Correlations in Partonic and Hadronic Interactions 2020 (CPHI-2020)

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First circular

The Science Motivation

The understanding of the structure of hadrons and nuclei, and in particular of spatial and transverse momentum dependent distributions of partons (3D PDFs), are key questions of the modern nuclear physics. The knowledge of 3D partonic structure of nucleons and nuclei is crucial for studies in ℓN, e^+e^-, and hadron-hadron colliders (even at the LHC energies). Relevant data are being or are planned to be collected at different laboratories all over the world: BNL, CERN, DESY, FNAL, JLab, and KEK.

Flavor decomposition of 3D PDFs requires reliable and model independent technique for the extraction of transverse momentum dependent distribution and fragmentation functions from the experimental observables. Various assumptions involved in preliminary extraction of 3D PDFs from available data, have yet to allow credible estimates of systematic uncertainties associated with those assumptions, preventing also useful projections for the statistics needed for extraction of relevant 3D PDFs. A similar situation exists for hadron-hadron e^+e^- collision experiments looking to extract 3D PDFs from their already collected, and anticipated data.

Factorization, operator definitions and gauge invariance of parton densities are important ingredients of the 3D PDF extraction framework. During the past several years enormous efforts have been devoted on understanding how various spin-azimuthal asymmetries observed in semi-inclusive and exclusive measurements can be described in terms of QCD factorization using 3D PDFs, in particular Transverse Momentum Dependent PDFs (TMDs) and Generalized Parton Distributions (GPDs).

Recently, significant disagreements have been reported in comparison of theoretical predictions, based on combination of TMD factorization and collinear factorization and experimental measurements for various transverse momentum distributions of hadrons in ℓN [1] and e^+e^- [2], and dileptons in Drell-Yan process [3]. Those observations emerge into a new crisis, the "q_T-crisis". Correlations in partonic and hadronic interactions, which may be responsible for observed disagreements, provide important information on underlying dynamics, manifesting themselves in variety of observables widely recognized as key objectives of, e.g. the forthcoming COMPASS (CERN) polarized deuteron run in 2021, JLab 12 GeV upgrade, various activities at RHIC and KEK, the LHC fixed target projects (LHCSpin, After@LHC) and a driving force behind construction of the future Electron Ion Collider (EIC).

Various assumptions used in different extraction frameworks require strict procedures for validation of the extracted 3D PDFs. Development of calculational tools, which would allow for easy comparison of results, in the extraction and validation stage, will be important to understand systematics due to different models and parametrizations. A crucial prerequisite for a global analysis is the development of a Monte Carlo event generators including transverse degrees of freedom in a systematic way that is applicable in a wide range of energies. Several

programs have been developed covering different aspects of TMD and GPD analysis and using different sets of models for TMDs and GPDs.

Observables involving hadrons produced in the target fragmentation region, which could be studied e.g. at EIC, can shed further light on the non-perturbative structure of the nucleon. Extending the studies of the nucleon structure beyond the traditional current fragmentation, when a hadron in the target fragmentation region is observed in association with another hadron in the current fragmentation region will provide a new window to study the nucleon complex structure.

In spite of being now available for a decade and in spite of numerous dedicated theoretical and phenomenological studies, the underlying mechanisms for observables at $1/Q$ level remain not understood and the issue of factorization is not clarified. Twist-3 azimuthal asymmetries were the first experimentally established single spin phenomena in Semi-Inclusive Deep Inelastic Scattering (SIDIS), and are among the largest and clearest asymmetries measured at HERMES (DESY), COMPASS (CERN) and CLAS (JLab). The detailed understanding of these data belongs to the most important and challenging goals.

It is relevant to investigate to what extent 3D proton structure may be important not only for factorization of hard processes but also for the understanding of soft particle production and, in particular, of the multi-parton interactions which are found to be needed at low to moderate transverse momenta for Monte Carlo simulations to describe experimental data on underlying events, particle multiplicities and spectra. Double parton interactions including parton's transverse momentum dependence are starting to be investigated, as is the role of parton's transverse momentum in the interpretation of energy flow measurements, charged particle multiplicities, and underlying events at the LHC Run II energies. The associated initial-state / final-state color correlations at small q_T could be studied to examine factorization-breaking contributions in the region of very small transverse momenta.

Another direction of current research activities involves the QCD studies in the nuclear medium. Many aspects of related research envisioned for 12 GeV JLab program has direct relevance for LHC physics, such as: the detailed extraction of nuclear PDFs including $x > 1$ region, understanding of the dynamics of the nuclear medium modification of QCD observables as well using tagged processes to study the space time evolution of quarks to observed hadrons.

Apart from experimental and theoretical efforts concentrated on imaging of the three-dimensional structure of the nucleon in momentum space, since many years the world-wide activities are focused on another riddle related to the structure of the nucleon, the famous proton-radius puzzle. Different independent precision measurements of the electric mean-square charge radius of the proton are required to solve the existing discrepancy between electron- and muon-based determinations of the proton size.

The week-long workshop on Correlations in partonic and hadronic interactions (CPHI-2020) will take place at CERN in Geneva, Switzerland, from February 3$^{\mathbf{rd}}$ to 7$^{\mathbf{th}}$, 2020. Further practical information can be obtained from the workshop Indico-page (under construction): https://indico.cern.ch/e/CPHI-2020

The workshop will focus on the steps needed for development of theory and phenomenology involved in the extraction of TMDs and GPDs from existing and future data from ℓN, e^+e^-, and hadron-hadron facilities at BNL, CERN, DESY, FNAL, JLab, and KEK, with controlled systematics over various assumptions involved in the process.

The following list represents several current key questions of nuclear structure to be addressed by proposed workshop.

1) Transverse Structure of the nucleon and QCD issues associated with the 3D structure

- **Factorization issues in hadron production.**
- **Study of the QCD evolution properties of 3D PDFs.**
- **Evolution of TMDs and fits to physical cross sections.**
- **3D PDFs from Lattice QCD.**
- **New insights on 3D PDFs from non-perturbative models.**
- **Radiative corrections to hard scattering in exclusive and semi-inclusive processes.**

2) Measurements and global analysis of 3D PDFs

- **Phenomenology of 3D parton distribution and fragmentation functions.**
- **Leptoproduction with fixed target facilities at CERN, JLab and EIC.**
- **Measurements from hadron-hadron colliders and e^+e^- facilities.**
- **Drell-Yan lepton pair production and Drell-Yan plus jets.**
- **MC generators for global analysis of 3D PDFs.**
- **Validation of extraction frameworks, extraction of 3D PDFs.**

3) Partonic Structure beyond Densities

- **Generalized Transverse Momentum Distributions and their relations with GPDs and TMDs.**
- **Target fragmentation and conditional probabilities**
- **Higher twist asymmetries in hard scattering processes.**
- **Soft particle production and multi-parton interactions.**
- **"Proton radius puzzle" from electron-proton and muon-proton scattering experiments**

4) QCD in the Nuclear Environment

- **Medium modifications of TMDs and GPDs**
- **PDF medium modifications and short-range nucleon correlations**
- **Flavor dependence of medium modification effects**
- **Nuclear partonic distributions including x>1 region**
- **Tagged SIDIS processes off nuclear targets**
- **Hadronization processes in Nuclear SIDIS**
- **Hard nuclear QCD processes and Color transparency**

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References

[1] J. O. Gonzalez-Hernandez, T. C. Rogers, N. Sato and B. Wang, *Challenges with Large Transverse Momentum in Semi-Inclusive Deeply Inelastic Scattering*, *Phys. Rev.* **D98** (2018) 114005, [1808.04396].

[2] E. Moffat, T. C. Rogers, N. Sato and A. Signori, *Collinear Factorization in Wide-Angle Hadron Pair Production in e^+e^- Annihilation*, 1909.02951.

[3] A. Bacchetta, G. Bozzi, M. Lambertsen, F. Piacenza, J. Steiglechner and W. Vogelsang, *Difficulties in the description of Drell-Yan processes at moderate invariant mass and high transverse momentum*, *Phys. Rev.* **D100** (2019) 014018, [1901.06916].