TMDPortal

A virtual-access portal for the study and extraction of transverse-momentum-dependent distributions

A. Bacchetta[a,1], V. Bertone[b], M. Boglione[c], G. Bozzi[d], M. G. Echevarria[e], E. R. Nocera[c], Marco Radici[f], Gunar Schnell[e,g], I. Scimemi[h], A. Signori[c], A.Vladimirov[h], P. Zurita[h]

[a] Department of Physics, University of Pavia and INFN - Sezione di Pavia, Via Bassi 6, I-27100 Pavia, Italy
[b] IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France
[c] Department of Physics, University and INFN of Turin, Via Pietro Giuria 1, I-10125 Torino, Italy
[d] Department of Physics, University and INFN of Cagliari, Cittadella Universitaria, I-09042 Monserrato, Italy
[e] Department of Physics and EHU Quantum Center, University of the Basque Country UPV/EHU, 48080 Bilbao, Spain
[f] INFN - Sezione di Pavia, Via Bassi 6, I-27100 Pavia, Italy
[g] IKERBASQUE, Basque Foundation for Science, 48009 Bilbao, Spain
[h] Department of Theoretical Physics & IPARCOS, Complutense University of Madrid, 28040 Madrid, Spain

1 Scientific context and objectives

Over the past few decades, the study of hadron structure has been catalysed by the tremendous performance of past and present high-energy colliders, such HERA, Tevatron, and the LHC. These facilities have pushed the precision of collinear parton distribution functions (PDFs) to an unprecedented level. This impressive achievement stems from a coherent and relentless effort aimed at developing and benchmarking computational tools and from constant methodological improvements, often based on machine-learning techniques, which were made available to the community. This allows for an efficient and precise evaluation of predictions to the highest theoretical accuracies and for a wide range of processes and observables necessary to extract PDFs from data.

Transverse-momentum-dependent distributions (TMDs) appear to be following the same path of PDFs. As a matter of fact, these distributions enter the computation of a wide range of observables, which are currently being measured with great precision at BNL, CERN, KEK, and JLab, and that will be measured at the future Electron-Ion Collider (EIC). Moreover, fundamental parameters of the Standard Model, such as the mass of the W boson and the strong coupling, have proven to be sensitive to TMDs. Alongside, significant theoretical and methodological improvements related to the extraction of TMDs are being actively pursued. As of today, the perturbative accuracy of TMDs is comparable to that of PDFs and machine learning-techniques are being explored also for the extraction of TMDs. It is therefore necessary to support this growth with appropriate resources specifically devoted to the computational framework.

This intense experimental, theoretical, and methodological activity around TMDs brought these distributions to the forefront of the study of the hadronic structure and has the potential to pin them down to the same level of precision as PDFs. In this respect, it is of fundamental importance to foster the growth of this field by establishing a solid infrastructure of numerical tools aimed at the study of TMDs and their phenomenological implications. Following the example of PDFs and also leveraging the developments carried out during the implementation of the STRONG2020 programme, the purpose of this package is to provide users with a virtual-access (VA) portal through which TMD-related quantities can be evaluated relying on precise, efficient, and benchmarked software developed and maintained by expert and dedicated researchers. This will enable the community to exploit existing and forthcoming numerical tools to push the knowledge of TMDs in particular, and hadron structure in general, beyond its current boundaries.

1.1 Implementation

The primary goal of TMDPortal is to provide access, maintenance, and support to numerical tools related to TMDs through a centralised web portal. The implementation hinges on two main pivots:

---

[1] Coordinator.

1. harmonisation and deployment of existing codes into a common interface;
2. development and deployment of new software aimed at providing further functionality.

Preparatory work will be devoted to the **benchmark of different approaches** to TMD factorisation & transverse-momentum resummation, such as those implemented in `arTeMiDe`, `NangaParbat`, and `DYTURBO`, which will provide the foundation to a **unified treatment of TMDs**. This benchmark will put us in a position to deploy all three codes on a **common web interface**, through which users will be able to produce predictions for the relevant processes and observables running any of these codes on a remote server. To set up the interface, we will benefit from the experience gathered with the `3DPartons/NLOAccess` VAs of STRONG2020.

On a later stage, we will set up a common **platform for the extraction of TMDs** from data using `arTeMiDe`, `NangaParbat`, or `DYTURBO`. To that end, we will use `xFitter`, which already provides a wide suite of fitting facilities and a standardised interface to experimental data. In this context, we will make available a wide set of TMD parametrisations, including **neural network parametrisations**. Resulting TMDs will be encapsulated in a **standardised format** in such a way that they can be released through the `TMDlib/TMDPlotter` interface, which in turn will also be integrated in TMDPortal. Collinear distributions are fundamental to extract TMDs. While PDFs are now well-established, **collinear fragmentation functions** (FFs) remain an area of active development. To support this evolving field, it is essential to provide the community with dedicated tools for the extraction of FFs from experimental data. To this purpose, we will integrate the fitting tool `MontBlanc` – already widely adopted for the extraction of FFs – in TMDPortal. Importantly, `MontBlanc` delivers FFs in the `LHAPDF` format, widely used for PDFs, which greatly facilitates their **interoperability** with other frameworks.

The unification of standards within TMDPortal opens a route towards new developments and better understanding of TMDs. In this respect, we plan to address the poorly known **gluon TMD** through **quarkonium production**. This development will be integrated in `NangaParbat` and thus made directly available through the web interface of TMDPortal.

2. Connection to Transnational Access infrastructures and Virtual Access projects

TMDPortal is naturally connected with the TA infrastructure planned at CERN (D. d'Enterria *et al.*) because TMDPortal plans to exploit experimental data delivered by the LHC experiments and COMPASS/AMBER. Therefore, participants to this package will often need access to CERN. TMDPortal is also tightly connected with three VA project proposals:

- VI GPDPortal (V. Bertone *et al.*),
- VI NuSKAT (P. Chatagnon *et al.*),
- VI NLOAccess (J.P. Lansberg *et al.*),
- TNI/VI PRODY (T. Galatyuk, M. Winn *et al.*).

3. Estimated budget request

We request 8 postdoc-years to be shared between the institutions involved for hiring personnel devoted to development, maintenance, and support of the TMDPortal infrastructure, for an estimated cost of 520 k€. Moreover, we request 80 k€ for the purchase of servers and cluster nodes needed to run the portal. Finally, we request 40 k€ to devote to the organisation of schools and workshops, and the training of users. The total cost amounts to 640 k€.

4. Participating and partner institutions

The following institutions will contribute to this project in quality of developers and maintainers of TMDPortal: IRFU/CEA Paris-Saclay, Universidad Complutense de Madrid, Universidad del País Vasco, Università di Cagliari, Università di Pavia, Università di Torino.