
# JRA4
# 3D STRUCTURE OF THE NUCLEON IN MOMENTUM SPACE (TMD-NEXT)

Alessandro Bacchetta
INFN Pavia

INFN
Istituto Nazionale di Fisica Nucleare

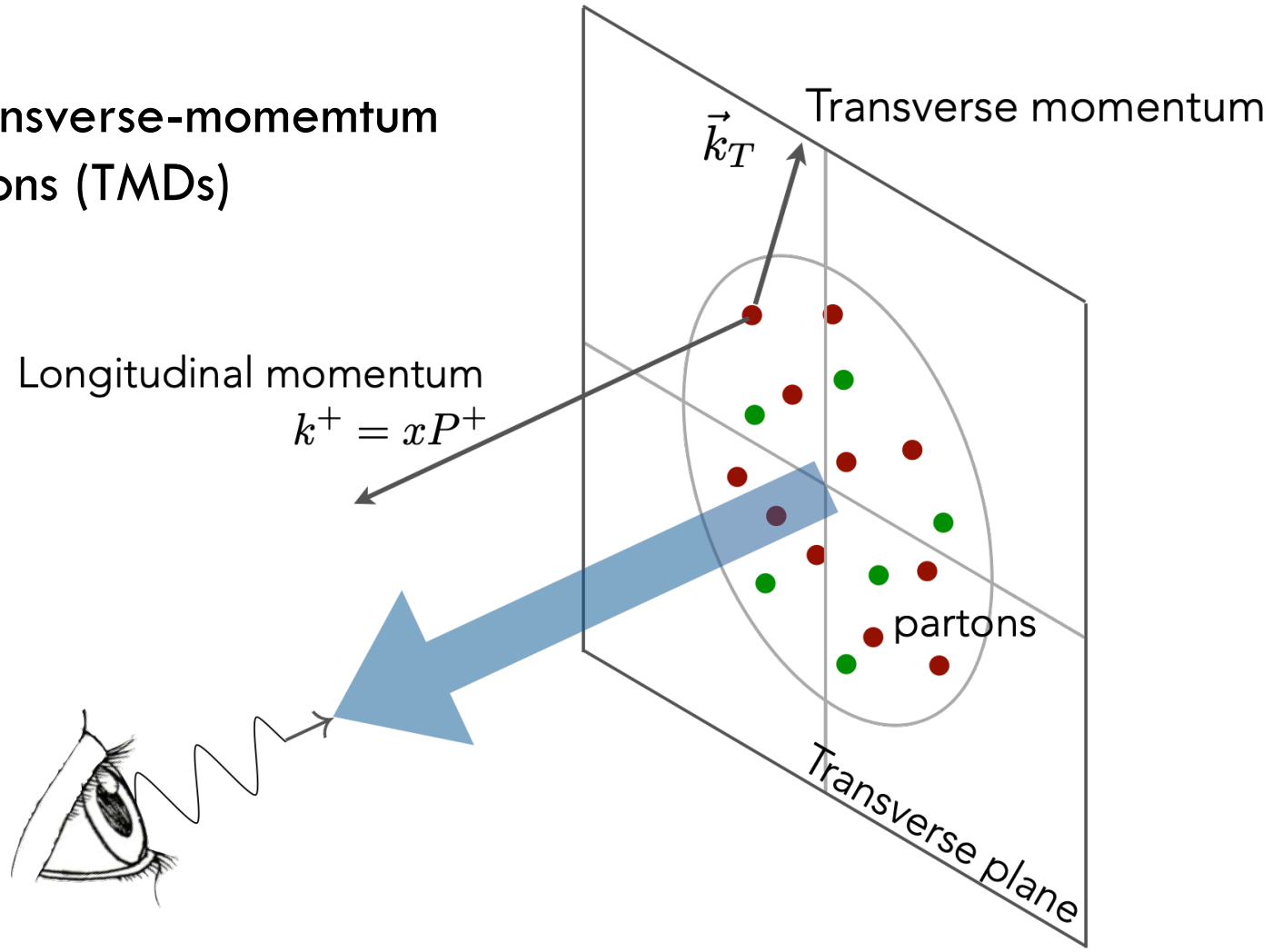
*This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093*

# TMD-NEXT NETWORK

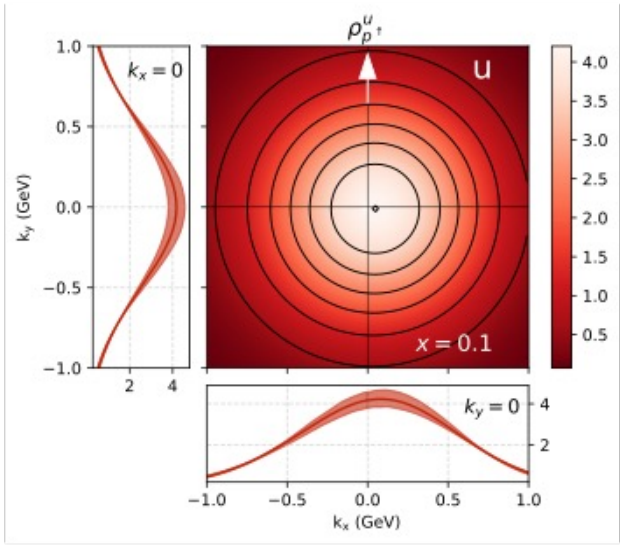
1. INFN
    1. Frascati
    2. Cagliari
    3. Ferrara
    4. Pavia
    5. Torino
    6. Trieste
2. CEA/IRFU Saclay
3. CNRS/CPHT Palaiseau
4. University of the Basque Country, Bilbao
5. LIP, Lisbon
6. Universidad Complutense, Madrid
7. Rijksuniversiteit Groningen
8. University of Montenegro

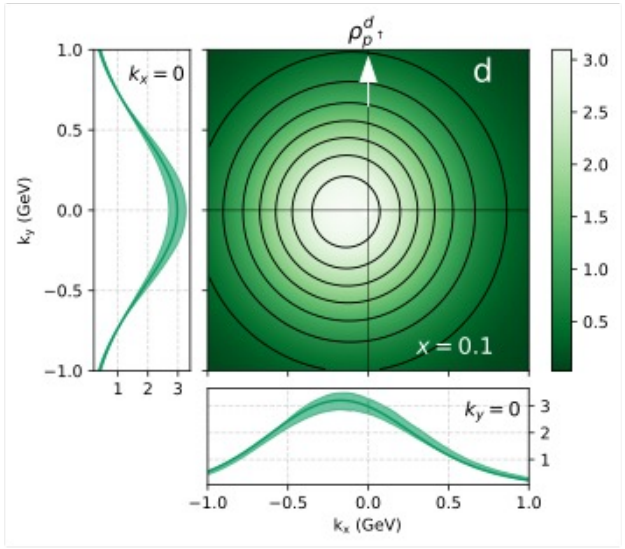
# GOALS OF THE WP

Study transverse-momemtum distributions (TMDs)



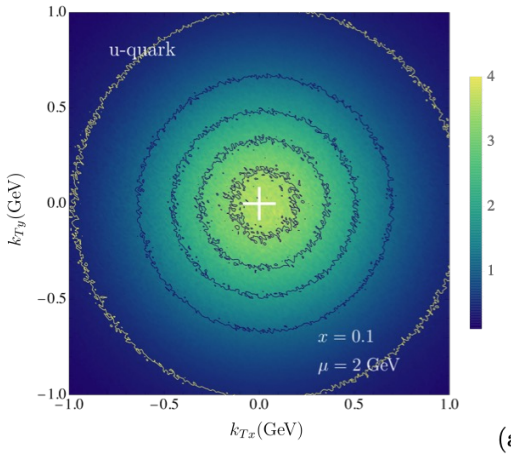
# EXAMPLE OF ACHIEVEMENTS



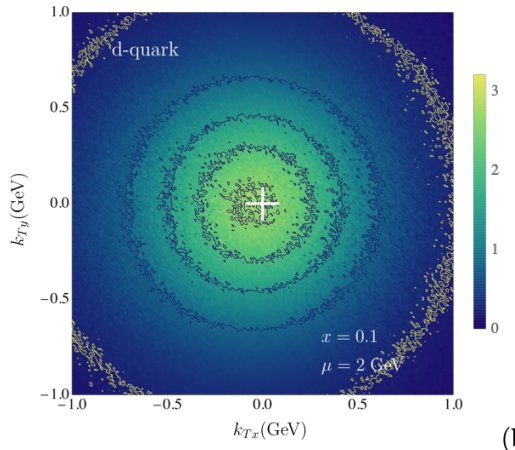




Q= 2GeV

Bacchetta, Delcarro, Pisano, Radici, arXiv:2004.14278



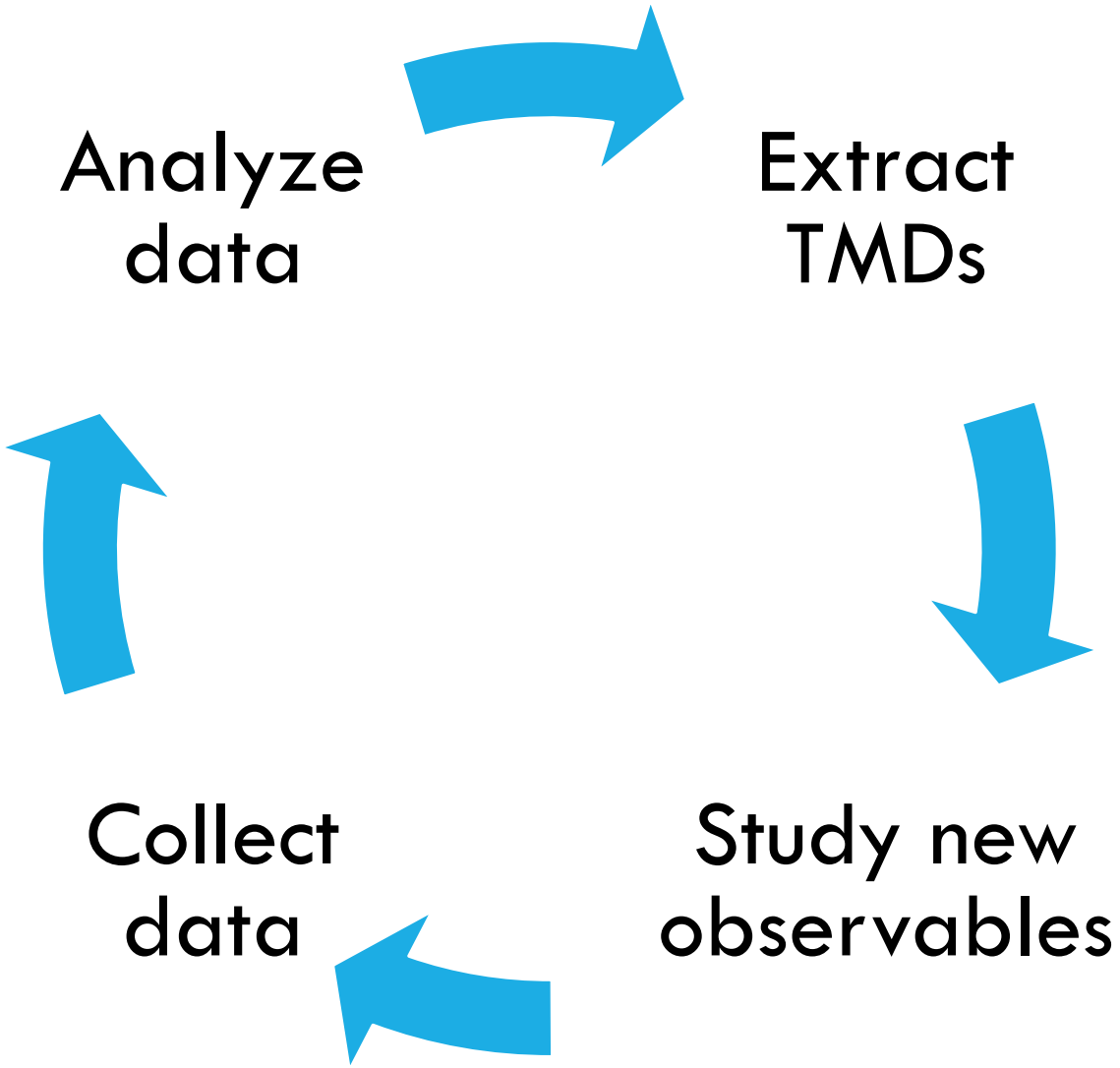

(a)




(b)

Bury, Prokudin, Vladimirov, arXiv:2103.03270

# GOALS OF THE WP



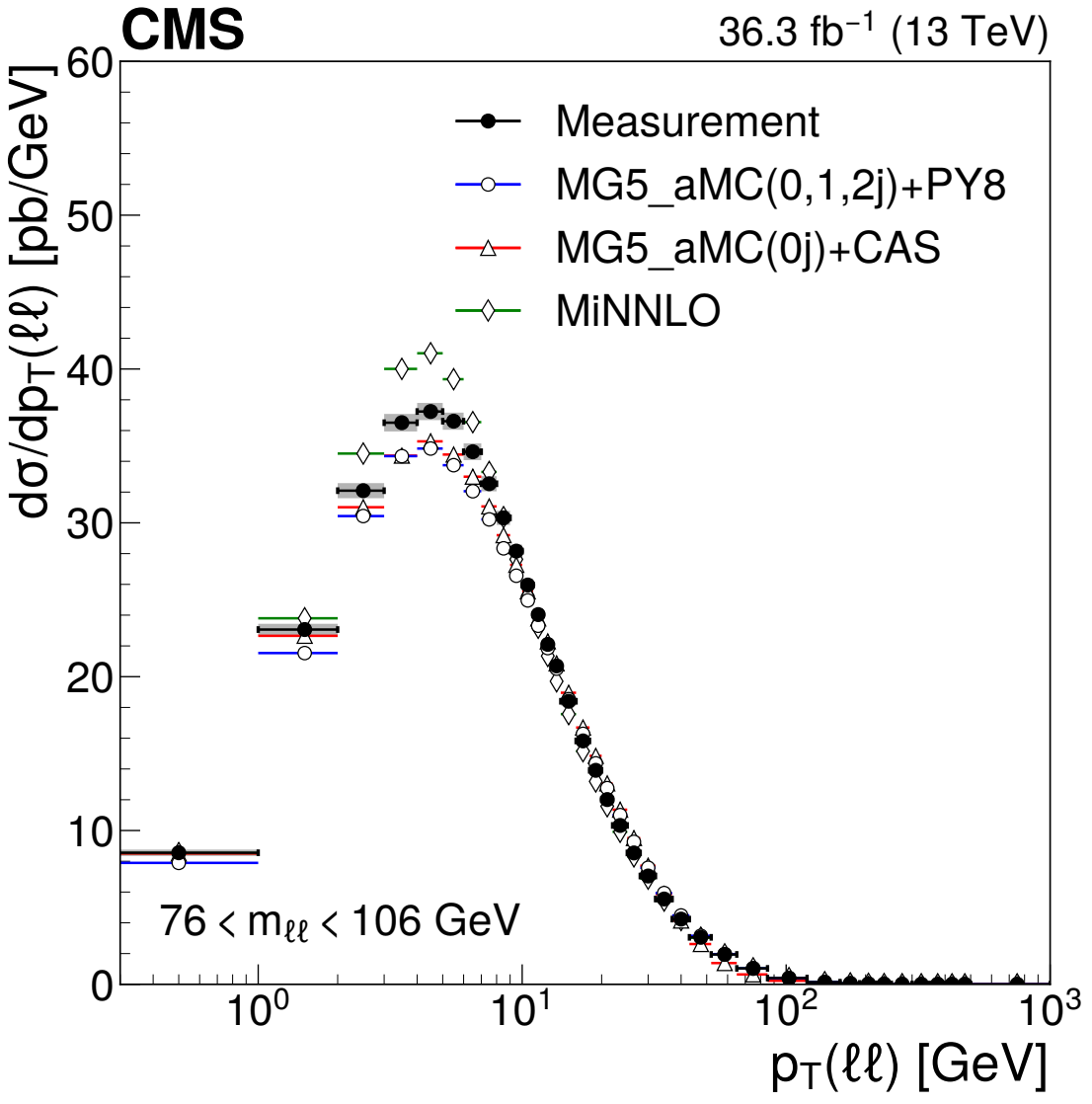
# COLLECT NEW DATA: SIDIS


The COMPASS run with transversely polarized deuterium target has started in June 22 and will last till November, useful for the determination of the down quark transversity distribution


The CLAS12 run with a longitudinally polarized target has started in June 22 and will last till spring 2023. Useful for studies of helicity distribution.

# ANALYZE DATA: DY

The final version of the DY paper over a wide mass range is submitted to the arXiv and the journal (EPJC) (arXiv:2205.04897)

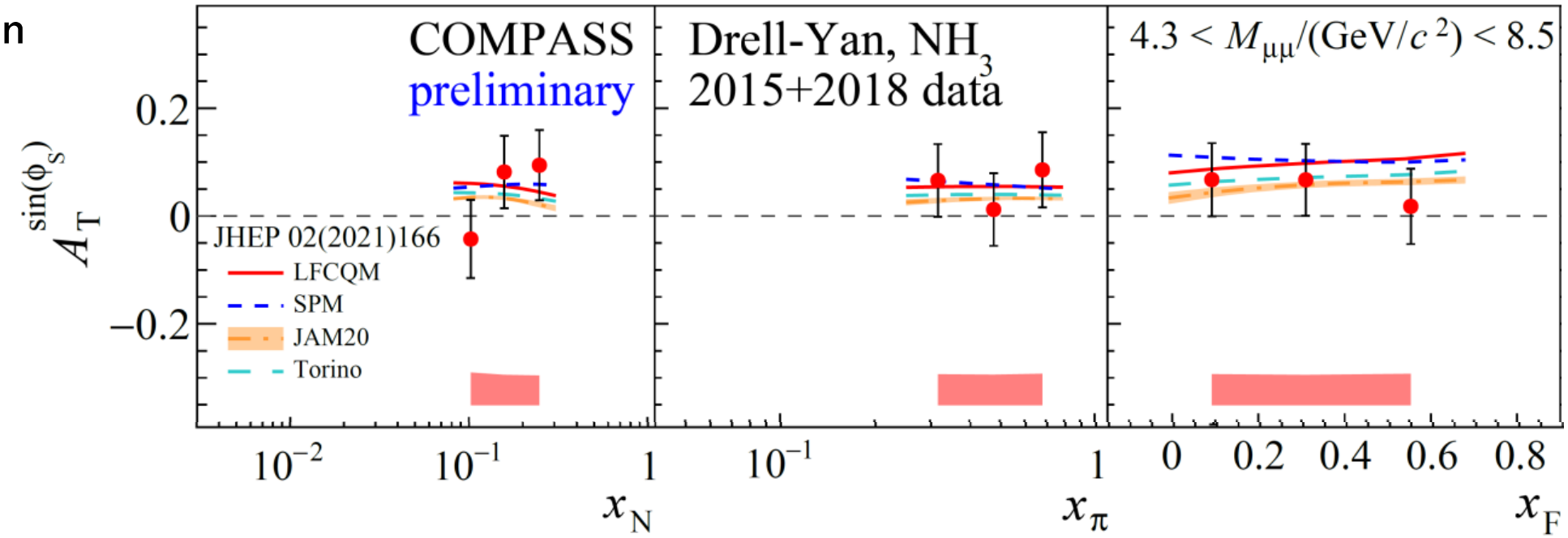


# ANALYZE DATA: DY

Drell-Yan

Preliminary results for Drell-Yan single spin asymmetries in the high mass range (4.3 – 8.5 GeV) from the full data sample collected in 2015 and 2018 have been released.

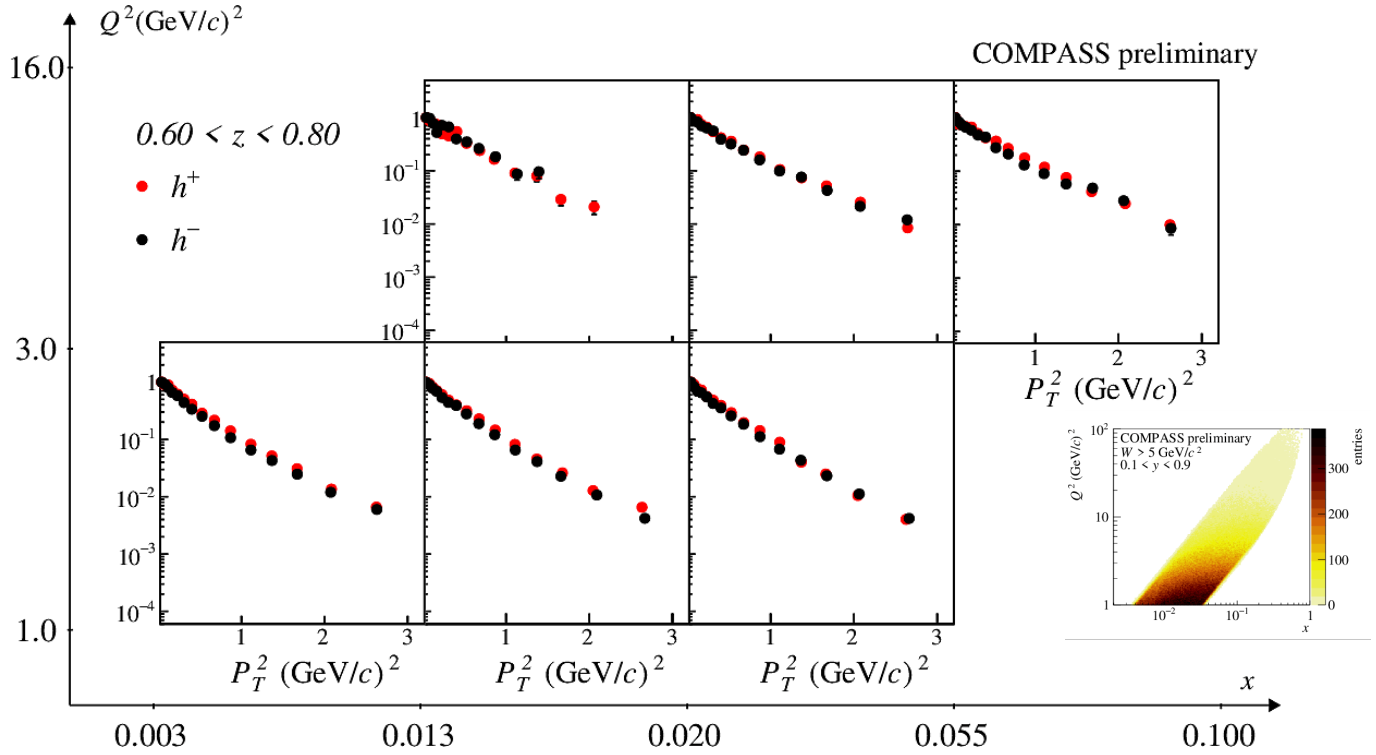
Analysis of unpolarized cross section under way



# ANALYZE DATA: SIDIS

Semi-inclusive DIS

Analysis of pion and kaon multiplicities in SIDIS reaction.
Analysis of hadron multiplicities off proton target



# ANALYZE DATA: $E^+E^-$


Analysis of BELLE data progressing slowly

People outside the WP are working to bring analysis ready for internal collaboration review.

Planning for a fragmentation workshop early 2023 in progress, which will allow for further dedicated working time on Belle analysis and publication preparation.

Additional manpower is being hired to set up a fragmentation function framework for Belle II and strengthen the current Belle analysis team.

# EXTRACT QUARK TMDS

- Bury, Hautmann, Leal-Gomez, Scimemi, Vladimirov, Zurita, arXiv:2201.07114

Extraction of unpolarized TMDs from Drell-Yan data taking flavor dependence into consideration

- Bacchetta, Bertone, Bissolotti, Bozzi, Cerutti, Piacenza, Radici, Signori (MAP collaboration) arXiv:2206.07598

Extraction of unpolarized TMDs from SIDIS and Drell-Yan

- Cerutti, Rossi, Venturini, Bacchetta, Bertone, Bissolotti, Radici (MAP collaboration), arXiv:2210.01733

Extraction of pion unpolarized TMDs from Drell-Yan

- Boglione, Gonzalez-Hernandez, Simonelli, arXiv:2206.08876

Extraction of unpolarized TMD FF from thrust-dependent data in $e^+e^-$ annihilation

- D'Alesio, Gamberg, Murgia, Zaccheddu, arXiv:2209.11670

Extraction of the polarizing TMD FF from a fit of double and single-inclusive Lambda production in $e^+e^-$ annihilation

# EXAMPLE OF EXTRACTED QUARK TMDS

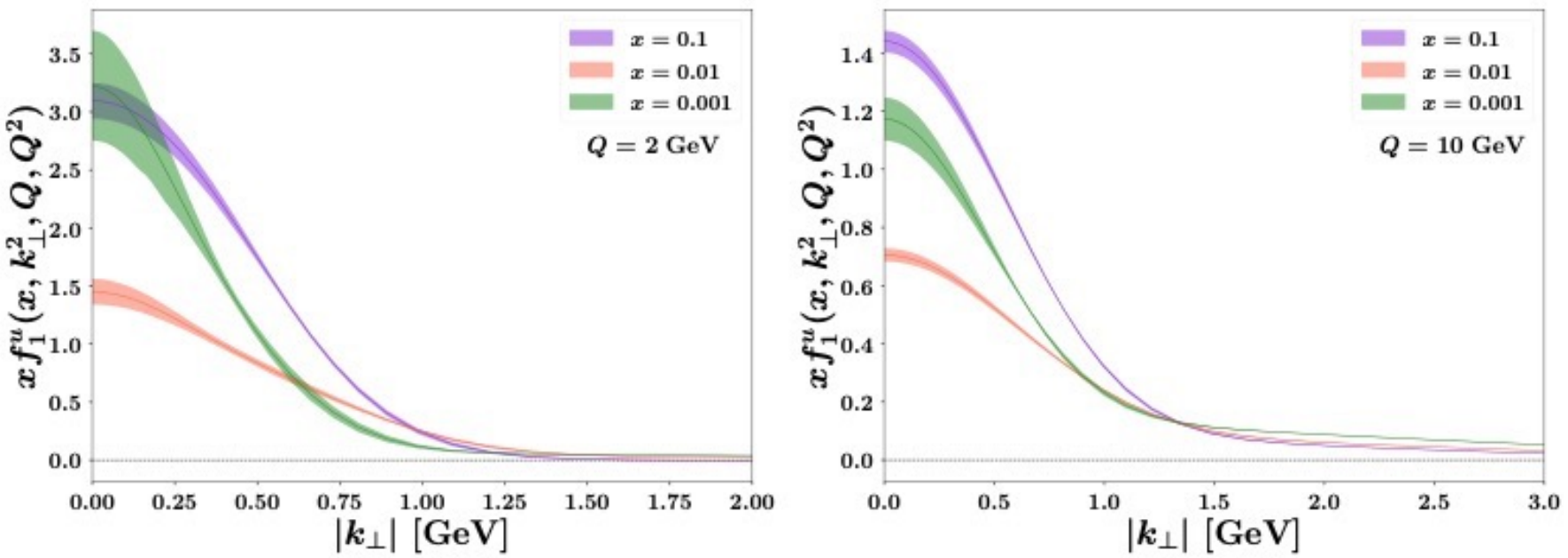
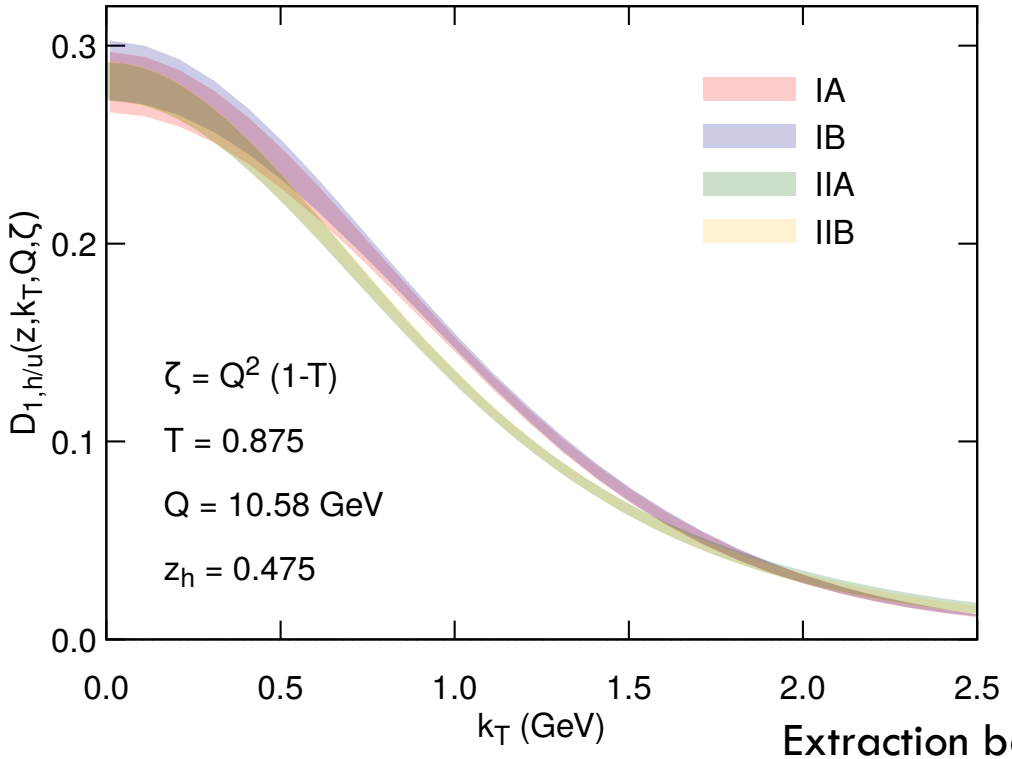



FIG. 13: The TMD PDF of the up quark in a proton at $\mu = \sqrt{\zeta} = Q = 2$ GeV (left panel) and 10 GeV (right panel) as a function of the partonic transverse momentum $|\boldsymbol{k}_\perp|$ for $x = 0.001$, 0.01 and 0.1. The uncertainty bands represent the 68% CL.

arXiv:2206.07598

# EXAMPLE OF EXTRACTED QUARK FRAGMENTATION FUNCTIONS

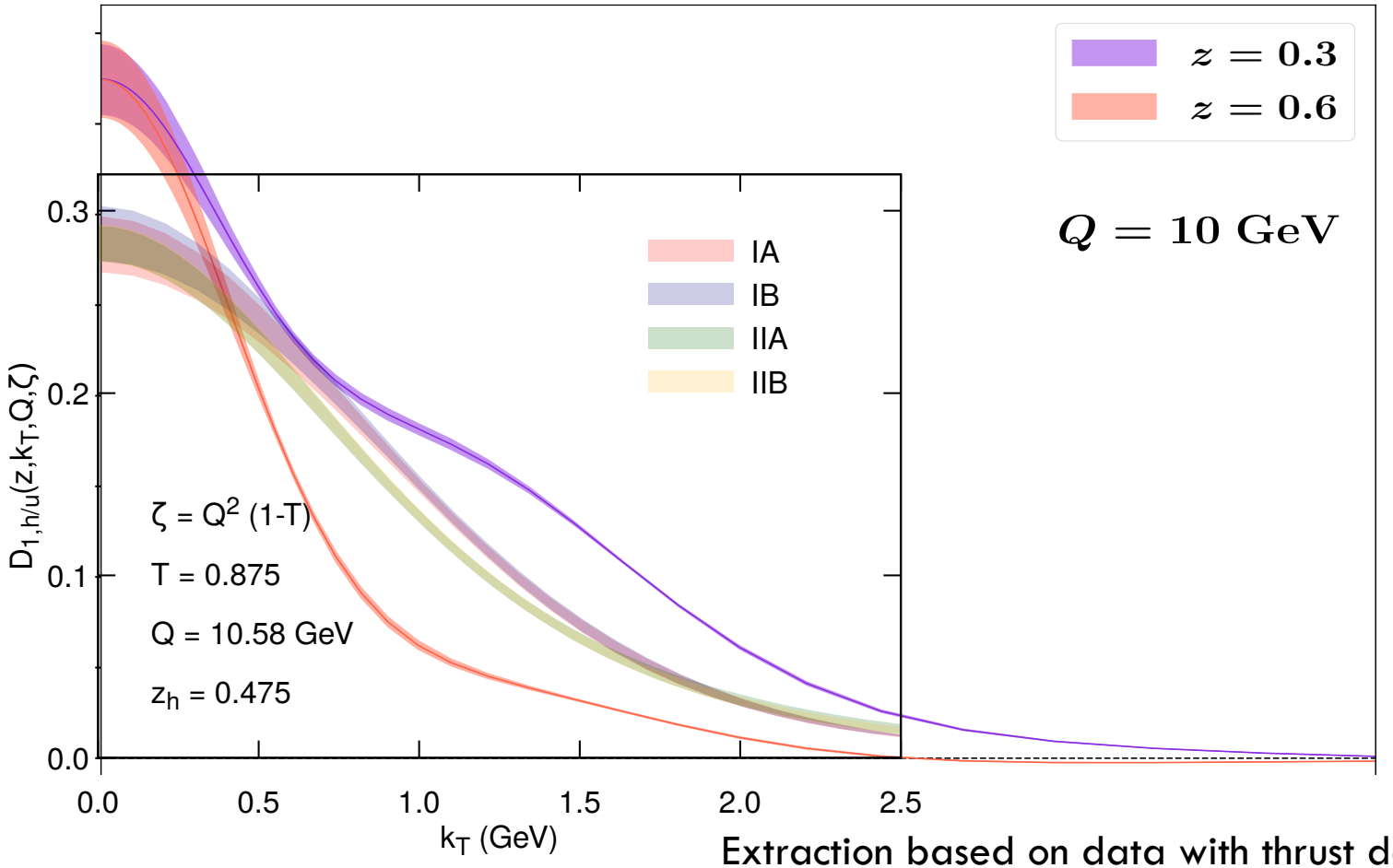



Extraction based on data with thrust dependence (T).

Not exactly the same objects as standard TMDs.

arXiv:2206.08876

# EXAMPLE OF EXTRACTED QUARK FRAGMENTATION FUNCTIONS




arXiv:2206.07598

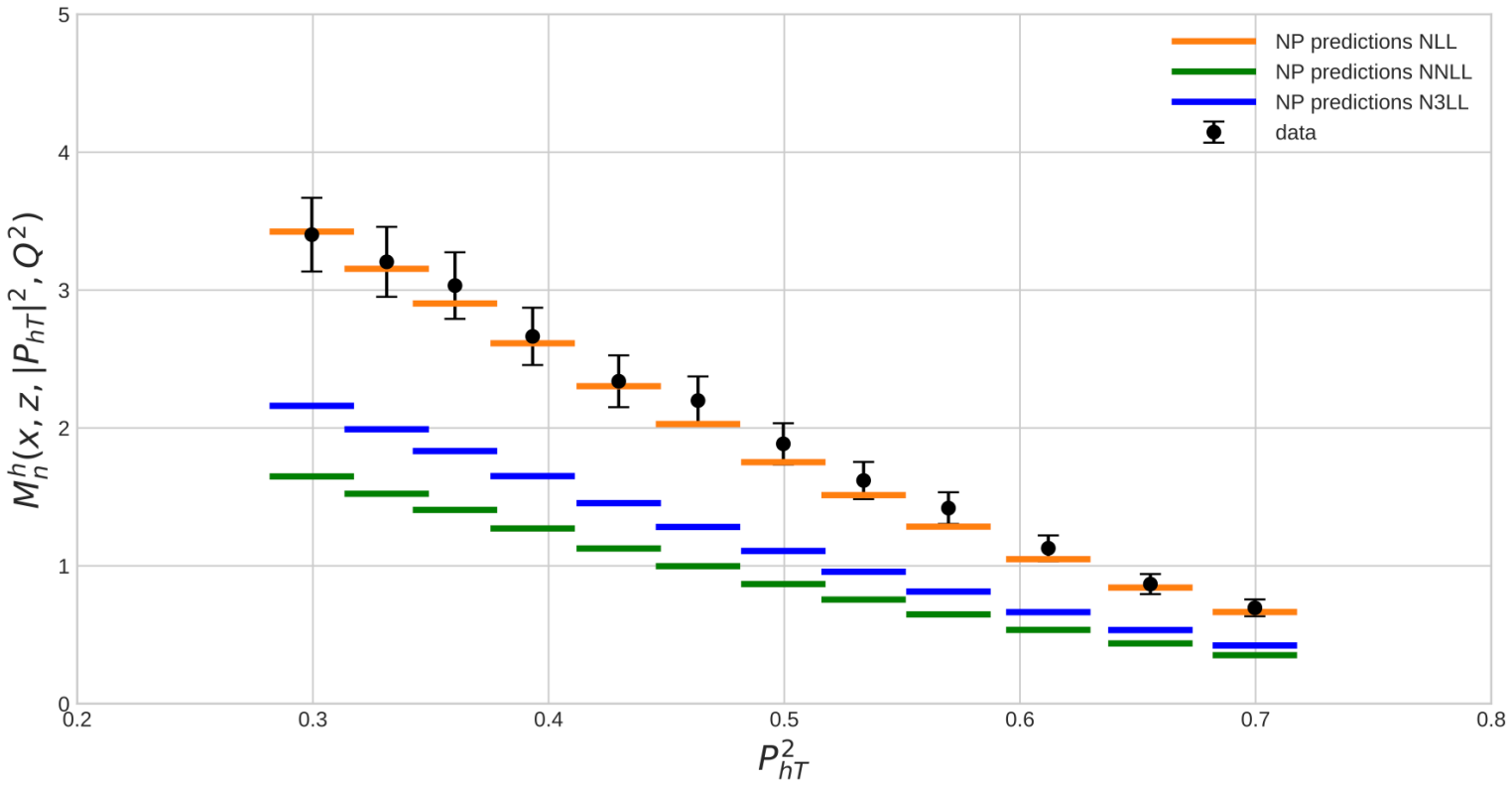
Extraction based on data with thrust dependence (T).

Not exactly the same objects as standard TMDs.

arXiv:2206.08876

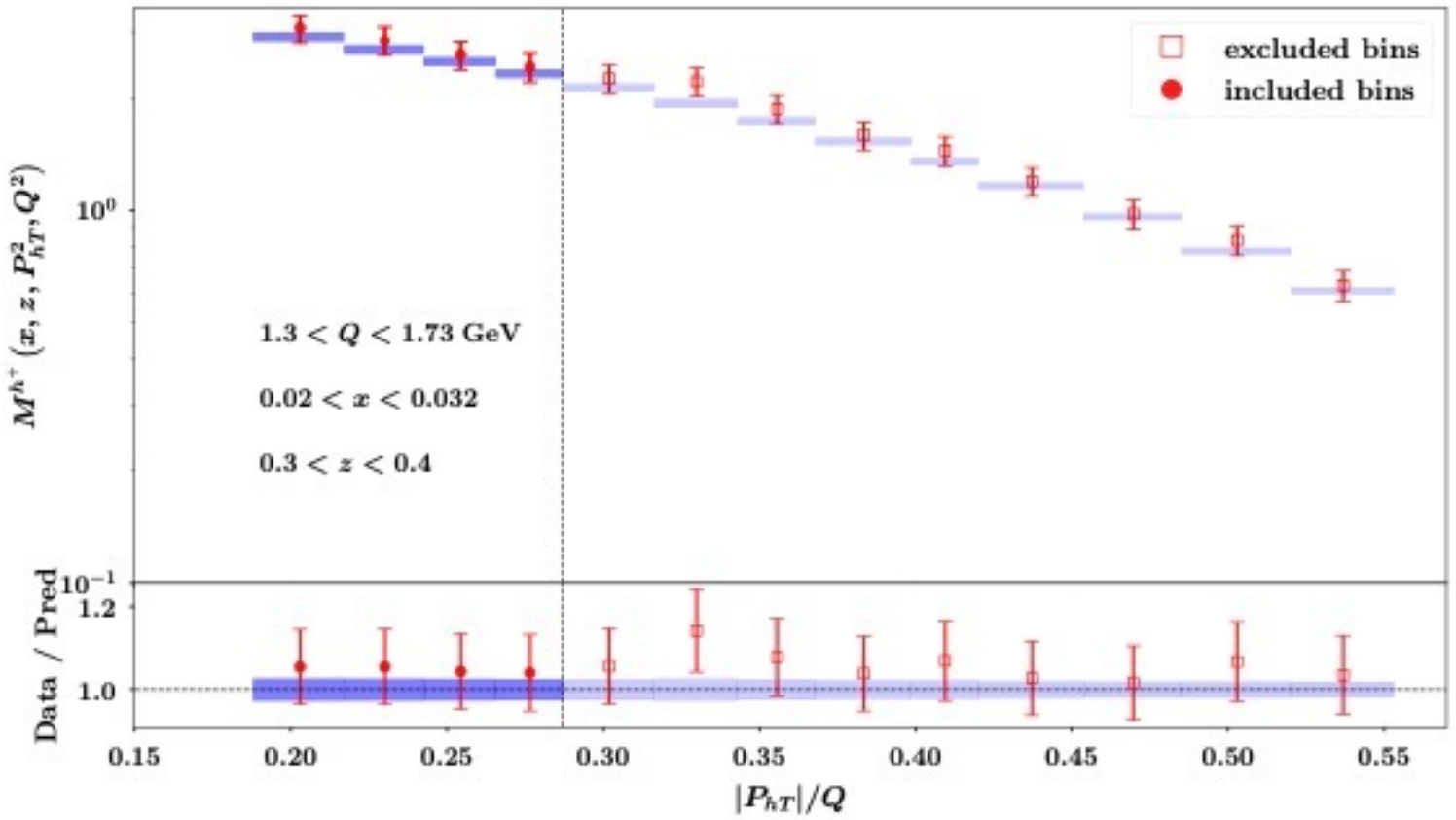
# PROBLEMS WITH SIDIS NORMALIZATION?

Increasing the accuracy, the normalization of the SIDIS cross section decreases (too much?)




Different conclusions in MAP22 (arXiv:2206.07598) and SV19 (arXiv:1912.06532) extractions

# PROBLEMS WITH EXTENSION OF TMD REGION?

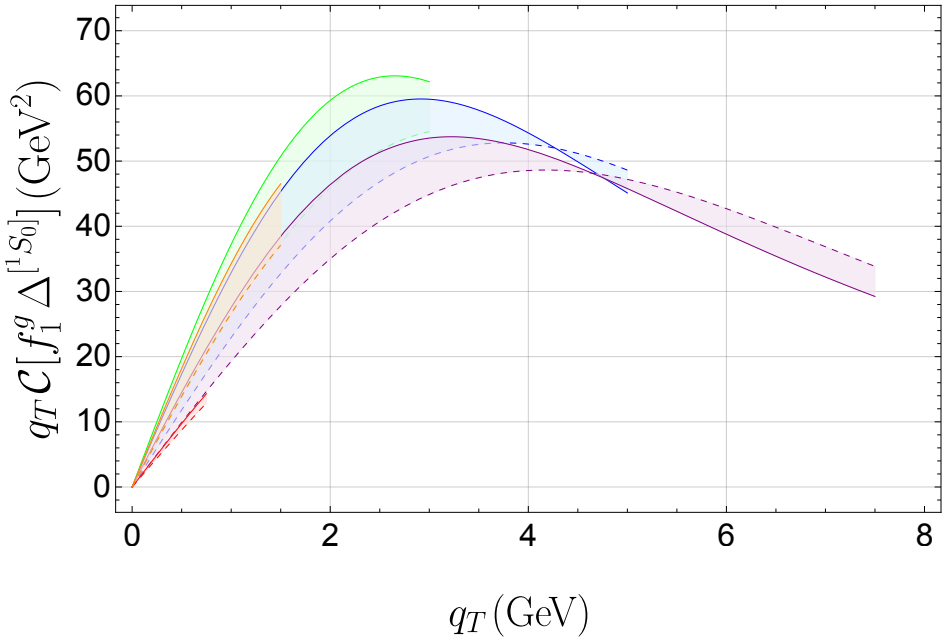


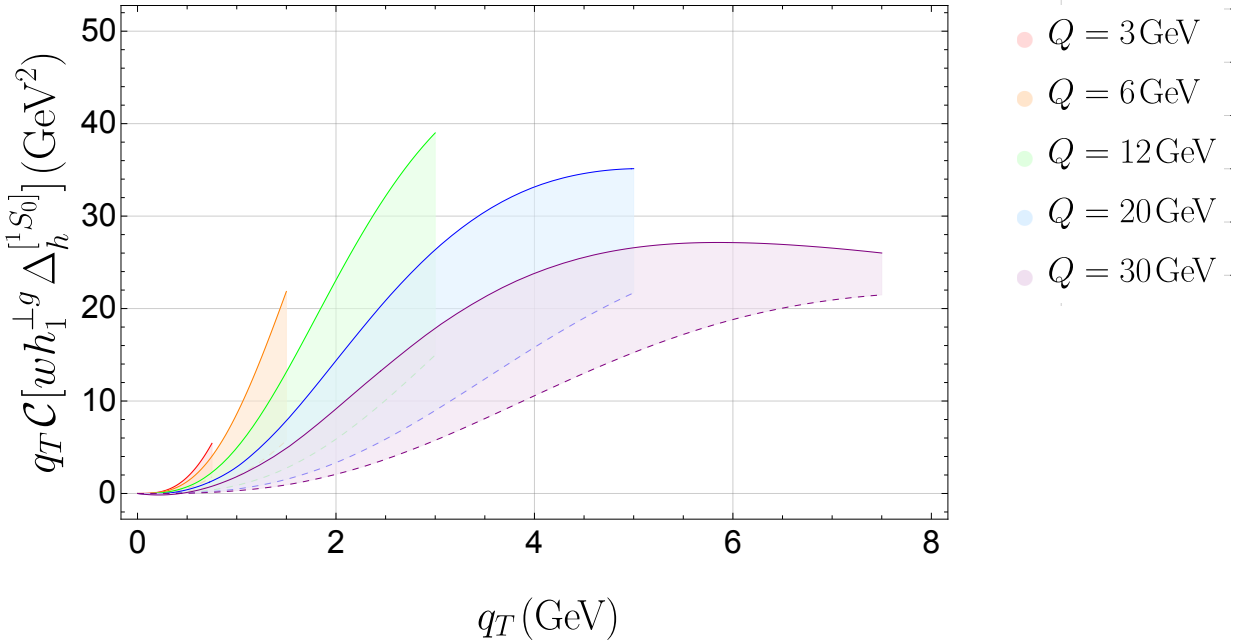

In principle, the TMD description should be applicable at low $P_T$ but in practice it describes data up to large $P_T$

# STUDY NEW OBSERVABLES: GLUONS

$$e(l) + p(P_h) \to e(l') + J/\psi(P) + X$$

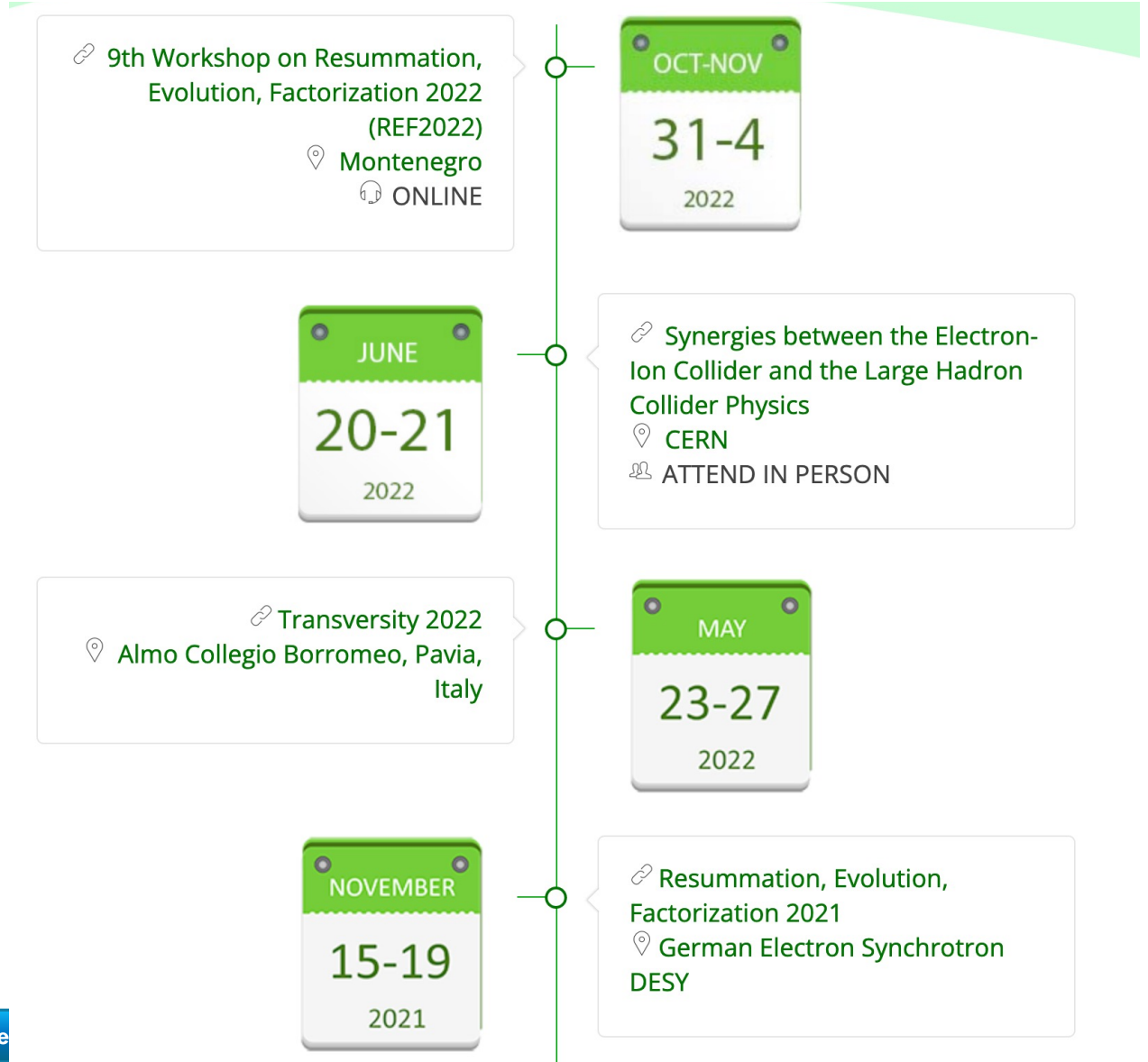
arXiv:2204.01527




See also talk by J. Bor yesterday for Double J/ψ production

# WORKSHOP ORGANIZATION



# TASKS

Red: unlikely to be completed by Nov 23, maybe with extension
Blue: likely to be completed, especially with extension

| | |
|---|---|
| **1. Analysis of Drell-Yan data** | |
| 1.1 Analysis of Drell-Yan@COMPASS | ✓ Need to finalize unpolarized analysis |
| 1.2 Analysis of Drell-Yan@CMS | ✓ |
| **2. Analysis of semi-inclusive DIS data** | |
| 2.1 Analysis of SIDIS@COMPASS (unpolarized) | ✓ New data (proton): need to finalize analysis |
| 2.1 Analysis of SIDIS@COMPASS (polarized deuteron) | Data taking almost over. Need analysis |
| 2.2 Analysis of SIDIS@CLAS12 (polarized) | Data taking ongoing. Need analysis |
| **3. Analysis of electron-positron data** | |
| 3.1 Analysis of multiplicities@BELLE | Analysis progressing slowly |
| 3.2 Analysis of azimuthal modulations@BABAR | ✗ No manpower |
| **4. Quark TMD extractions** | |
| 4.1 Extraction of unpolarized and polarized TMD PDFs and FFs | ✓ More efforts to study polarized TMDs |
| **5. Gluon TMD studies** | |
| 5.1 Study of factorization in gluon-dominated processes | ✓ |
| 5.2 Identification of observables best sensitive to gluon TMDs | ✓ Better assessment of impact needed |
| 5.3 Estimates for quarkonium production in SIDIS | ✓ More estimates needed |

# PERSONNEL COSTS

(I indicate the foreseen number of person months in Strong2020. Contracts are usually longer thanks to matching funds. Months in financial reports should be typically more.)

- INFN Trieste: 1 Postdoc (A. Kerbizi), started on 04/2020, 6 person months ✅
- U. Montenegro: 1 PhD student (I. Bubanja), started 10/2020, 6 person months ✅
- Groningen: 1 PhD student (J. Bor), started 01/2021, 8 person months ✅
- INFN Frascati: 1 Postdoc (O. Soto), from 02/2021 to 06/2021, 5 person months ✅
- INFN Ferrara: 1 Technician position (L. Barion), started 07/2021, 5 person months ✅
- INFN Torino: 1 Postdoc position (A. Simonelli), started 10/2021, 5 person months ✅
- INFN Torino: 1 Postdoc position (F. Delcarro), started 07/2022, 5 person months ✅

- Bilbao: PhD position to start 2022/23 academic year (6 months)
- Other extra hirings are planned (Frascati, Torino, using overheads and/or combining with other WP money)