DY AT COMPASS: RECENT RESULTS ON TSAs

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on behalf of the COMPASS collaboration

4^{th} April 2017 – IWHSS Cortona,Italy

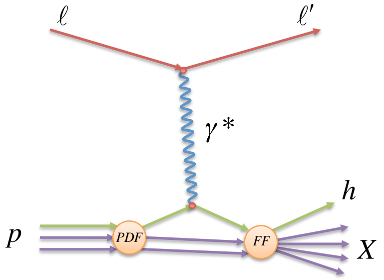
COMPASS

FCT
Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR
CERN/FIS–NUC/0017/2015

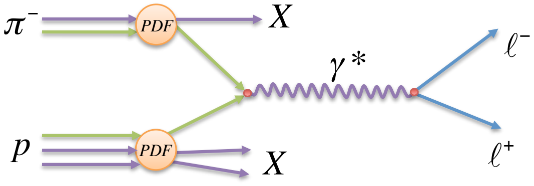
LIP

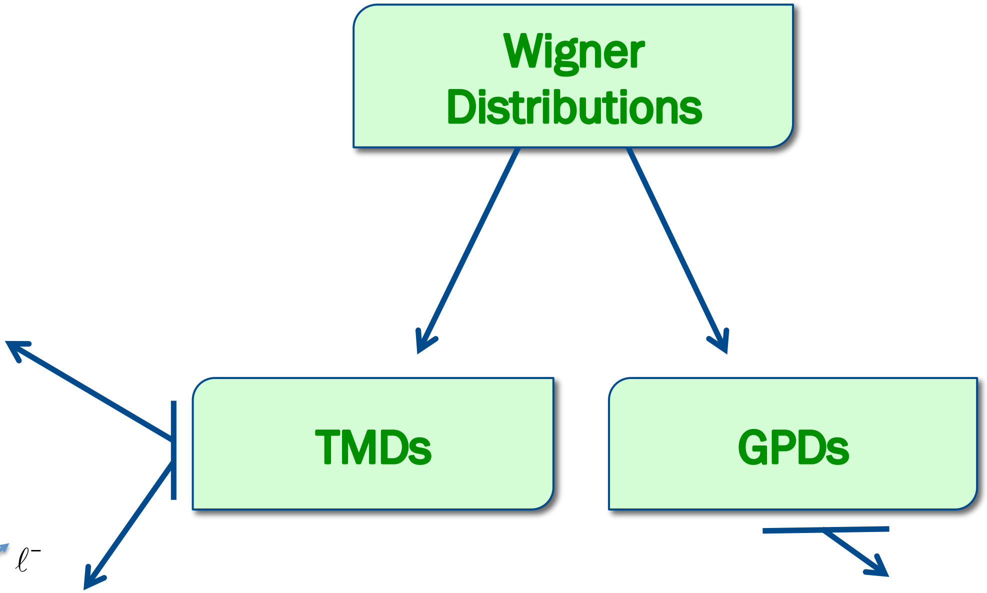
How are the partons distributed inside the nucleon?

SIDIS



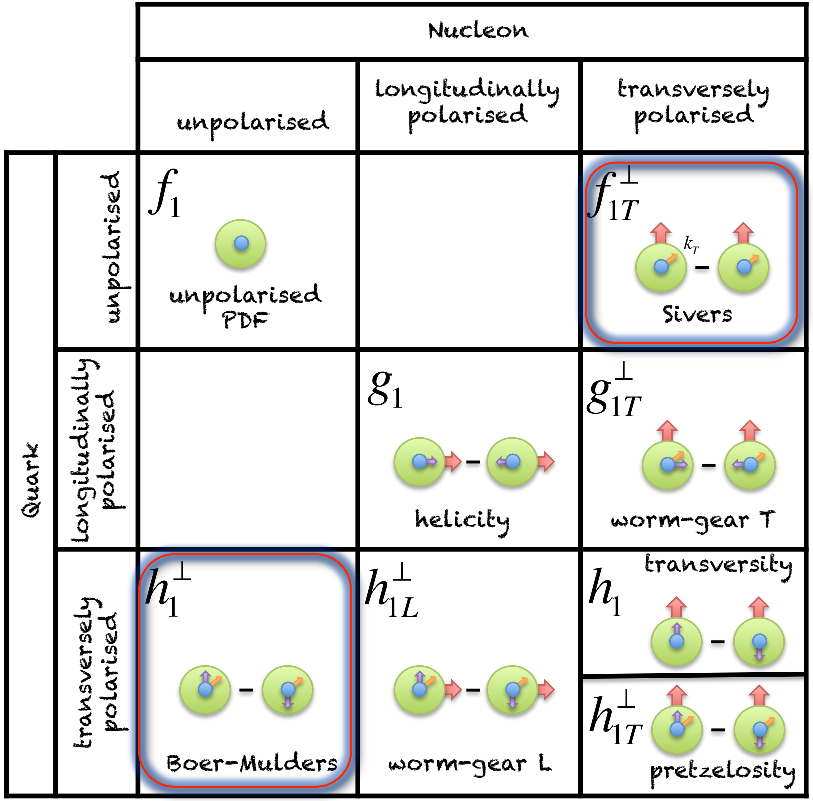
DY





For news on COMPASS results see talk of Mathias Gorzellik

Nucleon structure – TMD PDFs



COMPASS contribution:

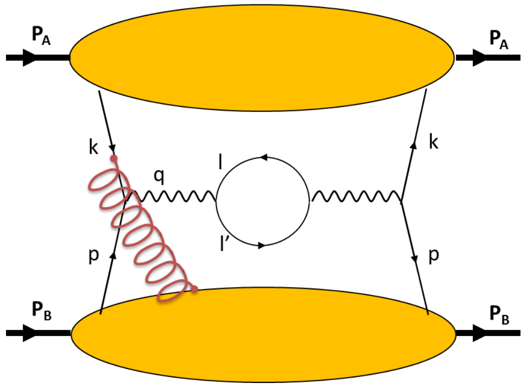
- Measurement of different asymmetries related to these TMDs
- Study of their dependence on different kinematic variables
- Access them through two different processes, SIDIS and DY

allows

Check of TMDs restricted universality of Sivers and Boer-Mulders using essentially the same setup

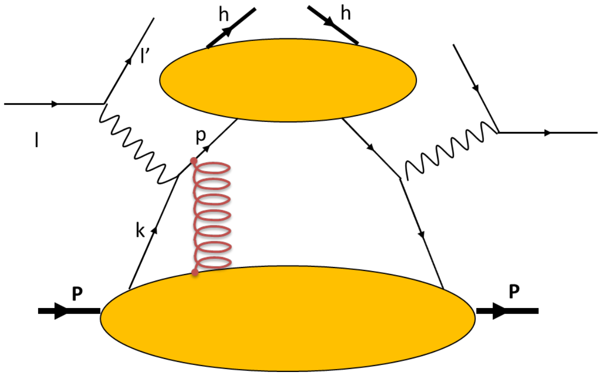
Sivers sign change

DY



QCD gluon gauge link in the initial or in the final state

SIDIS

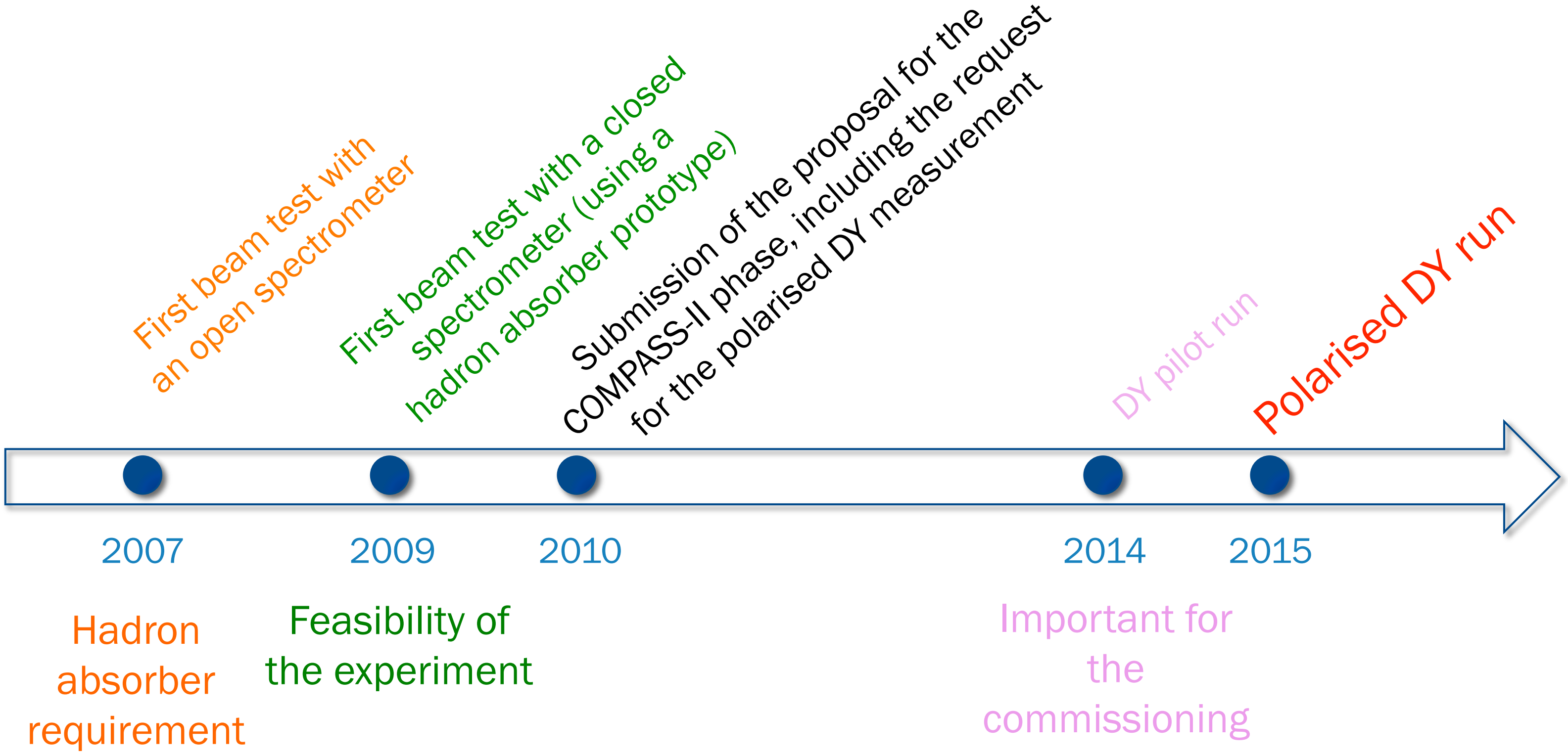


$$f_{1T}^{\perp}(x,k_T)|_{DY} = -f_{1T}^{\perp}(x,k_T)|_{SIDIS}$$

Crucial test of the QCD TMD approach

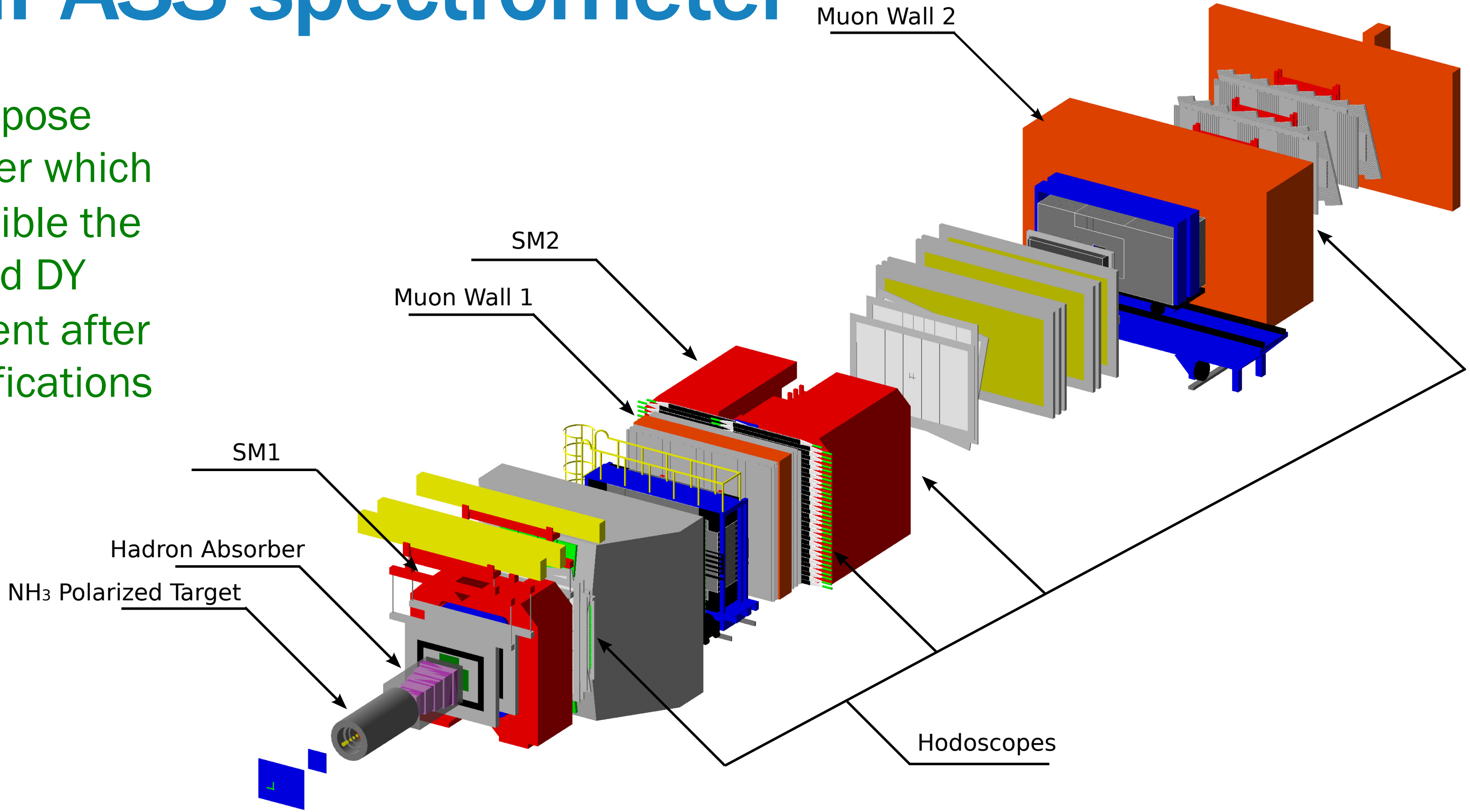
First result on the Sivers asymmetry from DY in following slides

On the road for the polarised DY measurement in COMPASS

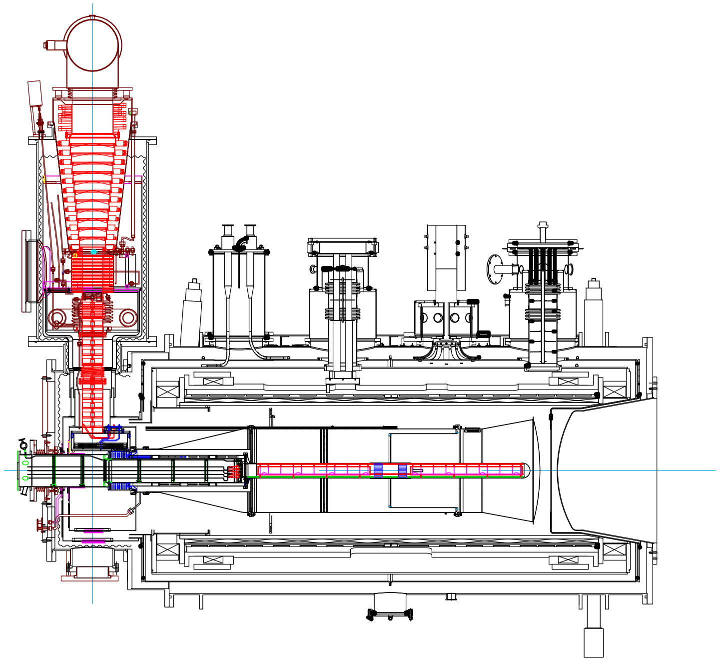


COMPASS spectrometer

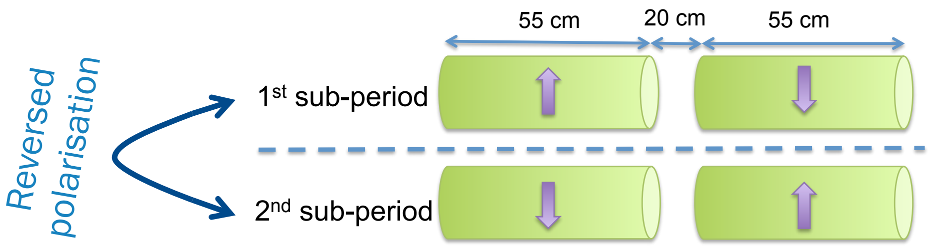
Multipurpose spectrometer which made possible the polarised DY measurement after some modifications



Polarised target



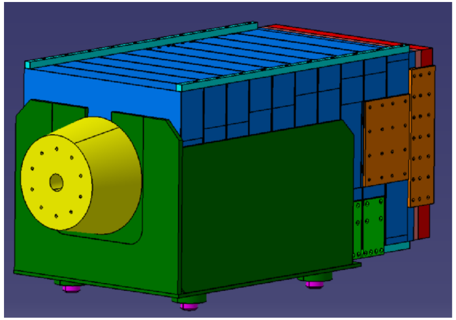
Two target cells of NH_3



Polarised in the transverse mode wrt beam and in opposite directions

Polarisation~73%
with 5% scale uncertainty

Hadron absorber

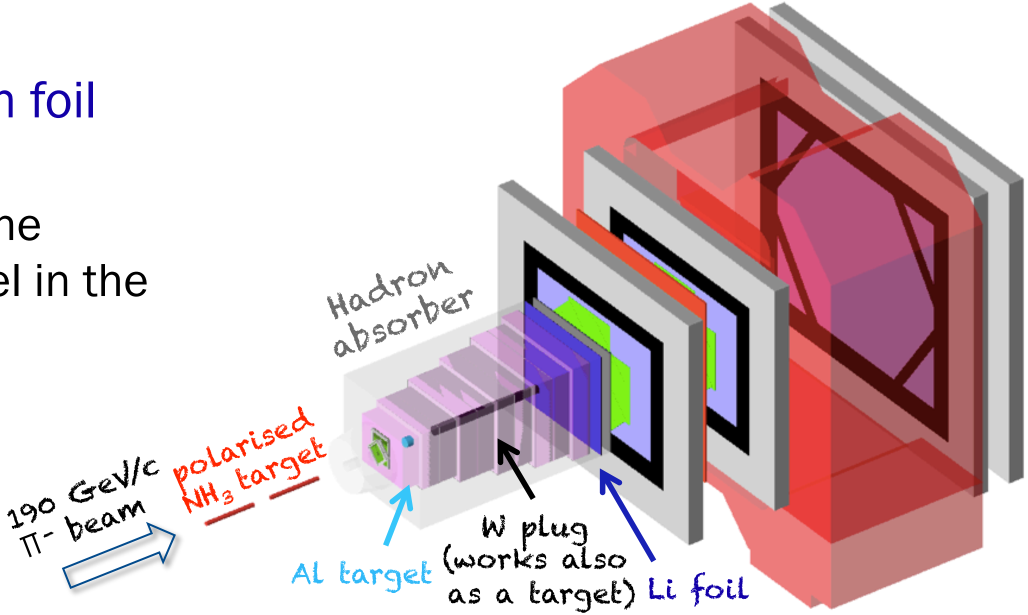


Located downstream of the polarised target:

- Stops hadrons and non interacting beam ☺
- Degrades resolutions ☹

In 2015 was also added a thin lithium foil downstream of the absorber:

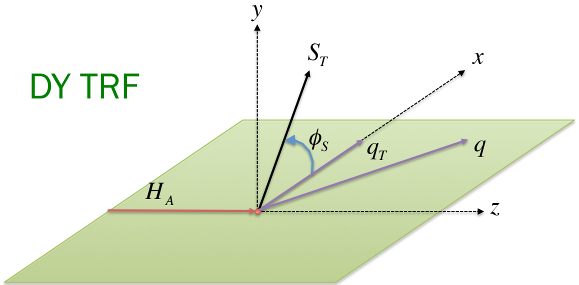
- Stops the slow neutrons produced in the absorber and reduce the radiation level in the first detectors ☺

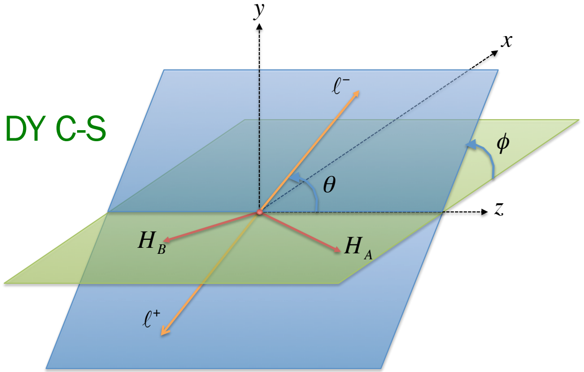


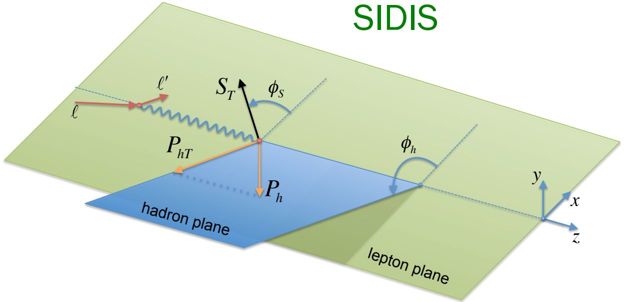
NOTE: For unpolarised studies, not covered in this talk, in addition to NH_3 target we have Al and W targets

DY and SIDIS cross-sections in terms of leading twist asymmetries

$$d\sigma^{DY} \propto \left(1+\cos^2(\theta)+\sin^2(\theta)A_{UU}^{\cos(2\phi)}\cos(2\phi)\right)+S_T\left[(1+\cos(\theta))A_{UT}^{\sin(\phi_S)}\sin(\phi_S)\right.$$
$$\left.+\sin^2(\theta)\left(A_{UT}^{\sin(2\phi-\phi_S)}\sin(2\phi-\phi_S)+A_{UT}^{\sin(2\phi+\phi_S)}\sin(2\phi+\phi_S)\right)\right]$$

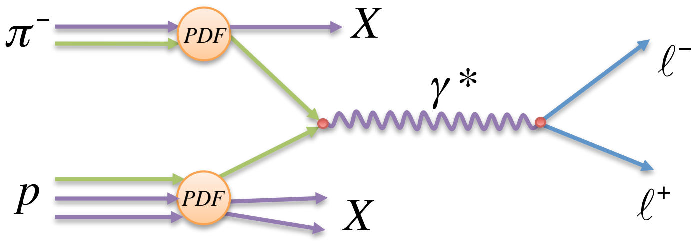


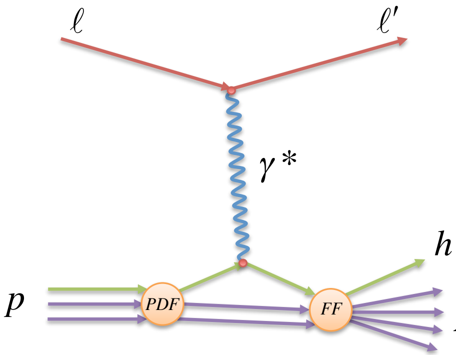




$$d\sigma^{SIDIS} \propto 1+\varepsilon\cos(2\phi_h)A_{UU}^{\cos(2\phi_h)}+S_T\left[\sin(\phi_h-\phi_S)A_{UT}^{\sin(\phi_h-\phi_S)}\right.$$
$$\left.+\varepsilon\sin(\phi_h+\phi_S)A_{UT}^{\sin(\phi_h+\phi_S)}+\varepsilon\sin(3\phi_h-\phi_S)A_{UT}^{\sin(3\phi_h-\phi_S)}\right]$$

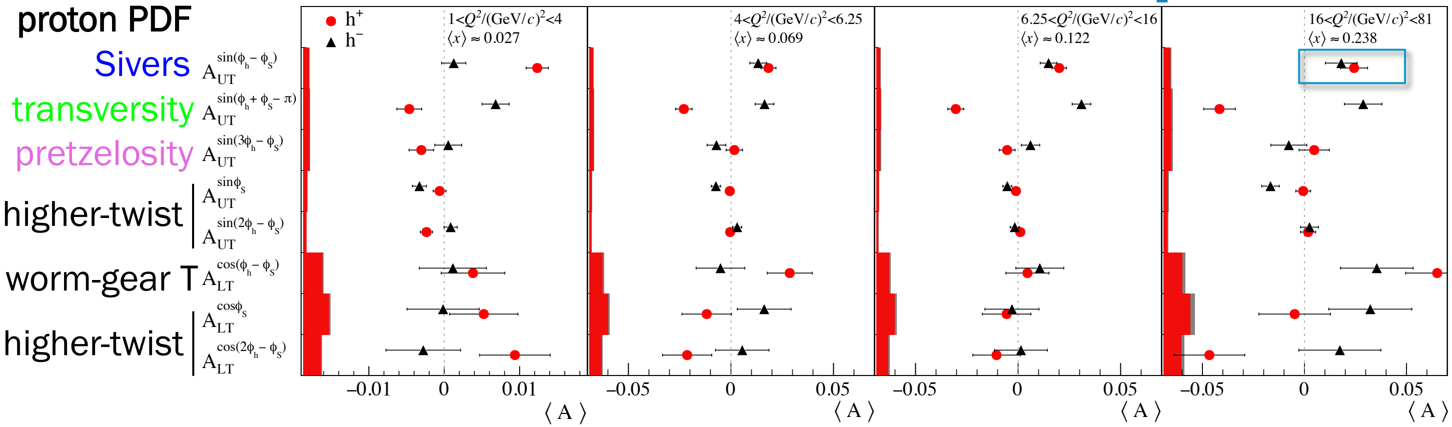
Leading twist asymmetries in DY and SIDIS



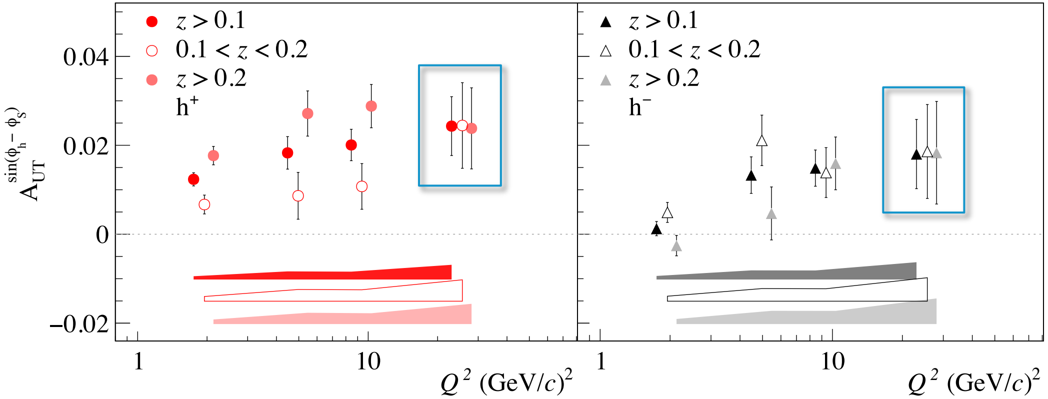


$A_{UU}^{\cos(2\phi)} \propto h_{1,\pi}^{\perp q} \otimes h_{1,p}^{\perp q}$	**Boer-Mulders**	$A_{UU}^{\cos(2\phi_h)} \propto h_1^{\perp q} \otimes H_{1q}^{\perp h}$
$A_{UT}^{\sin(\phi_S)} \propto f_{1,\pi}^{q} \otimes f_{1T,p}^{\perp q}$	**Sivers**	$A_{UT}^{\sin(\phi_h-\phi_S)} \propto f_{1T}^{\perp q} \otimes D_{1q}^{h}$
$A_{UT}^{\sin(2\phi-\phi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1,p}^{q}$	**transversity**	$A_{UT}^{\sin(\phi_h+\phi_S)} \propto h_1^{q} \otimes H_{1q}^{\perp h}$
$A_{UT}^{\sin(2\phi+\phi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1T,p}^{\perp q}$	**pretzelosity**	$A_{UT}^{\sin(3\phi_h-\phi_S)} \propto h_{1T}^{\perp q} \otimes H_{1q}^{\perp h}$

SIDIS TSAs in common DY phase space



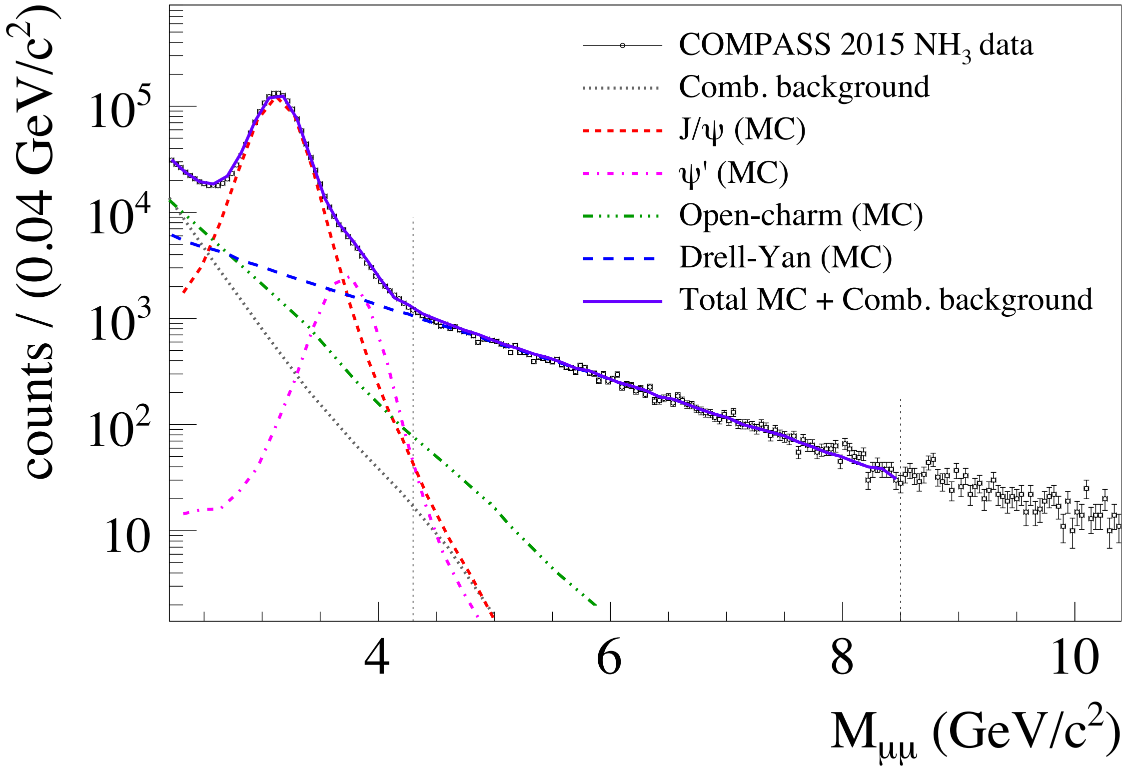
Paper submitted to PLB in September 2016 arXiv:1609.07374



The Sivers asymmetry extracted from SIDIS in the range $16<Q^2<81$, common to the mass range used in the DY TSAs extraction, is positive, with a significance of 3.2σ for h^+ (u quark dominance)

DY polarised data

Dimuon sample - Different contributions

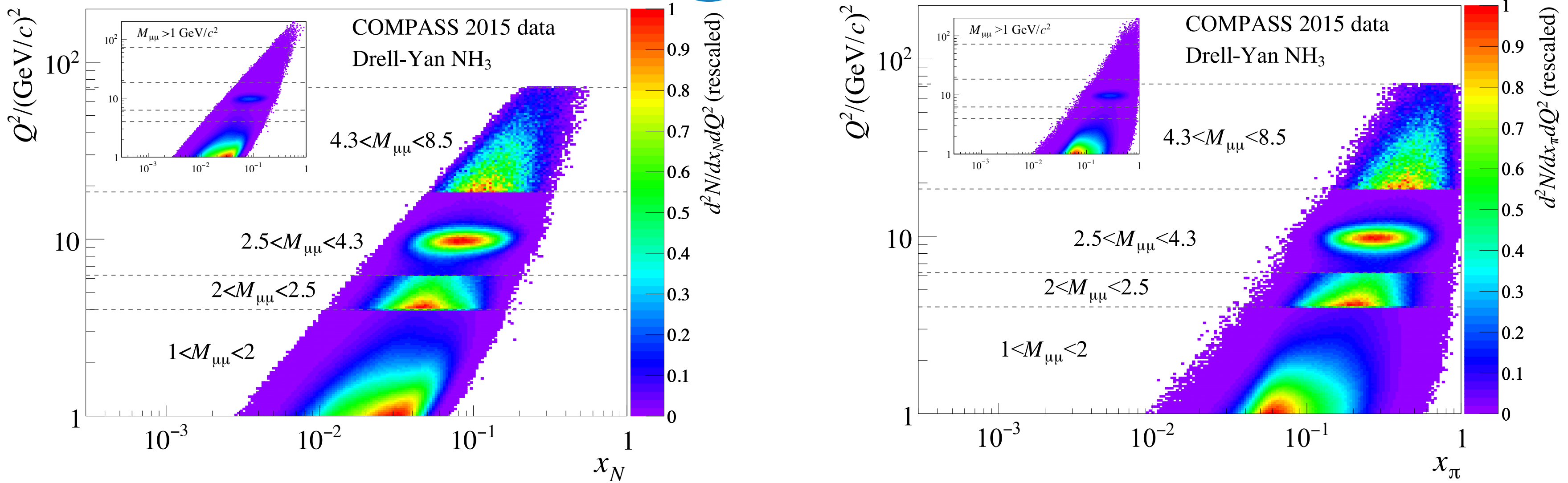


Data/reconstructed MC comparison shows a good agreement

The high mass dimuons 4.3<M<8.5 GeV/c^2 are mainly originated from the DY process with a small contamination of 4%

35 000 pairs will be used in the TSAs analysis

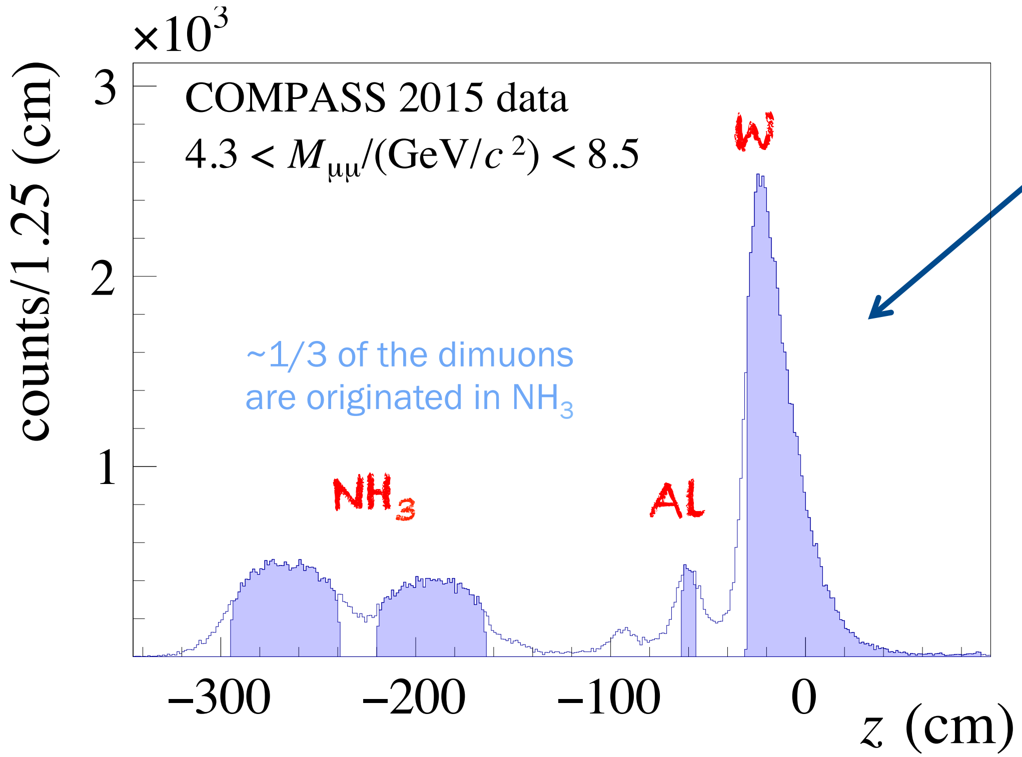
Dimuon mass ranges



For M<4.3 GeV/c^2 the interpretation of results is more difficult, DY starts to be highly contaminated.

A region of particular interest is the J/psi region. But the resolution is worse, and there are contributions from different processes. → Analysis is ongoing

Vertex distribution

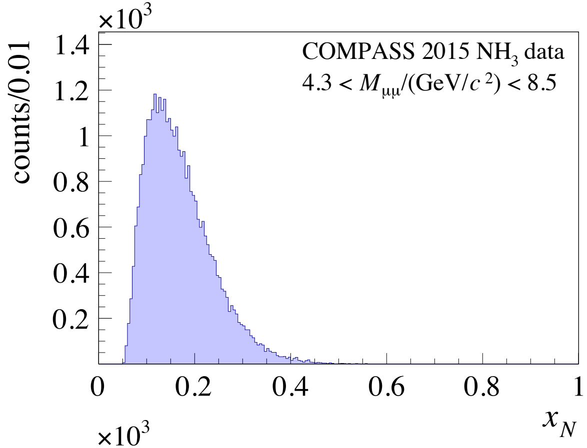


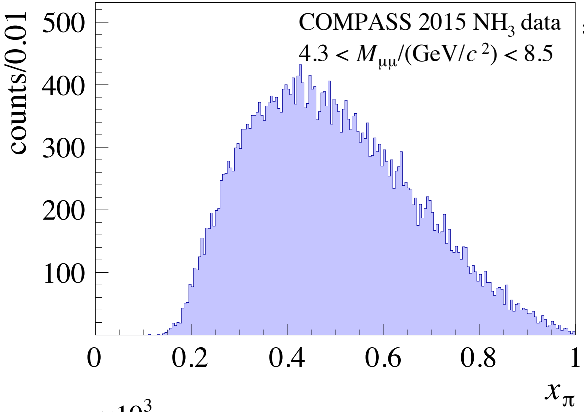
W is 120 cm long but the majority of the beam interacts in its beginning

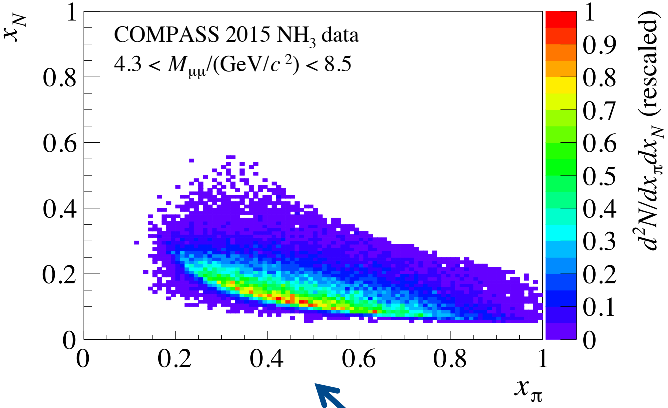
For TSAs analyses:
Only events from NH_3 cells are polarised

For unpolarised analyses:
Events from all 3 target types are useful

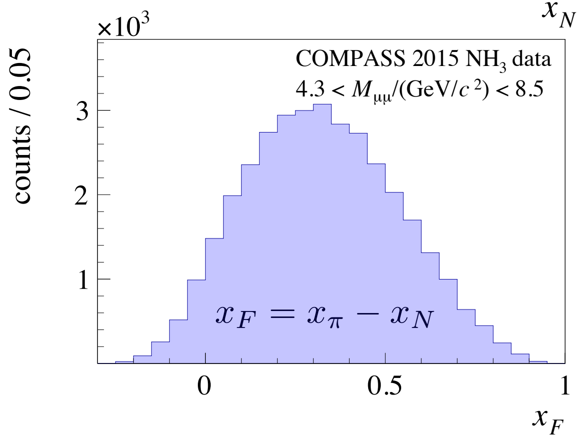
Kinematics in the high mass range

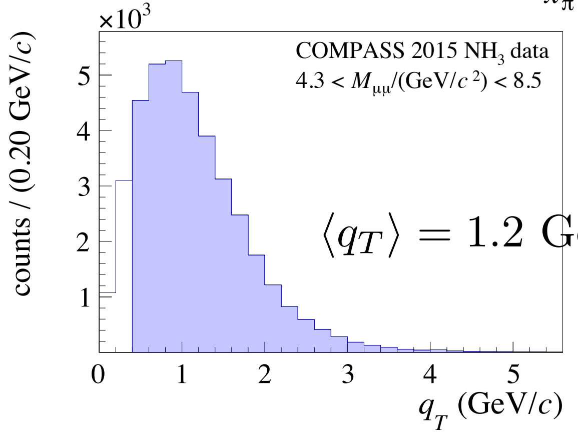






valence region dominance $\bar{u}|_\pi u|_p$

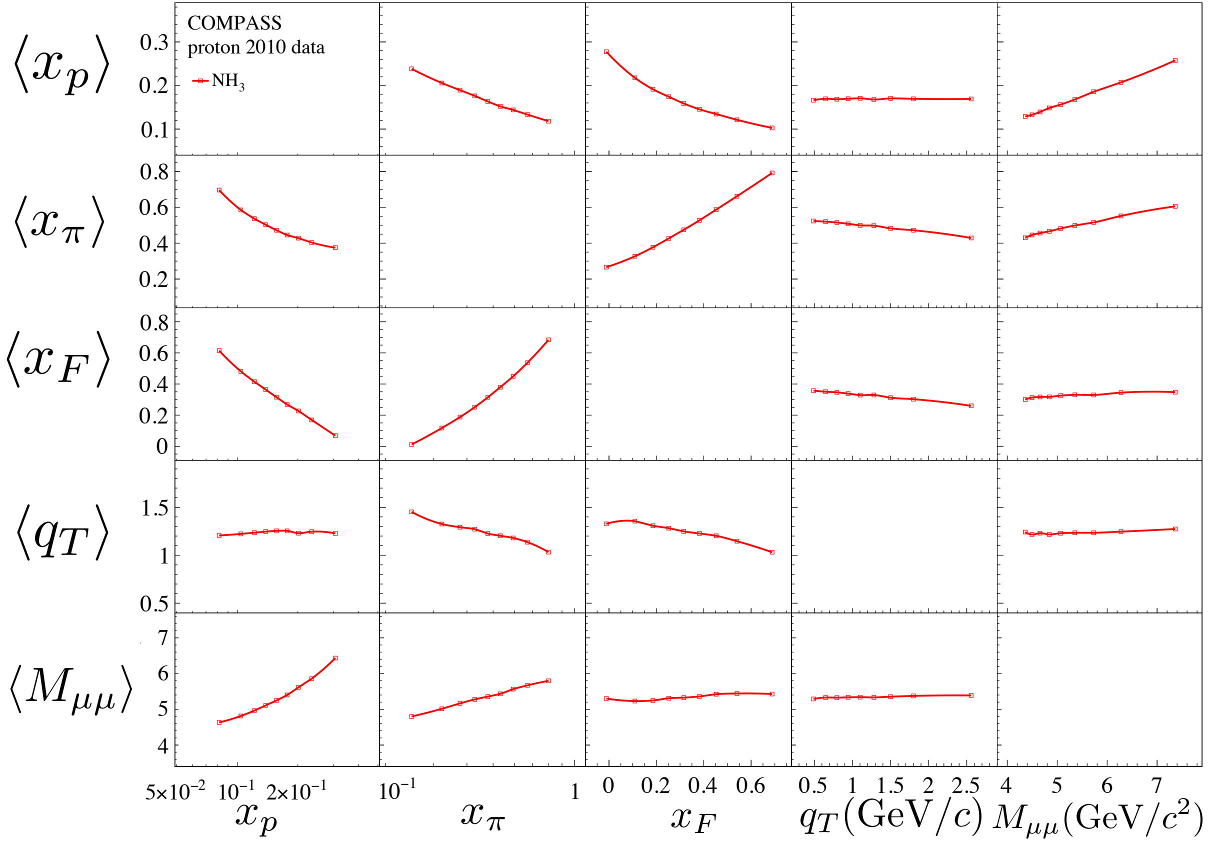




$$\langle q_T \rangle = 1.2\ \mathrm{GeV}/c \ll \langle M_{\mu\mu} \rangle = 5.3\ \mathrm{GeV}/c^2$$

TMD approach validity

Correlations between variables

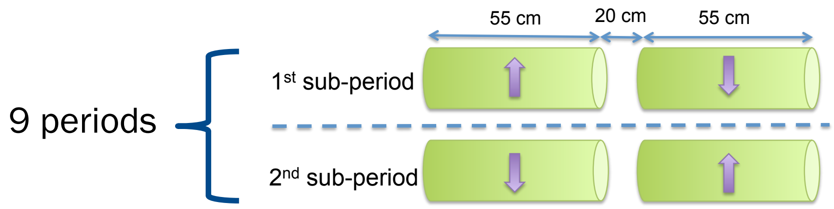


The asymmetries are extracted in different bins of x_p , x_π , x_F , q_T and $M_{\mu\mu}$

↓

Some are highly correlated, as expected

TSAs extraction



$$d\sigma^{DY} \propto 1 + D_{[\sin 2\theta]} A_{UU}^{\cos\phi} \cos\phi + D_{[\sin^2\theta]} A_{UU}^{\cos 2\phi} \cos 2\phi$$
$$+ S_T \Big[D_{[1+\cos^2\theta]} A_{UT}^{\sin\phi_S} \sin\phi_S$$
$$+ D_{[\sin^2\theta]} \left(A_{UT}^{\sin(2\phi-\phi_S)} \sin(2\phi-\phi_S) + A_{UT}^{\sin(2\phi+\phi_S)} \sin(2\phi+\phi_S) \right)$$
$$+ D_{[\sin 2\theta]} \left(A_{UT}^{\sin(\phi-\phi_S)} \sin(\phi-\phi_S) + A_{UT}^{\sin(\phi+\phi_S)} \sin(\phi+\phi_S) \right) \Big]$$

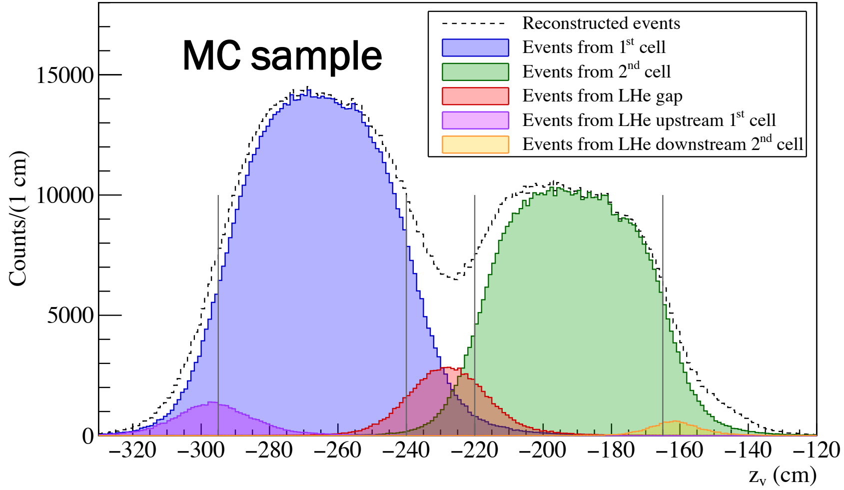
All the 5 TSAs are extracted simultaneously using an Unbinned Maximum Likelihood Method

$$A_{raw} = P_T f D_{[f(\theta)]} A_{phy}$$

The asymmetries are weighted, event by event, according to the corresponding depolarization and dilution factors

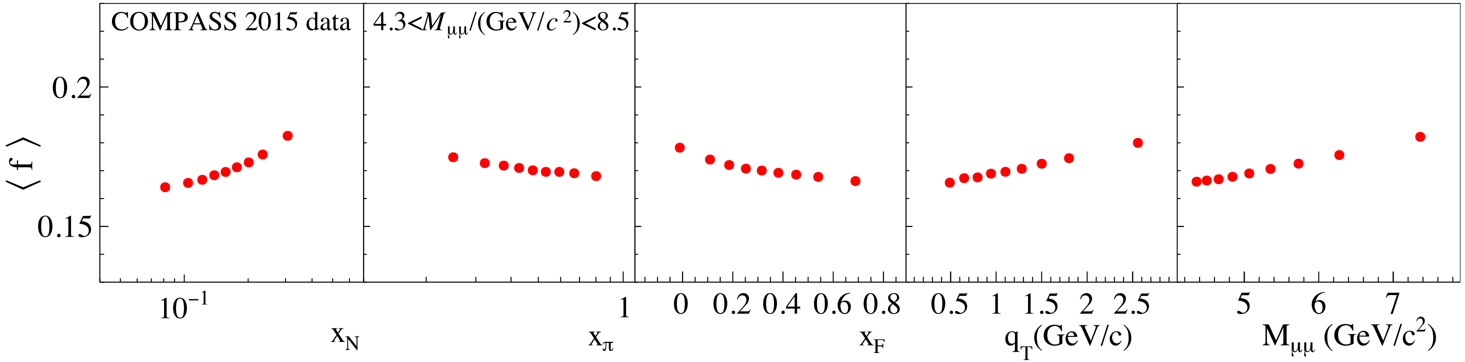
The asymmetries resulting from the fit are corrected by the average P_T in the corresponding period

TSAs extraction – dilution factor



$$f = \frac{n_H \sigma^{DY}_{\pi^- H}}{n_H \sigma^{DY}_{\pi^- H} + \Sigma_A n_A \sigma^{DY}_{\pi^- A}}$$

The dilution factor is corrected to account for the migration of events from one cell to the other (obtained with MC simulation)

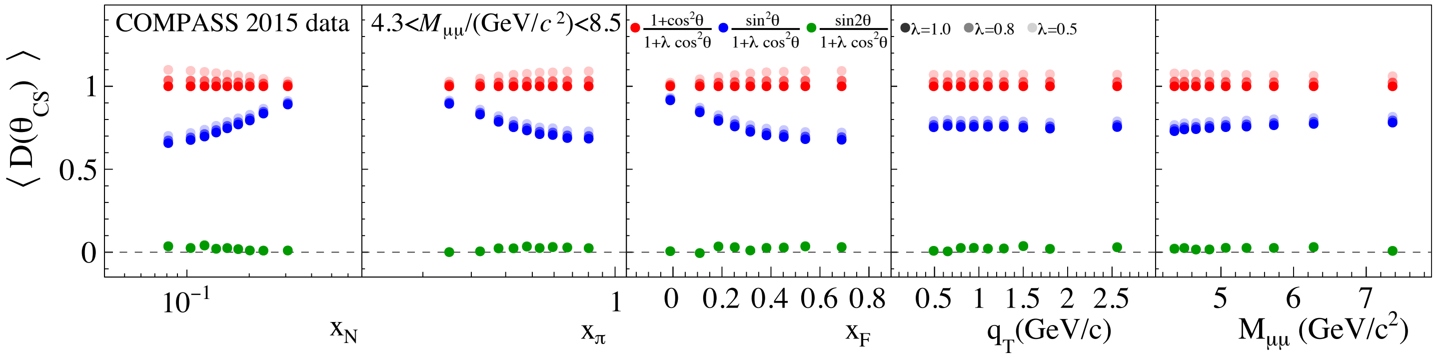


f~0.18
with 8% scale uncertainty

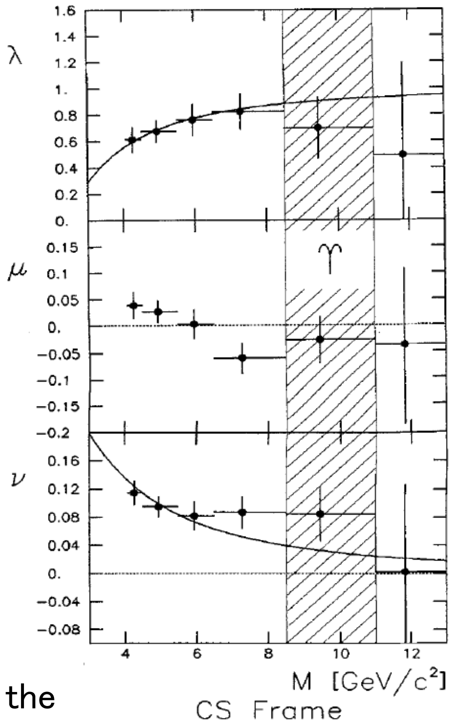
TSAs extraction – depolarisation factors

$$d\sigma^{DY} \propto 1 + D_{[\sin 2\theta]} A_{UU}^{\cos\phi} \cos\phi + D_{[\sin^2\theta]} A_{UU}^{\cos 2\phi} \cos 2\phi$$
$$+ S_T \Big[D_{[1+\cos^2\theta]} A_{UT}^{\sin\phi_S} \sin\phi_S$$
$$+ D_{[\sin^2\theta]} \left(A_{UT}^{\sin(2\phi-\phi_S)} \sin(2\phi-\phi_S) + A_{UT}^{\sin(2\phi+\phi_S)} \sin(2\phi+\phi_S) \right)$$
$$+ D_{[\sin 2\theta]} \left(A_{UT}^{\sin(\phi-\phi_S)} \sin(\phi-\phi_S) + A_{UT}^{\sin(\phi+\phi_S)} \sin(\phi+\phi_S) \right) \Big]$$

$$D_{[\sin 2\theta]} = \frac{\sin 2\theta}{1+\lambda\cos^2\theta}$$
$$D_{[1+\cos^2\theta]} = \frac{1+\cos^2\theta}{1+\lambda\cos^2\theta}$$
$$D_{[\sin^2\theta]} = \frac{\sin^2\theta}{1+\lambda\cos^2\theta}$$



NA10 Collaboration
Z. Phys. C 31 (1986) 513

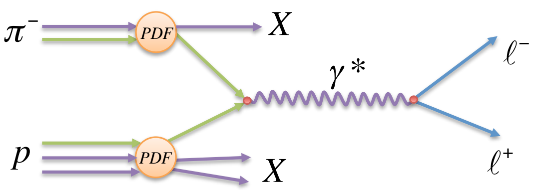


We have assumed **λ=1** in the TSAs extraction and assigned them a **-5% scale uncertainty** in the total experimental error

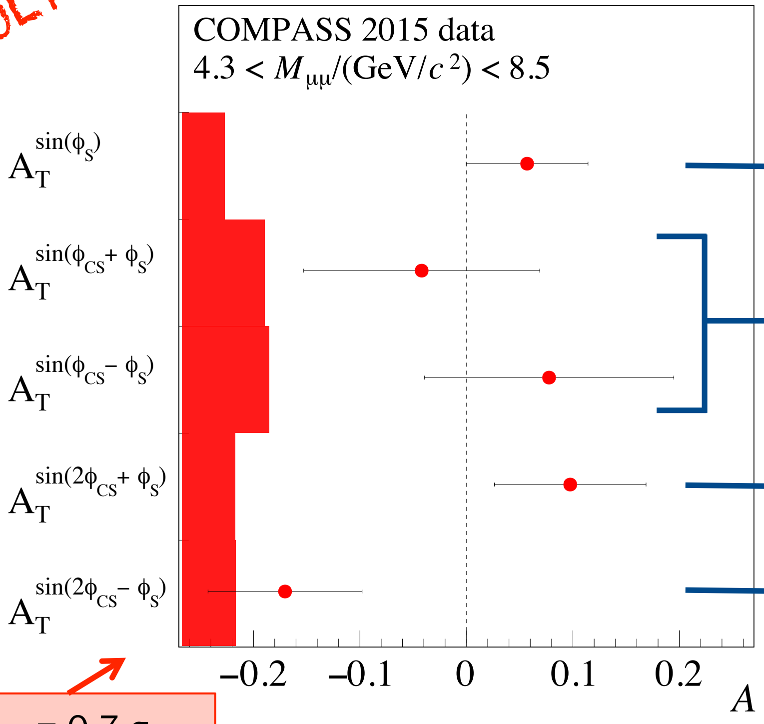
TSAs Results

TSAs

NEW RESULTS



$$d\sigma^{DY} \propto 1 + D_{[\sin 2\theta]} A_{UU}^{\cos\phi} \cos\phi + D_{[\sin^2\theta]} A_{UU}^{\cos 2\phi} \cos 2\phi$$
$$+ S_T \Big[D_{[1+\cos^2\theta]} A_{UT}^{\sin\phi_S} \sin\phi_S$$
$$+ D_{[\sin^2\theta]} \left(A_{UT}^{\sin(2\phi-\phi_S)} \sin(2\phi-\phi_S) + A_{UT}^{\sin(2\phi+\phi_S)} \sin(2\phi+\phi_S) \right)$$
$$+ D_{[\sin 2\theta]} \left(A_{UT}^{\sin(\phi-\phi_S)} \sin(\phi-\phi_S) + A_{UT}^{\sin(\phi+\phi_S)} \sin(\phi+\phi_S) \right) \Big]$$



$\sigma_{syst} = 0.7\ \sigma_{stat}$

Unpolarised PDF (π) ⊗ Sivers (p)

higher twist asymmetries

Boer-Mulders (π) ⊗ pretzelosity (p)

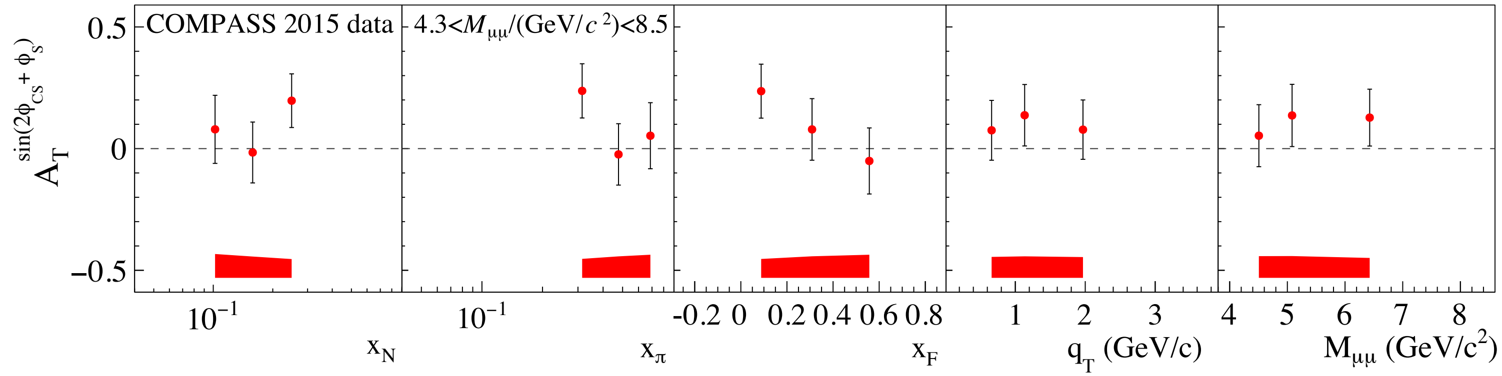
Boer-Mulders (π) ⊗ transversity (p)

Preprint: CERN-EP-2017-059
arXiv: 1704.00488

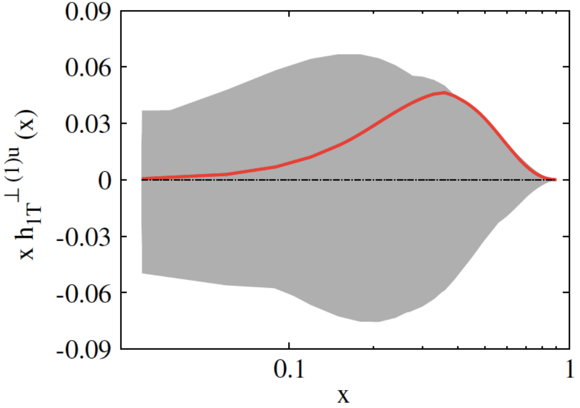
TSAs: pretzelosity

Boer-Mulders pretzelosity

$$A_{UT}^{\sin(2\phi+\phi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1T,p}^{\perp q}$$



pretzelosity function



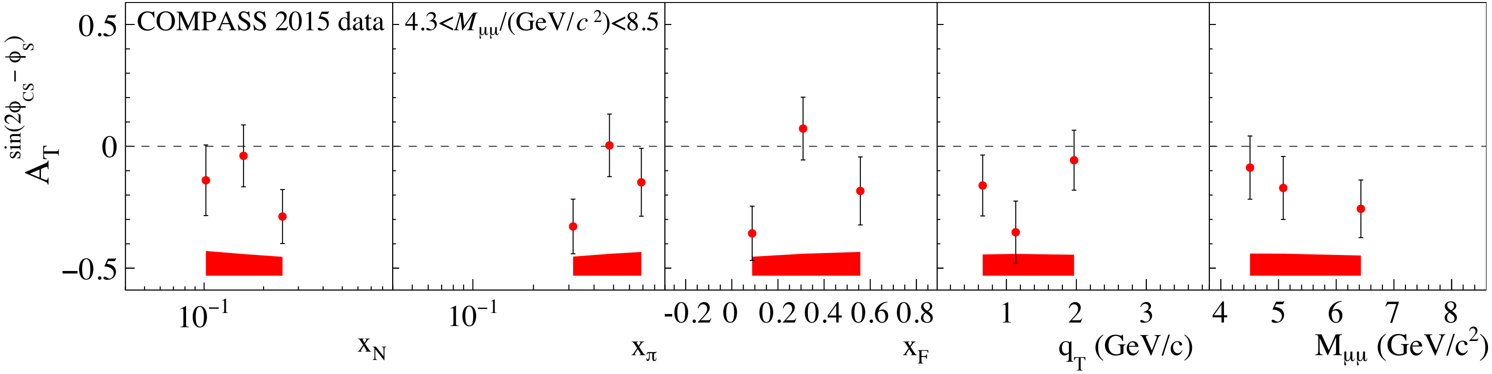
Asymmetry from SIDIS: Measurement compatible with zero within uncertainties

C. Lefky and A. Prokudin, PRD 91 (2015) 034010 pretzelosity function for u quark extracted from a fit to COMPASS, HERMES and JLab SIDIS data

TSAs: transversity

Boer-Mulders transversity

$$A_{UT}^{\sin(2\phi-\phi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1,p}^{q}$$

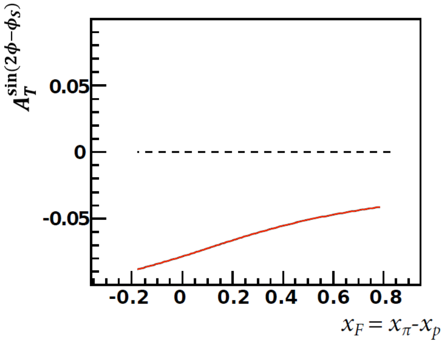


A. N. Sissakian et al.,
Phys. Part. Nucl. 41 (2010) 64

Asymmetry from SIDIS: Measurement positive for h⁻ and negative for h⁺

Compatible with our measurement

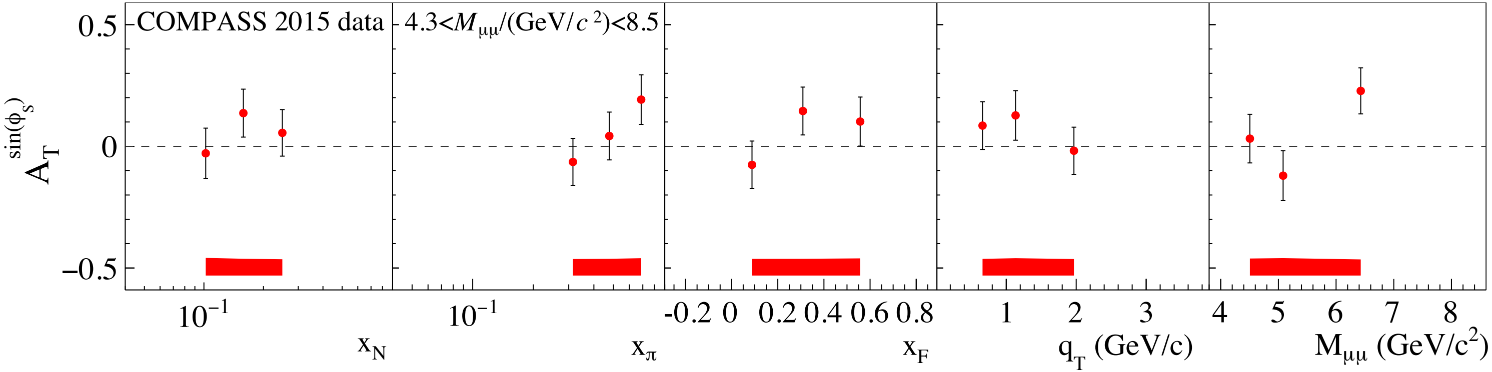
Twice larger than what we measured since the theta acceptance was assumed flat



TSAs: Sivers

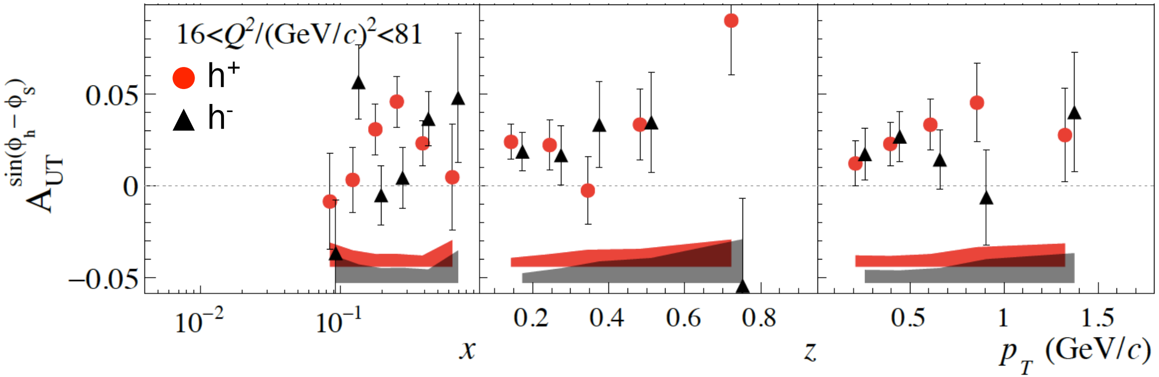
unp. PDF Sivers

$$A_{UT}^{\sin(\phi_S)} \propto f_{1,\pi}^{q} \otimes f_{1T,p}^{\perp q}$$

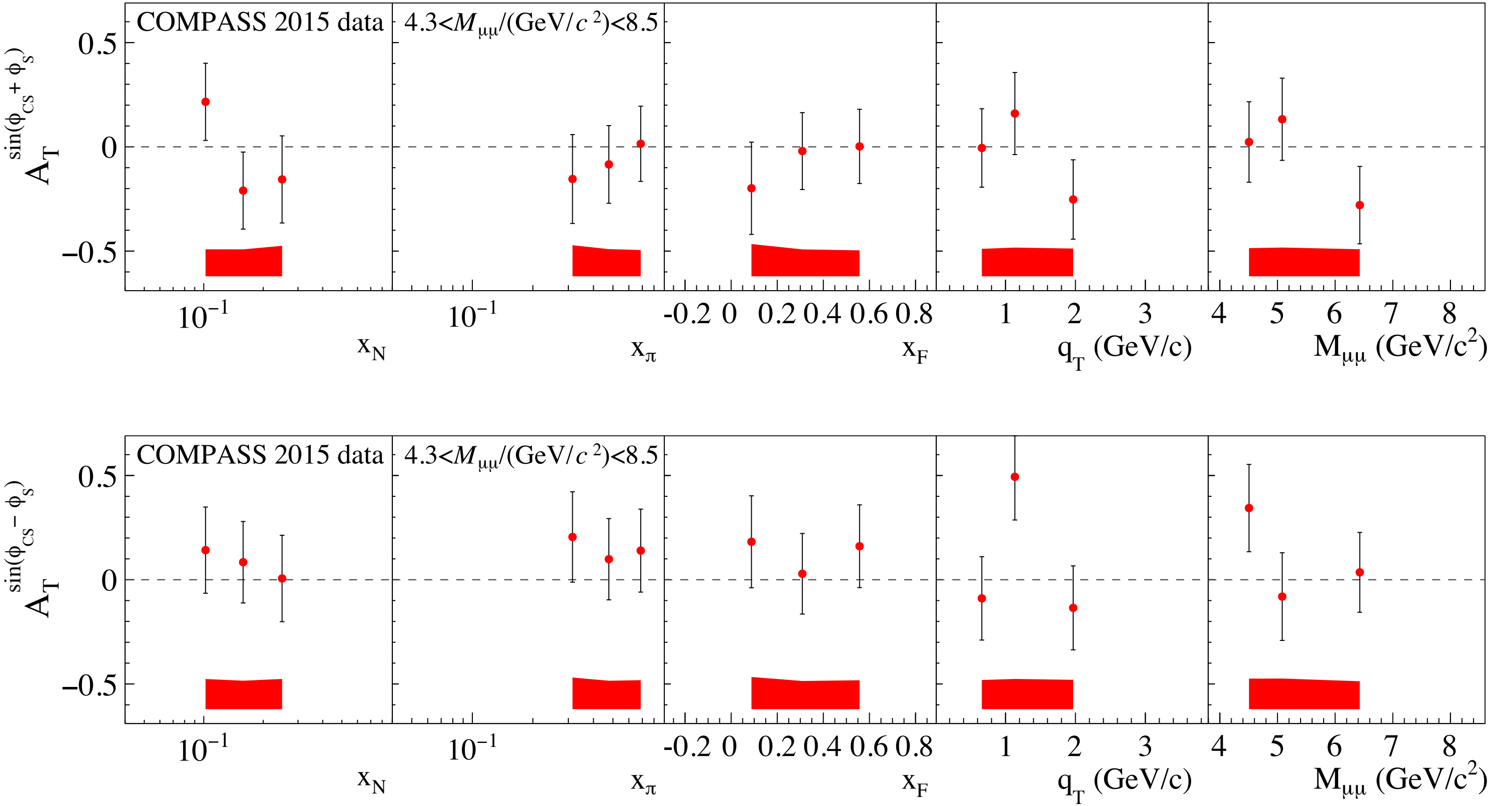


COMPASS collaboration arXiv:1609.07374

Asymmetry from SIDIS: Measurement positive for both hadron charges in the range $16 < Q^2 < 81$ (GeV/c)^2



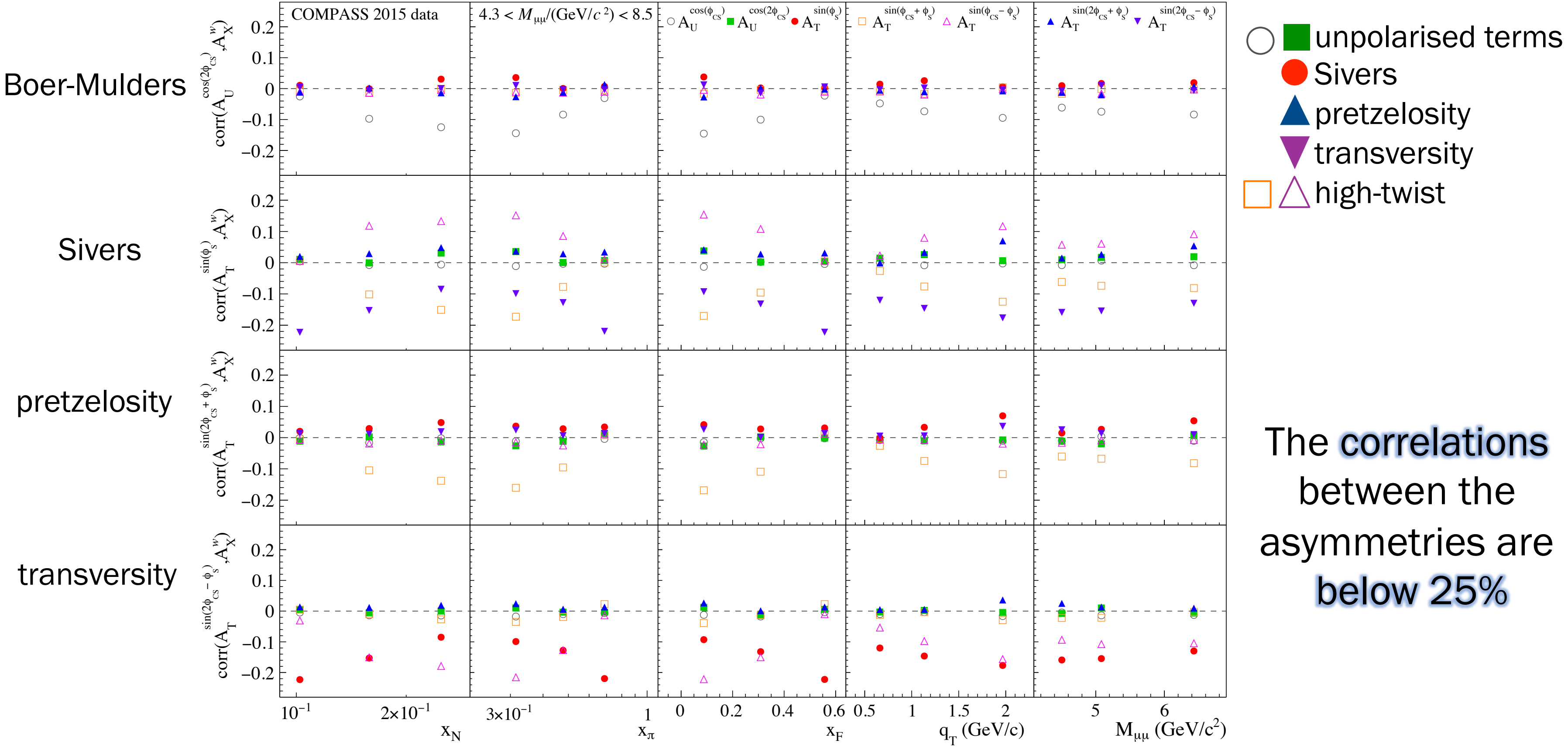
TSAs: Higher twist asymmetries



Asymmetries with large uncertainties

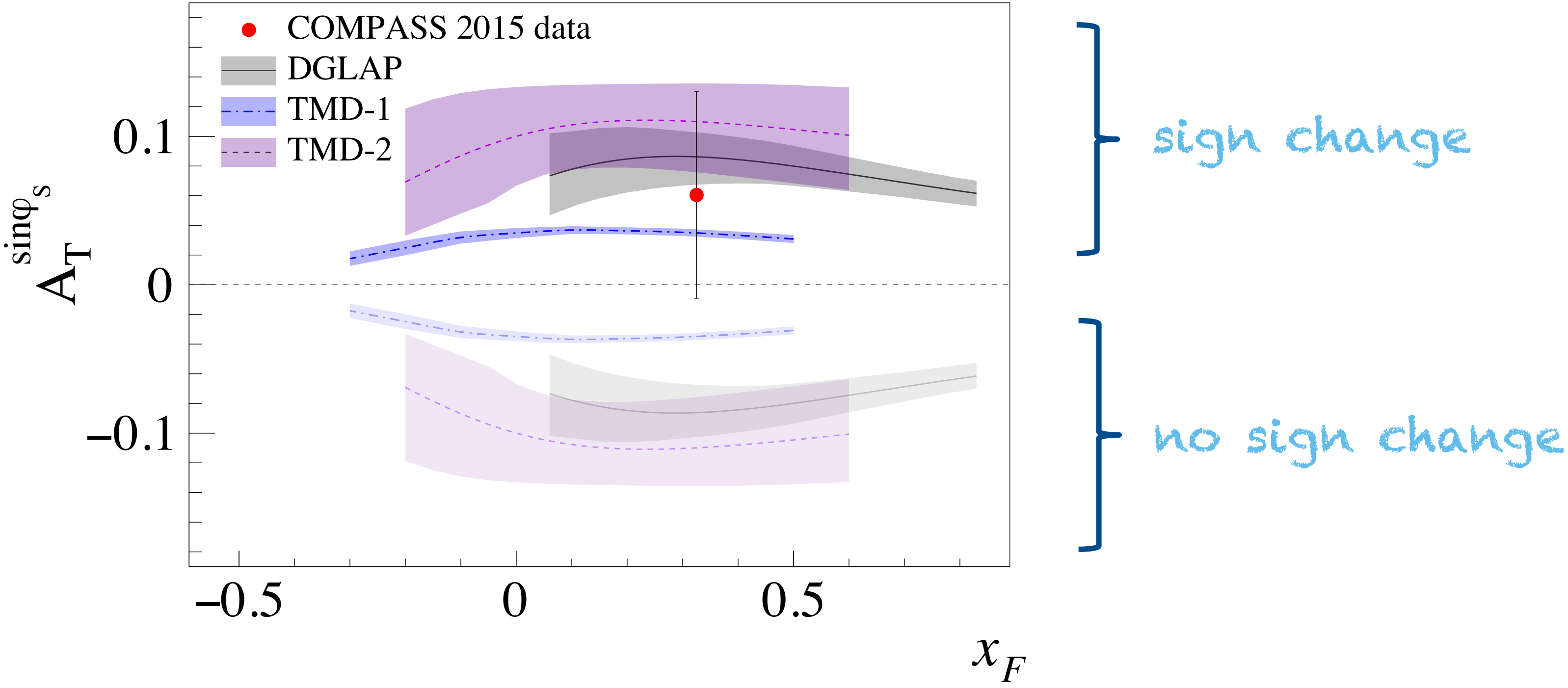
0.5 standard deviations from 0

TSAs: Correlation between asymmetries



The correlations between the asymmetries are below 25%

Sivers sign change



DGLAP (2016) M. Anselmino *et al.*, arXiv:1612.06413, fit to COMPASS, HERMES and JLab SIDIS data
TMD-1 (2014) M. Echevarria *et al.*, PRD 89 (2014) 074013, fit to COMPASS, HERMES and JLab SIDIS data, $0<p_T<1$ and $4<M<9$ GeV/c^2
TMD-2 (2013) P. Sun and F. Yuan, PRD 88 (2013) 114012, fit to COMPASS and HERMES data, $p_T<2$ GeV/c and $4<M<9$ GeV/c^2

Final remarks

2018

↓

2nd year of COMPASS polarised DY data taking

↓

More data to be analised

↓

Improvement of the experimental uncertainties

STAY TUNED