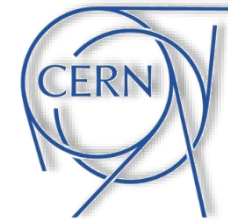


COMPASS-LHCspin synergies and bringing the communities together

Bakur Parsamyan



AANL(Yerevan), CERN
and
INFN (Torino)



LHCspin PBC meeting
February 15th 2024, CERN

COMPASSers entering the project

Currently:

- **AANL group**
 - Aram Kotzinian, Aram Movsisyan, B.P.
 - B.P. has got a CERN-SASS contract for one year (starting on 01.02.2024):
 - cit. “The third essential component of my activities will be devoted to the LHC-FT (fixed target) projects. I will enforce the existing teams with my group and bring my expertise in, e.g. (un) polarized Drell-Yan and J/psi production measurement programs. I aim to bridge COMPASS/AMBER and LHC-FT communities and propose and lead synergistic research programmes.”
- **Yamagata group (hardware oriented)**
 - Takahiro Iwata, Norihiro Doshita

Physics channels

Aram Kotzinian
Aram Movsisyan
Bakur Parsamyan
Chiara Oppedisano
Cynthia Hadjidakis
Luciano Pappalardo
Marco Mirazita
Marco Santimaria
Norihiro Doshita
Pasquale Di Nezza
Takahiro Iwata

COMPASS collaboration

Common Muon and Proton Apparatus for Structure and Spectroscopy



28 institutions from 14 countries
 – nearly 210 physicists (in 2023: start of the Analysis Phase)

3 new groups joined the COMPASS collaboration in 2023
 UCon (US), AANL (Armenia), NCU (Taiwan)

- CERN SPS north area
- Fixed target experiment
- Approved in 1997 (25 years)
- Taking data since 2002 (20 years)

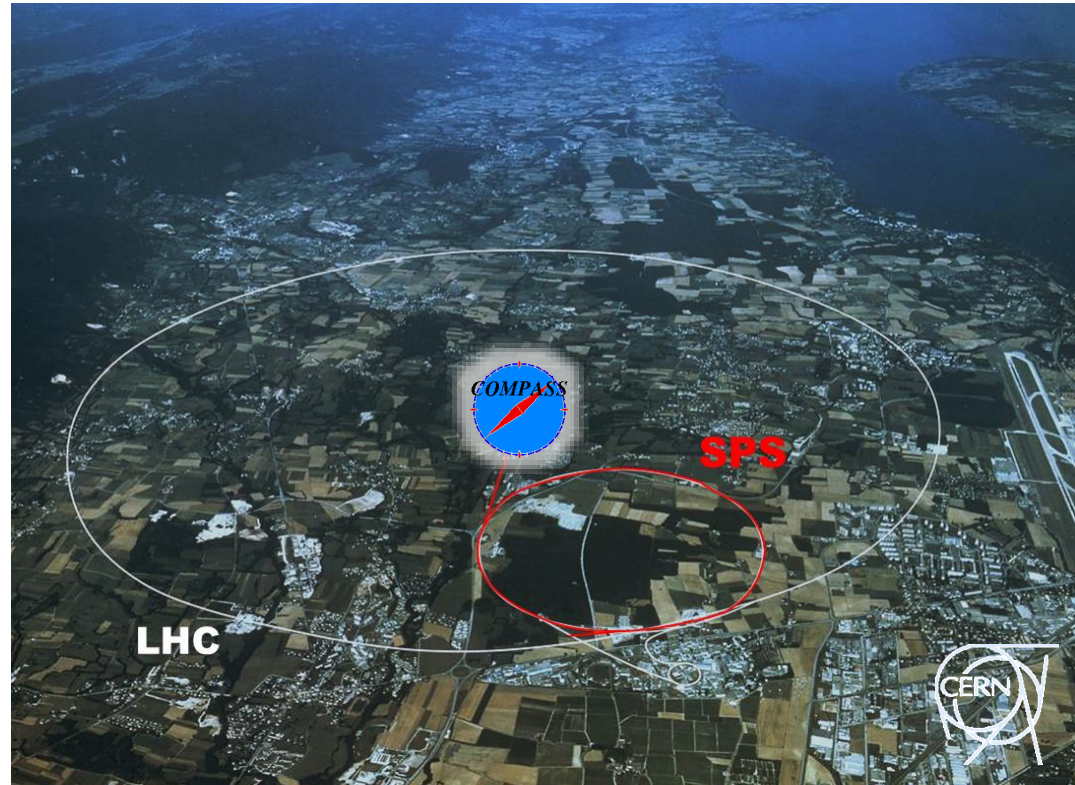
Wide physics program

COMPASS-I

- Data taking 2002-2011
- Muon and hadron beams
- Nucleon spin structure
- Spectroscopy

COMPASS-II

- Data taking 2012-2022
- Primakoff
- DVCS (GPD+SIDIS)
- Polarized Drell-Yan
- **Transverse deuteron SIDIS 2022**



COMPASS web page: <http://wwwcompass.cern.ch>





8th COMPASS "Analysis Phase" mini-workshop (COMAP-VIII); COMPASS & LHCspin

24 April 2024
CERN
Europe/Zurich timezone

The scientific programme of the series of COMPASS "Analysis Phase" mini-workshops is focused on the topics traditionally addressed by the COMPASS collaboration:


- Spin and 3D Structure Structure of the Nucleon
- DIS, SIDIS, DVCS, DVMP, Drell-Yan measurements
- TMDs, GPDs and GTMDs
- Fragmentation Functions
- Meson Structure and Spectroscopy
- Search for Exotics
- Monte-Carlo simulation tools and techniques
- Technical aspects and analysis techniques


The 8th edition of COMAP will be dedicated to synergies between COMPASS and LHCspin projects.

Starts 24 Apr 2024, 13:30
Ends 24 Apr 2024, 19:35

Europe/Zurich

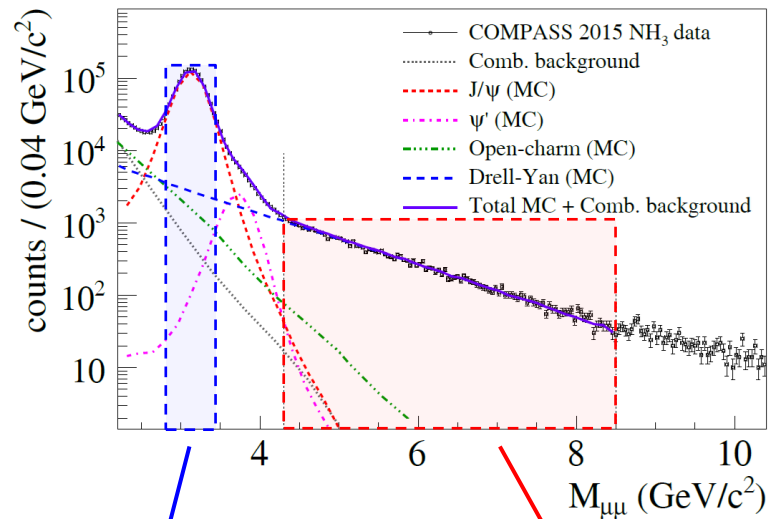
 [Bakur Parsamyan](#)
[Pasquale Di Nezza](#)

 CERN
892/1-D20
[Go to map](#)

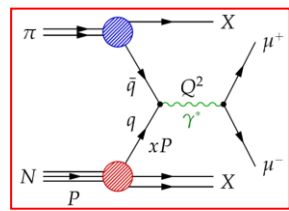
 There are no materials yet.



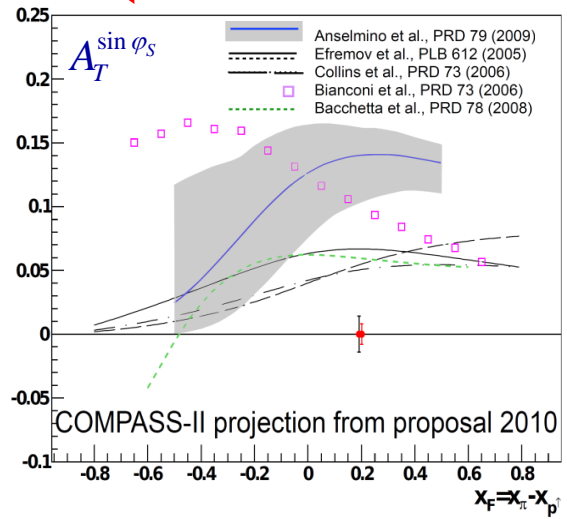
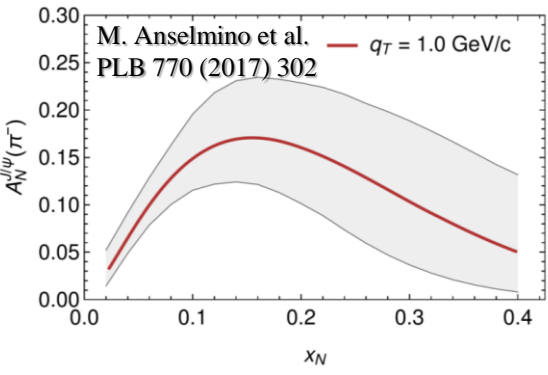
Single-polarized Drell-Yan cross-section at twist-2 (LO)



$$\frac{d\sigma^{LO}}{dq^4 d\Omega} \propto F_U^1 (1 + \cos^2 \theta_{CS})$$



$$\times \left\{ \begin{aligned} & 1 + D_{[\sin^2 \theta_{CS}]} A_U^{\cos 2\varphi_{CS}} \cos 2\varphi_{CS} \\ & + S_L \sin^2 \theta_{CS} A_L^{\sin 2\varphi_{CS}} \sin 2\varphi_{CS} \\ & + S_T \left[A_T^{\sin \varphi_S} \sin \varphi_S \right. \\ & \left. + D_{[\sin^2 \theta_{CS}]} \left(A_T^{\sin(2\varphi_{CS}-\varphi_S)} \sin(2\varphi_{CS} - \varphi_S) \right. \right. \\ & \left. \left. + A_T^{\sin(2\varphi_{CS}+\varphi_S)} \sin(2\varphi_{CS} + \varphi_S) \right) \right] \end{aligned} \right\}$$



$A_U^{\cos 2\varphi_{CS}} \propto h_{1,\pi}^{\perp q} \otimes h_{1,p}^{\perp q}$	Boer-Mulders (T-odd)
$A_T^{\sin \varphi_S} \propto f_{1,\pi}^q \otimes f_{1T,p}^{\perp q}$	Sivers (T-odd)
$A_T^{\sin(2\varphi_{CS}-\varphi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1,p}^q$	Transversity
$A_T^{\sin(2\varphi_{CS}+\varphi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1T,p}^{\perp q}$	Pretzelosity

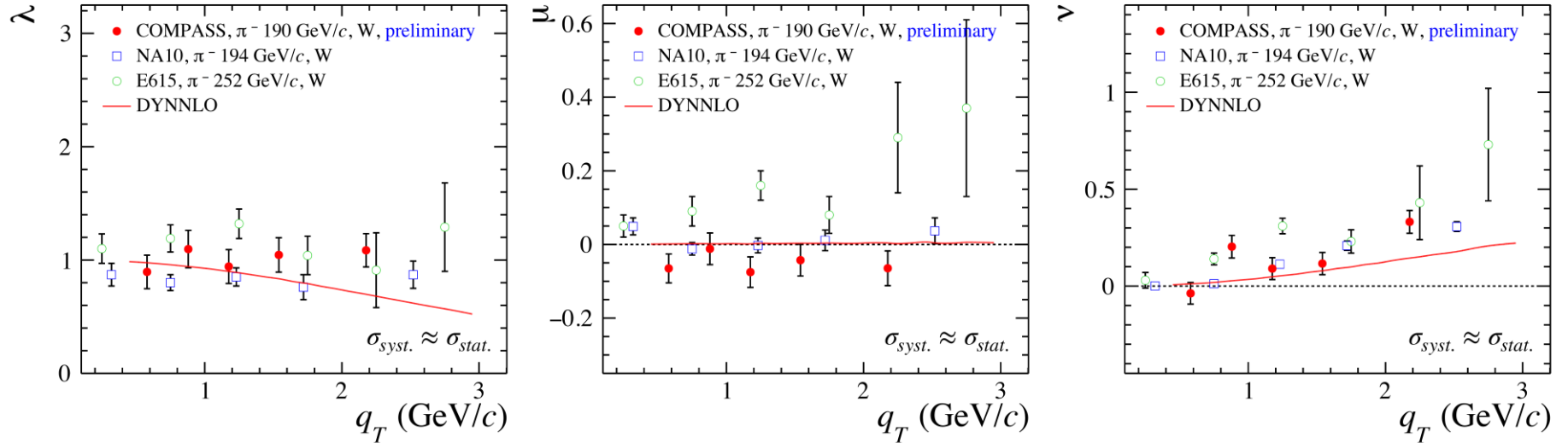
SIDIS \leftrightarrow Drell-Yan sign-change of the T-odd TMD PDFs

COMPASS phase-II proposal submitted in 2010 (Drell-Yan, DVCS,...)

Predictions for a large Sivers effect in Drell-Yan and J/psi at COMPASS \rightarrow sign change test

Unpolarized Drell-Yan results (high-mass range)

DY-2018 Tungsten data: Preliminary results Released for DIS-2021



Spin independent

$$\frac{d\sigma}{dq^4 d\Omega} \propto \hat{\sigma}_U \left\{ \begin{aligned} &1 + A_U^1 \cos^2 \theta_{CS} + \sin 2\theta_{CS} A_U^{\cos \varphi_{CS}} \cos \varphi_{CS} + \sin^2 \theta_{CS} A_U^{\cos 2\varphi_{CS}} \cos 2\varphi_{CS} \\ &+ S_T \left[\left(A_T^{\sin \varphi_S} + \cos^2 \theta_{CS} \tilde{A}_T^{\sin \varphi_S} \right) \sin \varphi_S \right. \\ &+ \sin 2\theta_{CS} \left(A_T^{\sin(\varphi_{CS} + \varphi_S)} \sin(\varphi_{CS} + \varphi_S) + A_T^{\sin(\varphi_{CS} - \varphi_S)} \sin(\varphi_{CS} - \varphi_S) \right) \\ &\left. + \sin^2 \theta_{CS} \left(A_T^{\sin(2\varphi_{CS} + \varphi_S)} \sin(2\varphi_{CS} + \varphi_S) + A_T^{\sin(2\varphi_{CS} - \varphi_S)} \sin(2\varphi_{CS} - \varphi_S) \right) \right] \end{aligned} \right\}$$

Transverse spin dependent

Spin Independent

$$A_U^1 = \lambda$$

$$A_U^{\cos \varphi_{CS}} = \mu$$

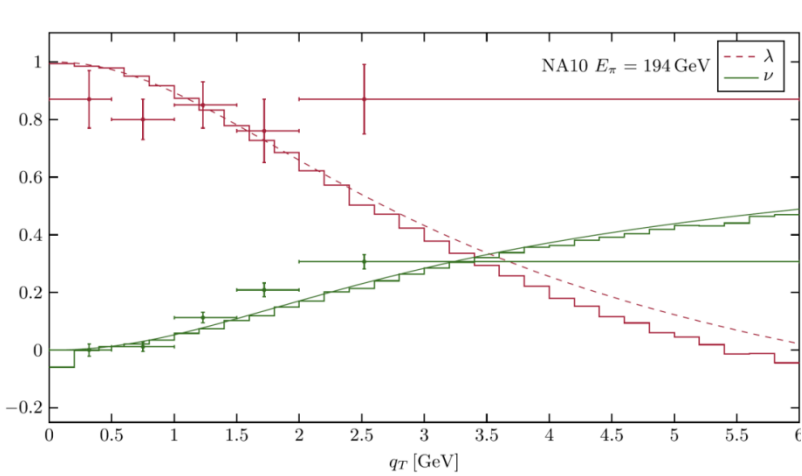
$$A_U^{\cos 2\varphi_{CS}} = \frac{\nu}{2}$$

$$\frac{d\sigma}{d\Omega} \propto \frac{3}{4\pi} \frac{1}{\lambda + 3} \left[1 + \lambda \cos^2 \theta_{CS} + \mu \sin 2\theta_{CS} \cos \varphi_{CS} + \frac{\nu}{2} \sin^2 \theta_{CS} \cos 2\varphi_{CS} \right]$$

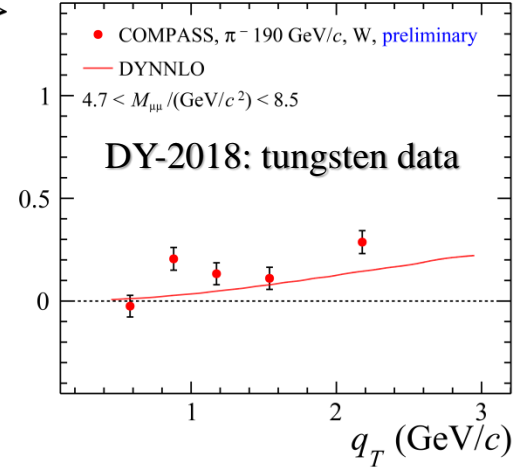
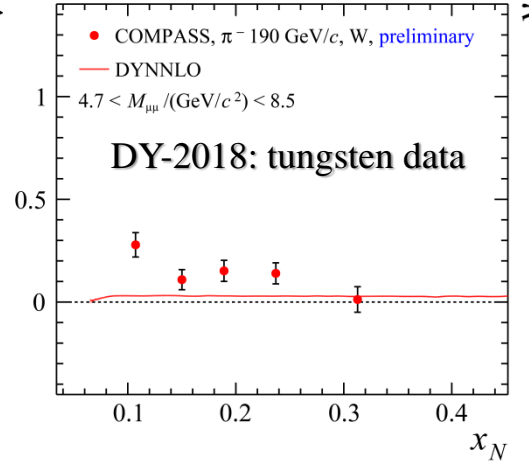
Unpolarized Drell-Yan results (high-mass range)

M. Lambertsen, W. Vogelsang **PRD93, 114013 (2016)**

Preliminary results Released for DIS-2021

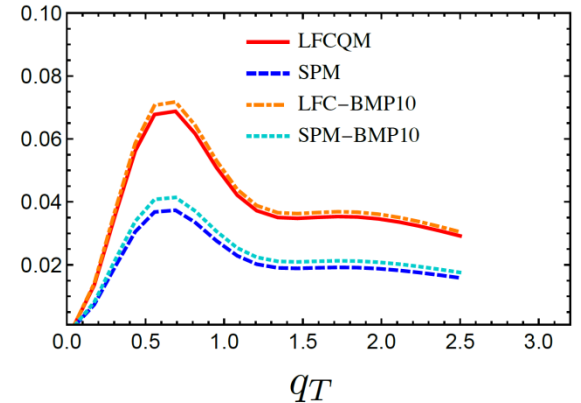
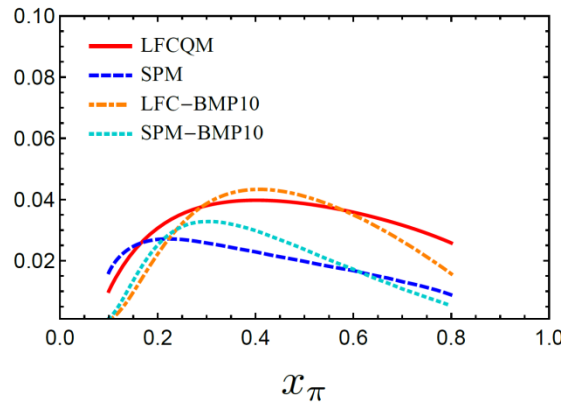
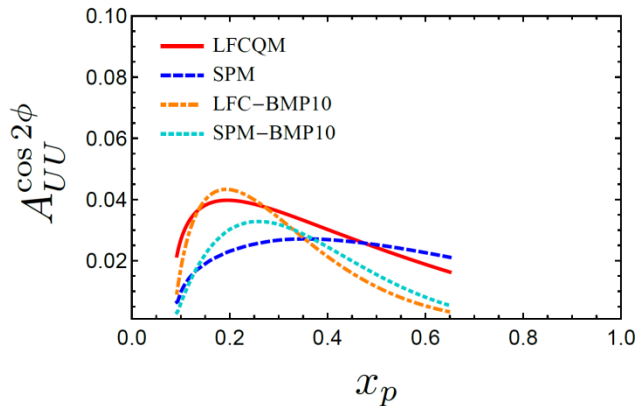


NA10 data **Z.Phys.C 37,545(1988)**



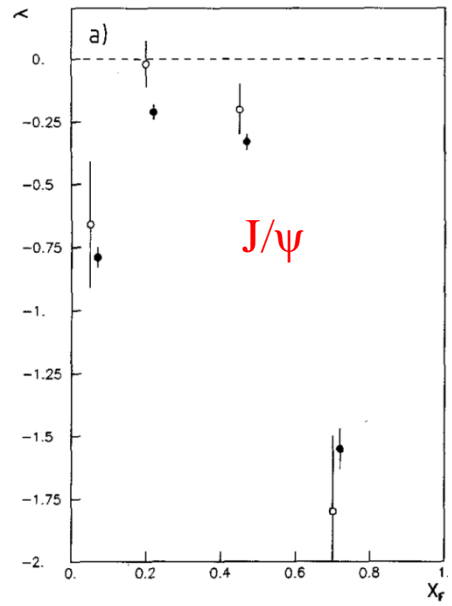
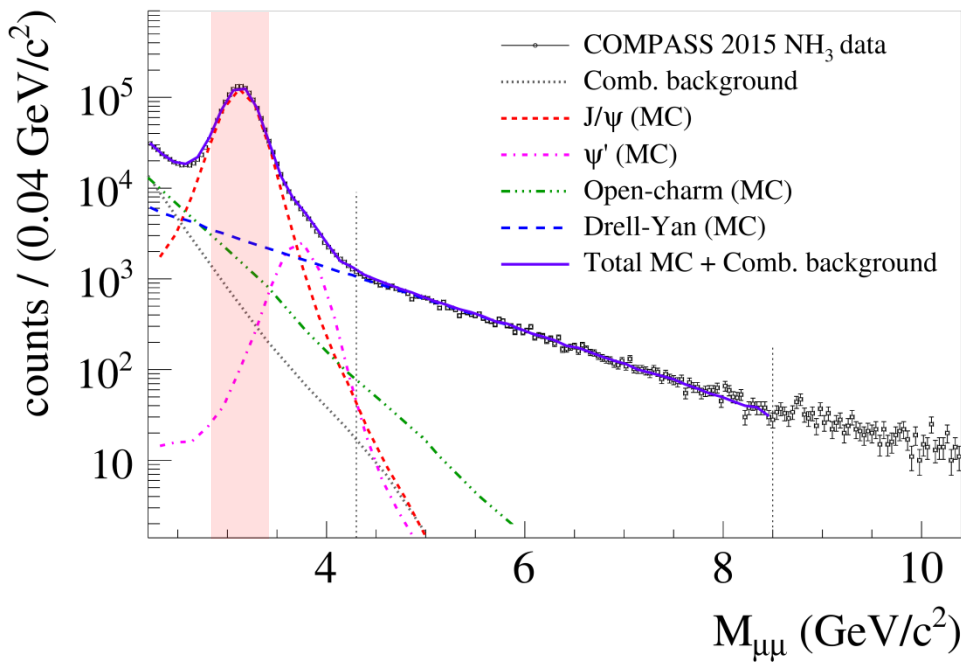
DY-2018 NH₃ data: ongoing analysis

S. Bastami, L. Gamberg, B. Parsamyan, B. Pasquini, A. Prokudin and P. Schweitzer, **JHEP 02, (2021),166**



Is there a room for BM at low (COMPASS) q_T ? What about the J/ψ channel?

Drell-Yan 2015-2018 TSAs: J/ψ mass range



NA3:
200 GeV/c π^-
 H and Pt
 Z.Phys.C
 Particles and Fields
 20, 101-116 (1983)

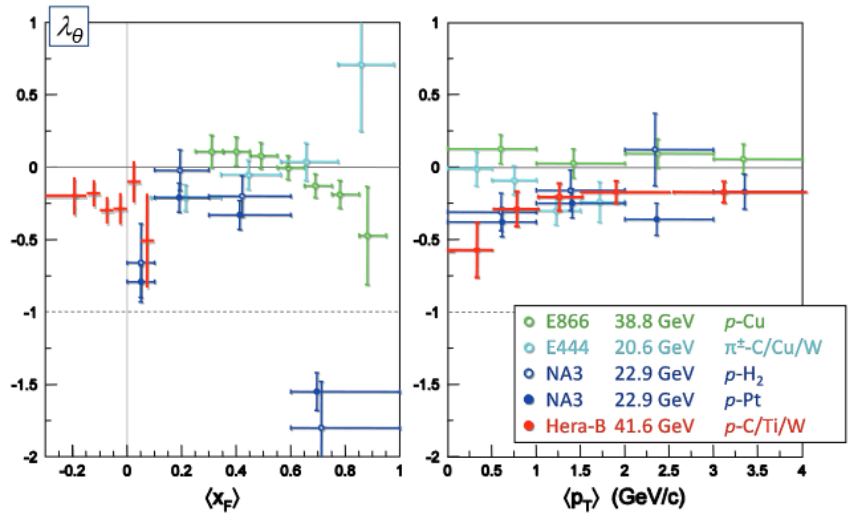
For the TSA analysis we choose $\lambda=0$

Expectations (PLB 770(2017)302):

- Assuming $q\bar{q}$ -annihilation as dominant channel for J/ψ production at COMPASS
- Neglecting gluon fusion contribution and the role of feed-down J/ψ mesons
- Large asymmetry is expected

Necessary inputs

- Dilution factor and feed down contribution NRQCD (I. Denisenko, M. Nefedov)
- Event mixing study
- Extraction of λ -asymmetry – **stalled**



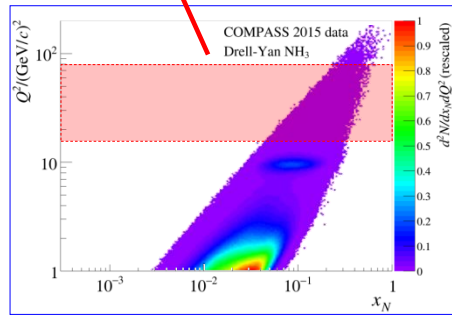
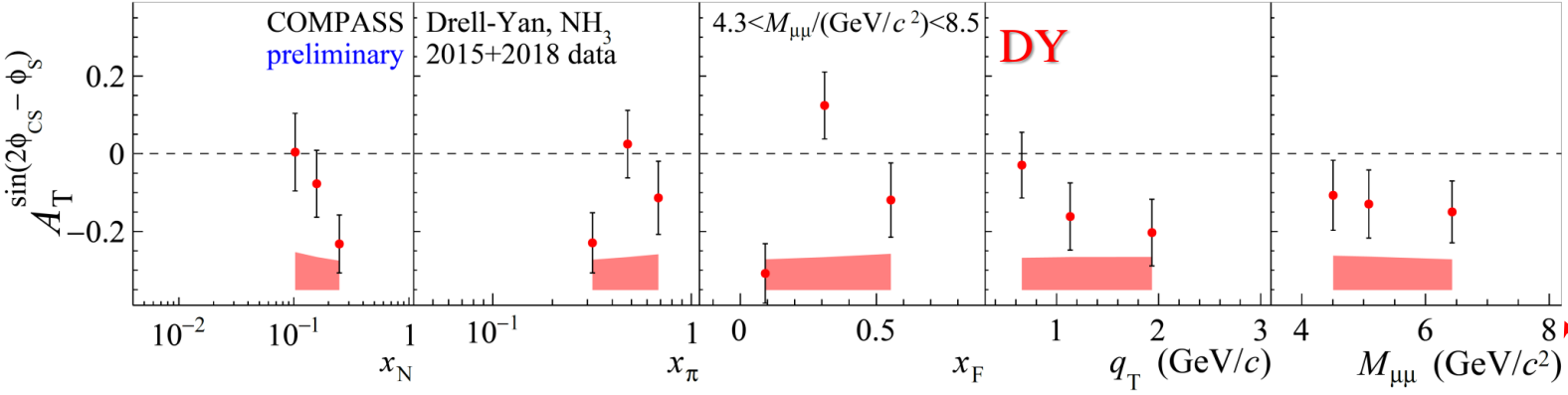
Drell-Yan TSAs – Transversity

Transversity DY TSA

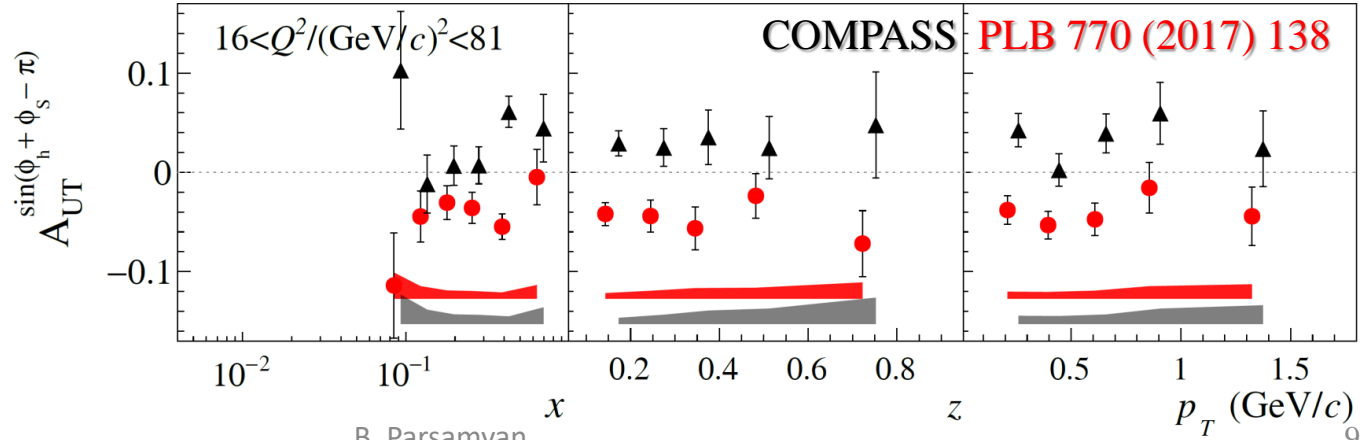


$$\frac{d\sigma}{dq^4 d\Omega} \propto 1 + \dots + S_T \left[D_{[\sin^2 \theta_{CS}]} A_T^{\sin(2\varphi_{CS} - \varphi_S)} \sin(2\varphi_{CS} - \varphi_S) + \dots \right]$$

$$A_T^{\sin(2\varphi_{CS} - \varphi_S)} \propto h_{1,\pi}^{\perp q} \otimes h_{1,p}^q$$



Collins SIDIS TSA

$$A_{UT}^{\sin(\phi_h + \phi_s)} \propto h_1^q \otimes H_{1q}^{\perp h}$$


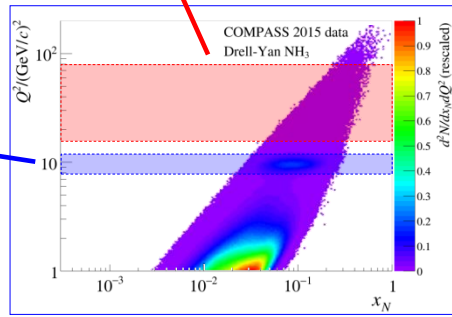
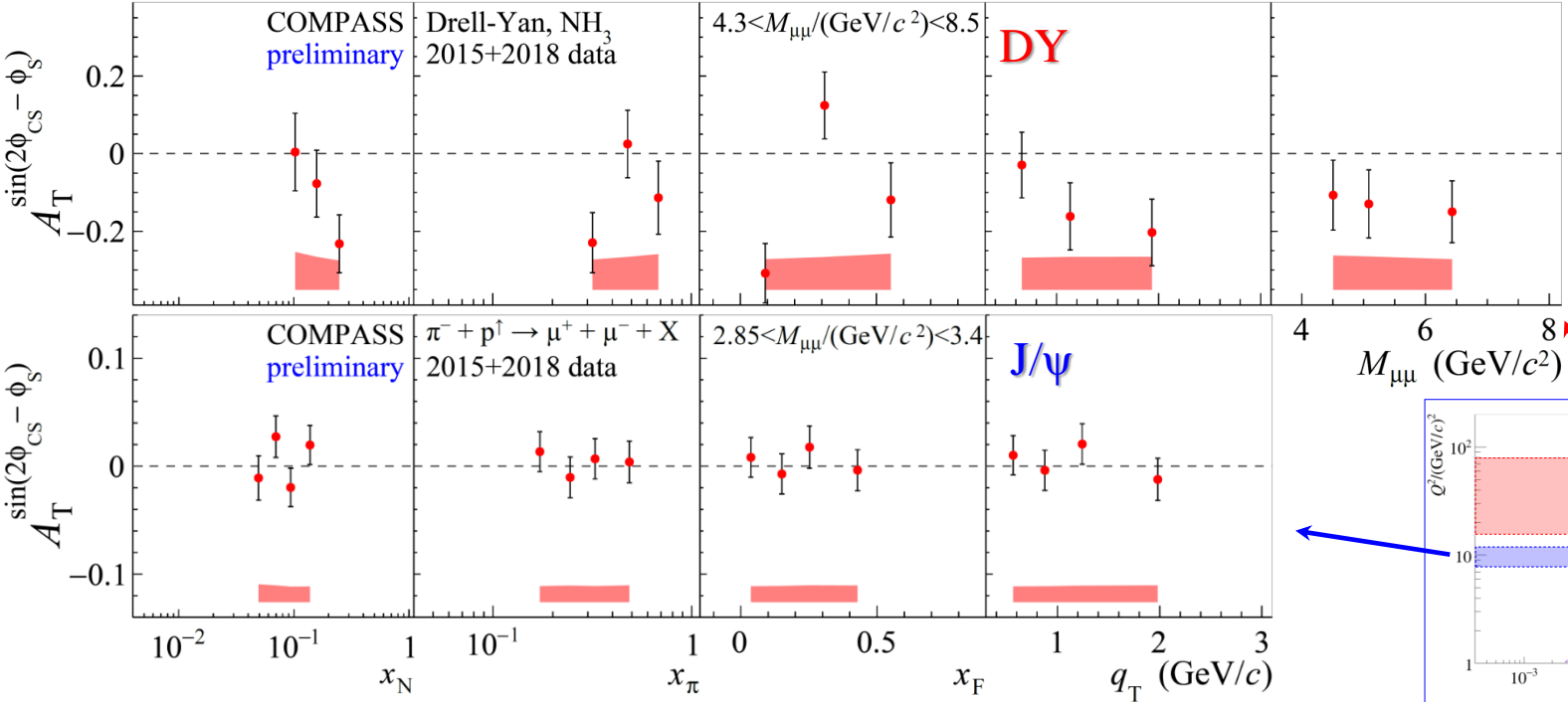
Drell-Yan TSAs – Transversity

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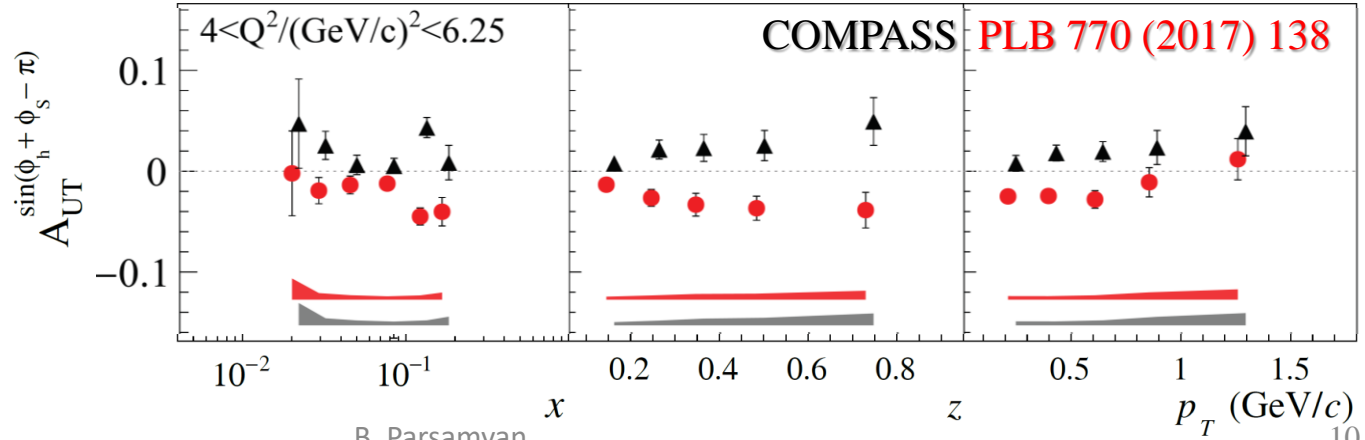


$$\frac{d\sigma}{dq^4 d\Omega} \propto 1 + \dots + S_T \left[D_{[\sin^2 \theta_{CS}]} A_T^{\sin(2\varphi_{CS}-\varphi_S)} \sin(2\varphi_{CS}-\varphi_S) + \dots \right]$$



Collins SIDIS TSA

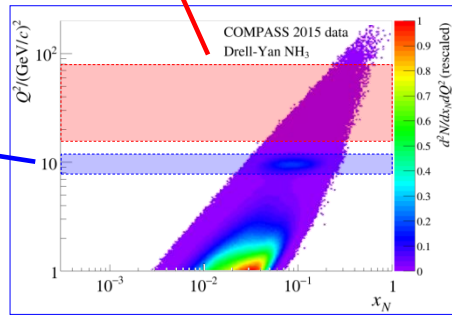
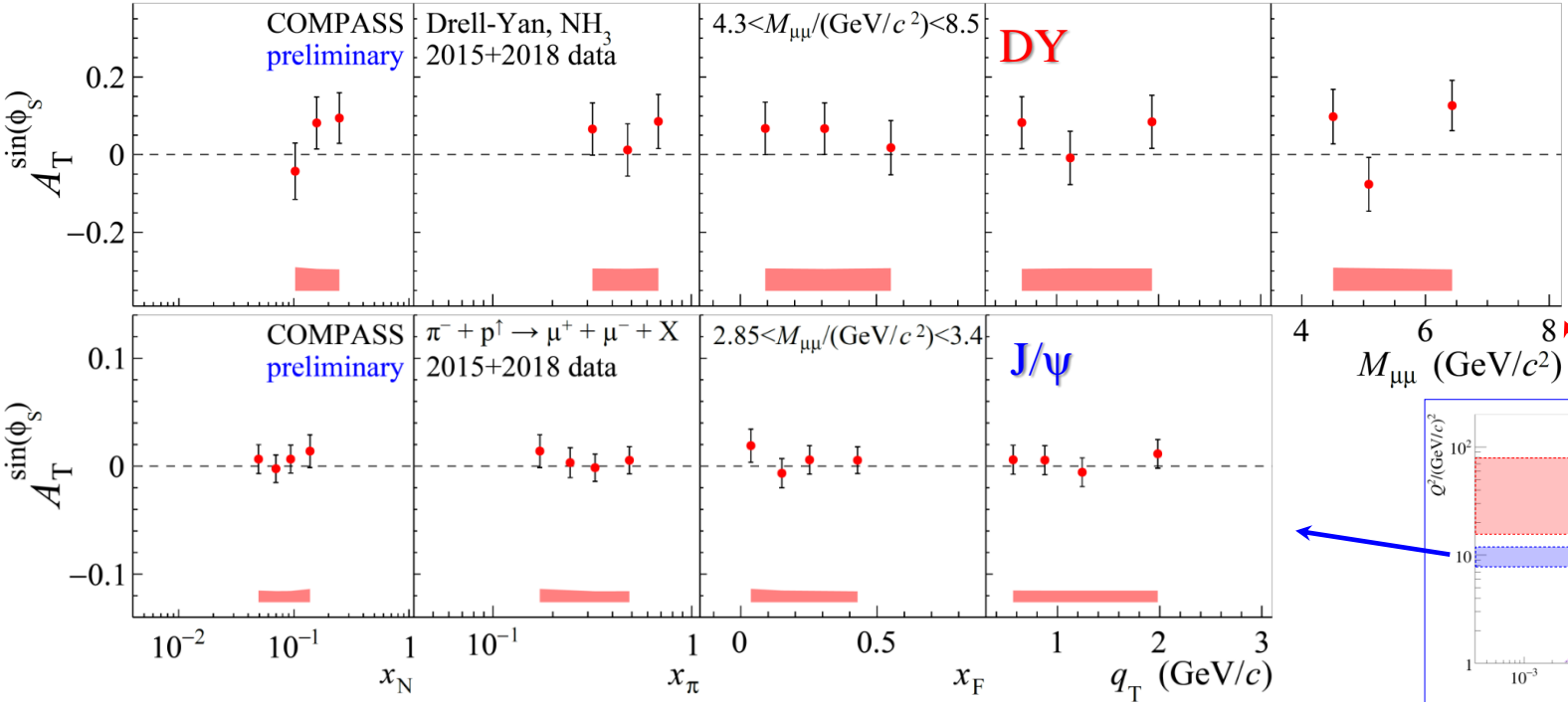
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Drell-Yan TSAs – Sivers

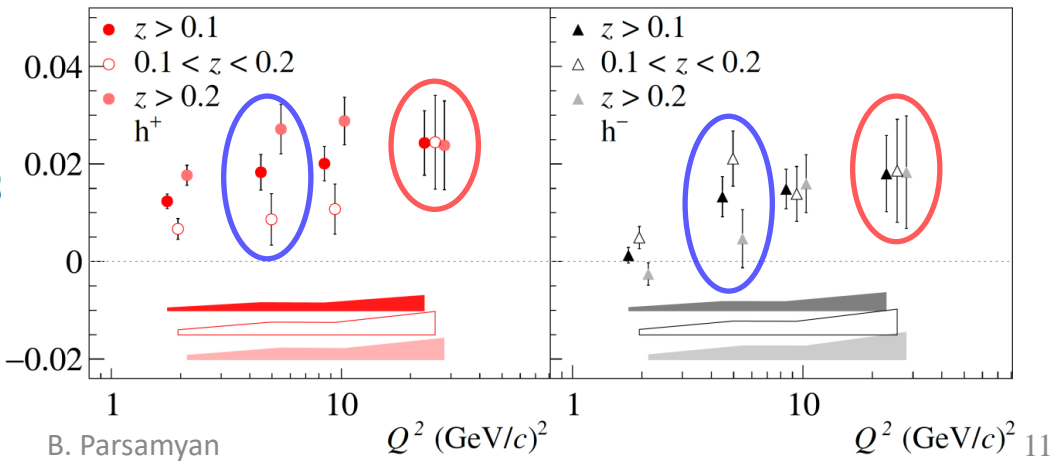
Sivers DY TSA
 $A_T^{\sin\phi_S} \propto f_{1,\pi}^q \otimes f_{1T,p}^{\perp q}$

$$\frac{d\sigma}{dq^4 d\Omega} \propto 1 + \dots + S_T \left[A_T^{\sin\phi_S} \sin\phi_S + \dots \right]$$



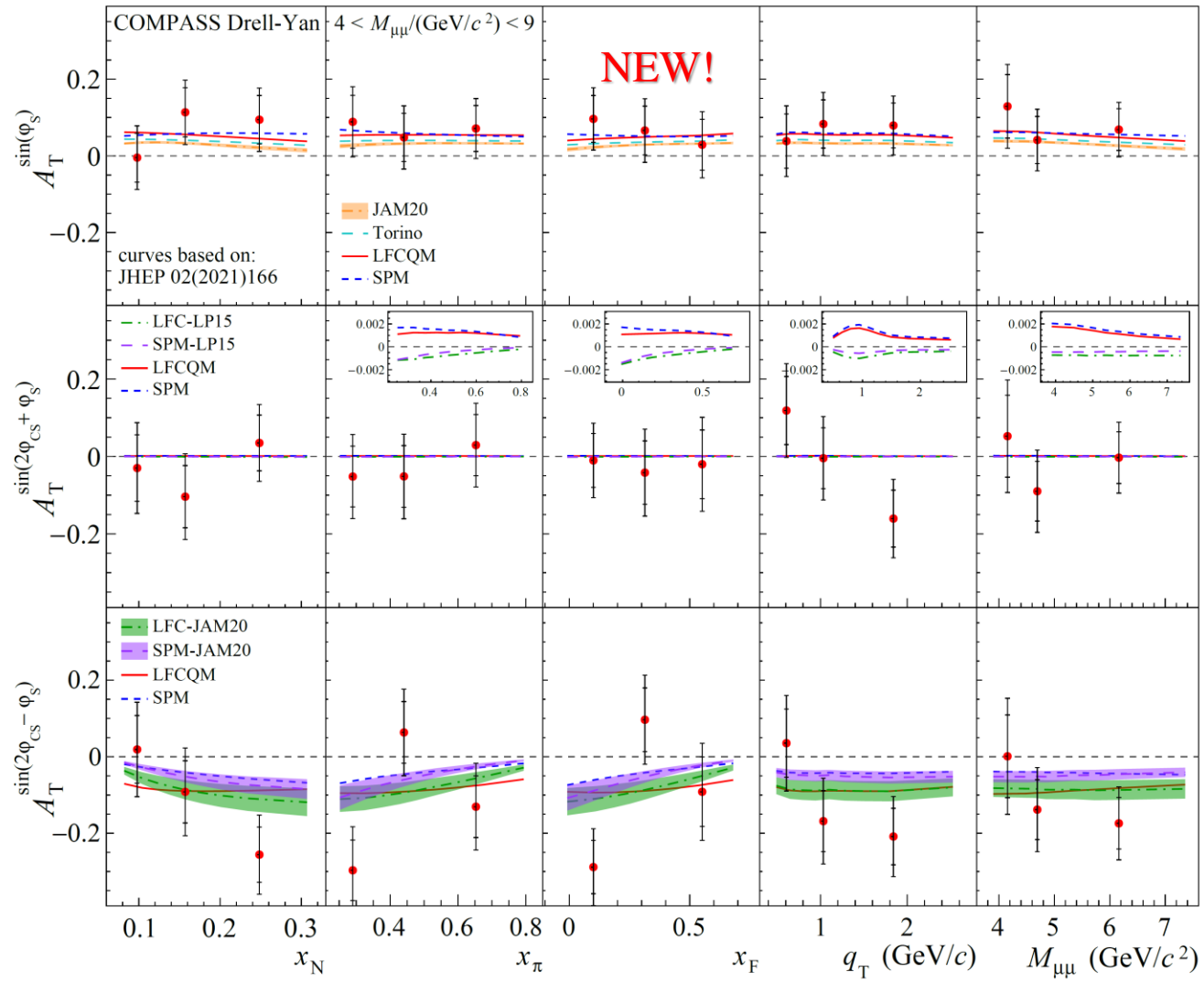
Sivers SIDIS TSA
 $A_{UT}^{\sin(\phi_h - \phi_S)} \propto f_{1T}^{\perp q} \otimes D_{1q}^h$

COMPASS
PLB 770 (2017) 138



DY TSAs at COMPASS (high-mass range)

Final COMPASS results on the transverse-spin-dependent azimuthal asymmetries in the pion-induced Drell-Yan process [hep-ex/2312.17379](https://arxiv.org/abs/hep-ex/2312.17379)



Drell-Yan measurements

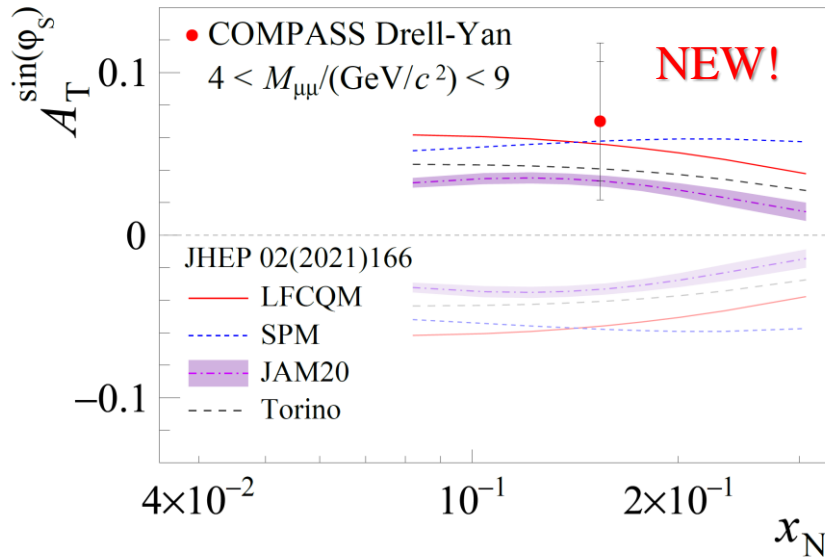
- Ruled out predictions for large asymmetries
- General agreement with currently available model calculations
- **COMPASS data favors the sign-change hypothesis for the Sivers TMD PDF**
- **COMPASS data also favors pion Boer-Mulders TMD PDF sign-change (model-based)**

J/ψ production channel

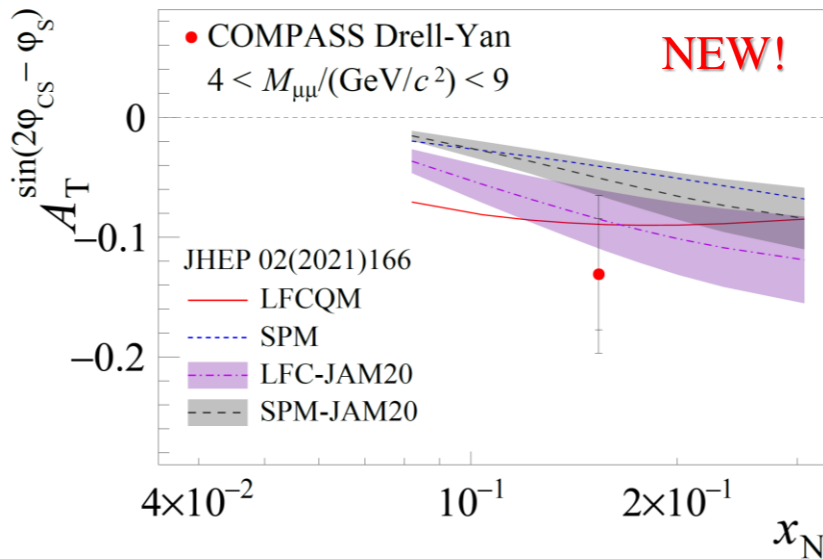
- All TSAs are small and compatible with zero
- **Hint that J/ψ production might go via gluon-gluon fusion in COMPASS**
- Access to small gluon TMDs?

DY TSAs at COMPASS (high-mass range)

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sign change test



sign change test

Drell-Yan measurements

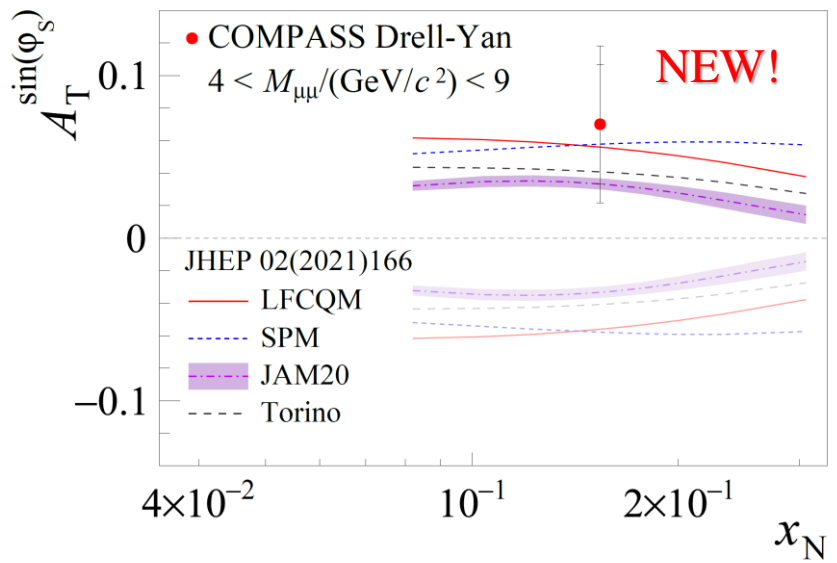
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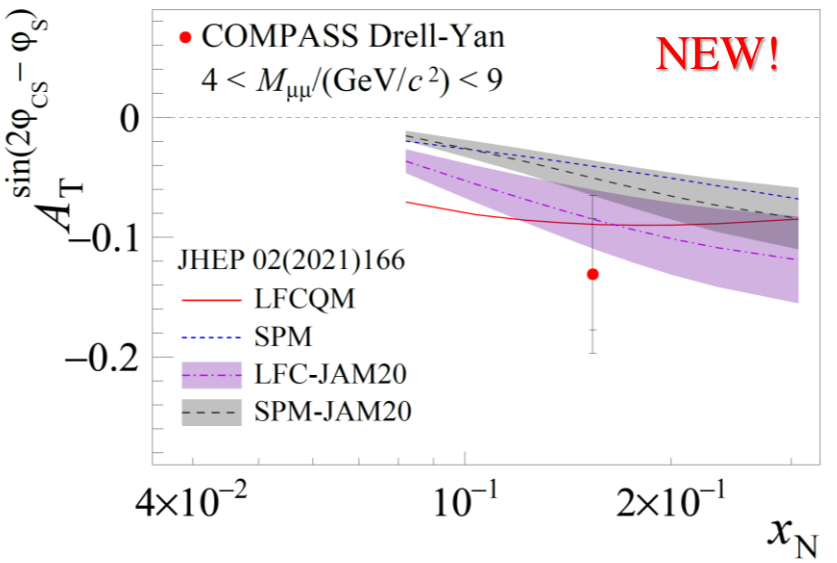
sign change test

Drell-Yan measurements

- Still large uncertainties (dilution factor, background, polarization)

J/ψ production channel

- Extraction of unpolarized asymmetries and x-sections is challenging. COMPASS was not really designed for these kind of cross-section measurements



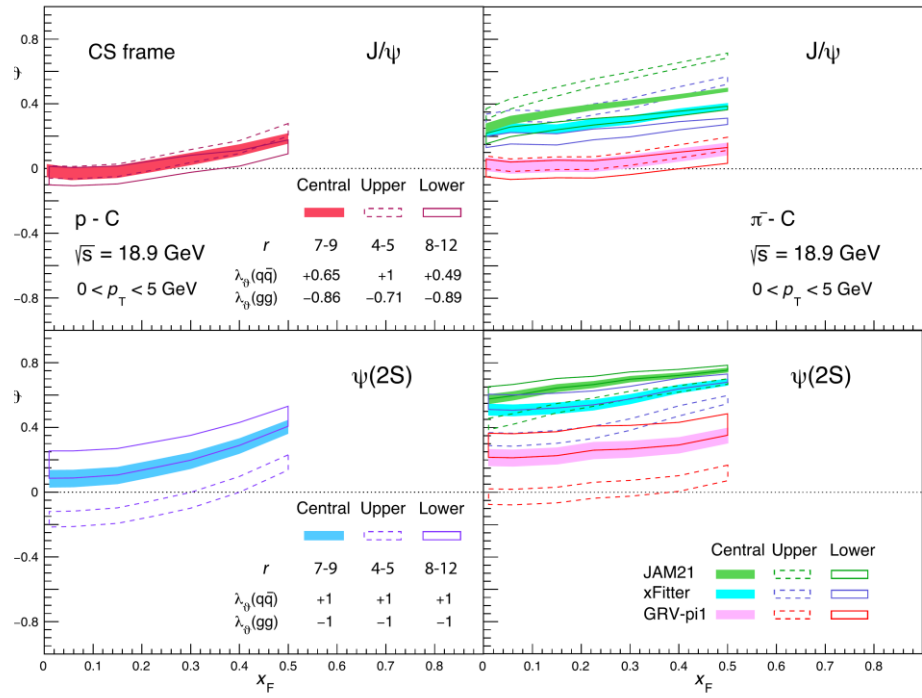
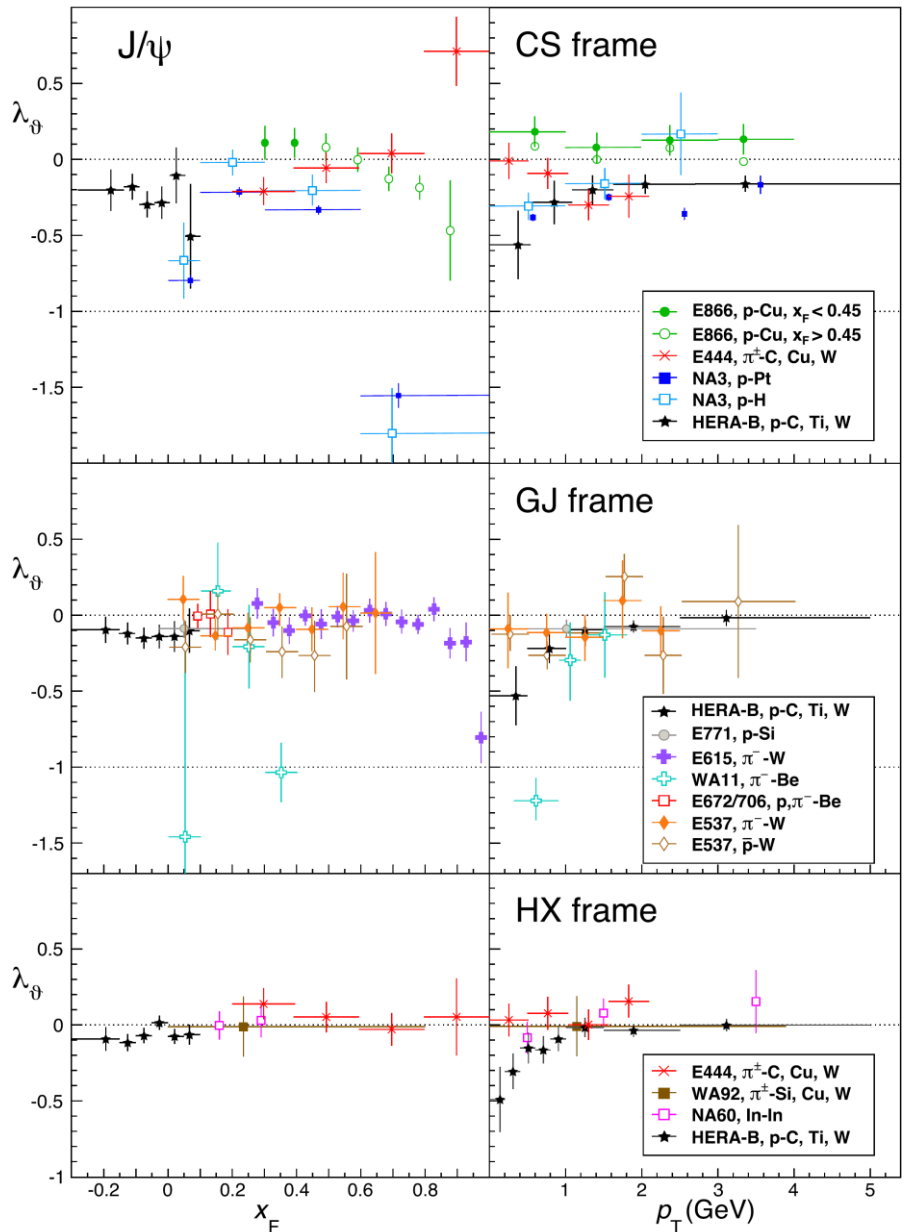
sign change test

The sign-change topic is not closed yet
 A lot of room for further studies
 and definite answers to be found

Charmonia polarization, production mechanisms, FD

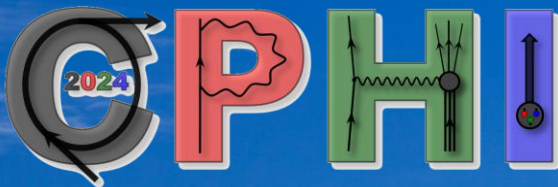


P. Faccioli et al.
 Physics Letters B 840(2023)13787



Predictions for COMPASS/AMBER

Important channel to access the information about production mechanisms...
 A self-consistency test that one can perform.



Joint XX-th International Workshop on *COMPASS* Hadron Structure and Spectroscopy



and 5-th Workshop on Correlations in Partonic and Hadronic Interactions

<https://indico.cern.ch/e/IWHSS-CPHI-2024>

Yerevan, Armenia
30 September – 4 October, 2024

