obtained using

- **Belle results for pion and pion-pair asymmetries**

  PRL 107(2011)072004, PRD78(2008)032011 / 86(2012)039905

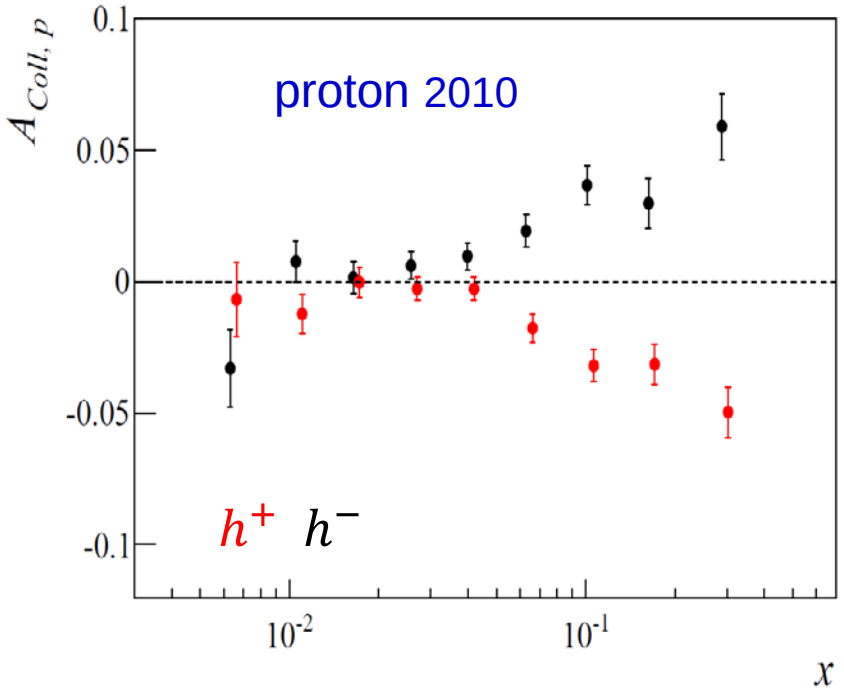
- **COMPASS results on**
  - **p and d dihadron asymmetries vs x** (integrated over z, M)
  - **p and d Collins asymmetry vs x** (integrated over z, p_T)

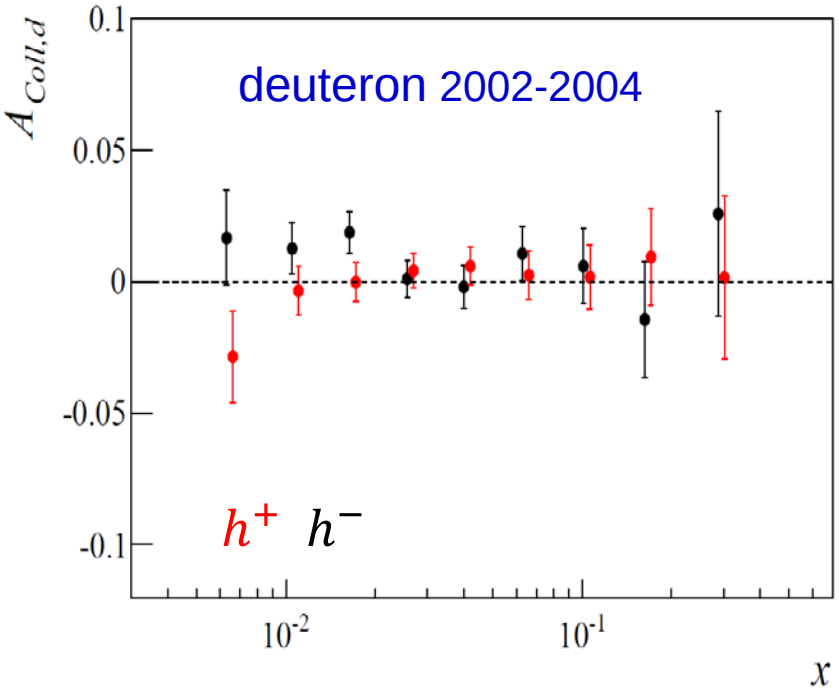
  h^+ and h^- assuming that all hadrons are pions

- **unpolarised PDFs and FFs parametrizations**
  - **PDFs: CTEQ5D**
  - **FFs: DSS LO**

- first shown @ QCD Evolution 2014, in Santa Fe, NM
- then @ SPIN 2014 in Beijing, China
- published as A. Martin, F. Bradamante and V. Barone, Phys.Rev. D91 (2015) no.1, 014034

Collins asymmetry – COMPASS data





charged hadrons

Collins asymmetry – COMPASS data

$$A^h_{Coll}(x,z) = \frac{\sum_{q\bar{q}} e_q^2 x h_1^q(x) \otimes H_{1q}^{\perp h}}{\sum_{q\bar{q}} e_q^2 x f_1^q(x) \otimes D_{1q}^h}$$

"gaussian ansatz":

$$A^{\pm}_{Coll}(x,z) = C_G \cdot \frac{\sum_{q,\bar{q}} e_q^2 x h_1^q(x) H_{1q}^{\pm}(z)}{\sum_{q,\bar{q}} e_q^2 x f_1^q(x) D_{1q}^{\pm}(z)} \qquad H_{1q}^{\pm} = H_{1q}^{\perp(1/2)\, h^{\pm}}$$

$$C_G = \frac{1}{\sqrt{1 + z^2 < p_{h_1}^2 > / < p_{H_1}^2 >}}$$

Efremov et al., PRD73 (2006)

we have assumed

- $C_G = 1$
- the usual relations among the FFs
- $H_{1s}^{\pm} = H_{1\bar{s}}^{\pm} = 0$ and c quark contributions to be negligible

Collins asymmetry – COMPASS data

the measured asymmetries as function of x can be written as

$$A^{+}_{Coll,p} = \frac{< H_1^{fav} >}{< D_1^{fav} >} \frac{4(xh_1^u + \alpha x h_1^{\bar{u}}) + (\alpha x h_1^d + x h_1^{\bar{d}})}{d_p^+}$$

$$A^{-}_{Coll,p} = \frac{< H_1^{fav} >}{< D_1^{fav} >} \frac{4(\alpha x h_1^u + x h_1^{\bar{u}}) + (x h_1^d + \alpha x h_1^{\bar{d}})}{d_p^-}$$

$$A^{+}_{Coll,d} = \frac{< H_1^{fav} >}{< D_1^{fav} >} \frac{(xh_1^u + x h_1^d)(4+\alpha) + (x h_1^{\bar{u}} + x h_1^{\bar{d}})(1+4\alpha)}{d_d^+}$$

$$A^{-}_{Coll,d} = \frac{< H_1^{fav} >}{< D_1^{fav} >} \frac{(xh_1^u + x h_1^d)(4\alpha+1) + (x h_1^{\bar{u}} + x h_1^{\bar{d}})(4+\alpha)}{d_d^-}$$

$$\alpha = \frac{<H_1^{dis}>}{<H_1^{fav}>} = \begin{cases} -1 & \text{a1} \\ -\dfrac{< D_1^{dis} >}{< D_1^{fav} >} & \text{a2} \end{cases}$$

corresponding quantities with unpol PDFs and FFs

from Belle

Collins asymmetry – COMPASS data

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corresponding quantities with unpol PDFs and FFs

from Belle

in each x bin, the only unknowns are the

u, u-bar, d and d-bar

quark transversity PDFs

Collins asymmetry – Belle data

we have used the asymmetry (corrected for charm contribution)

$$A_{12}^{UL}(z_1, z_2) = \frac{< s^2 >}{< 1 + c^2 >} \left[P_U(z_1, z_2) - P_L(z_1, z_2) \right]$$

integrated over M_1, M_2

where

$$P_U(z_1, z_2) = \frac{\sum_q e_q^2 [H_{1q}^+(z_1) H_{1\bar{q}}^-(z_2) + H_{1q}^-(z_1) H_{1\bar{q}}^+(z_2)]}{\sum_q e_q^2 [D_{1q}^+(z_1) D_{1\bar{q}}^-(z_2) + D_{1q}^-(z_1) D_{1\bar{q}}^+(z_2)]}$$

$$P_L(z_1, z_2) = \frac{\sum_q e_q^2 [H_{1q}^+(z_1) H_{1\bar{q}}^+(z_2) + H_{1q}^-(z_1) H_{1\bar{q}}^-(z_2)]}{\sum_q e_q^2 [D_{1q}^+(z_1) D_{1\bar{q}}^+(z_2) + D_{1q}^-(z_1) D_{1\bar{q}}^-(z_2)]}$$

$$H_{1q}^{\pm} = H_{1\,(q\to\pi^{\pm})}^{\perp\,(1/2)}, \quad D_{1q}^{\pm} = D_{1\,(q\to\pi^{\pm})}$$

Efremov et al., PRD73 (2006)
Bacchetta et al., PLB659 (2008)
Anselmino et al., PRD75 (2007)
Seidl et al., PRD78 (2008)

Collins asymmetry – Belle data

for the FFs we have made the assumptions

$$H_1^{fav} = H_{1u}^{+} = H_{1d}^{-} = H_{1\bar{u}}^{-} = H_{1\bar{d}}^{+}$$
$$H_1^{dis} = H_{1u}^{-} = H_{1d}^{+} = H_{1\bar{u}}^{+} = H_{1\bar{d}}^{-}$$

(same for D)

ignoring the c and s quark contributions, in the case $z_1 = z_2 = z$ it is

$$A_{12}^{UL}(z) = \frac{< s^2 >}{< 1 + c^2 >} \left[\frac{H_1^{fav}(z)}{D_1^{fav}(z)}\right]^2 B(z)$$

where $B(z) = \dfrac{b(z)[1 + a^2(z)] - [1 + b^2(z)]a(z)}{b(z)[1 + b^2(z)]}$ $a(z) = \dfrac{H_1^{dis}(z)}{H_1^{fav}(z)}$ $b(z) = \dfrac{D_1^{dis}(z)}{D_1^{fav}(z)}$

Collins asymmetry – Belle data

we have done 2 alternative assumptions

a1 $H_1^{fav}(z) = -H_1^{dis}(z) \quad i.e. \quad a(z) = -1$

a2 $\dfrac{H_1^{fav}(z)}{D_1^{fav}(z)} = -\dfrac{H_1^{dis}(z)}{D_1^{dis}(z)} \quad i.e. \quad a(z) = -b(z)$

both in agreement with the considerations on the “interplay between the Collins and the dihadron FFs”

and already used / suggested / found as a result of global fits

- **these assumptions allow to evaluate** $\dfrac{H_1^{fav}(z)}{D_1^{fav}(z)}$ **in the four** z **bins**
- **the values are then fitted with a function of z**

Collins asymmetry – Belle data

finally :

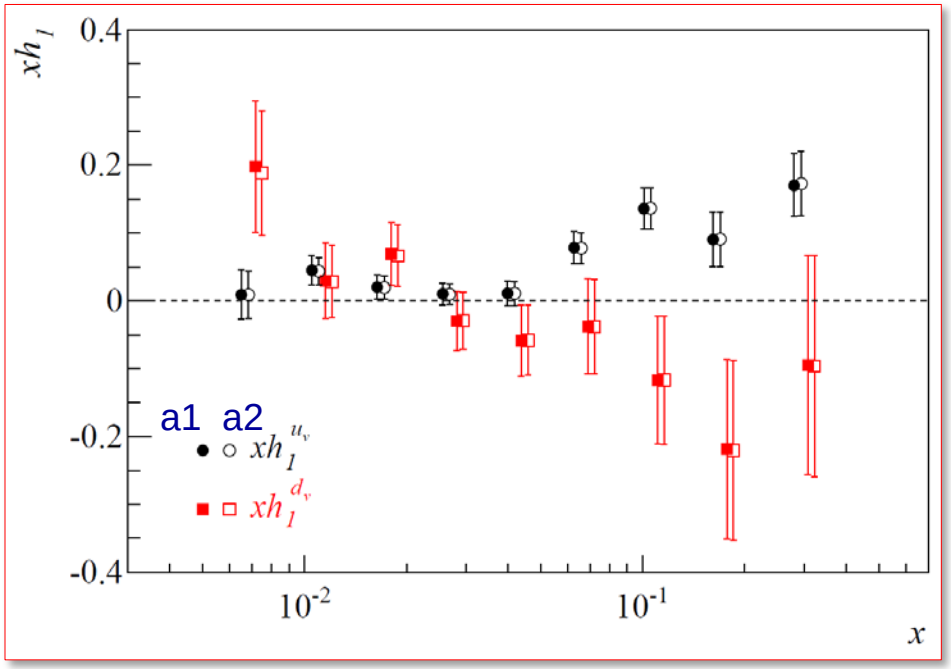
a1 $\dfrac{< H_1^{fav} >}{< D_1^{fav} >} \sim 0.12$ **a2** $\dfrac{< H_1^{fav} >}{< D_1^{fav} >} \sim 0.17$

assumed to be constant in Q^2

i.e. the evolution of H_1^{fav} is the same as that of D_1^{fav}

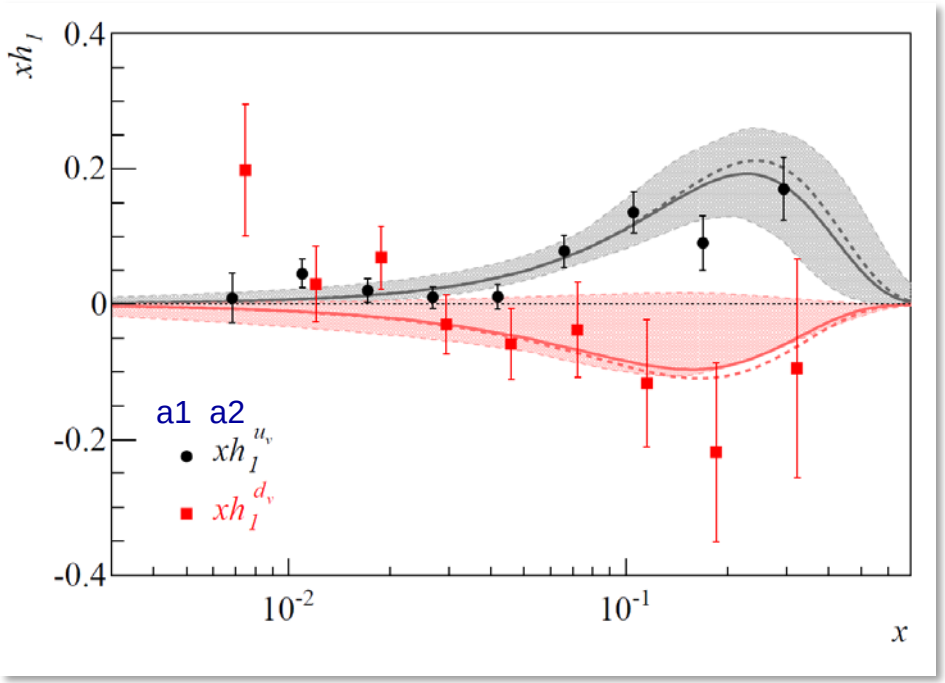
if the evolution of H_1^{fav} is negligible, the analysing powers at COMPASS Q^2 decrease by ~ 10%

Collins asymmetry – transversity



$xh_1^{u_v}$ and $xh_1^{d_v}$
for a1 and a2

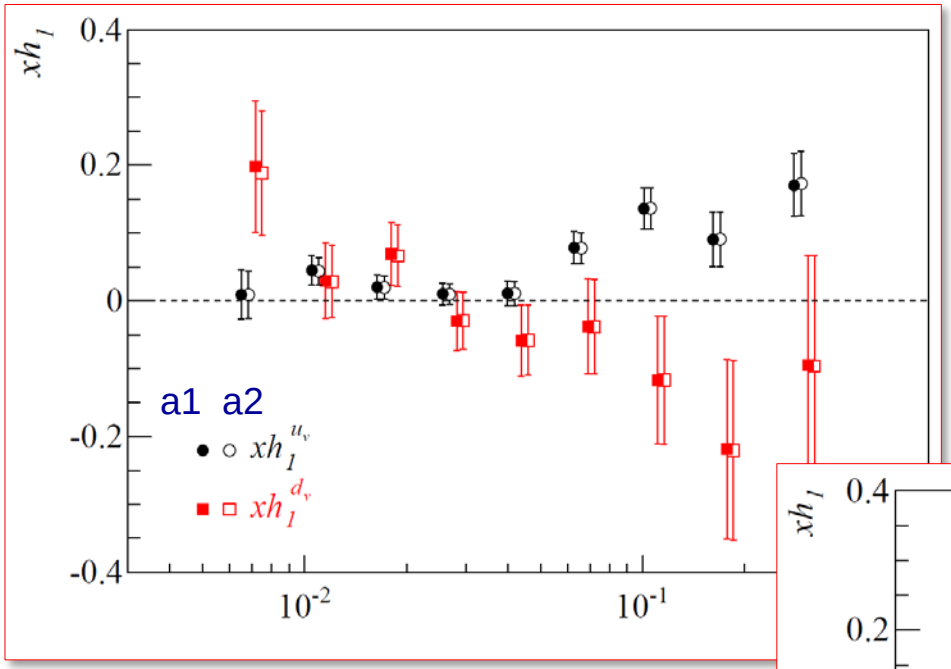
Collins asymmetry – transversity



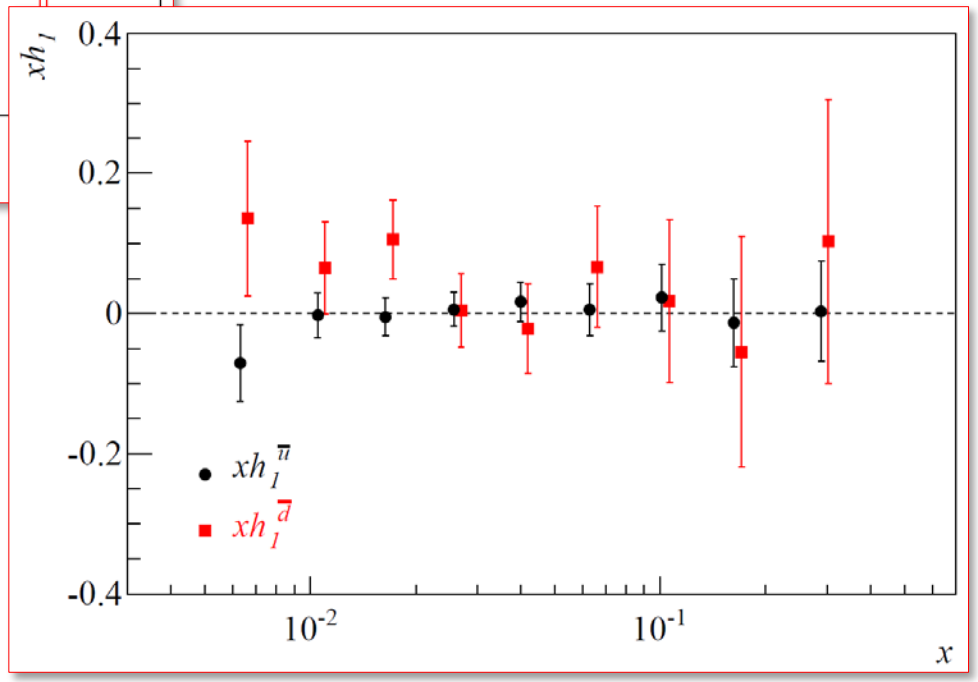
$xh_1^{u_v}$ and $xh_1^{d_v}$
for a1 and a2

Anselmino et al., 2013

Collins asymmetry – transversity

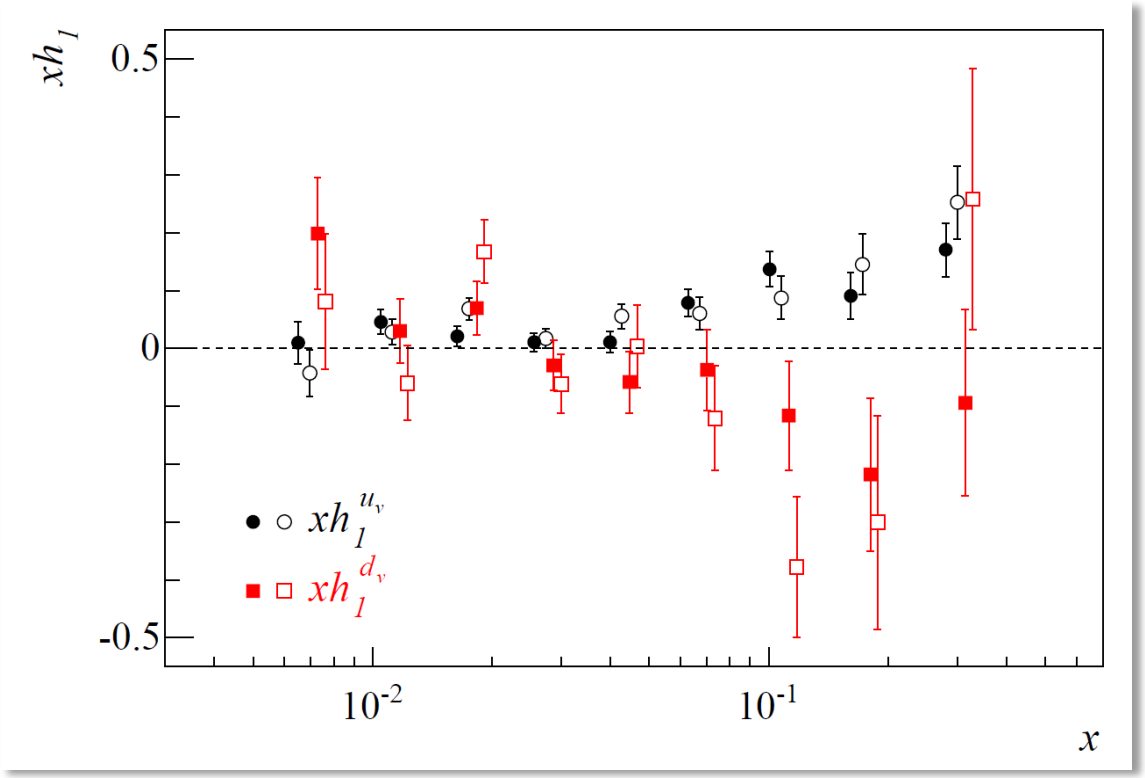


$xh_1^{u_v}$ and $xh_1^{d_v}$
for a1 and a2



$xh_1^{\bar{u}}$ and $xh_1^{\bar{d}}$

Collins asymmetry – transversity



$xh_1^{u_v}$ and $xh_1^{d_v}$ from single-hadron (closed points) **and from di-hadron** (open points) **asymmetries**

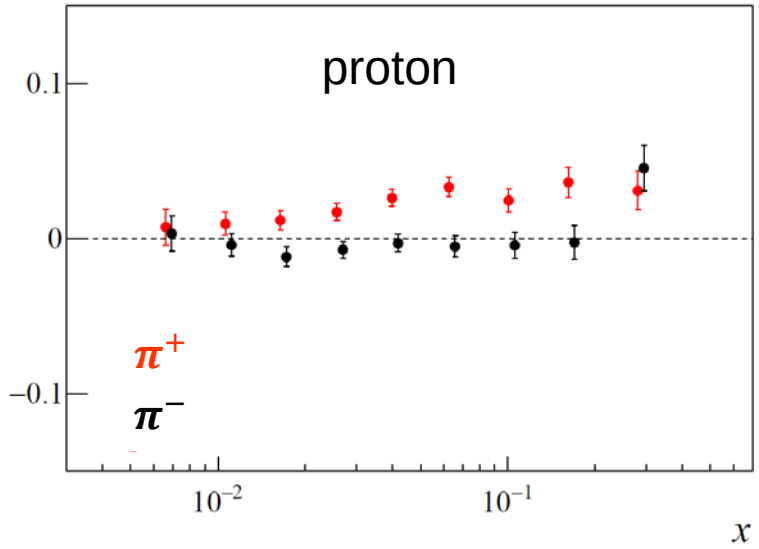
point-by-point extraction

The same method used for the Collins asymmetry has been used for the point-by-point extraction of the Sivers function from the pion and kaon Sivers asymmetries for proton and deuteron

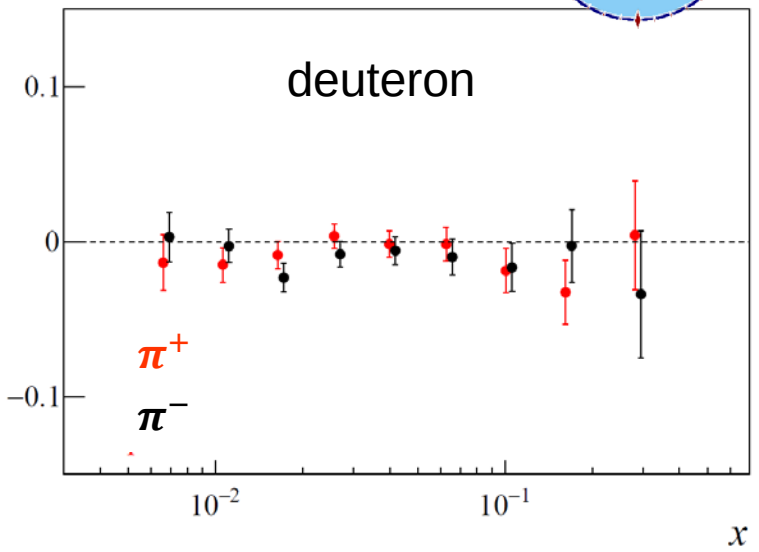
A. Martin, F. Bradamante and V. Barone,
Phys.Rev. D95 (2017) no.9, 094024

Sivers asymmetries

A_{Siv}

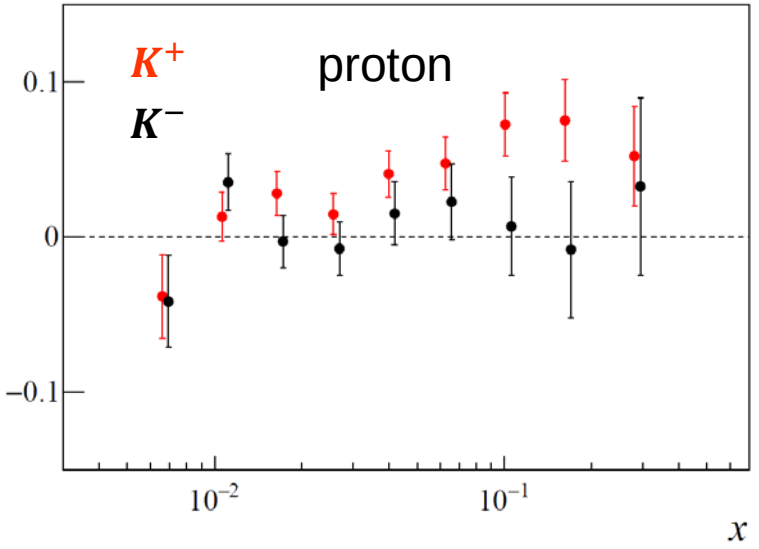


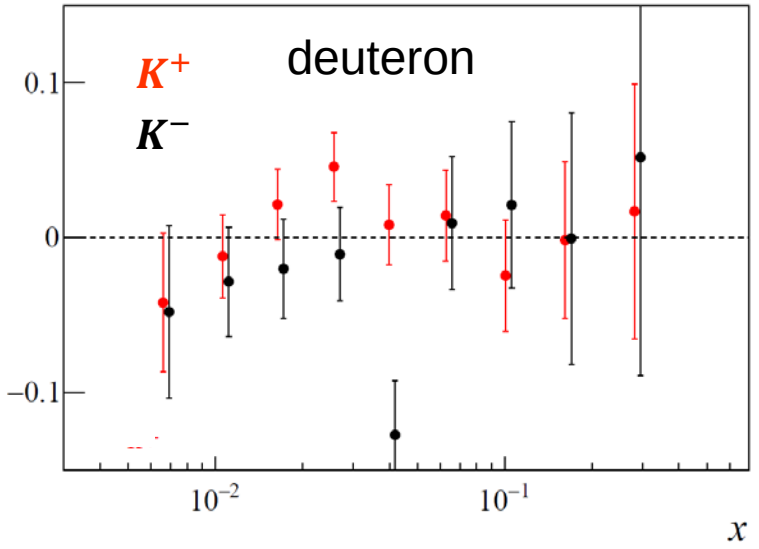
PLB 744 (2015) 250



PLB 673 (2009) 127

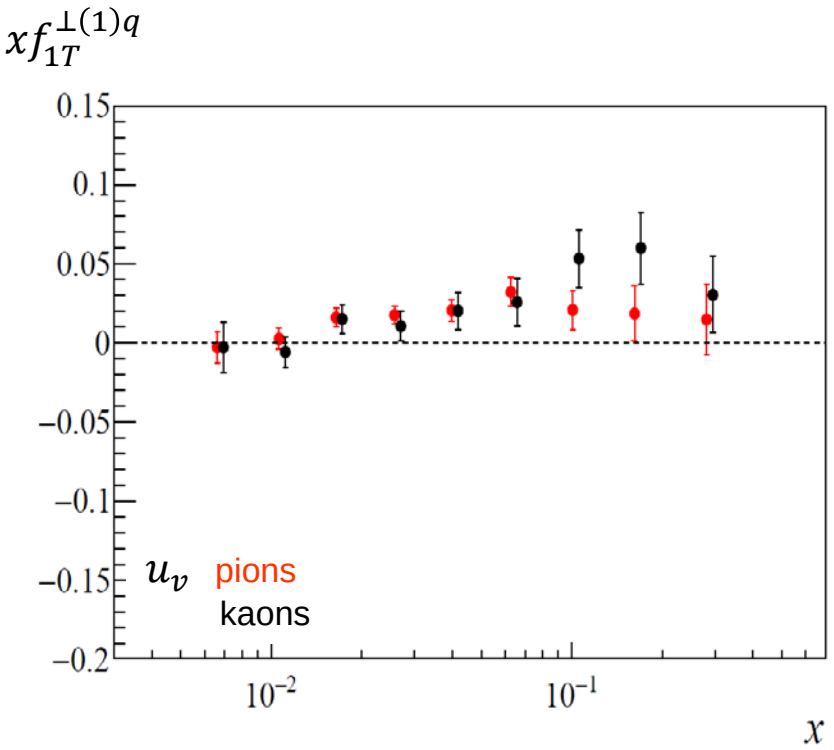
A_{Siv}

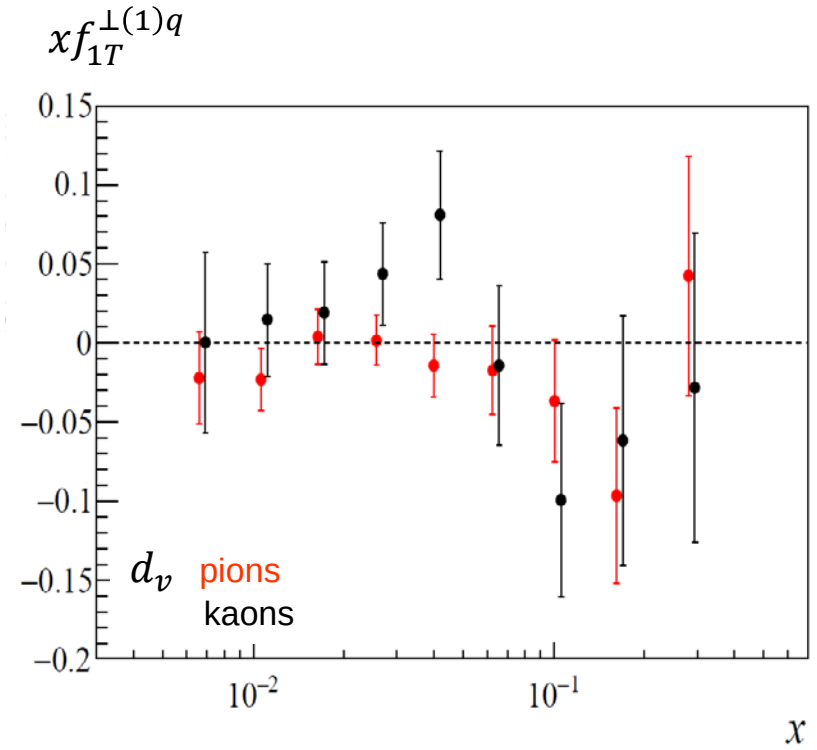




Sivers functions

results





A. Martin, F. Bradamante and V. Barone,
Phys.Rev. D95 (2017) no.9, 094024

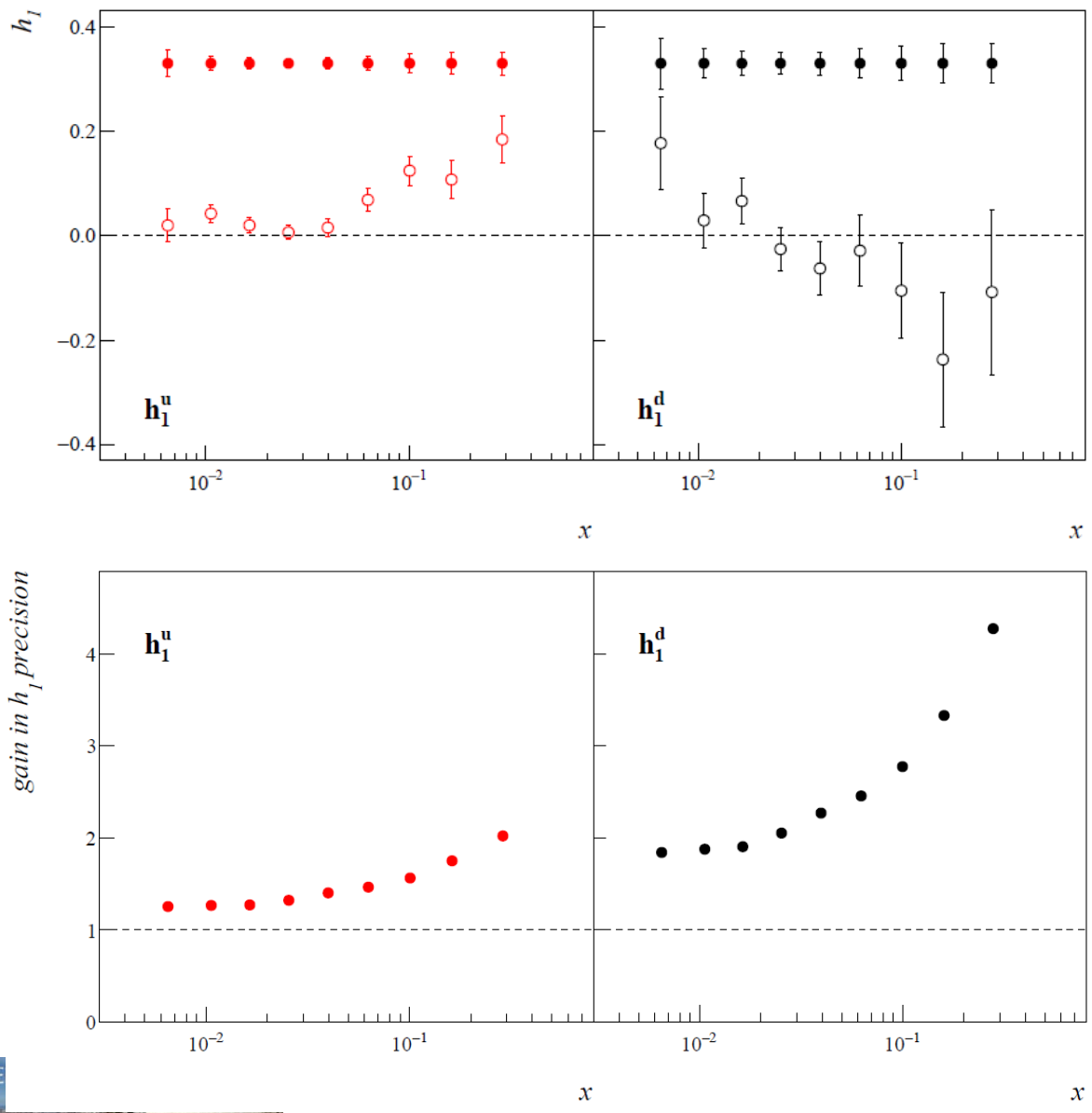
Transversity from COMPASS and Belle data

NEW

The same method used for the extraction of the Collins asymmetry has been used to estimate the impact of one year of COMPASS SIDIS measurement with

- **160 GeV/c momentum muons**
- **^{6}LiD transversely polarized target**

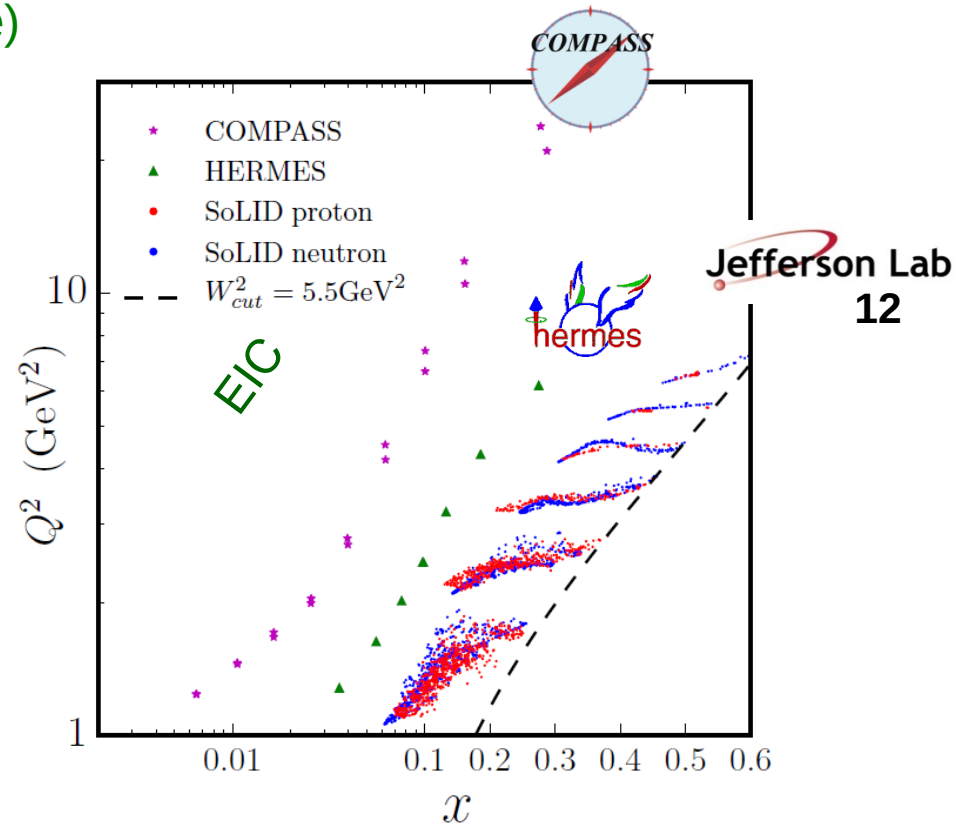
Transversity – valence



with one year of COMPASS SIDIS measurement with ^{6}LiD transversely polarized target

SIDIS experiments, transversely polarised target

JLab	(n only, over)
HERMES	(p only, over)
COMPASS	(p and d)
JLab12	(p and d/n, future)
EIC	(p and d, far future)



Z. Ye et al. JLAB-THY-16-2328

THANK YOU

for your attention