Future SIDIS measurements with a transversely polarized deuteron target at COMPASS

Anna Martin
Trieste University and INFN

on behalf of the
COMPASS Collaboration

Torino, 11 April 2019

d-quark transversity

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

proposal for
one year of running with the SPS high energy μ beam
to measure SIDIS off transversely polarised deuteron

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

approved by the CERN SPSC and Research Board
to run immediately after the LS2, in 2021

June 2018

this talk

- main motivations
- expected outcome

SIDIS

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

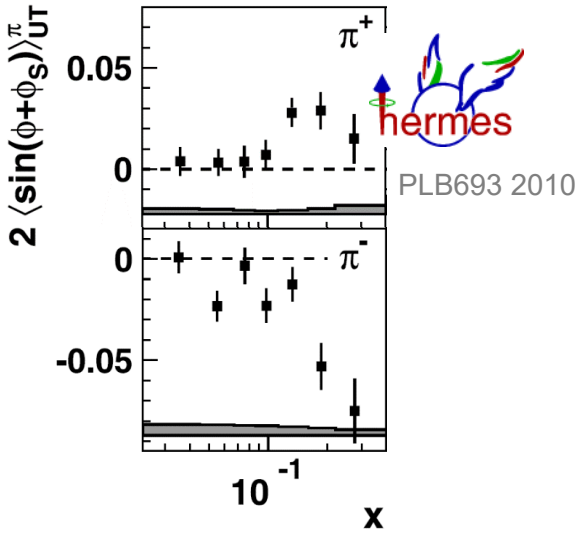
SIDIS off transversely polarized targets gives access to
the transverse spin degrees of freedom of the partons
and in particular to the
Transversity and Sivers functions

a relatively new field: first experimental data only in 2005
HERMES (p) and COMPASS (d)

since then, several transverse spin asymmetries have been more precisely measured on proton and deuteron

SIDIS off transversely polarised protons

very clear signals have been measured for the Collins asymmetry $\sim h_1^q \otimes H_{1q}^{\perp}$



PLB693 2010

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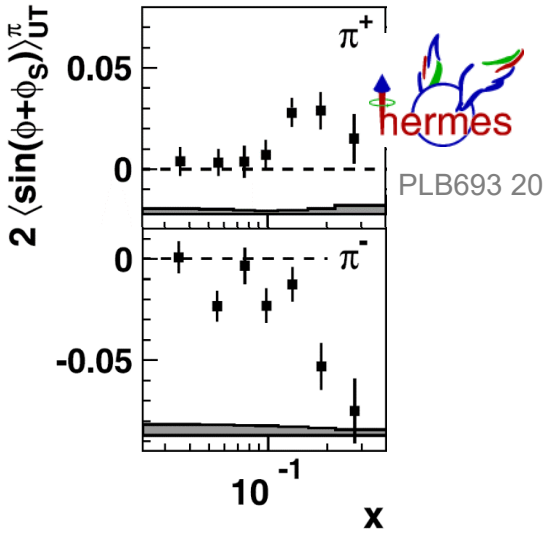

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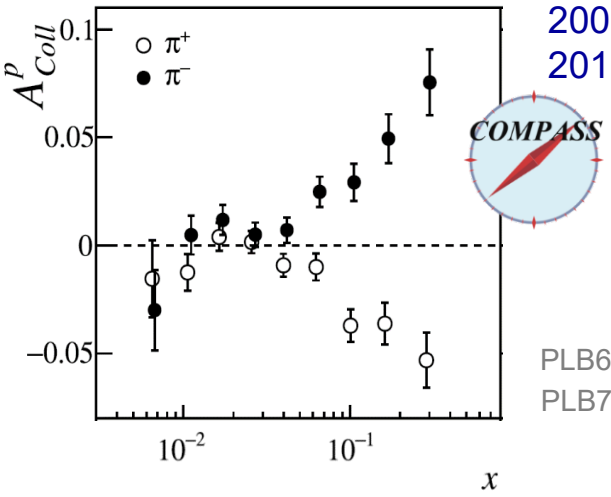

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2010 (100%)

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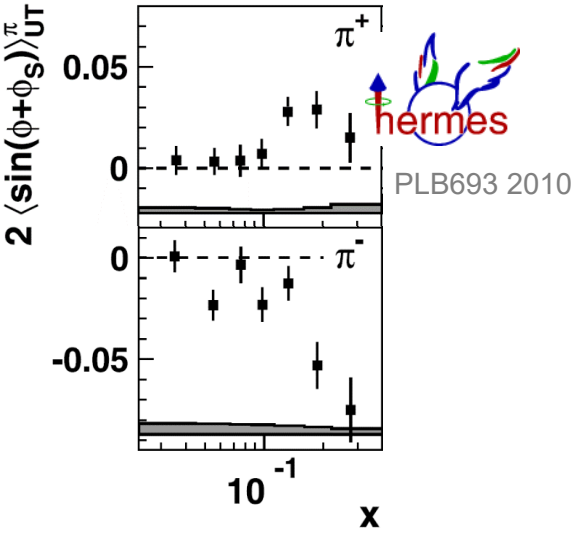

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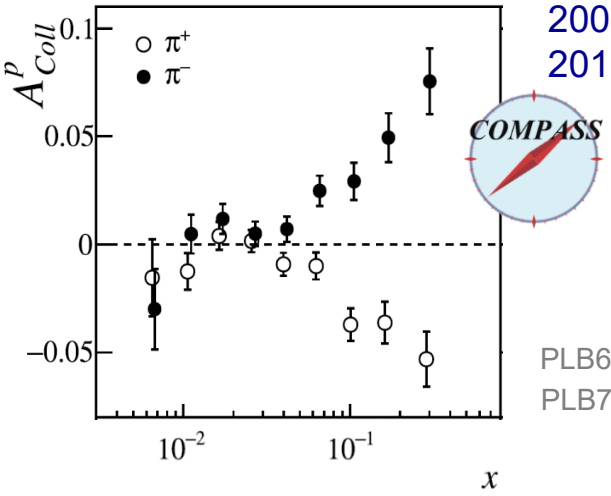

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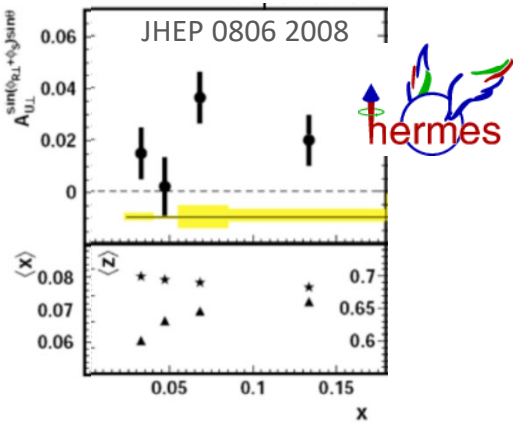
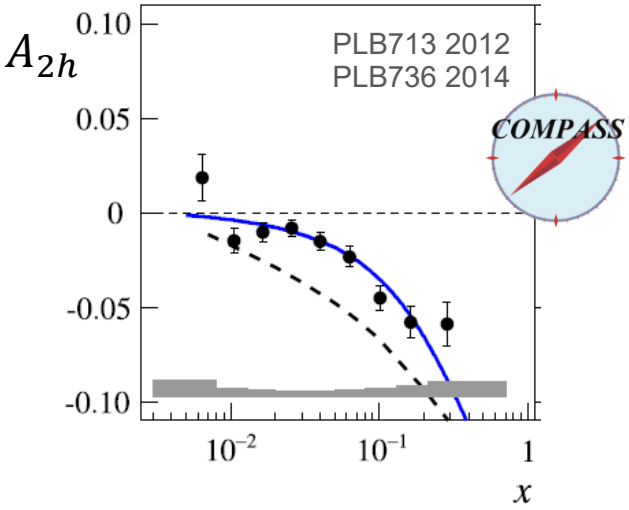
and for the di-hadron asymmetry

$\sim h_1^q \cdot H_q^{\angle}$





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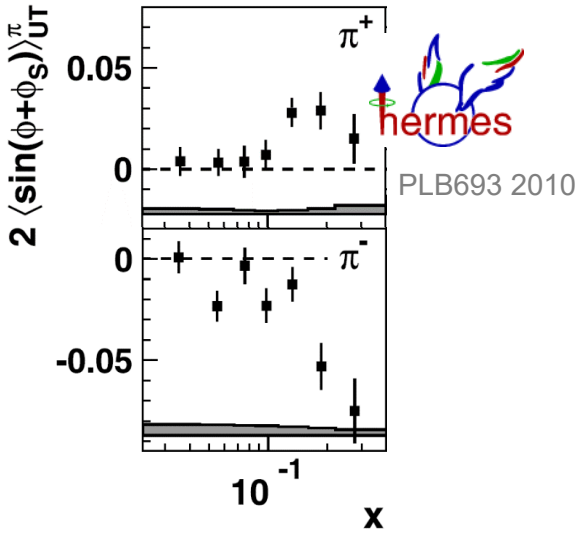

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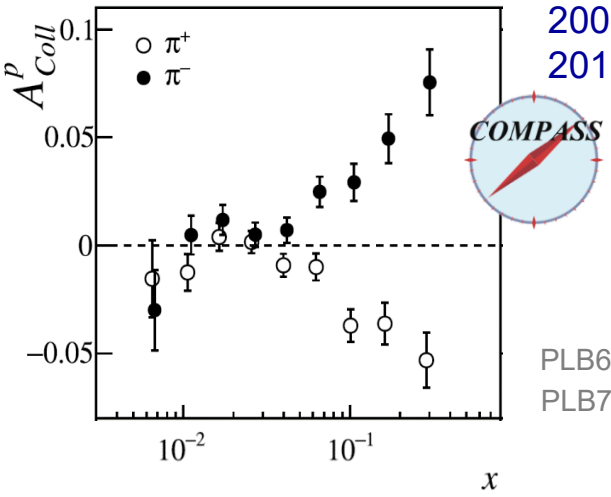

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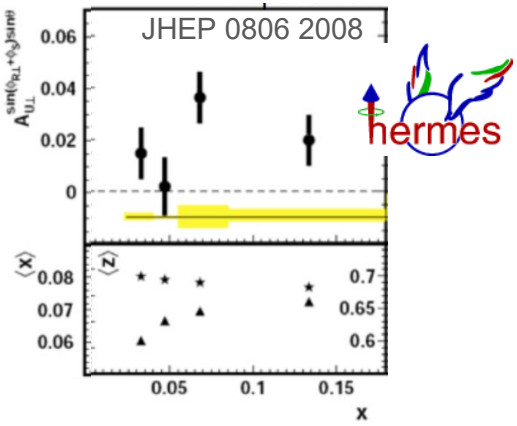
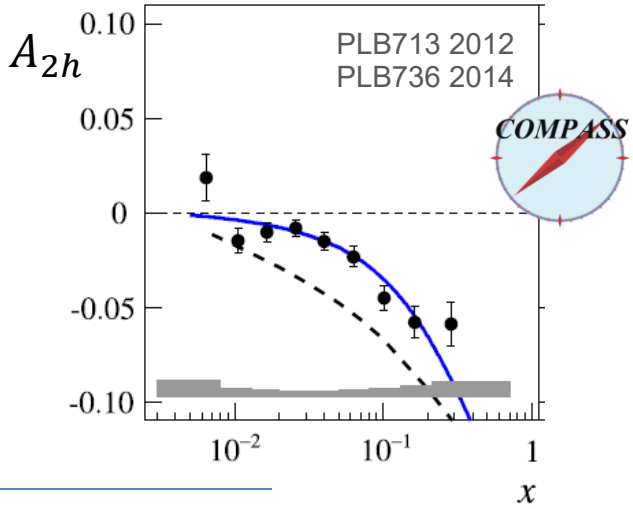


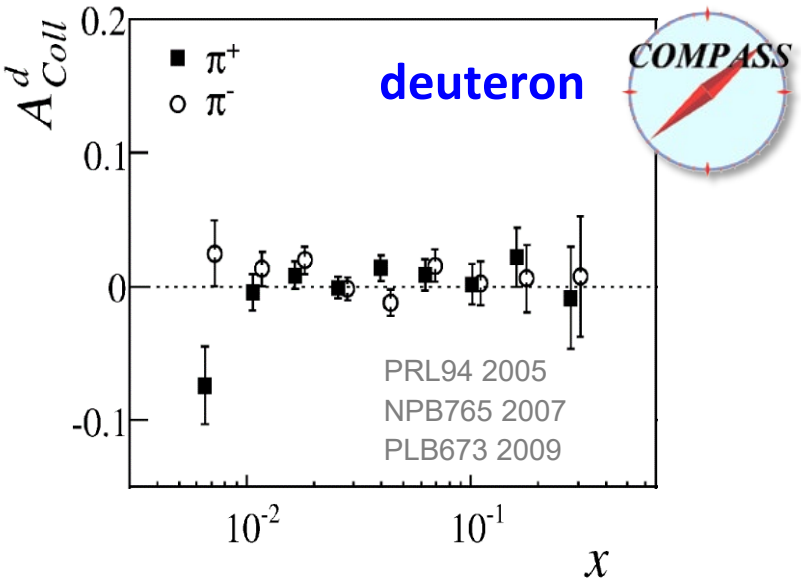


and for the Sivers asymmetry

SIDIS off transversely polarised deuterons

needed to perform flavour separation

results from COMPASS only, data collected in 2002, 2003 and 2004
(25% of running time, reduced acceptance)



Collins asymmetry
- compatible with zero
- large statistical uncertainties

similar results for
di-hadron asymmetries and
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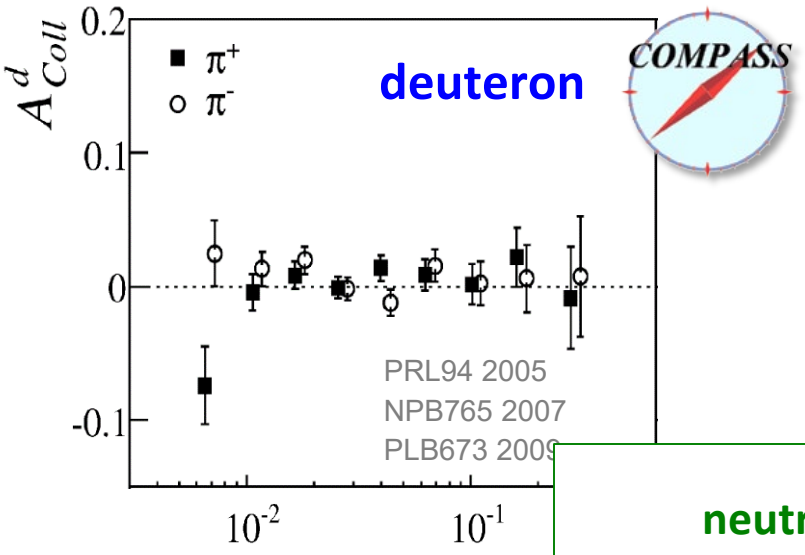

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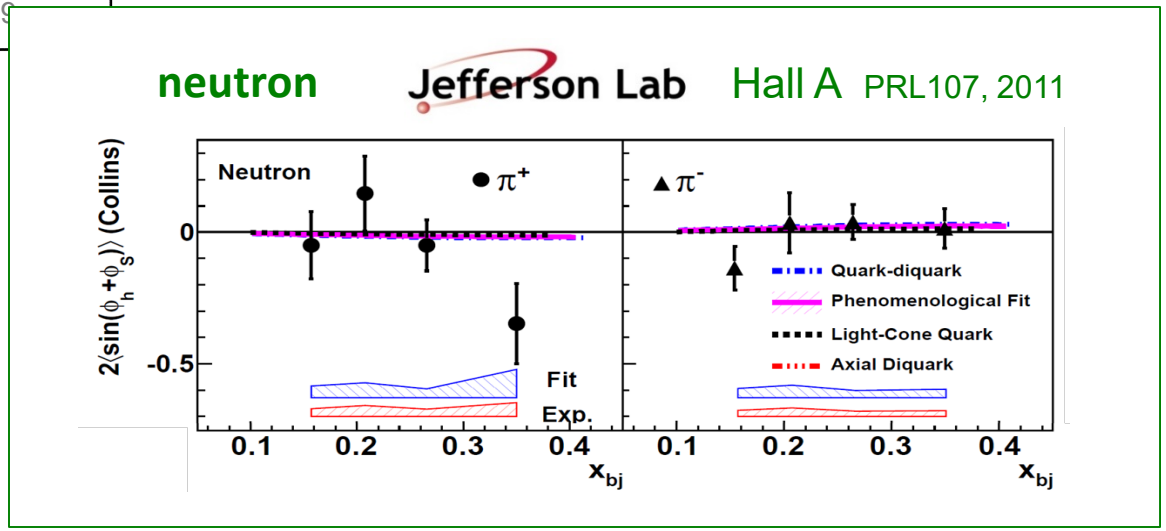

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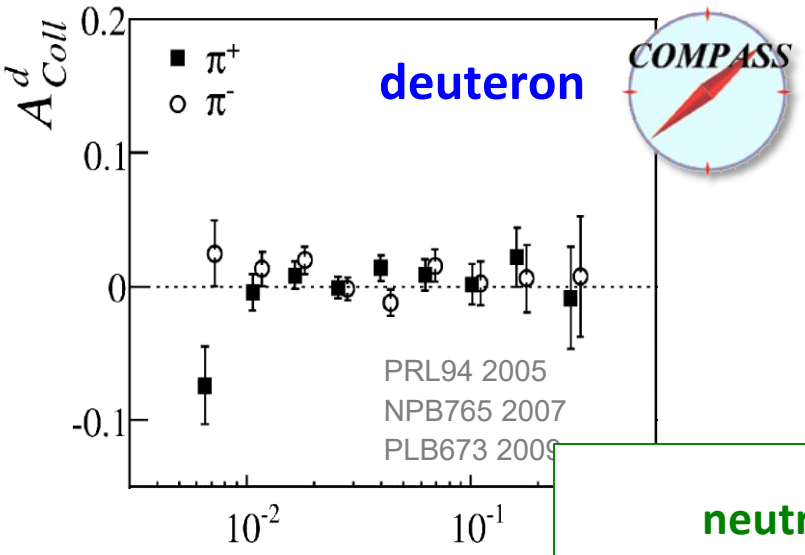

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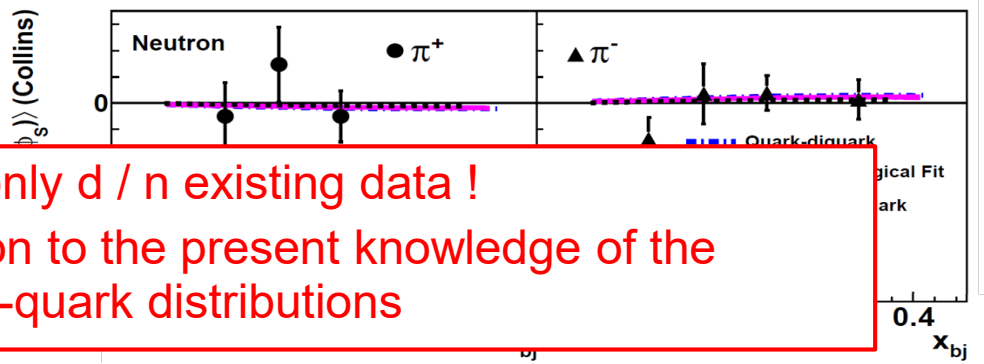
neutron Jefferson Lab Hall A PRL107, 2011

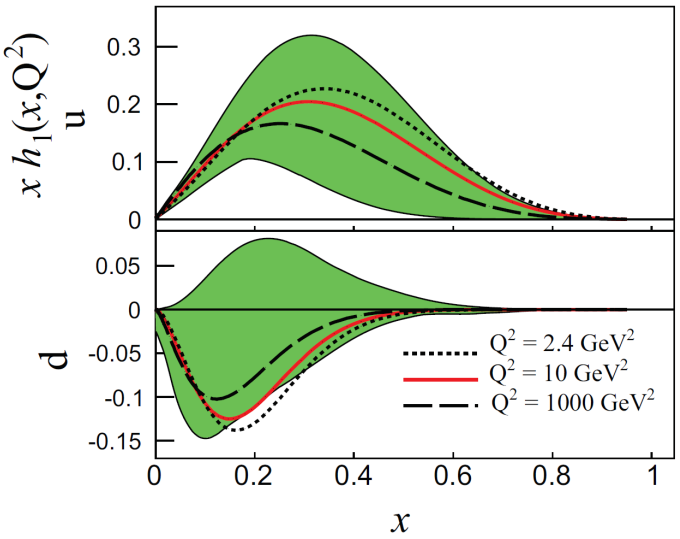


the only d / n existing data !
a strong limitation to the present knowledge of the d-quark distributions

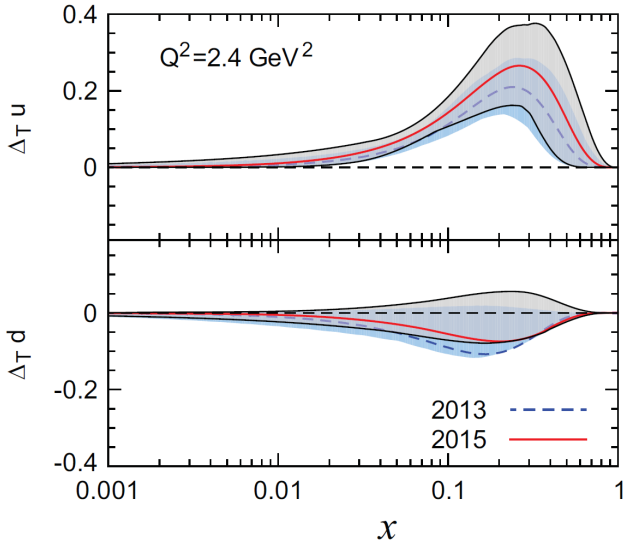
extraction of Transversity

global fits Collins SIDIS, e+e- data

Z.-B. Kang et al. PRD 2016



M. Anselmino et al.PRD2015



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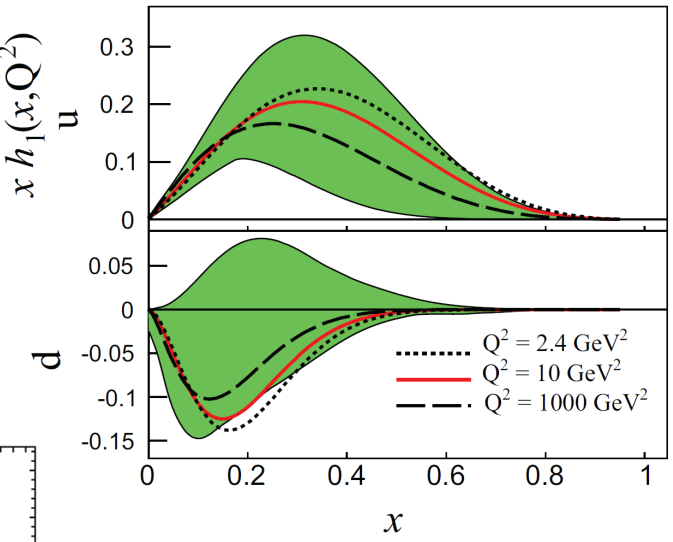

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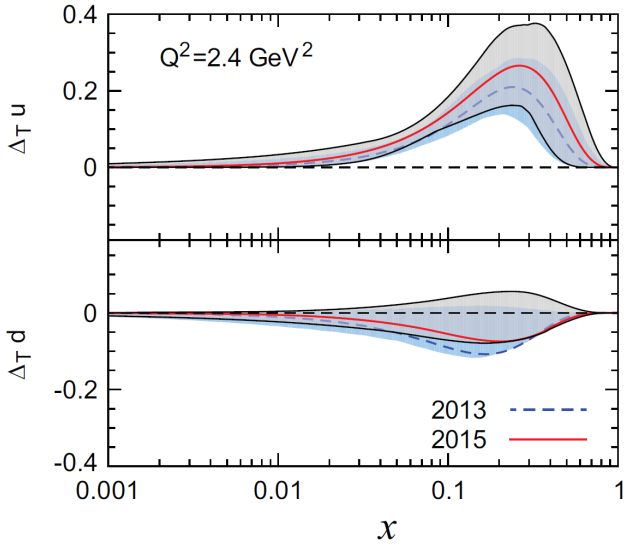

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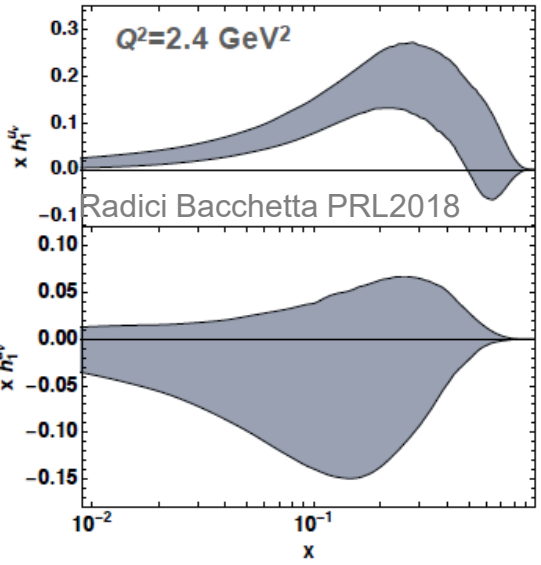

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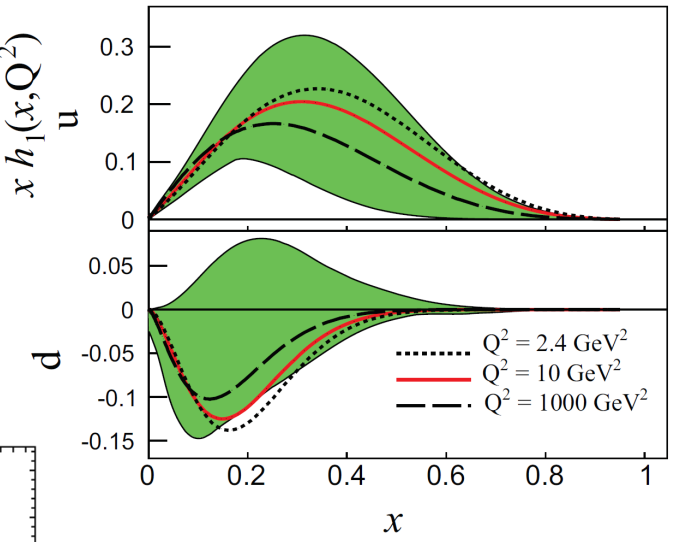

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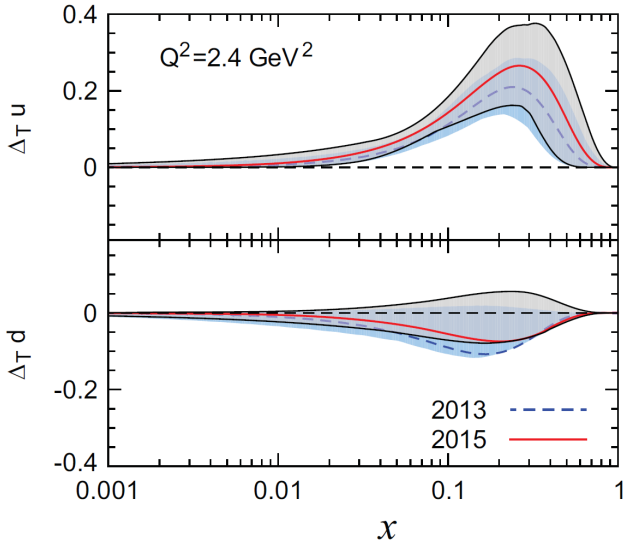

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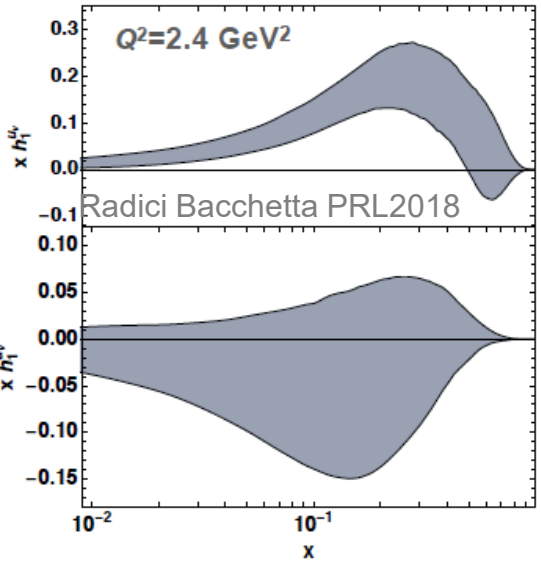
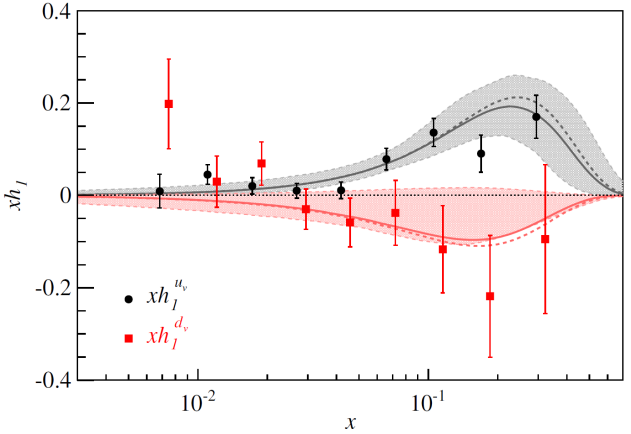


point by point extraction
COMPASSp and d,
e+e- data

A. M. F.B. V.B. PRD2015
vs M Anselmino et al PRD2013



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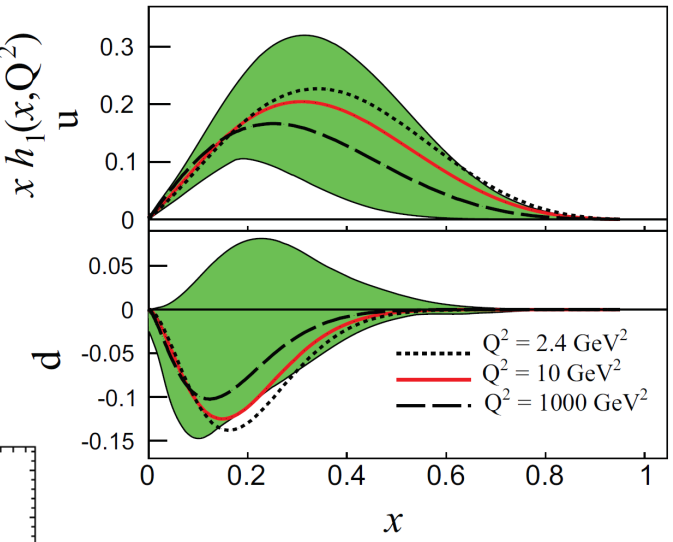

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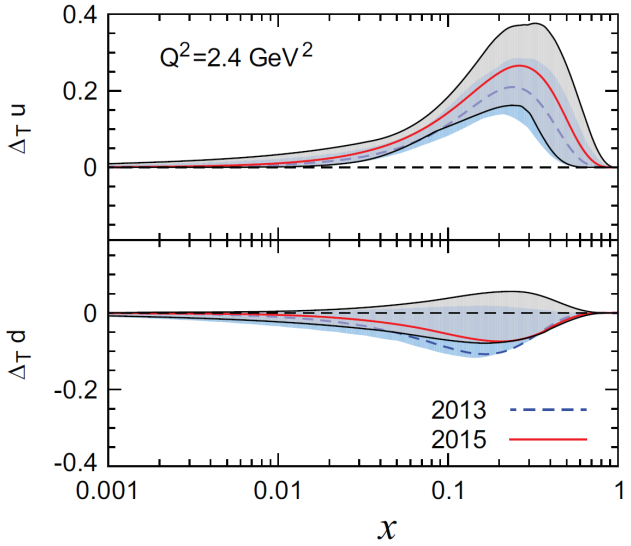

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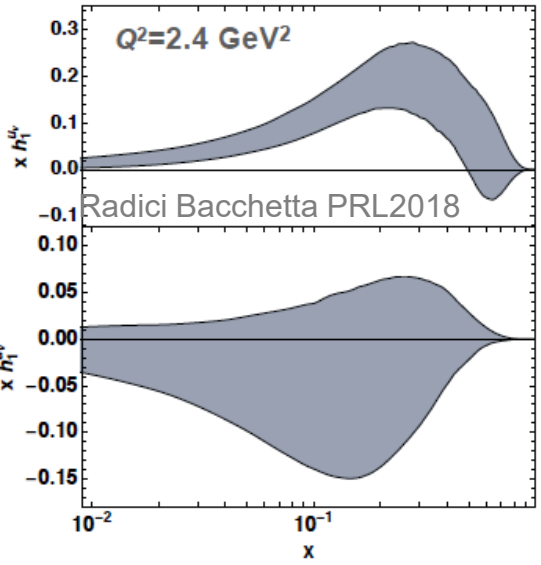

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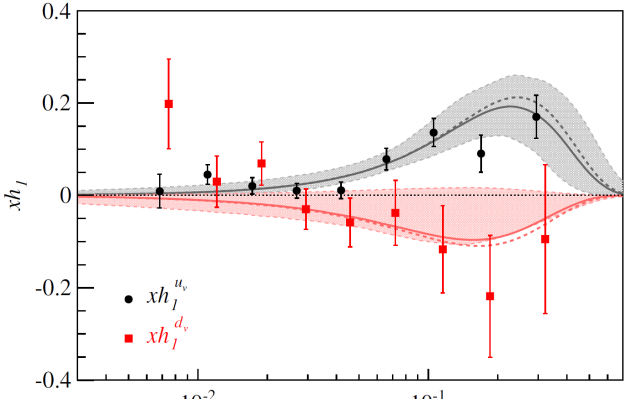


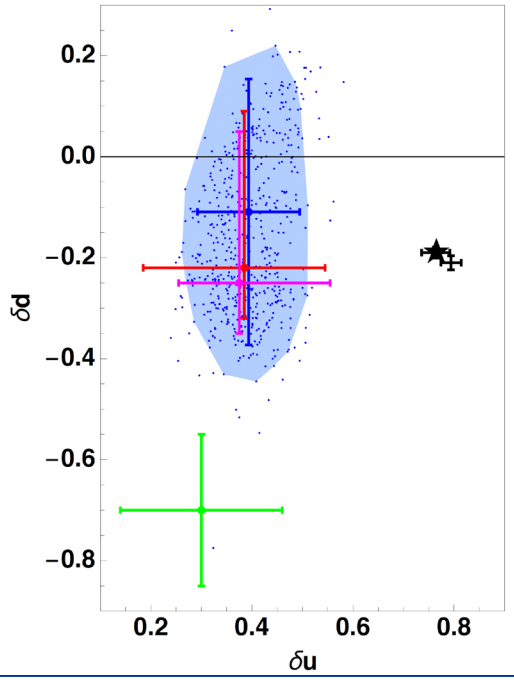
scarcity of deuteron (neutron) data
→ d-quark PDFs much worse determined than u-quark PDFs

nucleon tensor charge

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

A. Bacchetta, M. Radici
plenary, WG6

Tensor charge $$\delta q \equiv g_T^q = \int_0^1 dx \ \left[h_1^q(x,Q^2) - h_1^{\bar{q}}(x,Q^2)\right]$$



- Alexandrou et al., arXiv:1703.08788
- Gupta et al., arXiv:1806.09006
- Anselmino et al., arXiv:1303.3822
- Kang et al., arXiv:1505.05589
- Lin et al., arXiv:1710.09858
- Radici et al., arXiv:1802.05212

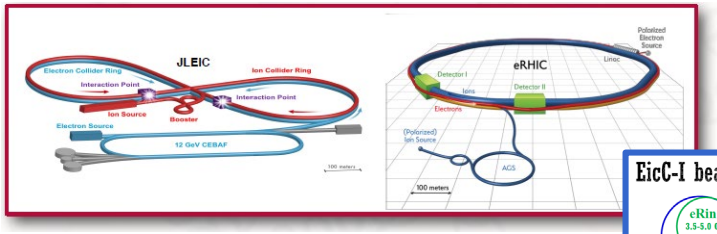
At the moment, there is a clear tension between extractions and lattice calculations

A. Bacchetta

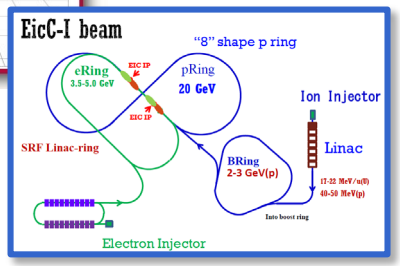
Experimental perspectives

SIDIS experiments with transversely polarised nucleons: future

EIC transversely polarised
(WG7) p and d/He3
high energy
high precision data



EicC



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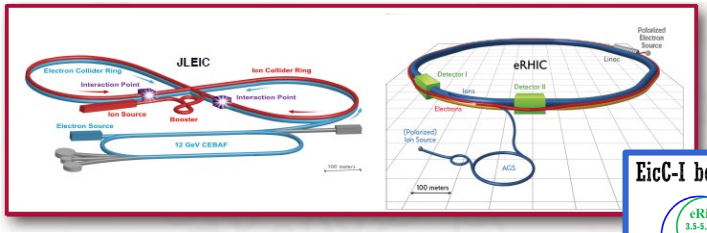

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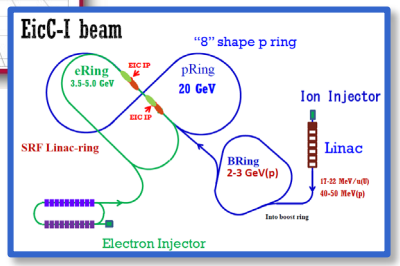
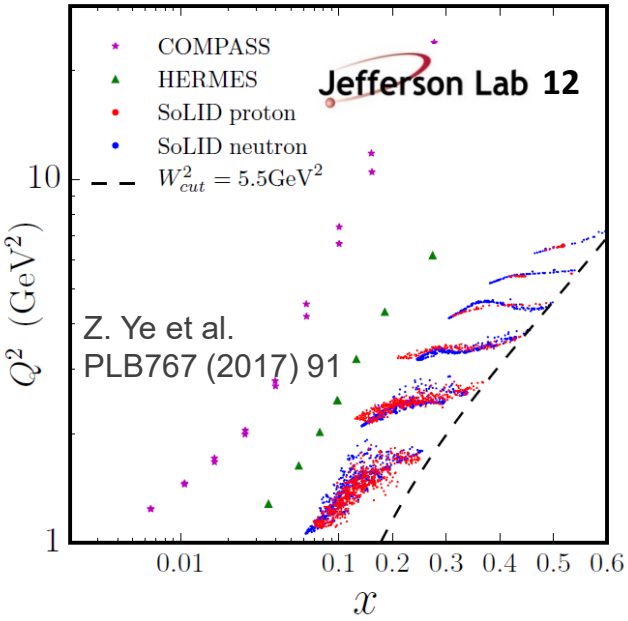


in the mean time

JLab12 transversely polarised p and d/He3,
in ~ 4 years ?



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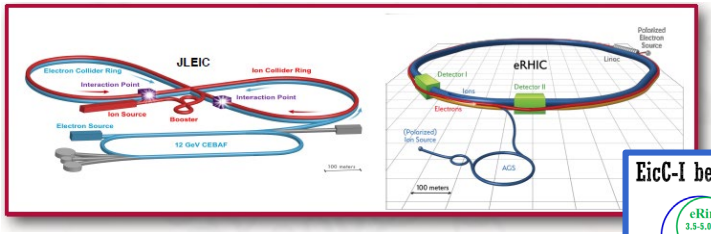

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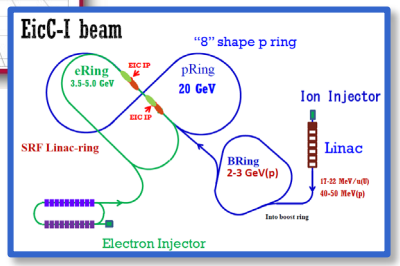

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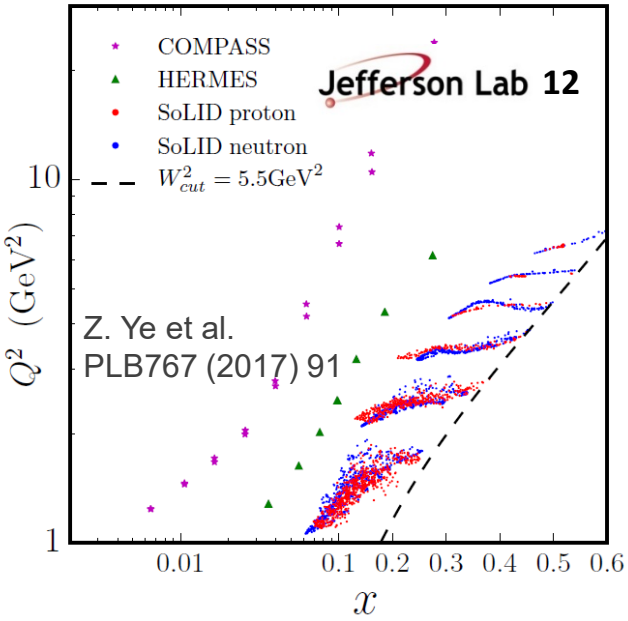
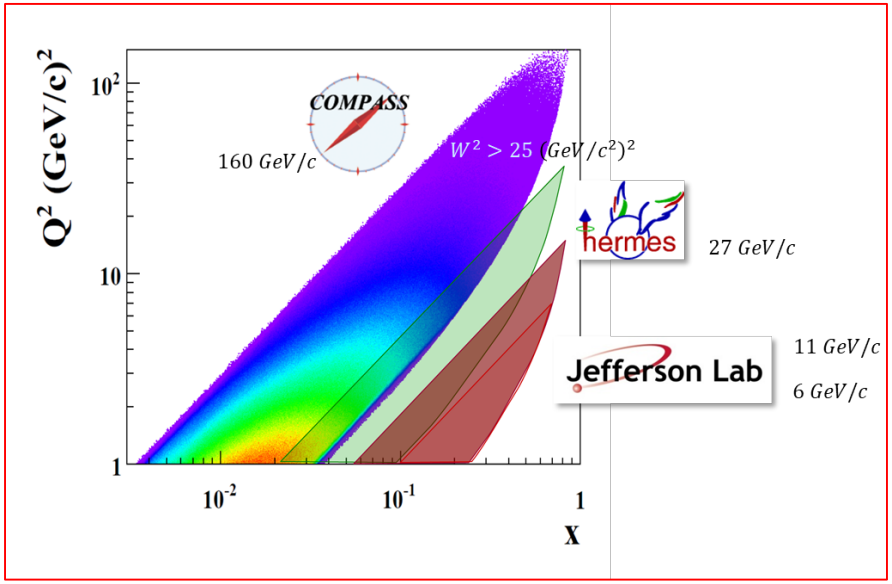


and COMPASS in 2021



Anna Martin

expected outcome of the 2021 COMPASS deuteron run

for the proposal we have evaluated the expected precision on

- the Collins asymmetry
- the transversity PDF
- the tensor charge

starting from the experience of the successful 2010 proton run

expected outcome of the 2021 COMPASS deuteron run

for the proposal we have evaluated the expected precision on

- **the Collins asymmetry**
- **the transversity PDF**
- **the tensor charge**

starting from the experience of the successful 2010 proton run

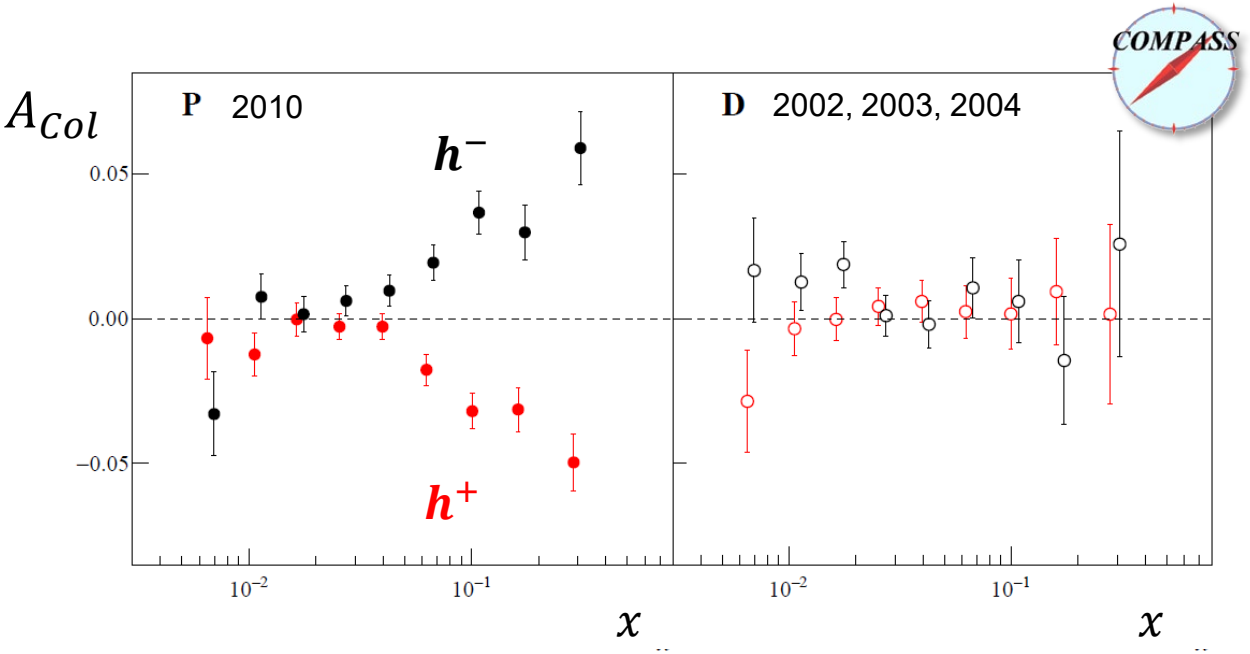
we assumed one year of data taking
with ^{6}LiD as in 2002 - 2004,
with the **same muon beam integrated intensity as in 2010** and
the **same spectrometer performances**

$$N_{d,h}^{1y} = N_{p,h} = 80 \cdot 10^6$$

$$\sigma_A \approx \frac{1}{fP}\frac{1}{\sqrt{N}} = \frac{1}{FOM}\frac{1}{\sqrt{N}}$$

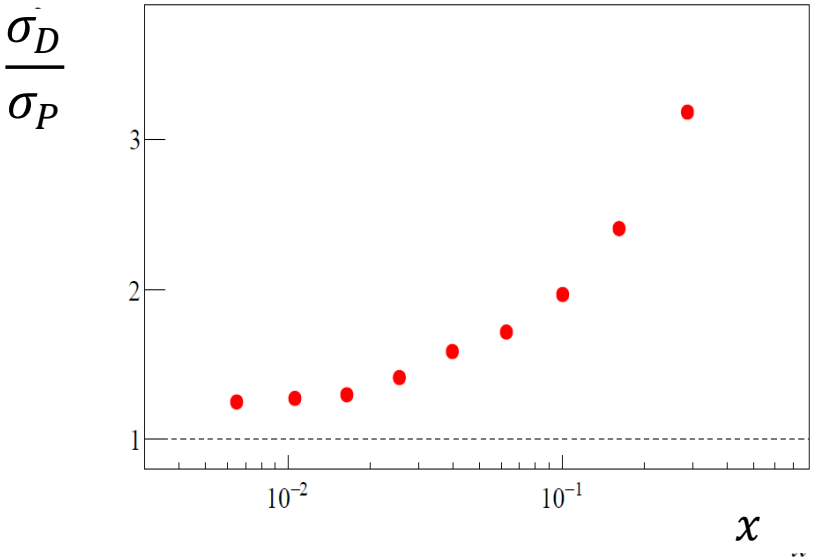
$$\frac{\sigma_{A_d}^{1y}}{\sigma_{A_p}^{2010}} = \frac{FOM_p}{FOM_d} = 0.62$$

Collins asymmetry – existing COMPASS data



present

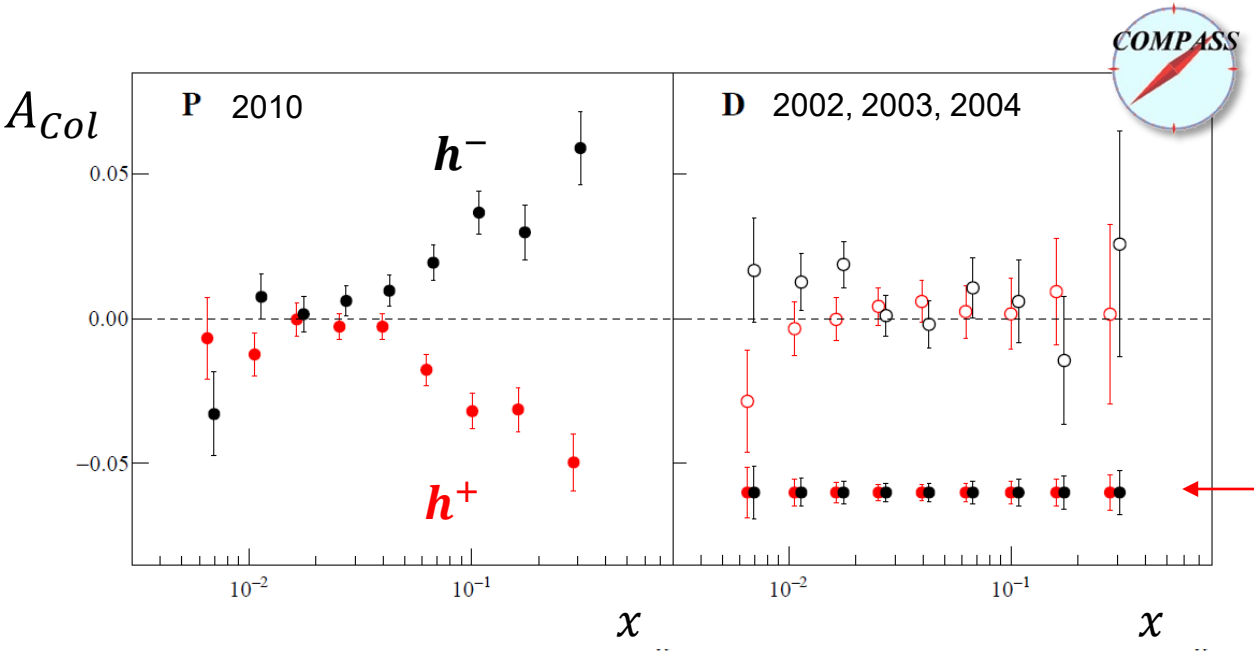
P 2007 data
non used here



three effects:

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

new deuteron data: impact on the Collins asymmetry



expected 2021 uncertainties

statistical uncertainties reduced by a factor 2 to 5 with respect to the present data

new deuteron data: impact on the Collins asymmetry

difference asymmetries – results

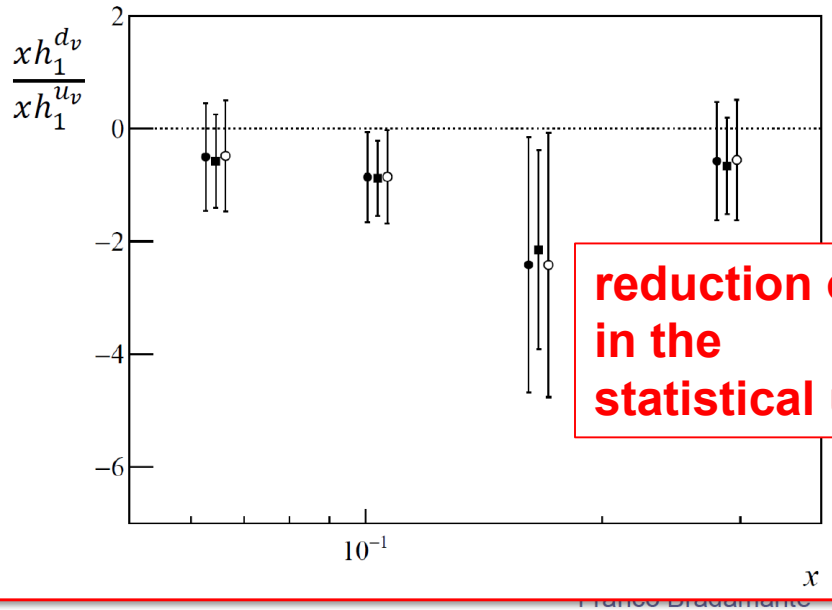
$$\frac{A_{D,d}}{A_{D,p}} = 3\,\frac{\sigma^{+}_{0,p} + \sigma^{-}_{0,p}}{\sigma^{+}_{0,d} + \sigma^{-}_{0,d}}\,\frac{h_1^{u_v} + h_1^{d_v}}{4h_1^{u_v} - h_1^{d_v}}$$

$$\frac{A'_{D,d}}{A'_{D,p}} = \frac{4f_1^{u_v} - f_1^{d_v}}{f_1^{u_v} + f_1^{d_v}}\,\frac{h_1^{u_v} + h_1^{d_v}}{4h_1^{u_v} - h_1^{d_v}}$$

→ $\boldsymbol{\frac{h_1^{d_v}}{h_1^{u_v}}}$

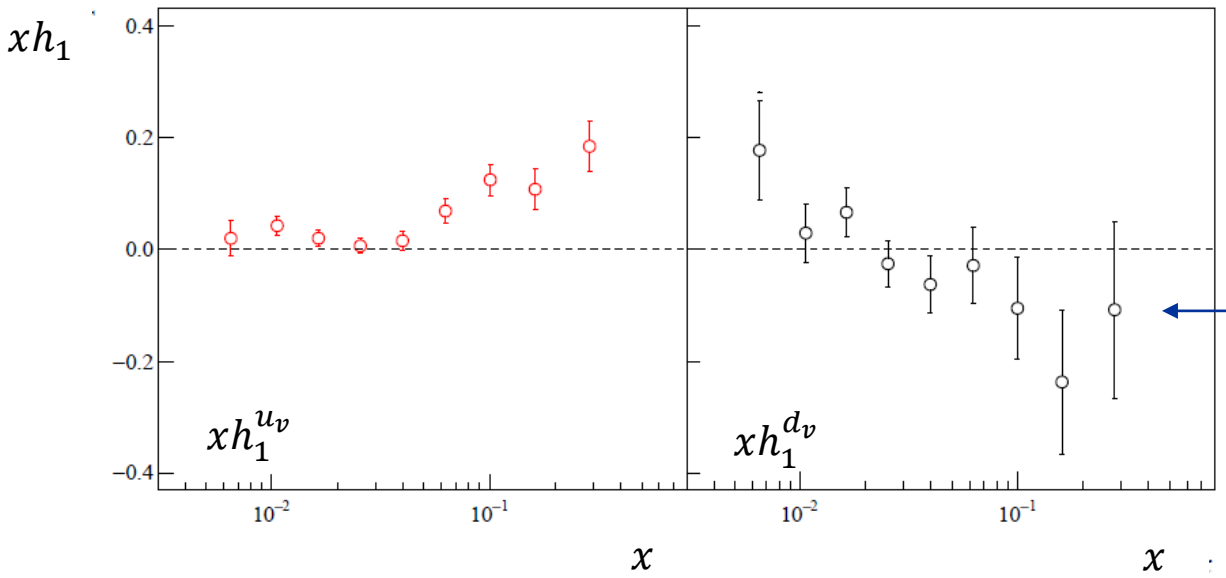
- from A_D
- from A'_D
- from $xh_1^{d_v}$ and $xh_1^{u_v}$

A. Martin, F.B., V. Barone
PRD91 2015



reduction of a factor ~4 in the statistical uncertainties

new deuteron data: impact for the transversity function

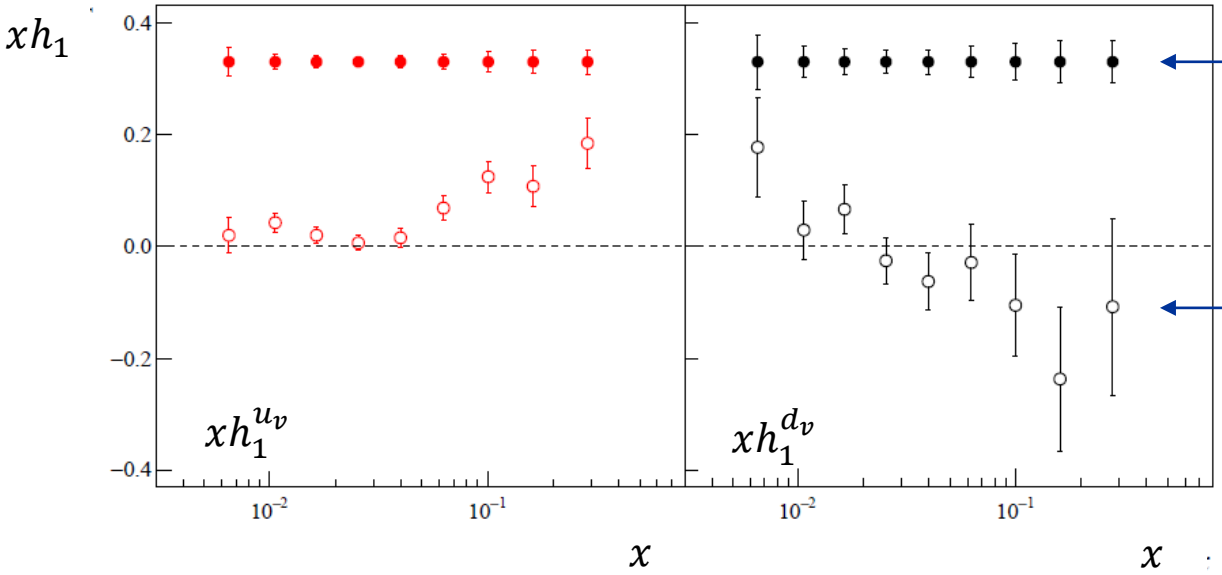


present

PRD 91(2015) 014034
from COMPASS p, d and e+e- data
we have followed the method in for all the transversity extraction

valence

new deuteron data: impact for the transversity function



projected

present

PRD 91(2015) 014034
from COMPASS p, d and e+e- data
we have followed the method in for all the transversity extraction

valence

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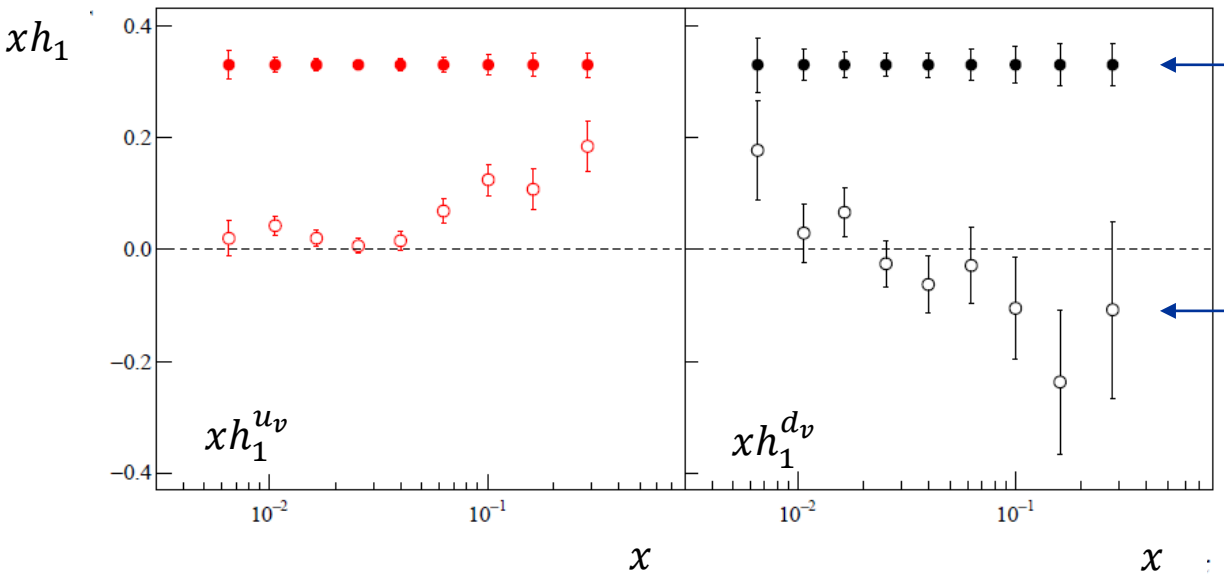

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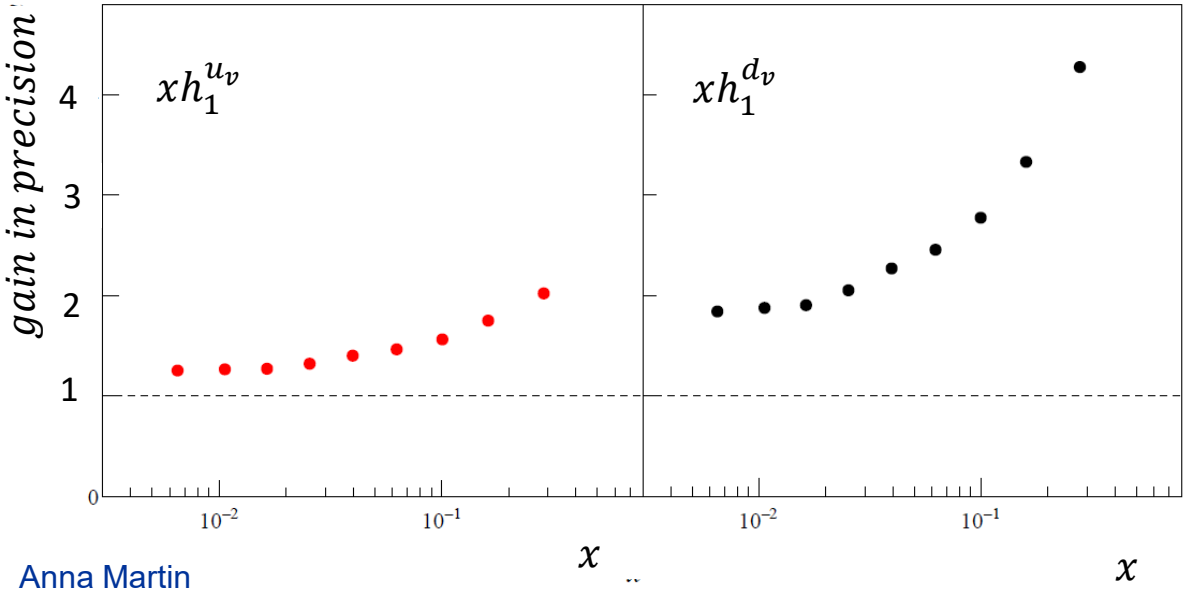

valence

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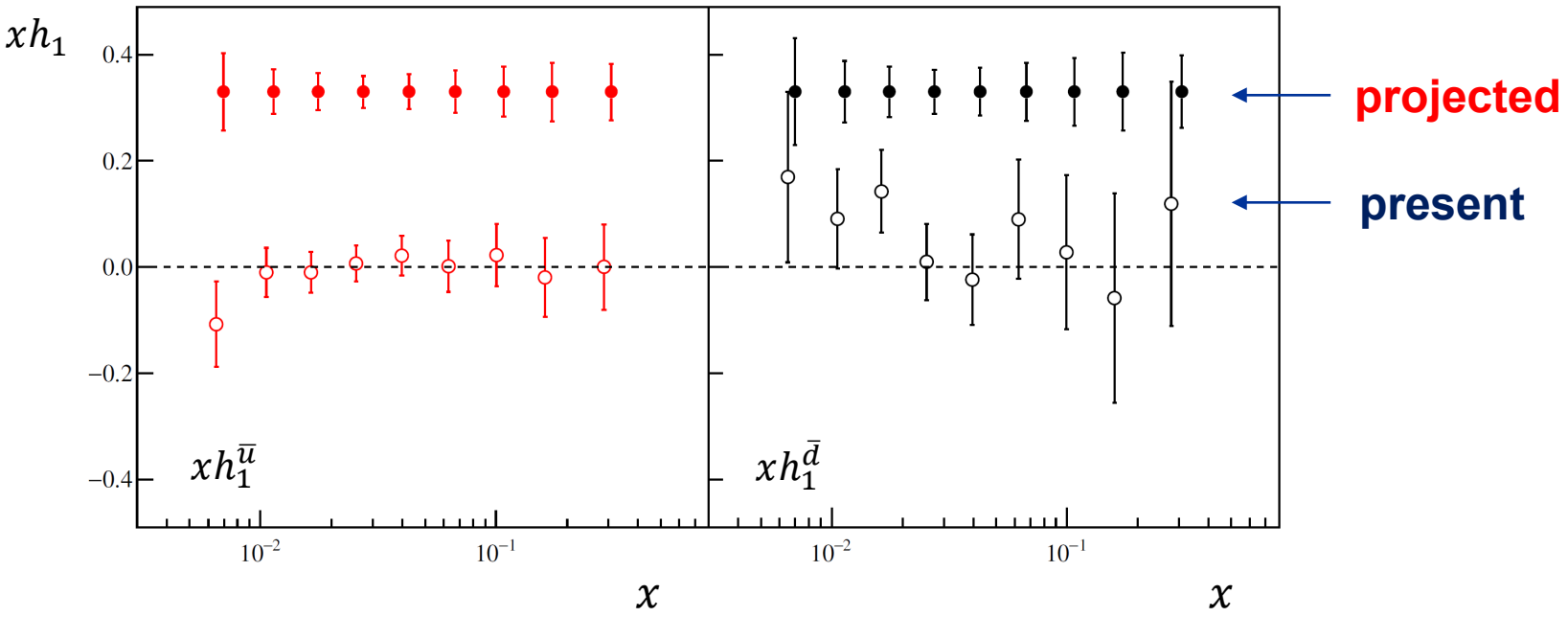
Transversity — sea



new deuteron data: impact for the tensor charge

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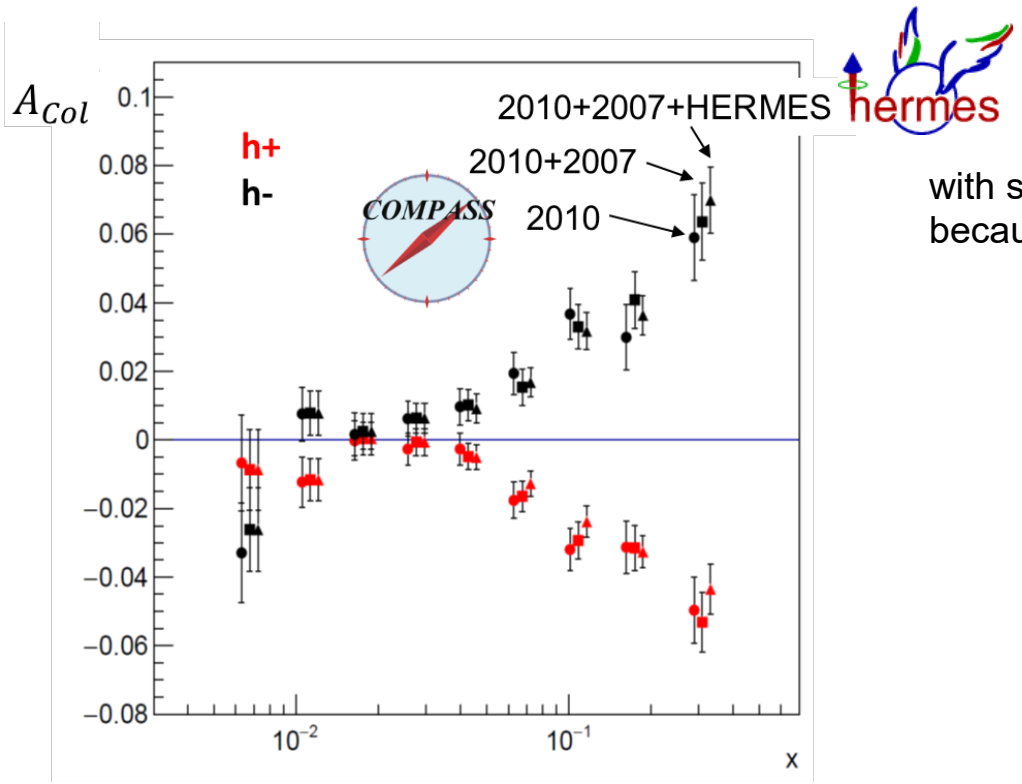
using all the existing proton data
COMPASS 2010 and 2007 plus HERMES ("P all")



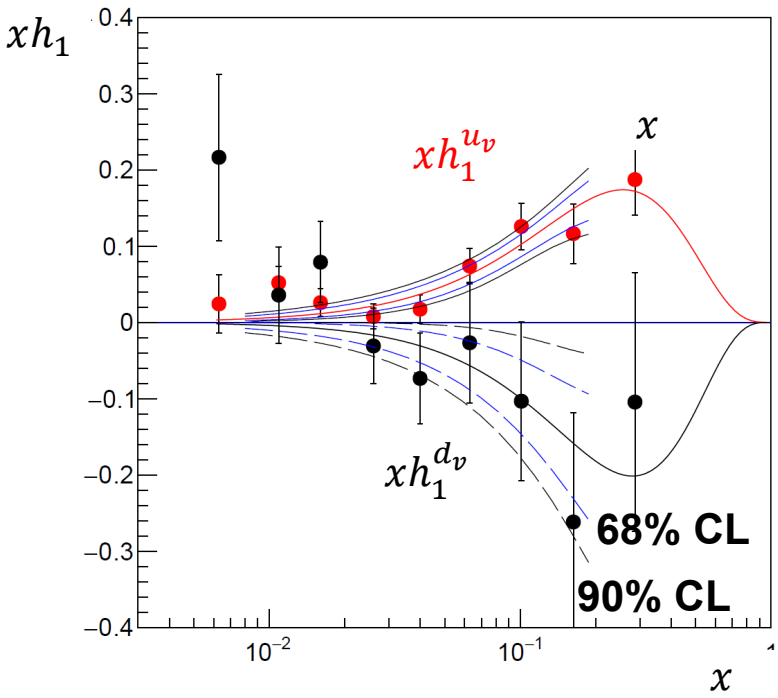
with some approximation
because of the different binning

new deuteron data: impact for the tensor charge

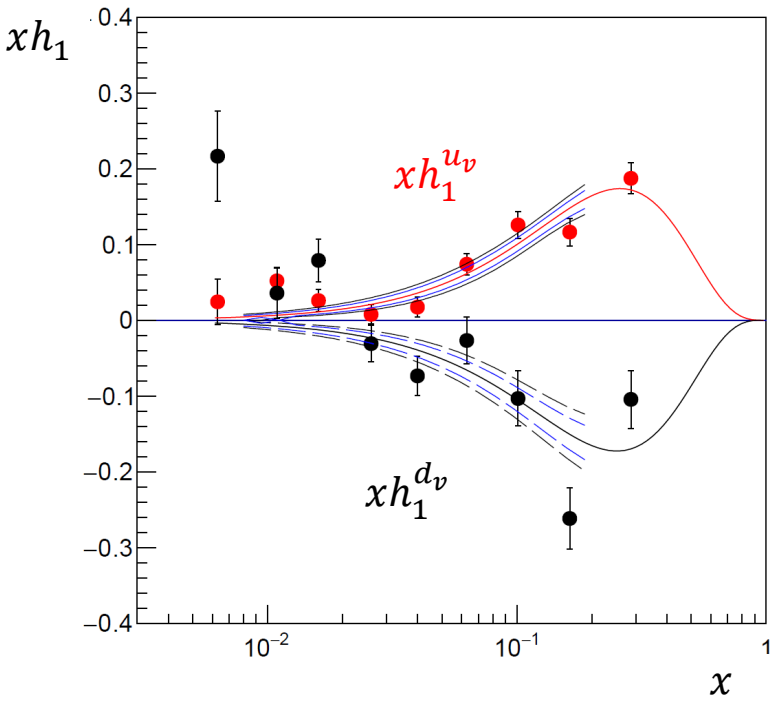
using all the existing proton data
COMPASS 2010 and 2007 plus HERMES ("P all")

using a simple parametrisation we have calculated the Confidence Levels from replicas

present
P all, **D 2002-2004**



projected
P all, **D 2021 only**



new deuteron data: impact for the tensor charge

using all the existing proton data
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final estimation of the statistical uncertainties in the COMPASS range

$\Omega_x: 0.008 \div 0.210$

	$\delta_u = \int_{\Omega_x} dx h_1^{u_v}(x)$	$\delta_d = \int_{\Omega_x} dx h_1^{d}(x)$	$g_T = \delta_u - \delta_d$
present	$0.201 \pm \mathbf{0.032}$	$-0.189 \pm \mathbf{0.108}$	$0.390 \pm \mathbf{0.087}$
projected	$0.201 \pm \mathbf{0.019}$	$-0.189 \pm \mathbf{0.040}$	$0.390 \pm \mathbf{0.044}$

Other measurements

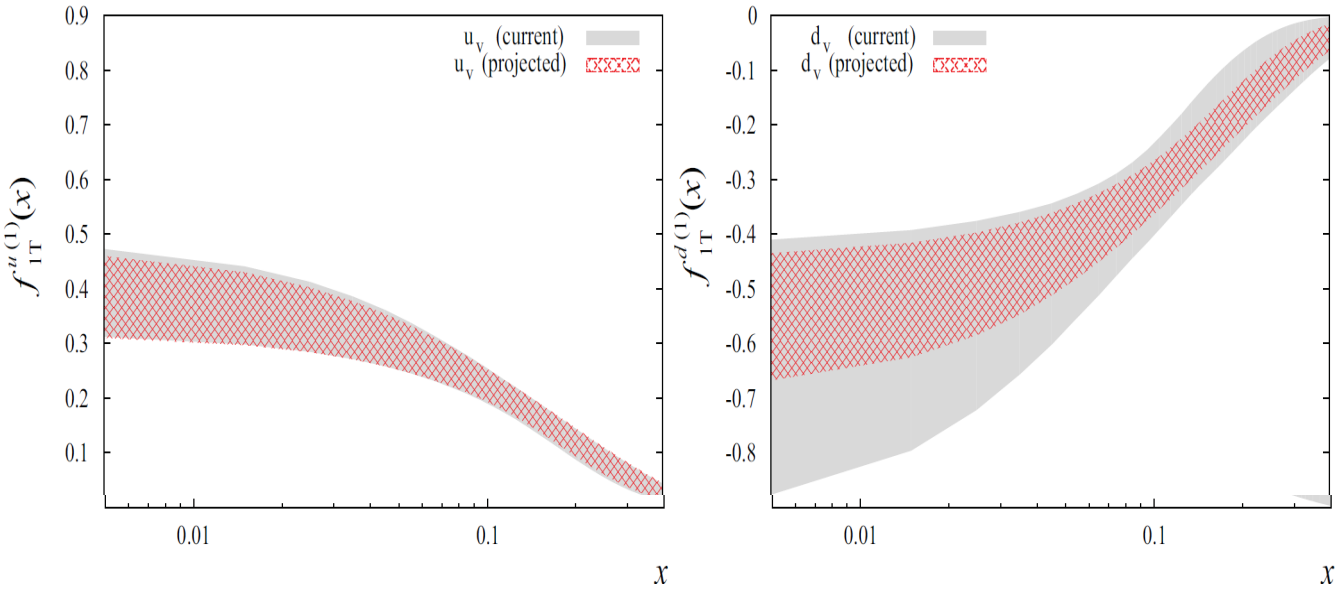
similar improvements are foreseen for all the other already measured transverse spin asymmetries:

- the two hadron asymmetries
- the Sivers asymmetry

Other measurements

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, Jlab)

projected: adding the COMPASS 2021 projected deuteron data

Other measurements

similar improvements are foreseen for all the other already measured transverse spin asymmetries:

- the two hadron asymmetries
- the Sivers asymmetry
- the transverse spin asymmetries “beyond Collins and Sivers”
- the transverse spin asymmetries in exclusive vector meson production
- ....

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- ....

and measurements we could in so far do on proton only

- the multidimensional measurement of the transverse spin asymmetries
- the P_T weighted Sivers asymmetries

will be performed for the first time on deuteron

summary

the 2021 deuteron run COMPASS will allow to complete the exploratory study of the transverse spin structure of the nucleon

the new data will allow to fully use the existing proton data and will be unique in the relatively short future, when only the JLab12 data, at smaller Q^2 and larger x, will become available

summary

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thank you !


XXVII International Workshop on Deep Inelastic Scattering
and Related Subjects
Torino (Italy), 8 - 12 April 2019

The Spectrometer

designed to

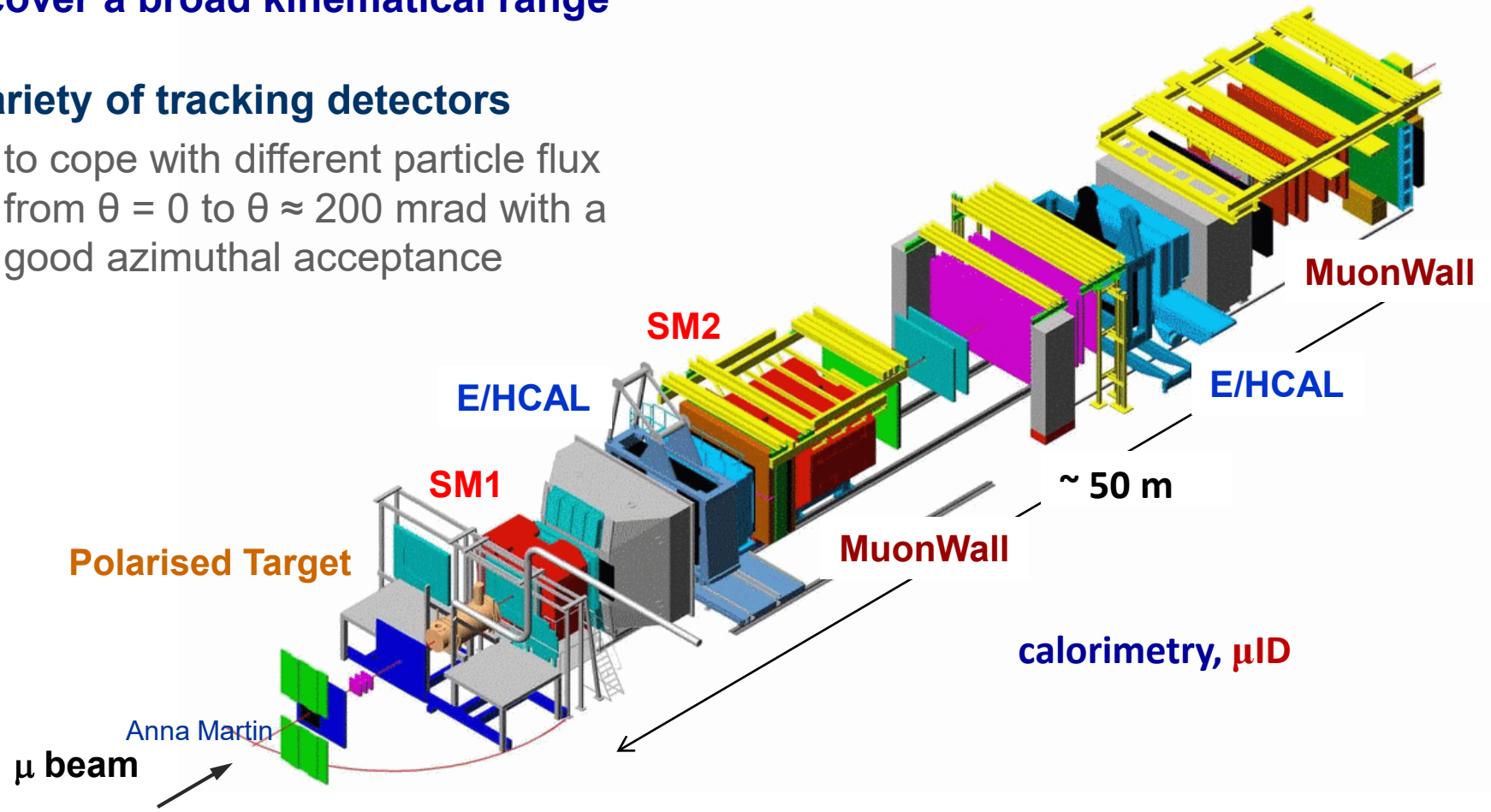
- **use high energy beams**
- **have large angular acceptance**
- **cover a broad kinematical range**

two stages spectrometer

- **Large Angle Spectrometer (SM1)**
- **Small Angle Spectrometer (SM2)**

variety of tracking detectors

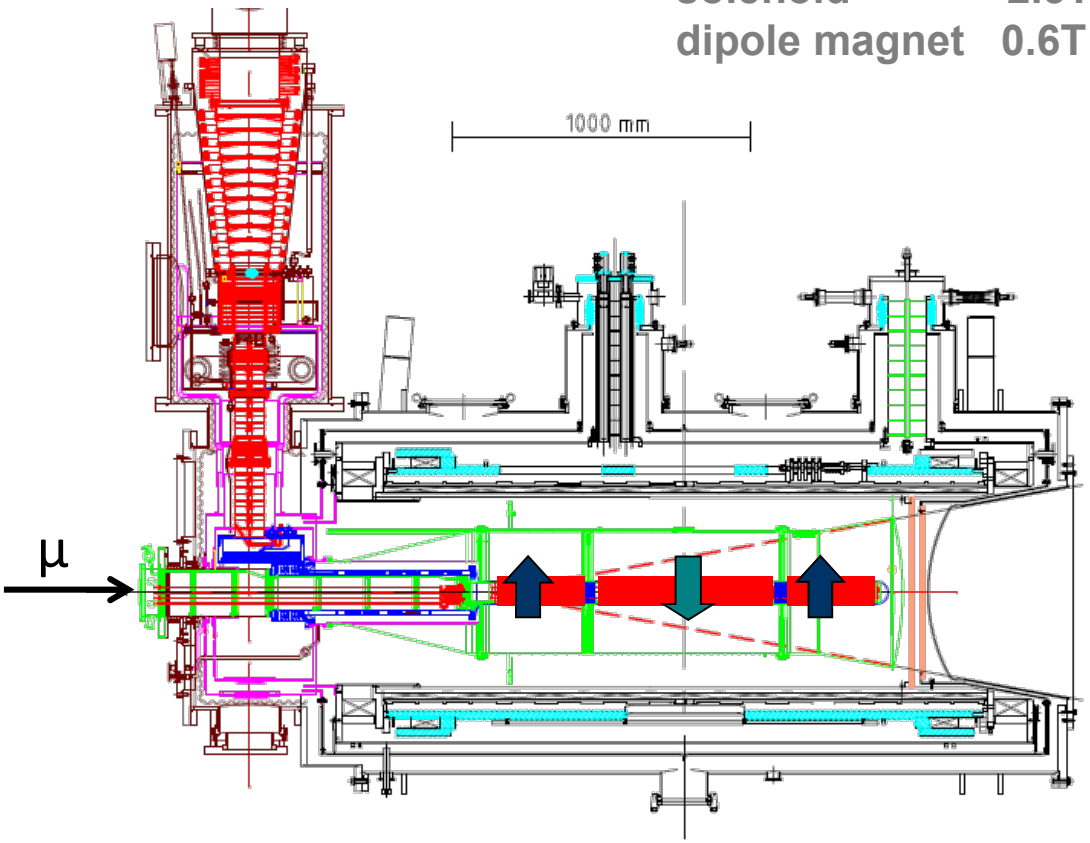
to cope with different particle flux from $\theta = 0$ to $\theta \approx 200$ mrad with a good azimuthal acceptance



The Polarized Target System (>2005)

^{3}He – ^{4}He 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

using all the existing p data

COMPASS 2010 and 2007, HERMES

no problem to add the 2007 data (HepData)

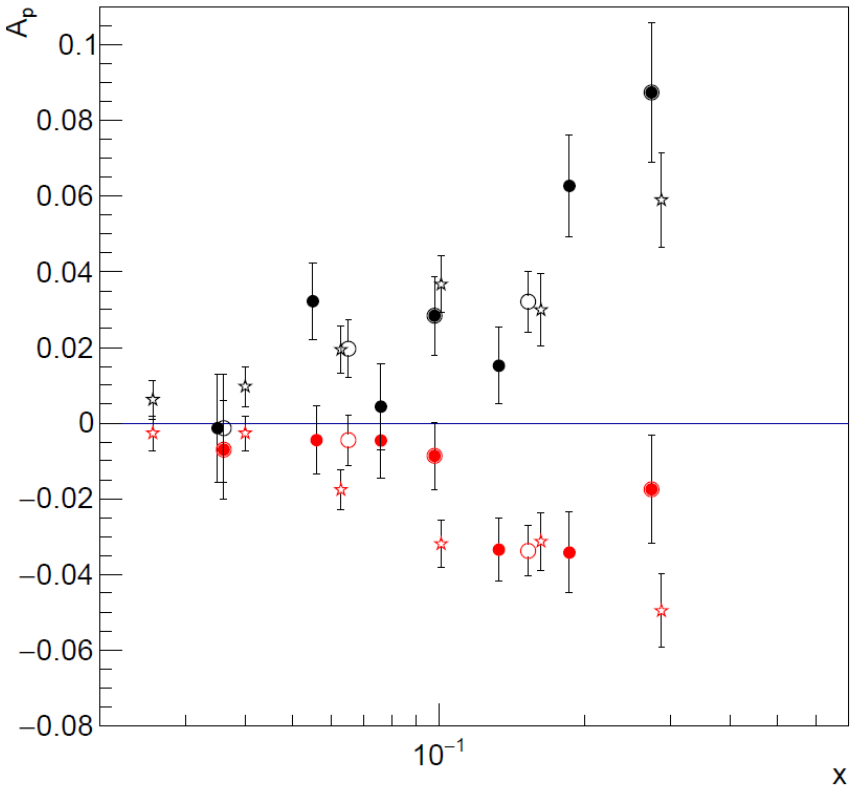
problems with HERMES

- 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



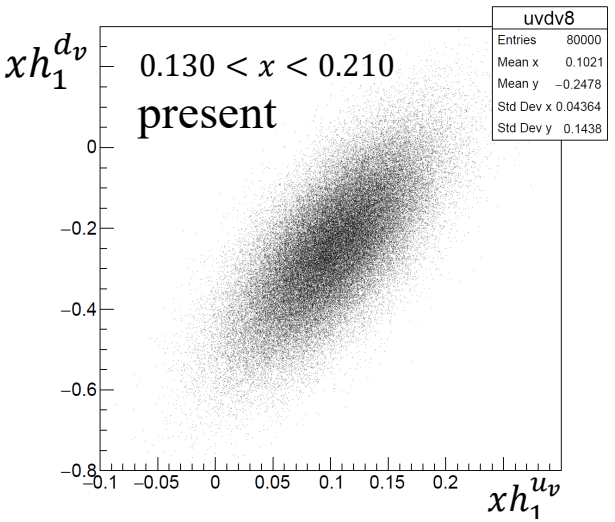
then weighted mean with COMPASS

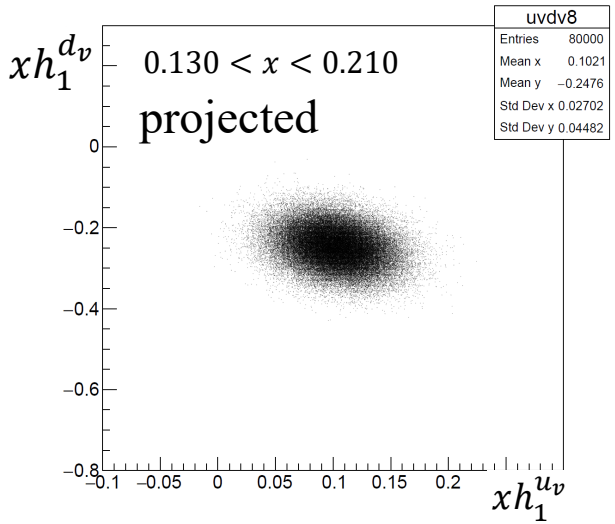
extraction of the tensor charge

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





replicas

complementarity with the 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

complementarity with the 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

Z. Ye et al.
PLB767 (2017) 91

- 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