The future
COMPASS SIDIS measurement
on transversely polarized deuterons

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on behalf of the
COMPASS Collaboration

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SPIN 2018
THE 23RD INTERNATIONAL SPIN SYMPOSIUM

SIDIS

is one of the most effective way to investigate the structure of the nucleon

SIDIS on transversely polarized target gives access to Transversity and TMD PDFs

a relatively NEW field   first experimental data only in 2005 HERMES and COMPASS

most of the data have been collected on PROTON targets

only few data exist on a DEUTERON target (COMPASS, 2002-2004 runs) **and on a NEUTRON target** (JLab6, Hall A)

Experimental status

SIDIS experiments, transversely polarised target

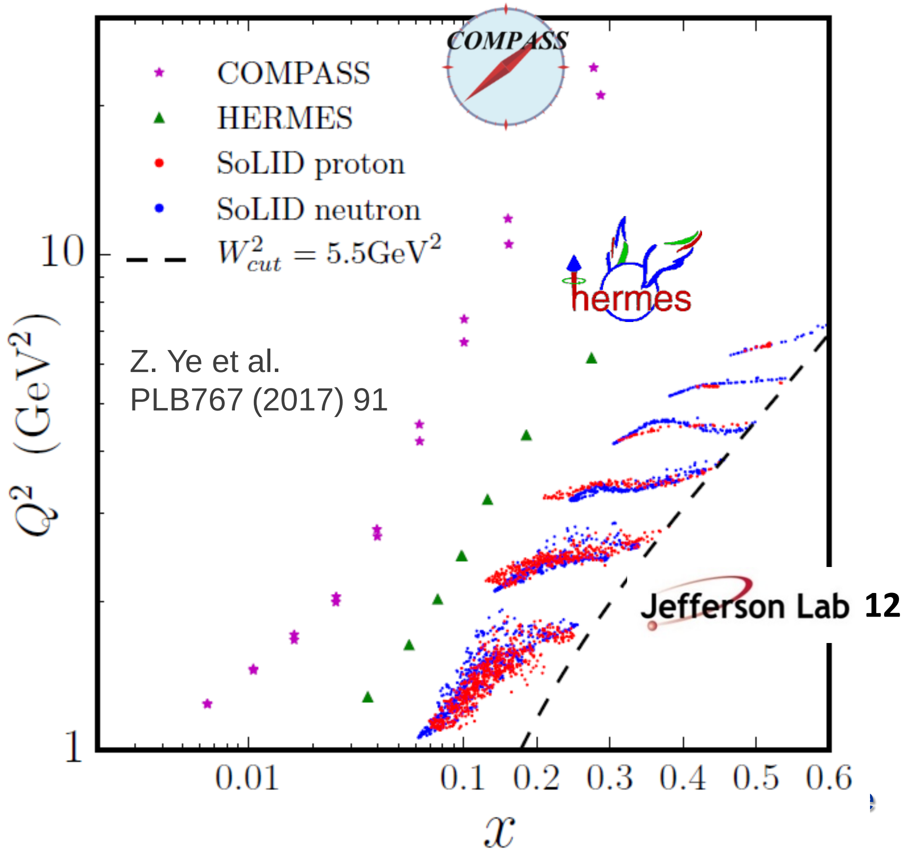
JLab6 (n only, over)
HERMES (p only, over)

some complementarity

COMPASS (d 2002,2003, 2004 *25%* p 2007 *50%*, 2010 *100%*) *small acceptance (SMC PTM)*

JLab12 (p and d/n, > 2019

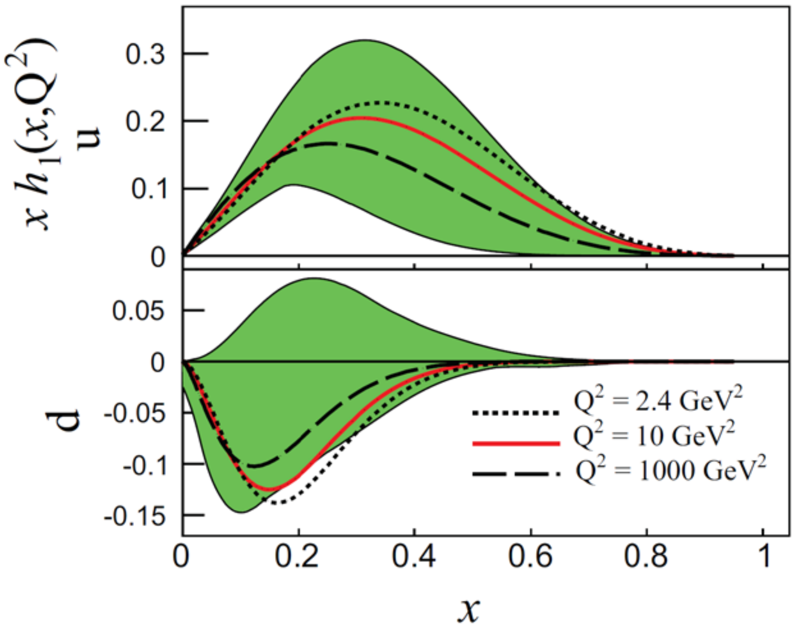
EIC (p and d, > 202x)



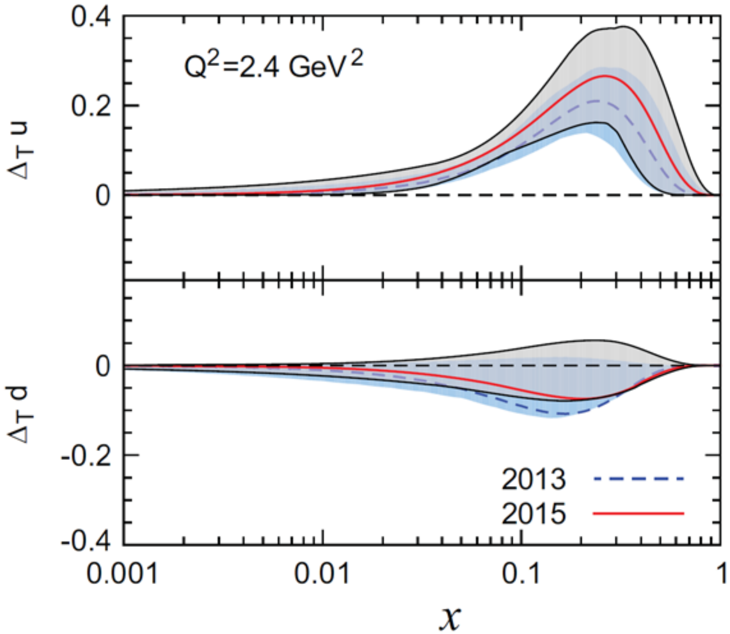
lack of deuteron (neutron) data
→ d-quark PDFs much worse determined than u-quark PDFs

The case for transversity

global fits

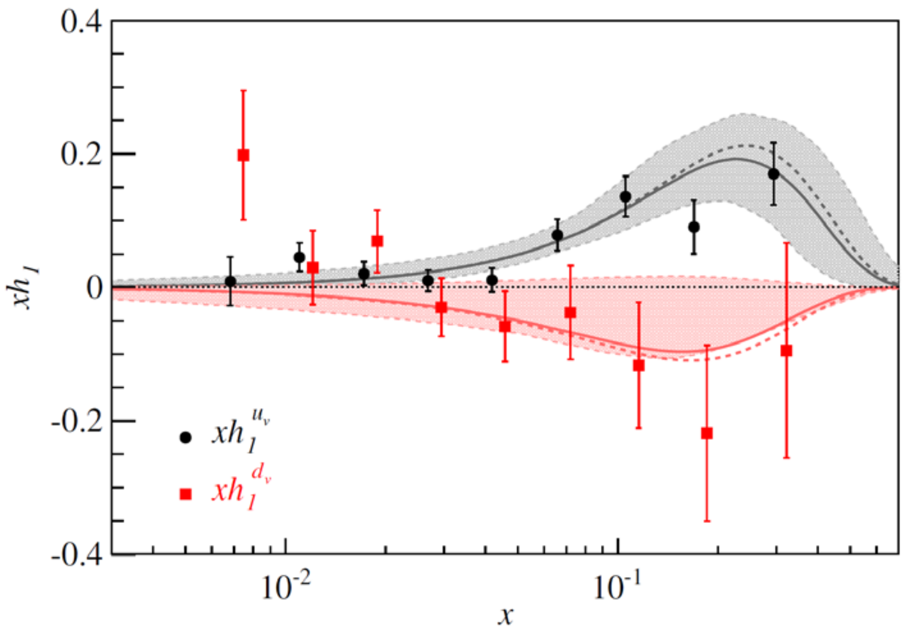


Z.-B. Kang et al.
Phys. Rev. D 93 (2016) 014009



M. Anselmino et al.
Phys. Rev. D 92 (2015) 114023

The case for transversity



points: point-by-point extraction from COMPASS p and d data and Belle data

no Sofer bound

A. Martin et al. PRD 91(2015) 014034

curves and bands: fit of COMPASS, HERMEs and Belle data

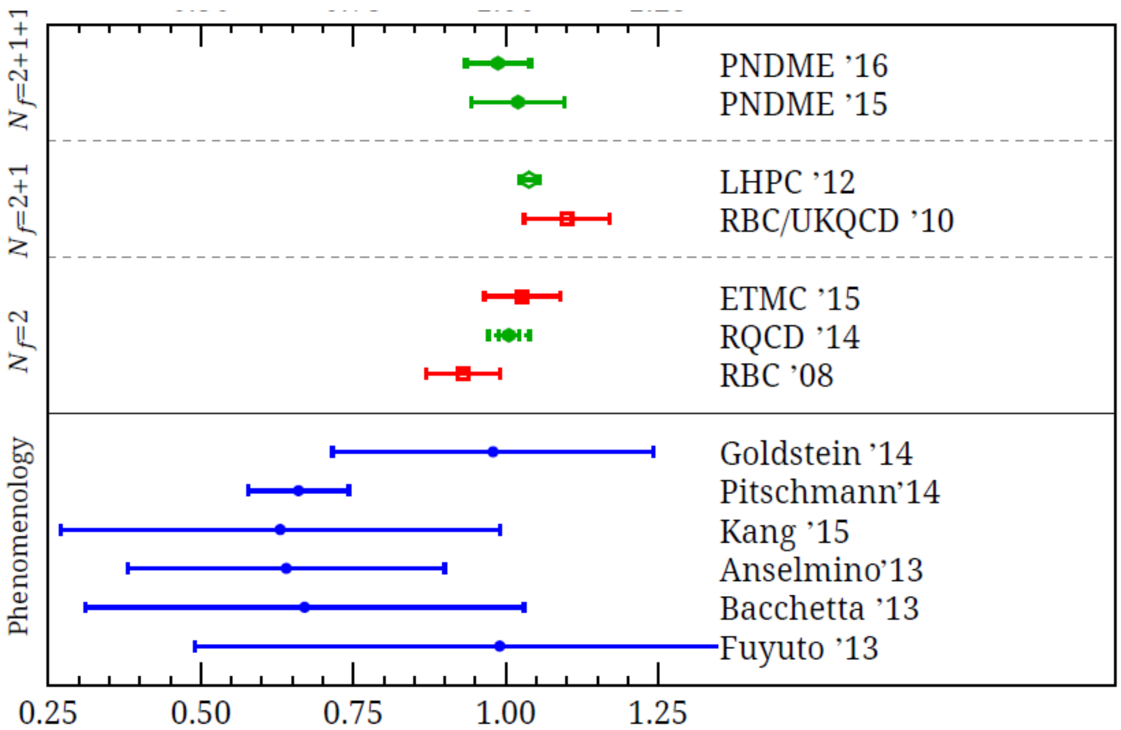
M. Anselmino et al, PRD 87 (2013) 094019

Q^2=10 GeV^2

The nucleon tensor charge

$$\boxed{g_T = \delta u - \delta d}$$

$$\delta q(Q^2) = \int_0^1 dx[h_1^q(x, Q^2) - h_1^{\bar{q}}(x, Q^2)]$$



T. Bhattacharya et al., PRD94 (5) (2016) 054508

CERN-SPSC-2017-034
SPSC-P-340-ADD-1
April 5, 2018

proposal for
one year of running
with transversely polarised deuteron
in the same conditions as in 2010

necessary to complete the exploratory COMPASS programme on the transverse spin nucleon structure

APPROVED by CERN SPSC
April 2018
and by the CERN Research Board
June 2018
to run immediately after the LS2, in 2021

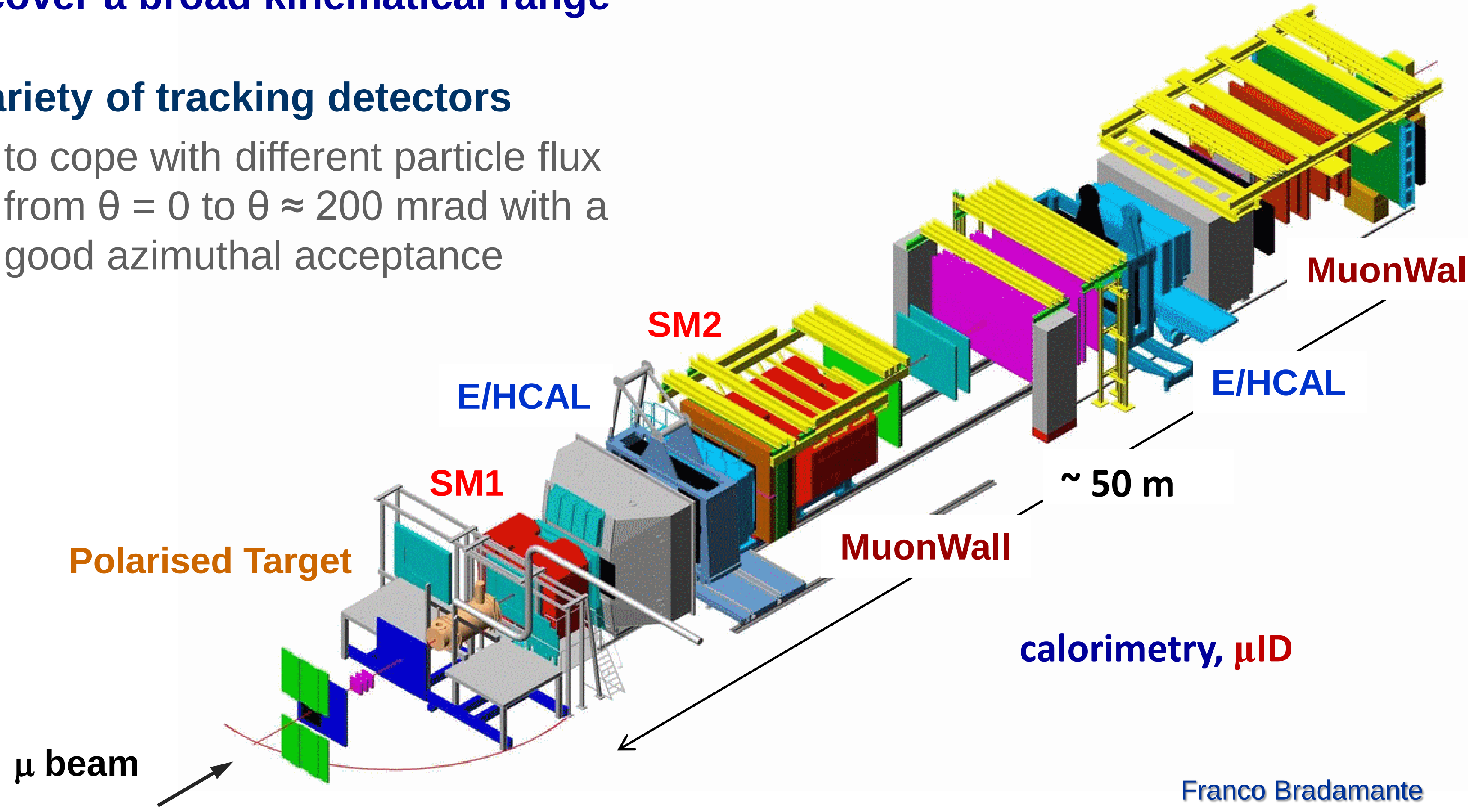
The Spectrometer

designed to
- **use high energy beams**
- **have large angular acceptance**
- **cover a broad kinematical range**

two stages spectrometer
- **Large Angle Spectrometer (SM1)**
- **Small Angle Spectrometer (SM2)**

variety of tracking detectors

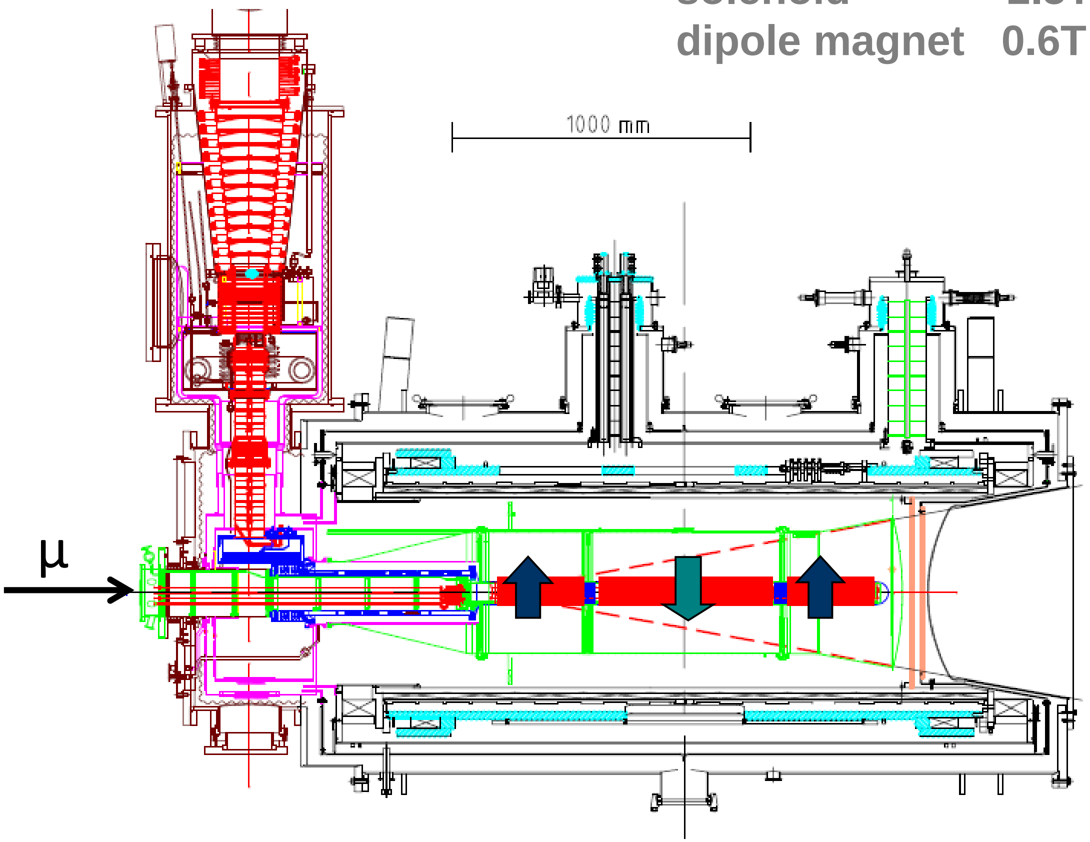
to cope with different particle flux from θ = 0 to θ ≈ 200 mrad with a good azimuthal acceptance



The Polarized Target System (>2005)

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

solenoid 2.5T
dipole magnet 0.6T



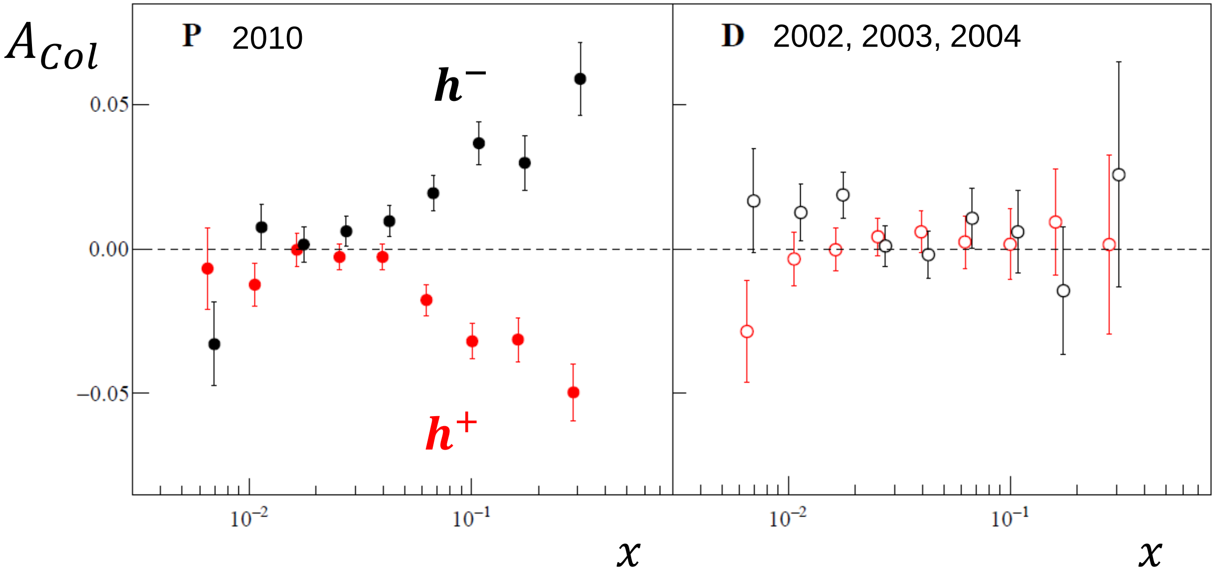
acceptance > ± 180 mrad

3 target cells
30, 60, and 30 cm long
opposite polarisation

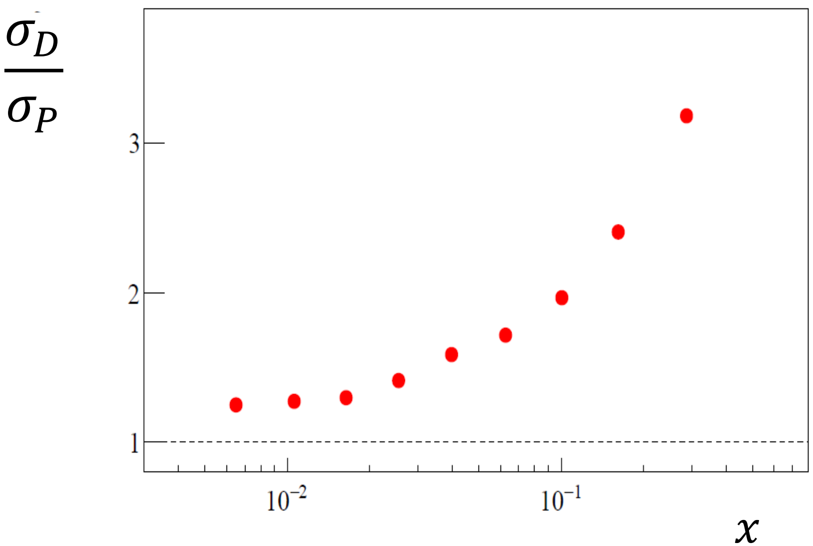
impact of the 2021 run
on transversity and tensor charge

expected statistical errors on
- **the Collins asymmetry**
- **the transversity PDF**
- **the tensor charge**

Collins asymmetry – existing COMPASS data



P 2007 data non used in this first exercise



three effects:

1. **running time**
2. **FoM**
3. **acceptance**

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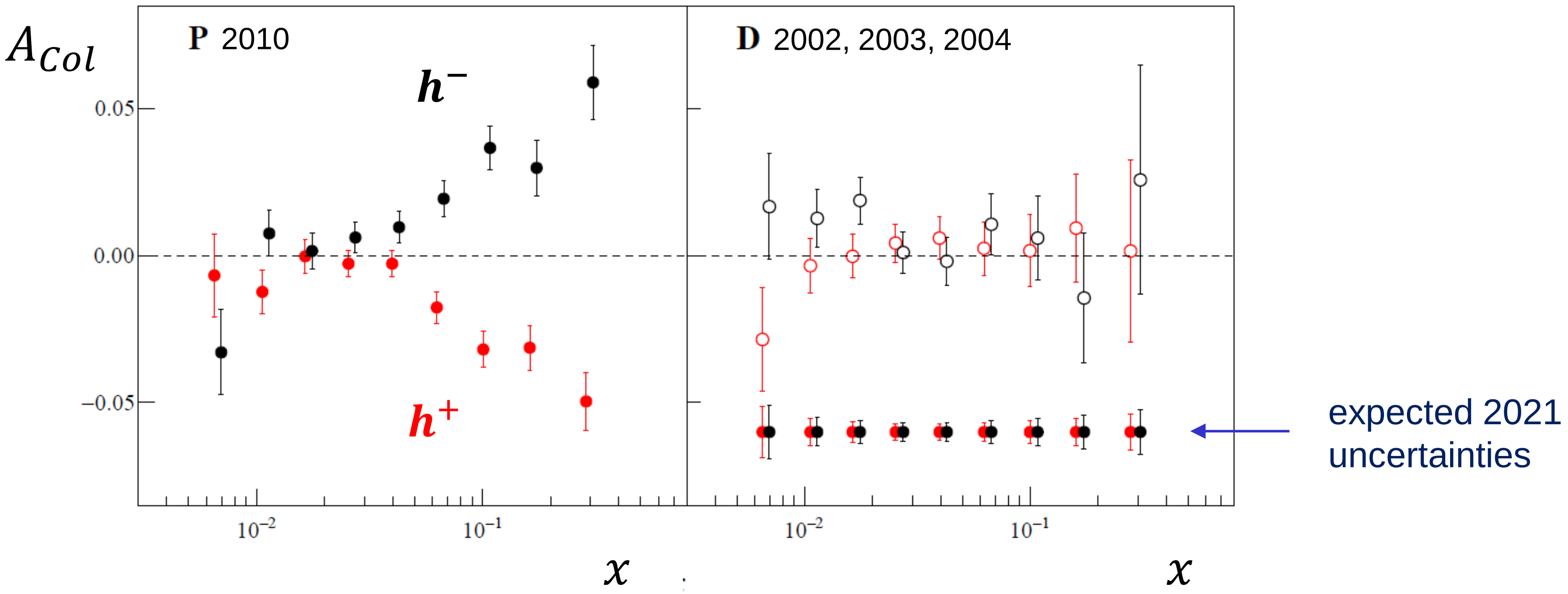
Collins asymmetry – expected statistical uncertainties

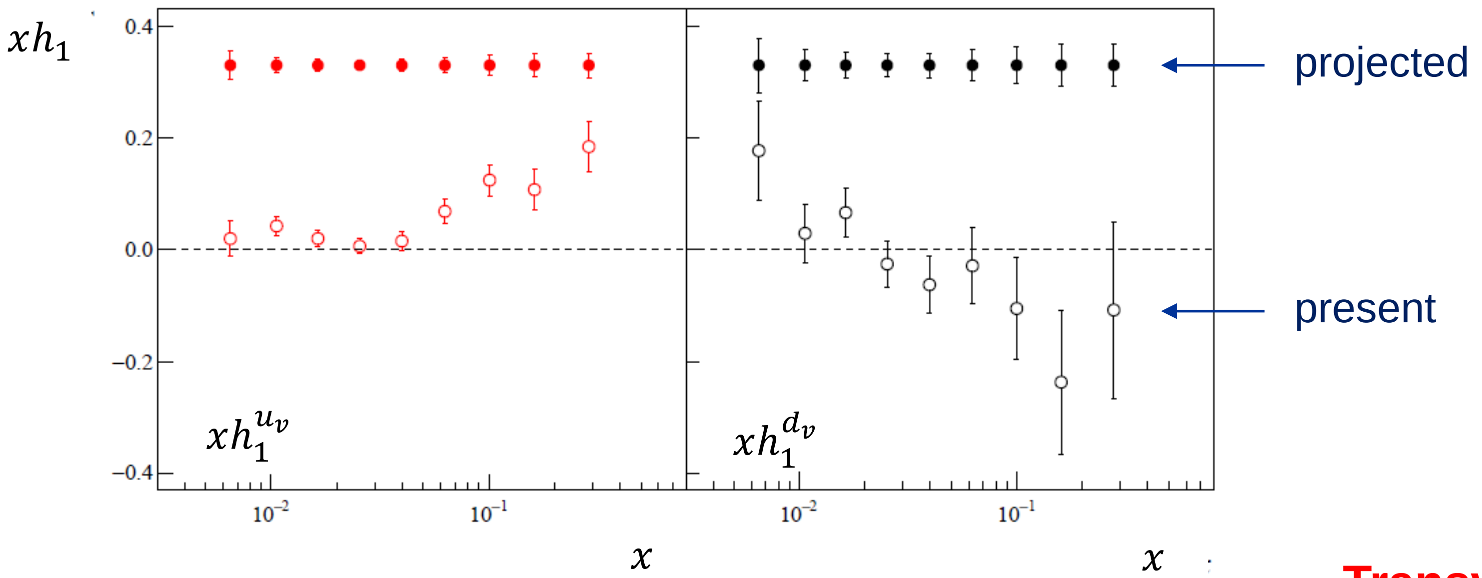
one year of data taking with ^{6}LiD as in 2002 - 2004,
same muon beam integrated intensity and same spectrometer as in 2010

$$\sigma_A \approx \frac{1}{fP}\frac{1}{\sqrt{N}} = \frac{1}{FOM}\frac{1}{\sqrt{N}} \qquad N_{d,h}^{1y} = N_{p,h} = 80 \cdot 10^6$$

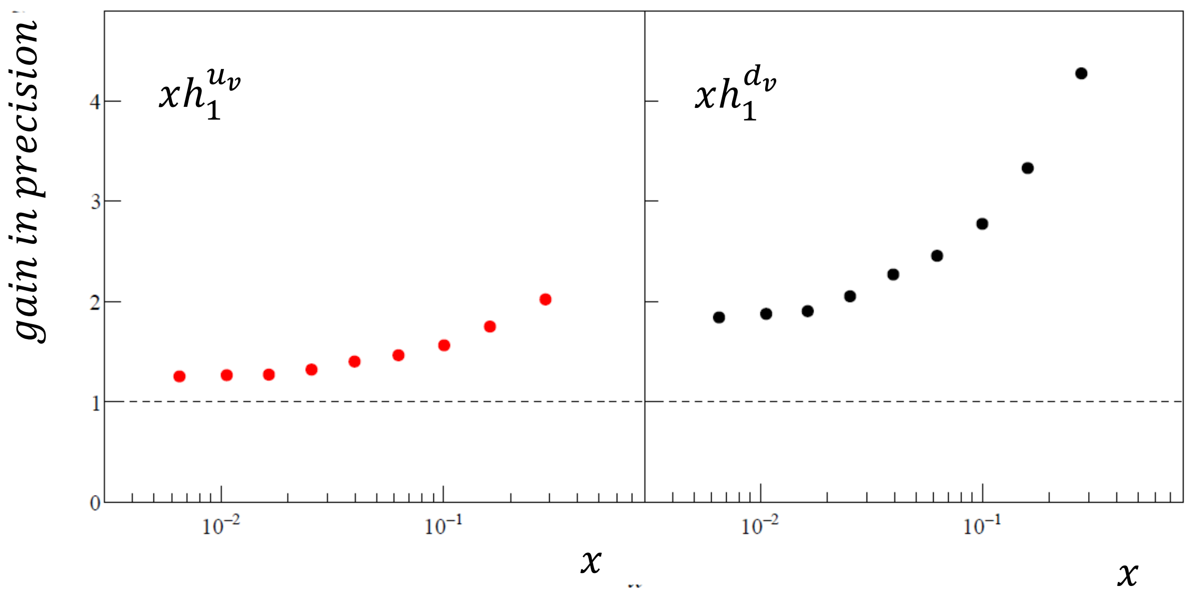
$$\boxed{\frac{\sigma_{A_d}^{1y}}{\sigma_{A_p}} = \frac{FOM_p}{FOM_d} = 0.62}$$



Impact on transversity extraction

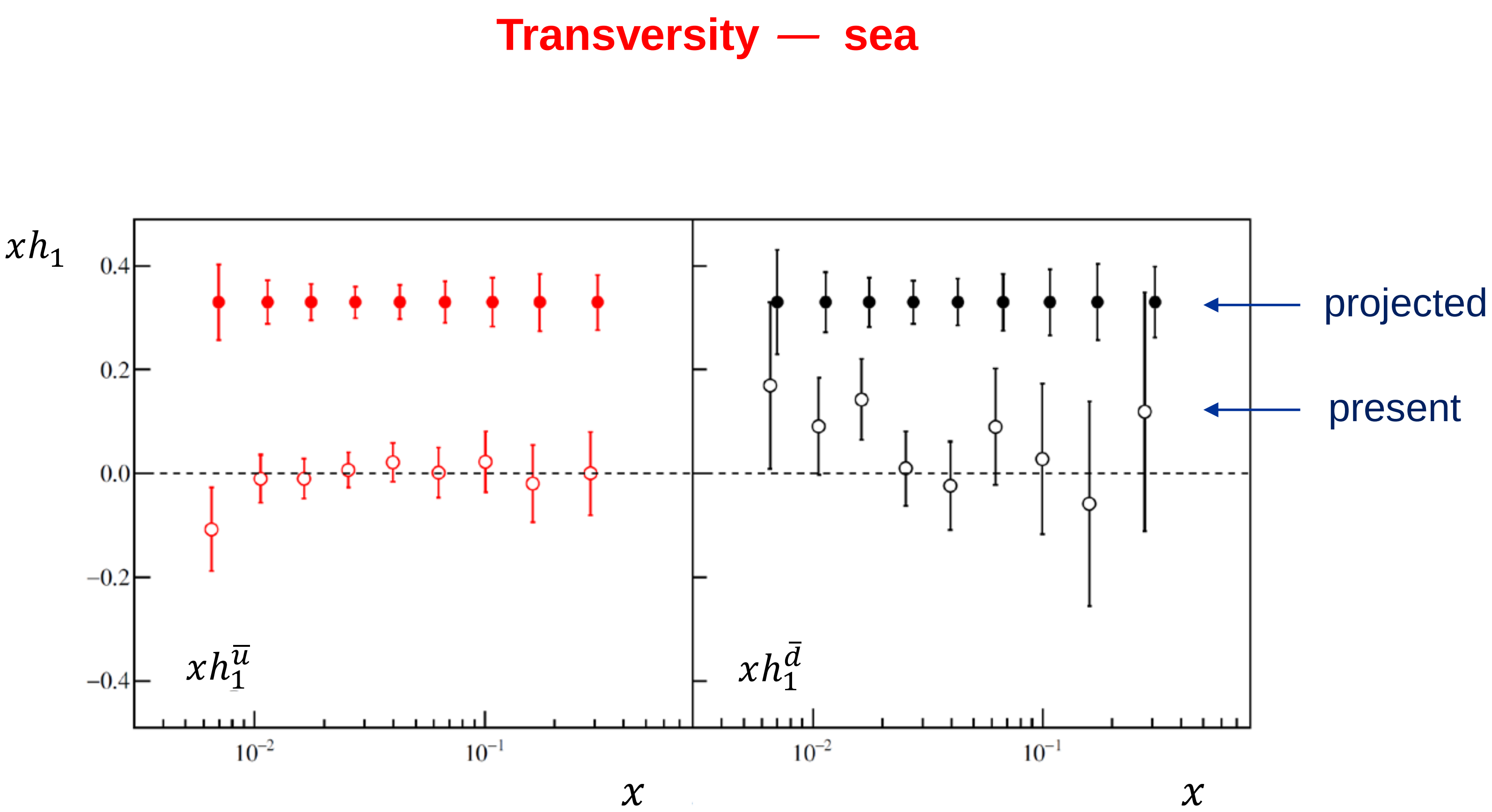


Transversity valence



for all the transversity extraction we have followed the method in PRD 91(2015) 014034

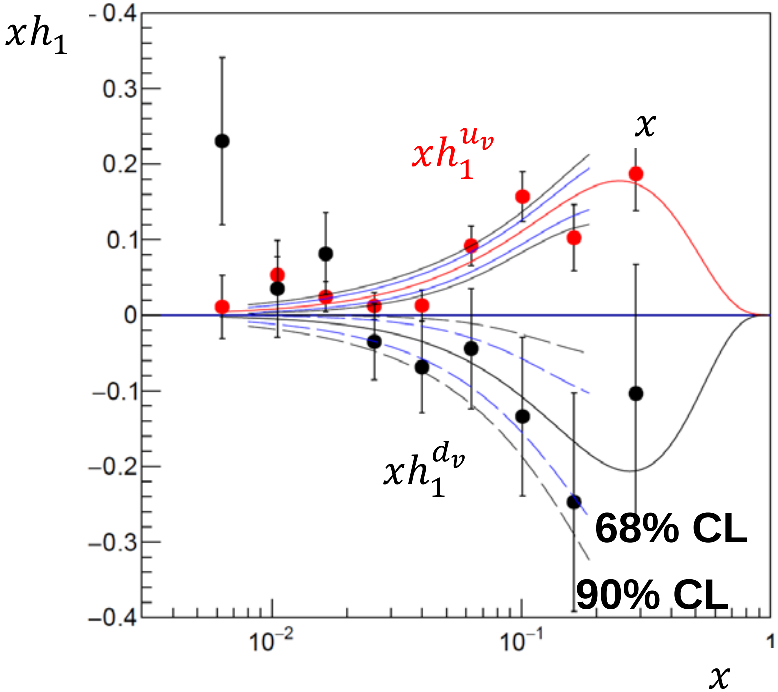
Impact on transversity extraction



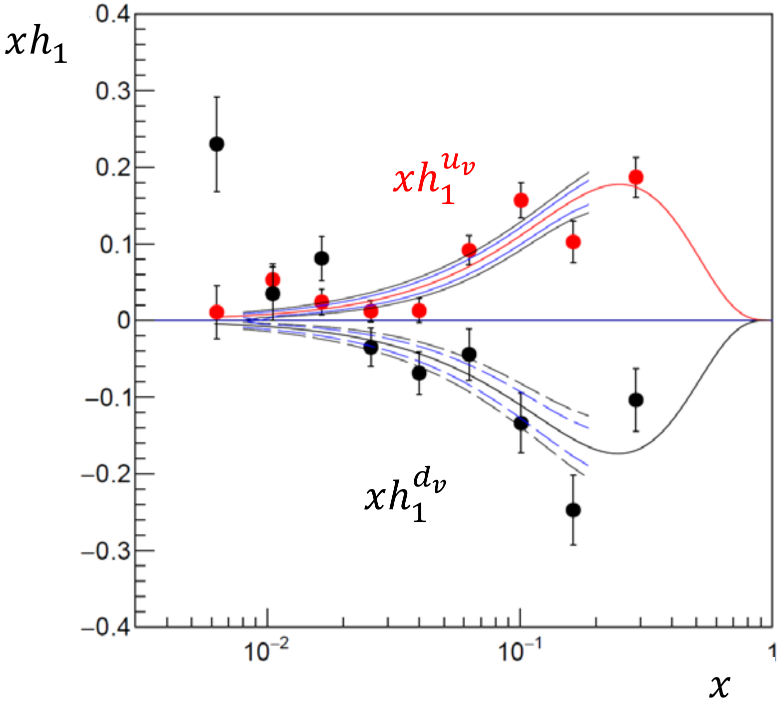
Impact on transversity extraction

Confidence Levels for $xh_1^{u_v}$ and $xh_1^{d_v}$ from replicas

present
P 2010 only
D 2002-2004



projected
P 2010 only
D 2021 only



Extraction of the tensor charge

correlation between $xh_1^{u_v}$ and $xh_1^{d_v}$

x-bin	$\rho(xh_1^{u_v}, xh_1^{d_v})$	
	present	projected
0.003-0.008	0.377	-0.166
0.008-0.013	0.385	-0.174
0.013-0.020	0.392	-0.179
0.020-0.032	0.446	-0.181
0.032-0.050	0.517	-0.179
0.050-0.080	0.561	-0.189
0.080-0.130	0.624	-0.209
0.130-0.210	0.701	-0.242
0.210-0.70	0.783	-0.308

calculated

Extraction of the tensor charge

correlation between $xh_1^{u_v}$ and $xh_1^{d_v}$

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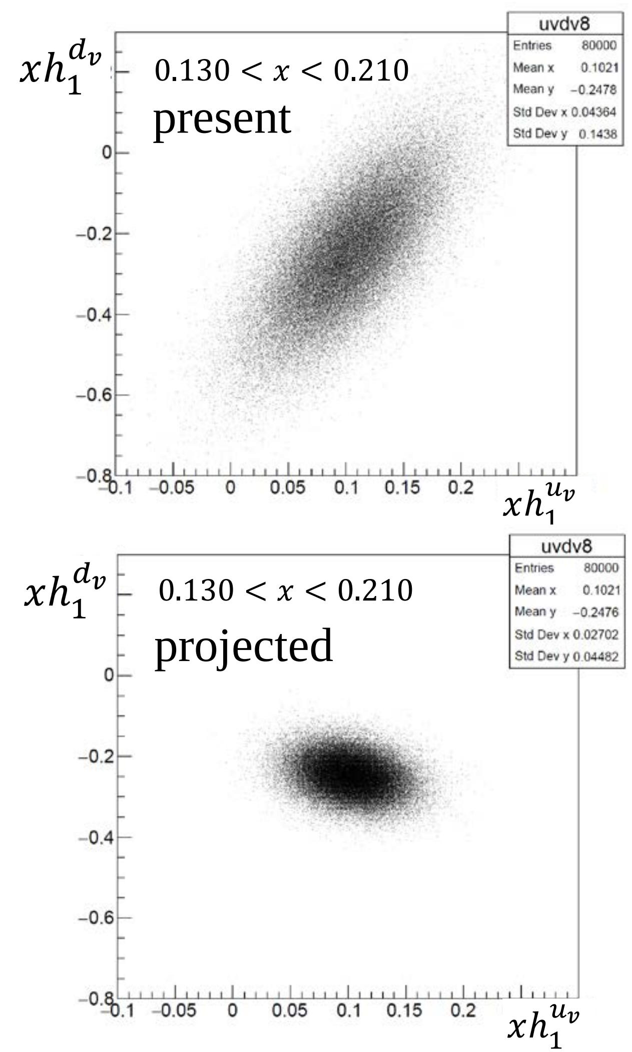
calculated



replicas

Extraction of the tensor charge

statistical uncertainties

evaluated by numerical integration
in the 7 bins $0.008 < x < 0.210$

	$\delta_u = \int_{\Omega_x} dx h_1^{u_v}(x)$	$\delta_d = \int_{\Omega_x} dx h_1^{d_v}(x)$	$g_T = \delta_u - \delta_d$
present	0.218 ± 0.036	-0.206 ± 0.110	0.424 ± 0.093
projected	0.218 ± 0.025	-0.206 ± 0.043	0.424 ± 0.054

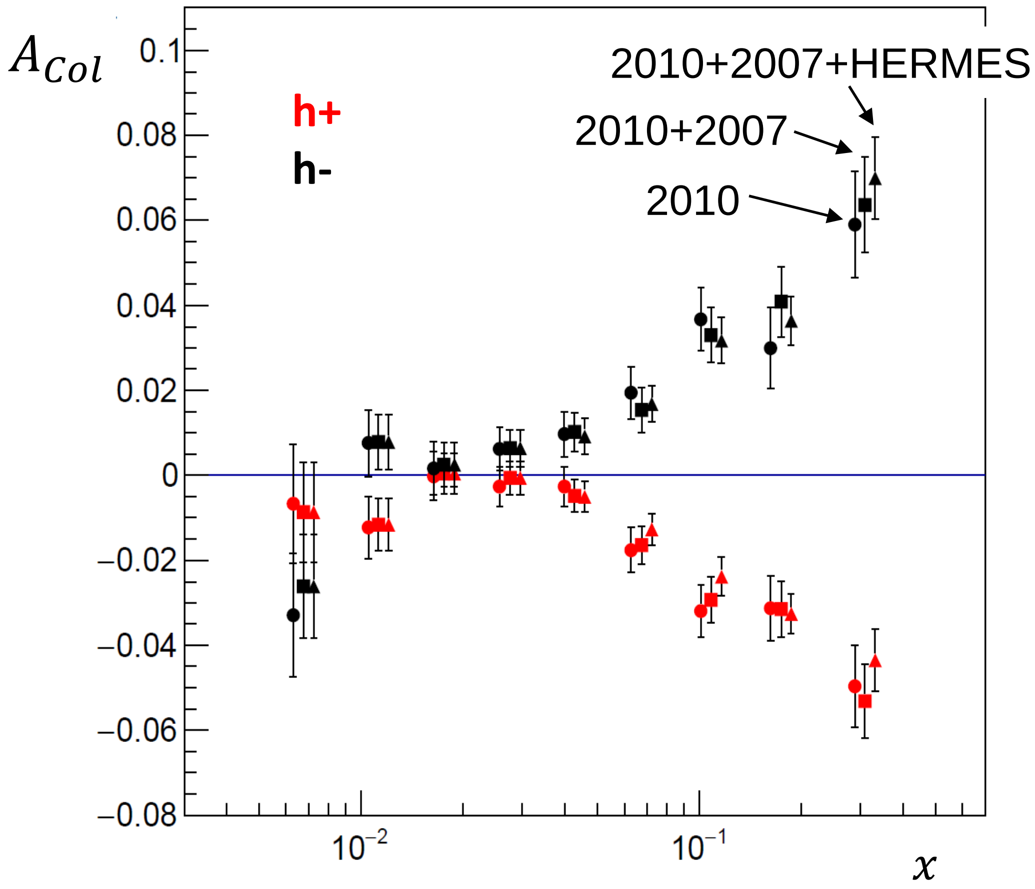
present: P 2010 only
D 2002-2004

Ω_x: $0.008 \div 0.210$

projected: P 2010 only
D 2021 only

Using all the existing proton data

“P all”: COMPASS 2010 and 2007 plus HERMES

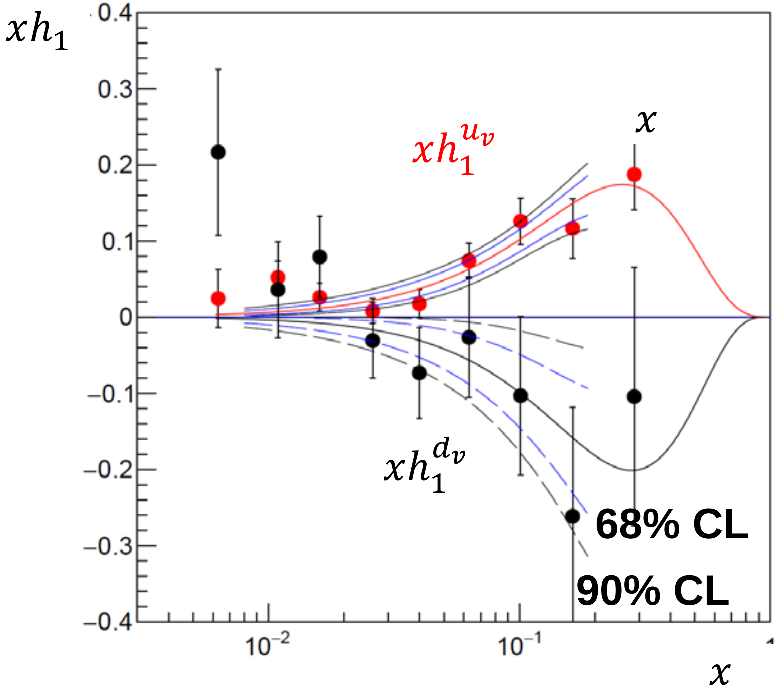


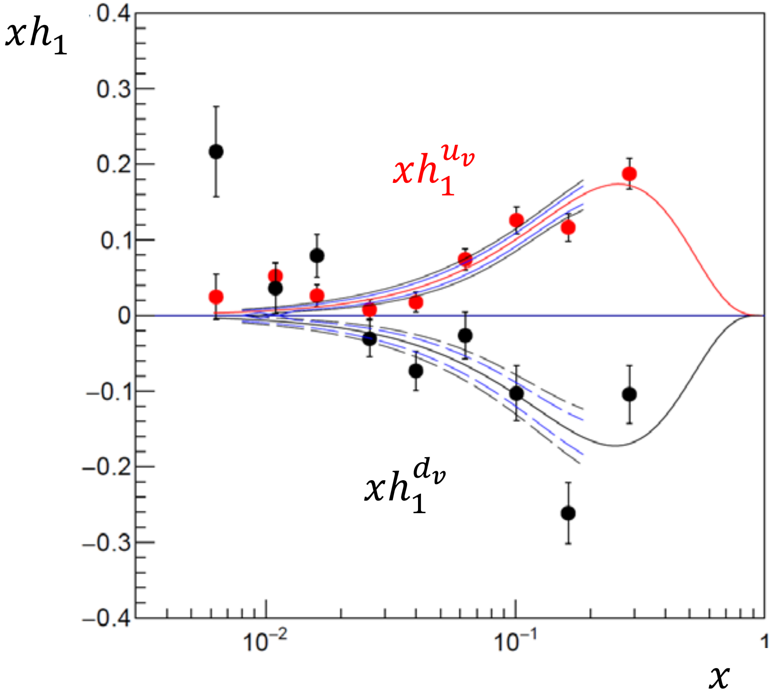
Using all the existing proton data

Confidence Levels for $xh_1^{u_v}$ and $xh_1^{d_v}$ from replicas

present
P all
D 2002-2004

projected
P all
D 2021 only





Using all the existing proton data

P all

	$\int dx h_1^{u_v}(x)$	$\int dx h_1^{d_v}(x)$	g_T
present	0.201 ± 0.032	-0.189 ± 0.108	0.390 ± 0.087
projected	0.201 ± 0.019	-0.189 ± 0.040	0.390 ± 0.044

P 2010 only

	$\delta_u = \int_{\Omega_x} dx h_1^{u_v}(x)$	$\delta_d = \int_{\Omega_x} dx h_1^{d_v}(x)$	$g_T = \delta_u - \delta_d$
present	0.218 ± 0.036	-0.206 ± 0.110	0.424 ± 0.093
projected	0.218 ± 0.025	-0.206 ± 0.043	0.424 ± 0.054

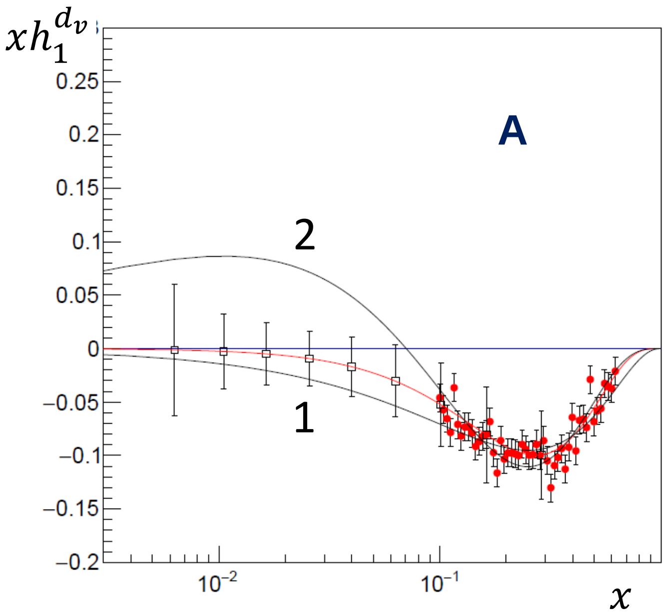
Complementarity with future SoLid results

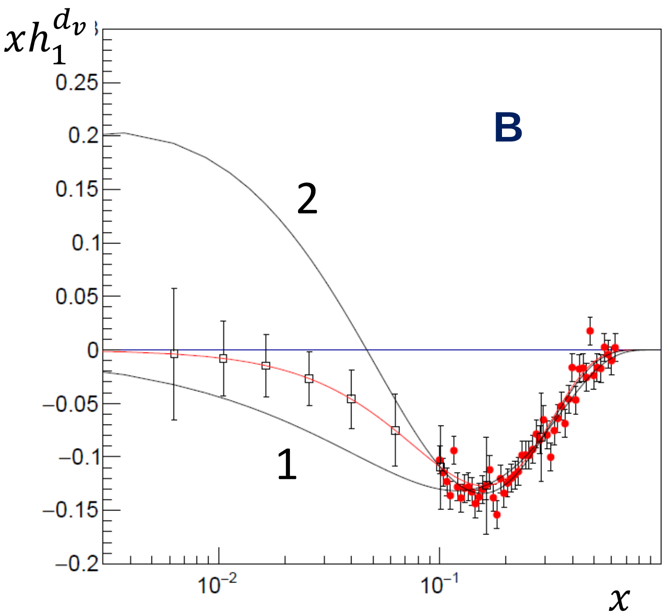
- we have assumed that from SoLid data one extract 50 values of $xh_1^{d_v}$ in the range $0.1 < x < 0.6$ with a statistical uncertainty of 0.013
- we have used two possible x dependences:

  A. $xh_1^{d_v} = -2.5\, x^{1.5}\, (1-x)^4$ B. $xh_1^{d_v} = -8\, x^{1.5}\, (1-x)^8$

  and generated the data accordingly
- we have looked for reasonable different parametrisations still in agreement with SoLid simulated data (p-value >0.10) finding the curves 1 and 2

Z. Ye et al. PLB767 (2017) 91





Other measurements

Of course similar improvements are foreseen for the measurements of all the other transverse spin asymmetries:

- the two hadron asymmetries
- the other single hadron asymmetries
- the g_2 structure function
- the multidimensional extraction of the transverse spin asymmetries
- the P_T weighted asymmetries
- the spin asymmetries in exclusive vector meson production
- ...

and in particular for the extracted Sivers functions

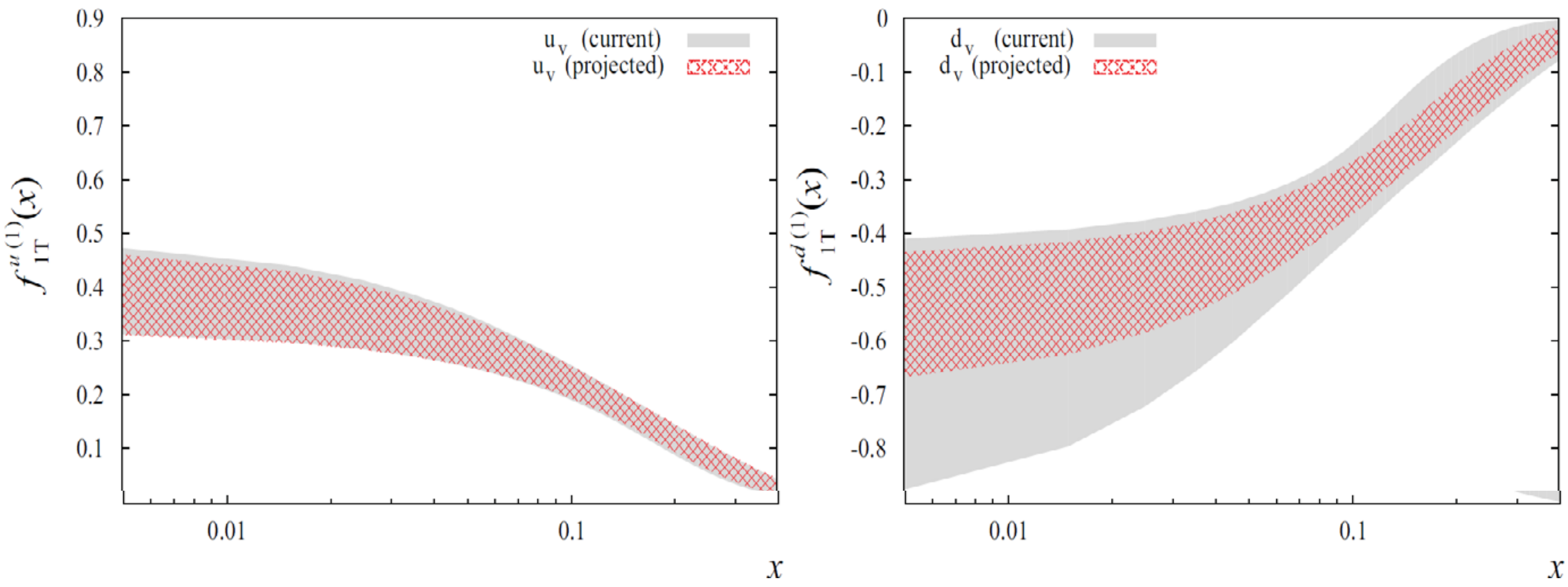
The Sivers function

Projection for the Sivers functions from global fits

courtesy of M. E. Boglione and J. O. Gonzalez

95% confidence level error bands in a fit of

- **current**: all the existing data on the Sivers asymmetry (COMPASS, HERMES and JLab) and
- **projected**: when the COMPASS 2021 projected deuteron data are added



Conclusions

to summarise, with the 2021 deuteron run we will complete the COMPASS programme, and fully use the existing proton data in a situation where in the relatively short future only JLab12 data at smaller Q^2 and larger x will be available

in particular we will

- **measure the deuteron asymmetry with statistical errors smaller than those for proton**

  σ_d ~ 0.62 σ_p (~0.007 in the last x bin)

- **allow for much more precise extractions of transversity and Sivers PDFs**

  u_v $[d_v]$ transversity: reduction by up to a factor 2 [4] in the statistical error and corresponding reduction on the tensor charge extraction

- **perform the other measurements we could do on proton only using the 2010 data**

  multiD analysis

  P_T weighted Sivers asymmetry

  ....

effect of using all the existing p data
(COMPASS 2010 and 2007, HERMES)

no problem to add the 2007 data (HepData)

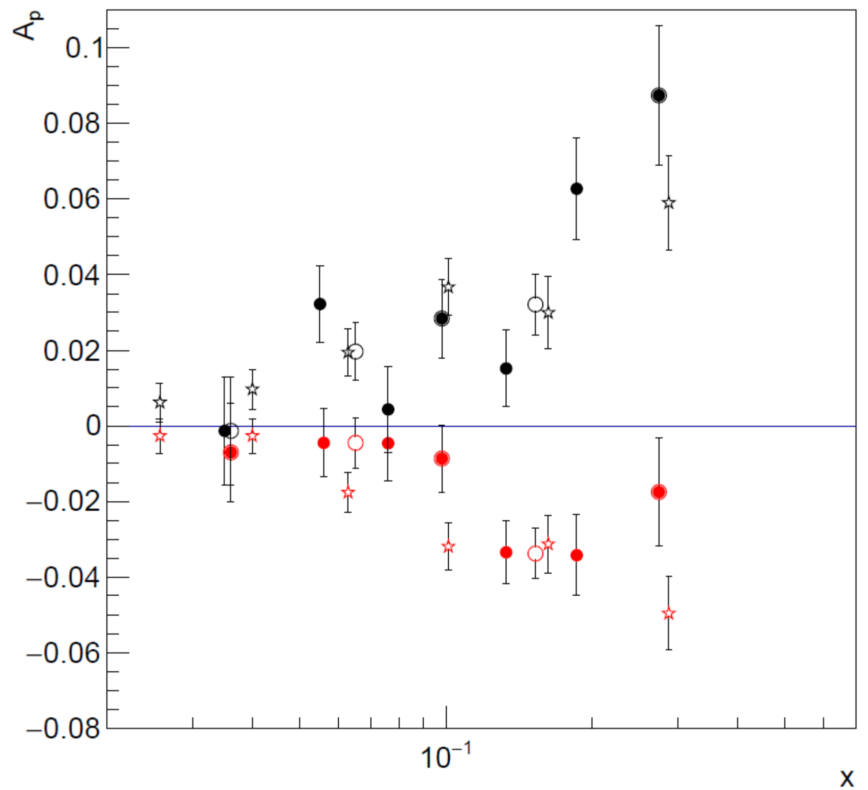
problems with HERMES

- D_{NN} corrections (easy)
- different energy and z<0.7 (neglected)
- different x binning

☆ COMPASS last 6 points

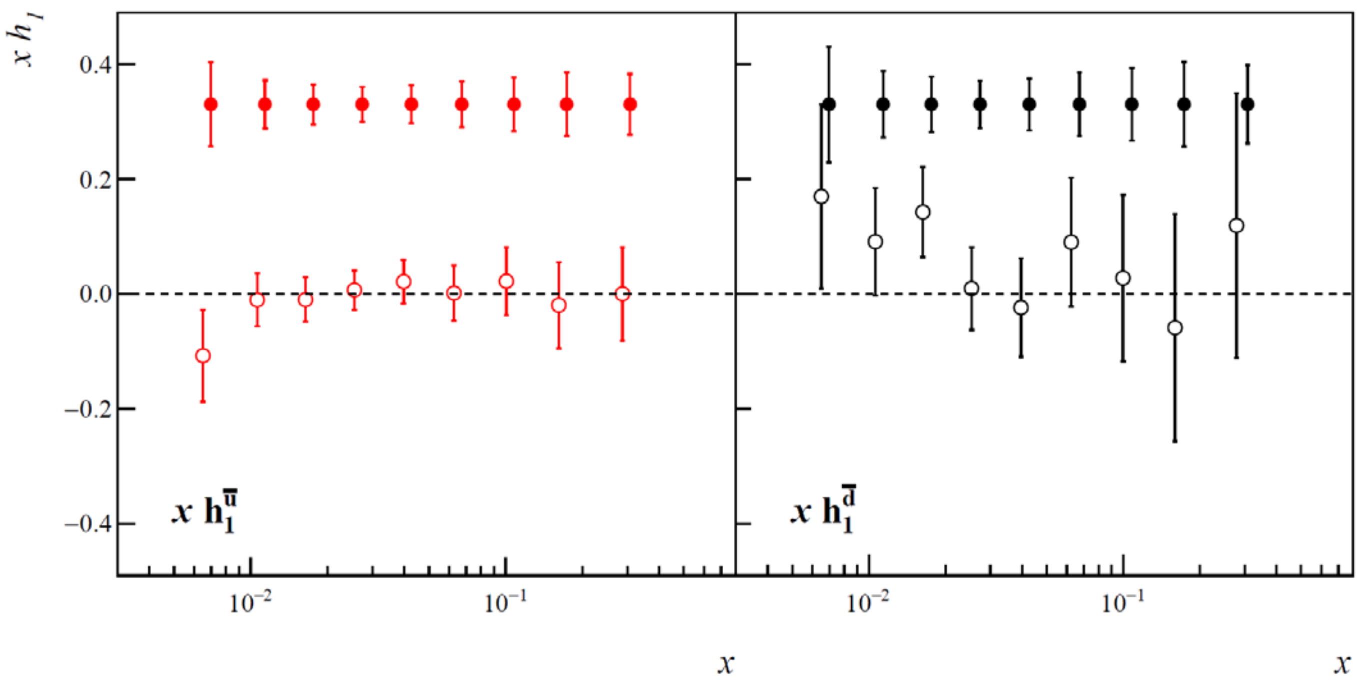
● ● HERMES original binning

○ ○ HERMES summing bins 2 3 and 5 6



then weighted mean with COMPASS
→ "CH now/proj"

the sea



complementarity with future SoLid results

strategy:

- assume an error (statistical) on $xh_1^{d_v}$

  SoLid: 600 points in $0.1\ (0.06) < x < 0.6$ for p and d (n)

  with $\Delta A_{p,d\ (n)} \simeq 0.01$

  → 50 point vs x for $xh_1^{d_v}$ with error 0.013 (?)
- assume a parametrization for $h_1^{d_v}$
- generate a set of “SoLid data” accordingly, with 0.013 statistical error
- fit the “SoLid data” with parametrizations with different behaviors at small x
- chose the parametrizations with $\chi^2 \leq \chi^2_{0.10}$ to look at the possible variations at low x

energy dependence and different cuts ignored