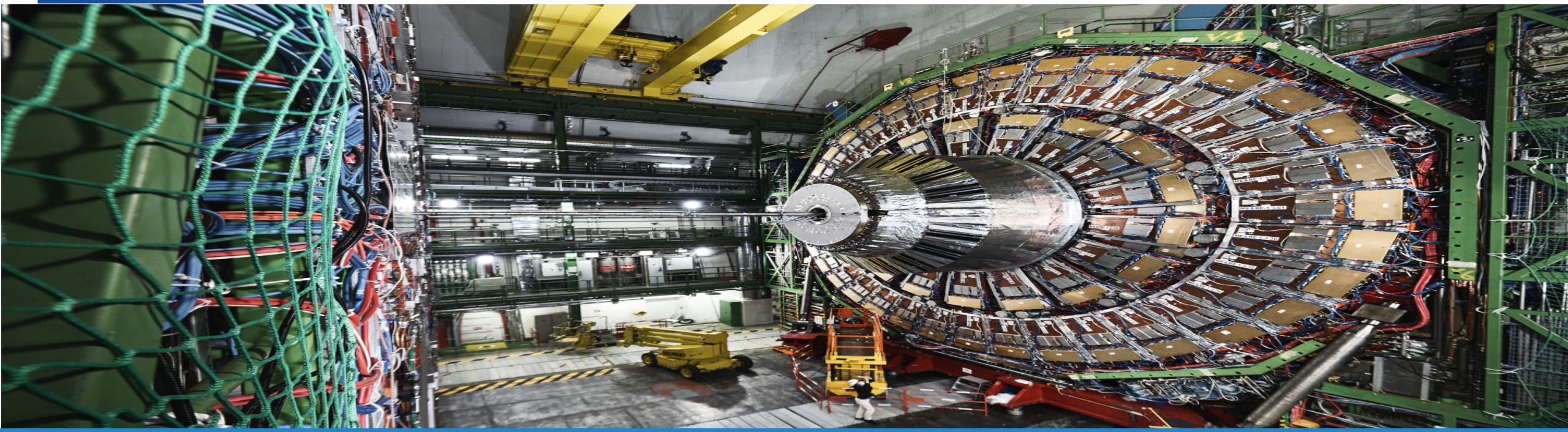


JRA4-WP22

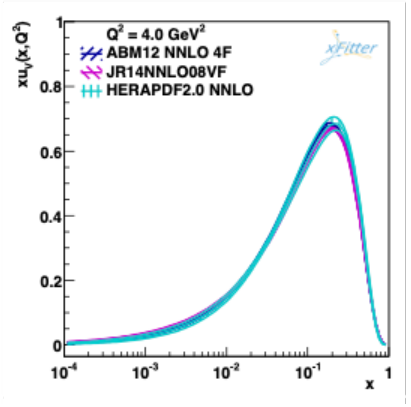
3D structure of the nucleon in momentum space (TMD-neXt)

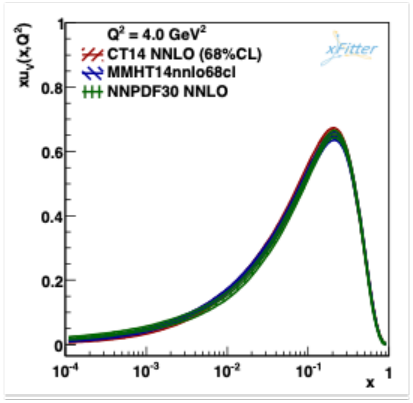
Alessandro Bacchetta

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

JRA4-WP22
3D structure of the nucleon in momentum space (TMD-neXt)

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



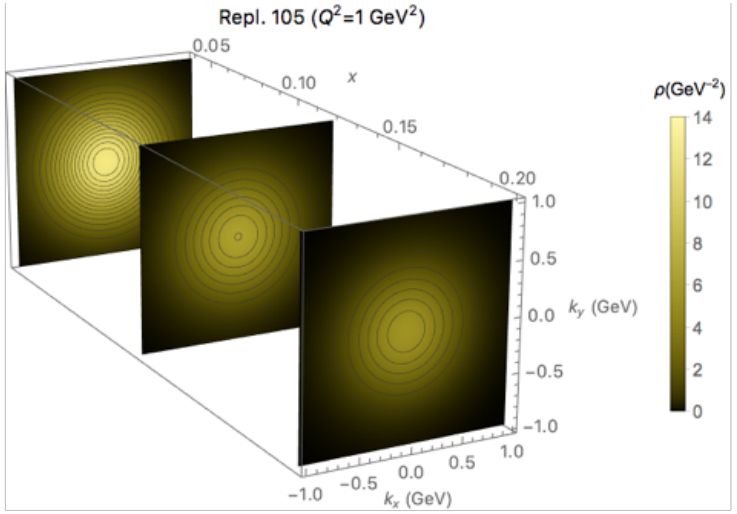


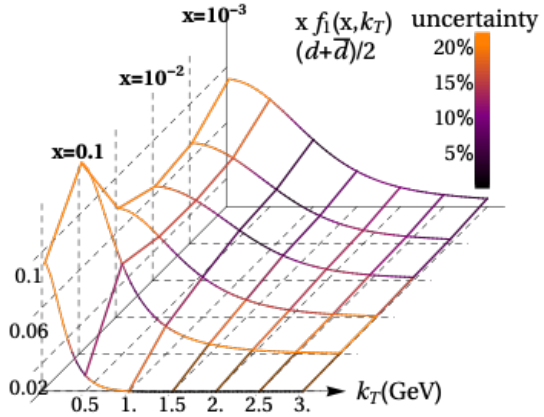
standard PDFs

JRA4

From standard PDFs to
Transverse-Momentum-Dependent PDFs

TMD PDFs

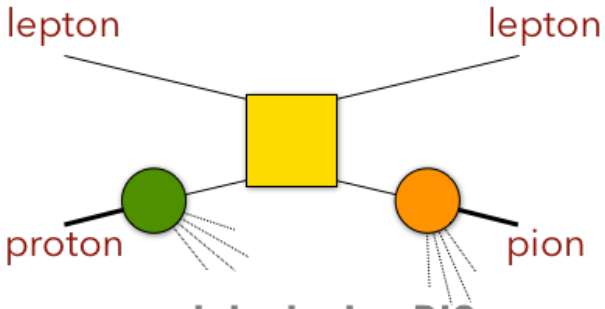




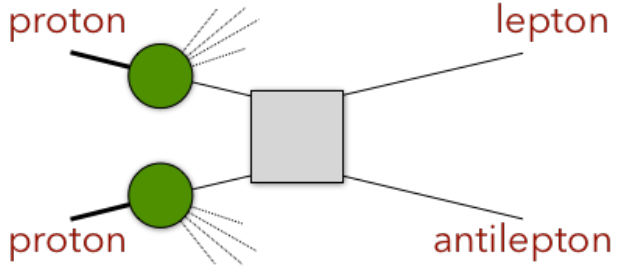
Bacchetta, Delcarro, Pisano, Radici, Signori, arXiv:1703.10157

Bertone, Scimemi, Vladimirov, arXiv:1902.08474

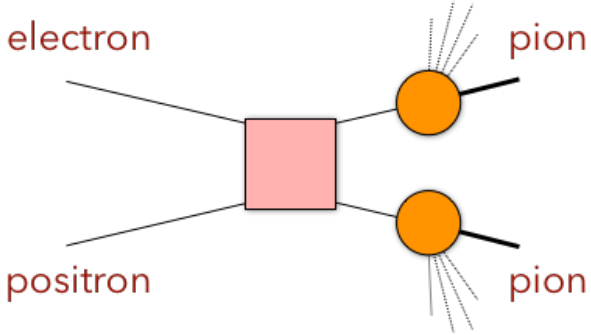
Where do you access TMDs?



semi-inclusive DIS



Drell-Yan



e^-e^+ to pions

Overall situation

- Complex WP, with theory and several experiments together
- Progress taking place in each task, only few criticalities
- Already more than 25 publications, mainly theory/phenomenology

(note: I will mention in the following only the publications of the last year that are more closely related to the tasks, but there are other publications)

- 70% of personnel costs already used/allocated (35 person months)
- Not much money spent on other costs

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 (8 person months), job already advertised
- Bilbao: PhD position to start 2021/22 academic year (6 months)

Other costs

- Other costs: participation to a few conferences and workshops, but only about 7000€ have been spent, also due to Covid
- If possible/necessary, money will be diverted to personnel costs

WP Tasks

- Task 1. Analysis of Drell-Yan data.
- Task 2. Analysis of semi-inclusive DIS data
- Task 3. Analysis of electron-positron data
- Task 4. Quark TMD extractions
- Task 5. Gluon TMD studies

Task 1
Analysis of Drell-Yan (DY) data

The analysis of COMPASS (2018 data taking) and CMS (2016 data taking) are in an advanced stage.

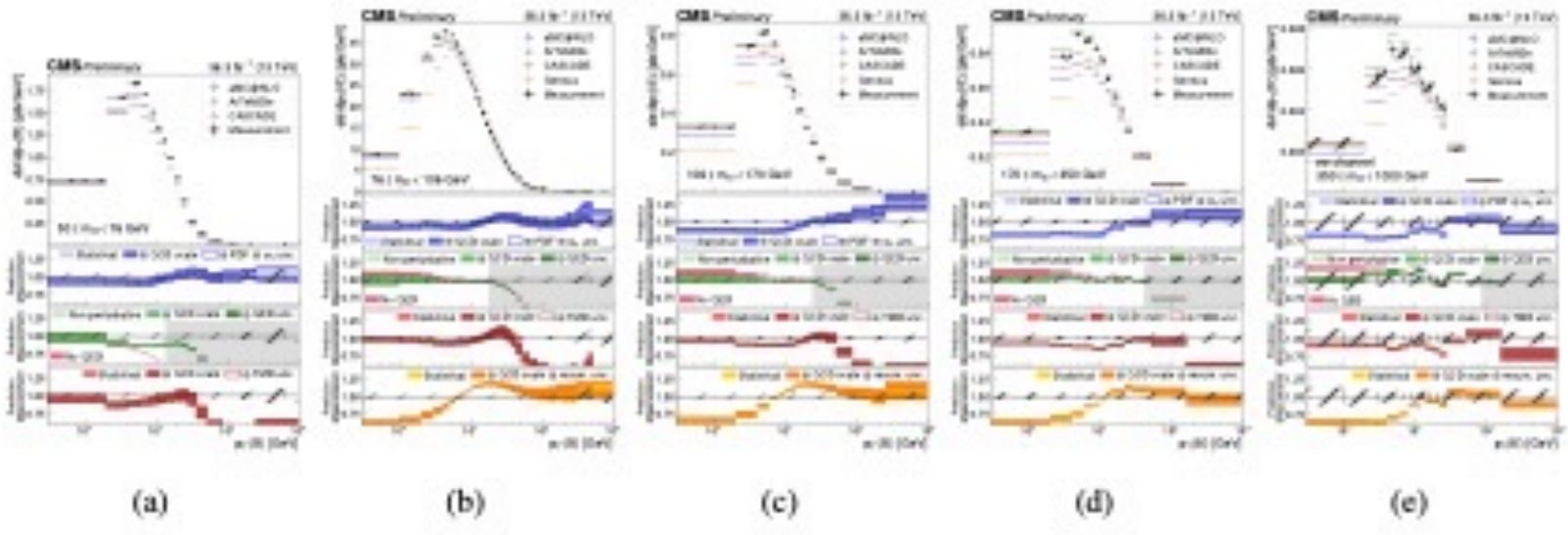
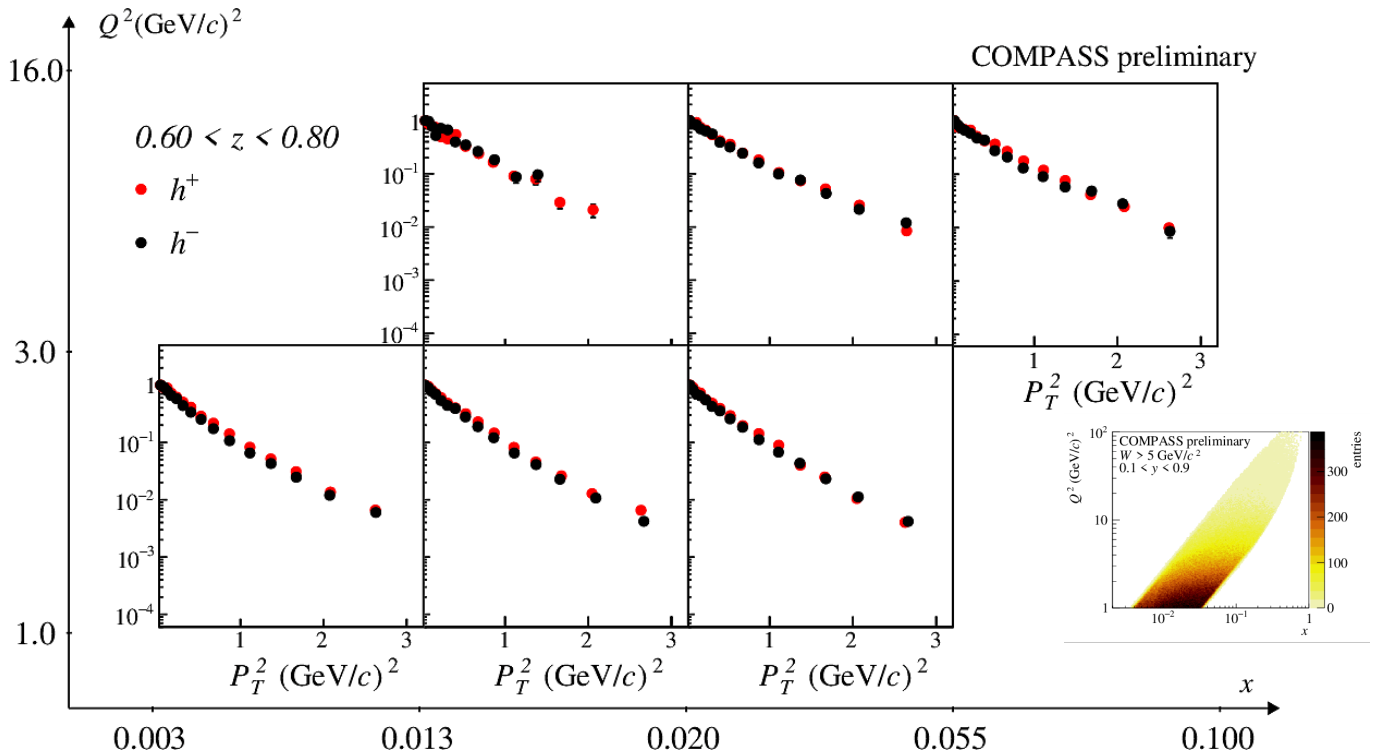


Figure 1: Differential cross sections in $p_T(ll)$: (a) $50 < m_{ll} < 76$ GeV (b) $76 < m_{ll} < 106$ GeV (c) $106 < m_{ll} < 170$ GeV (d) $170 < m_{ll} < 350$ GeV (e) $350 < m_{ll} < 1000$ GeV [10].

Proceedings of EPS-HEP2021
26-30 July 2021

Task 2
Analysis of semi-inclusive DIS data

The analysis of COMPASS proton-target data (2016 data taking) is getting ready for publication

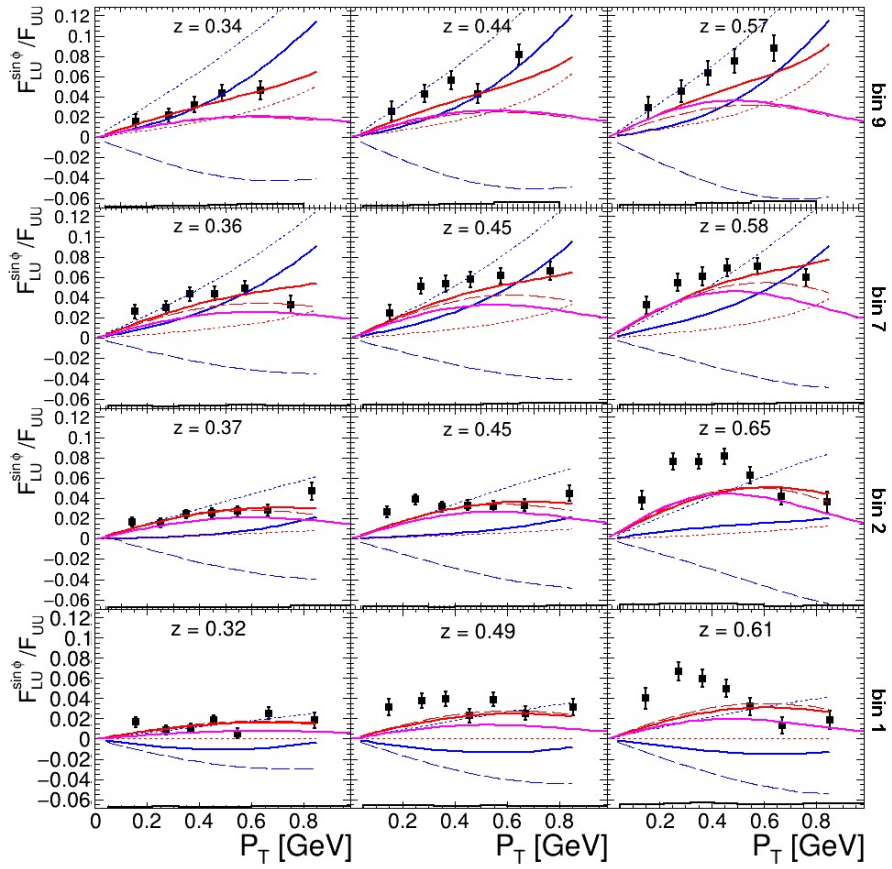


Task 2
Analysis of semi-inclusive DIS data

CLAS: first data with unpolarized beam on the arXiv:2101.03544

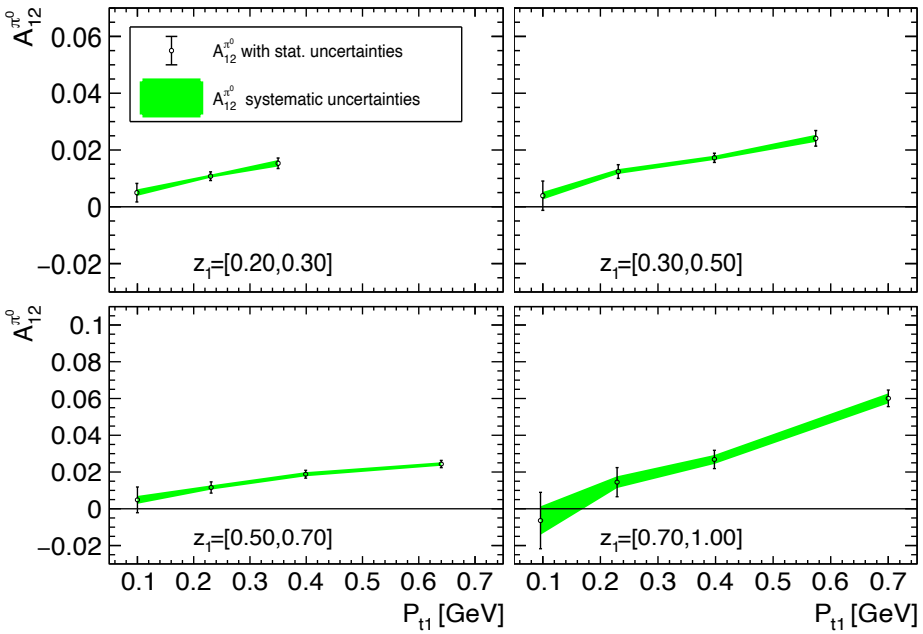
More publications with unpolarized target in preparation.

Measurements with longitudinally polarized target should start next summer.



Task 3
Analysis of e^+e^- annihilation

Azimuthal asymmetries at BELLE have been published **(arXiv:1909.01857)**.
Last year: Analysis of Belle e+e- progressing, albeit slowly. Development of a framework for tuning Pythia MC generator ongoing, aiming at reducing strong Pythia model dependence of systematics.



Task 4
Quark TMD extractions

No big steps this year (important results obtained before, and much time devoted to Electron-Ion Collider predictions)

Studies on the extraction of the Sivers TMD **(arXiv:2101.03955)**.

Model calculations of pion-nucleon Drell-Yan **(arXiv:2005.14322).**

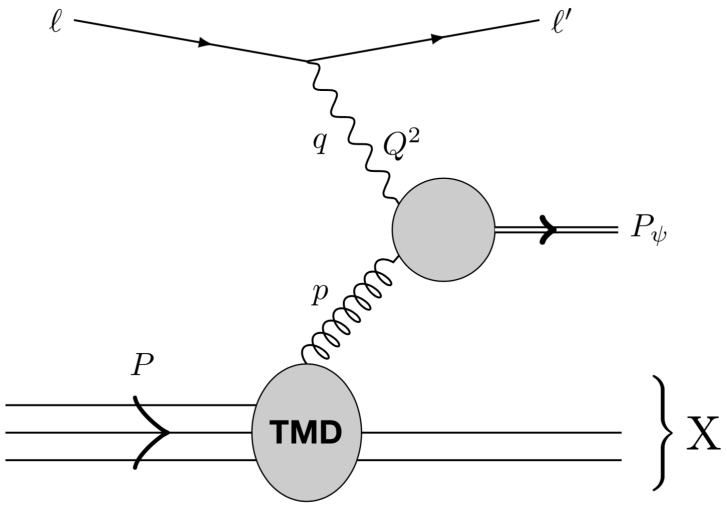
Theoretical studies of the PT-dependent cross sections in e^+e^- single hadron production, for TMD fragmentation functions **(arXiv:2007.13674, arXiv:2011.07366, arXiv:2109.11497, arXiv:2108.05632).**

Formal studies on TMD factorization for W-boson production **(arXiv:2011.05351)** and higher twist **(arXiv:2109.09771).**

Task 5
Gluon TMD studies

Theoretical studies of J/ψ production in SIDIS **(arXiv:2102.00003, arxiv:2110.07529)** and dijet and heavy-meson pairs **(arXiv:2008.07531).**

Sivers function in quarkonium production in hadronic collisions was studied **(arXiv:2011.10350)**



Dissemination: TMDlib

TMD plotter — Density as a function of k_t

HELMHOLTZ GEMEINSCHAFT

https://tmdlib.hepforge.org/

Home | TMD PDF | New PDFs | Publications | HEP Links

Parameters

X-axis: min = 0.1 max = 1000 GeV log lin

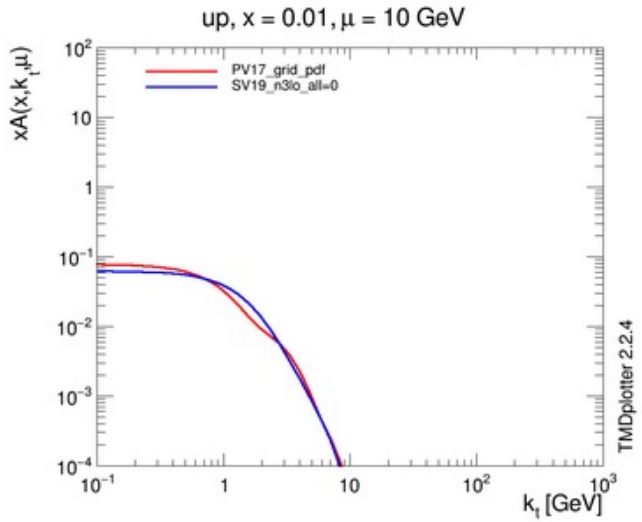
Y-axis: min = 0.0001 max = 100 log lin

ratio: min = 0.4 max = 1.6 log lin

Curves

1. up PV17_grid_pdf ×

1

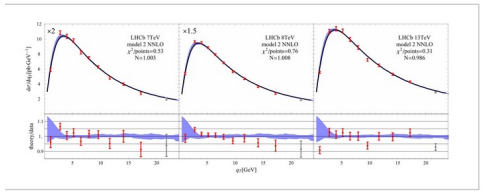


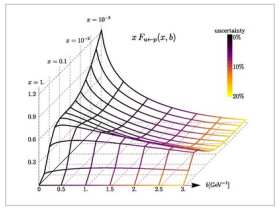
Dissemination: Nanga Parbat & arTeMiDe

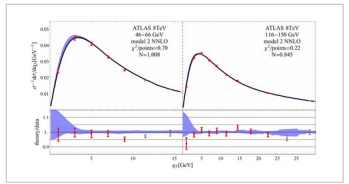
github.com/MapCollaboration/NangaParbat

Nanga Parbat: a TMD fitting framework

arTeMiDe



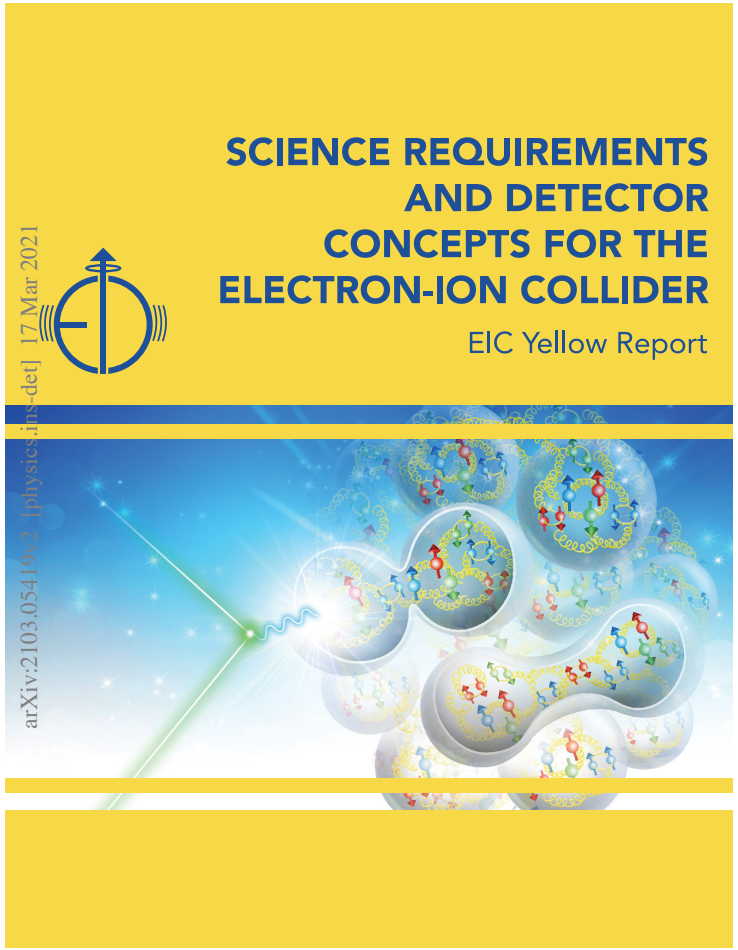




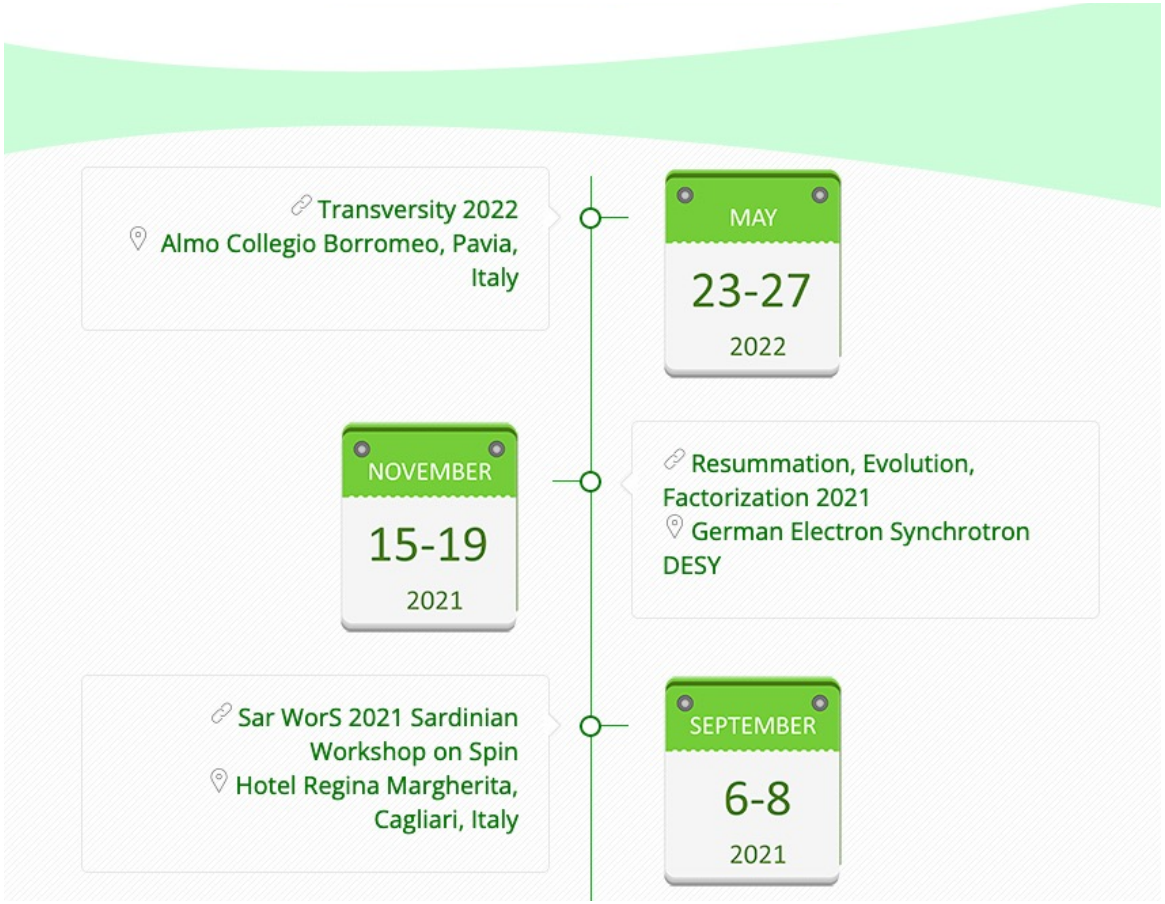
teorica.fis.ucm.es/artemide/

Contributions to future experiments

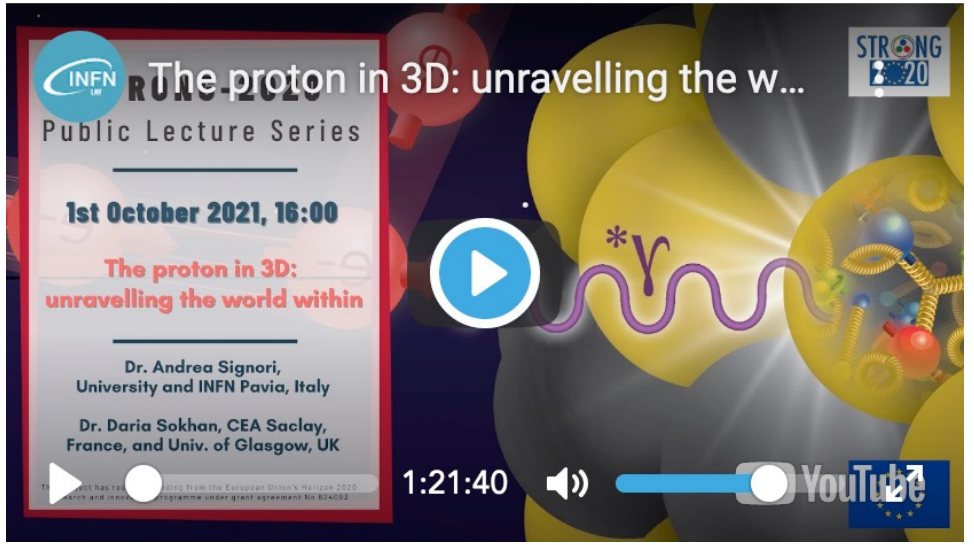
- Electron Ion Collider (**arXiv:2103.05419**)
- Positron beam at JLab **(arXiv:2007.15081)**
- Possible 24 GeV upgrade at Jlab



Workshops and outreach



Presence in Strong-2020 public lecture series and Strong-2020 YouTube channel



Deliverables

	Deliverable name	Date	
D22.1	TMD data from DY, SIDIS, e+e-	24, 36, 48	✅
D22.2	Parametrizations of TMD PDFs and FFs	48	✅
D22.3	Estimates of quarkonium production in electron-proton collisions	48	✅

- Some data from SIDIS and e+e- already published. Work in progress for DY.
- Parametrizations of TMD PDFs and FFs have been obtained and made available to public (also through VA2- 3D partons)
- Some estimates of quarkonium production in SIDIS already published.

Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS42	Implementation of polarized target at CLAS12	30 - INFN	15	Polarized target up and running

MS42 was supposed to be achieved by August 2020

Advancement: the longitudinal NH_3/ND_3 target is almost complete

Expected delivery date: run with longitudinally polarized target will start in June 2022

Comment on transverse target, the original hope was to use the tHD-ice transverse target. Unfortunately, tests from Nov 20 to Apr 21 showed an insufficient degree of polarization. A different target based on standard technologies will be used, but data taking will not start within Strong2020.

Expected results and impact

All experiments already provided some data useful for TMD studies.
More data in the pipeline.
CLAS will provide unpolarized and possibly longitudinally-polarized data.
BELLE has already produced some data, but we hope that unpolarized cross sections will also be published.

Two sets of unpolarized TMD PDFs and FFs are already available to public, not only through publications, but also throuh VA2 - 3D partons. Improved extractions (higher accuracy and more data) expected.

Results have already been used for studies related to Electron Ion Collider.

Impact expected also in comparison with LHC measurements and search for new physics.