Higher-twist corrections to nucleon tomography

In atoms we find negatively charged electrons, which to the best of our knowledge are elementary and point-like. Electrons surround positively charged nuclei made out of protons and neutrons, which are collectively referred to as the nucleons. Nucleons were believed to be elementary (like electrons) until experiments conducted in 1960s at Stanford Linear Accelerator Center (SLAC) revealed the actual constituents, whose existence was suggested even before by Hofstadter and his collaborators. The theory side has called those constituents partons (the name suggested by Feynman), which later have been identified as quarks and gluons.

The question we try to answer is how partons form nucleons and explain their properties, like spin and mass. Quantum chromodynamics (QCD) defines many types of objects describing a given nucleon in terms of partonic degrees of freedom. For instance, the so-called parton distribution functions (PDFs) describe how longitudinal momentum of a fast moving proton is described by longitudinal momenta of quarks and gluons. In this project, we are interested in even more informative objects, referred to as generalized partons distributions (GPDs). Among many features offered by GPDs, they in particular correlate information about longitudinal momenta of partons with information about positions of those partons in a plane perpendicular to the nucleon's motion. This kind of picture, where a spatial nature of protons and neutrons is revealed, is known as *the nucleon tomography.*

In a given process GPDs are ideally defined under the limit of infinite momentum of a probe penetrating the internal structure of the nucleon. Two such processes, which are prominent for current and near-future experimental programs, are: *i*) deeply virtual Compton scattering (DVCS), where virtual-photon converts into a real one after interacting with parton emitted from the nucleon, and *ii*) time-like Compton scattering (TCS), where after such interaction real photon converts into a virtual one. These processes have been measured in experiments at Jefferson Lab, CERN and DESY, and are subject of interest for future experiments, in particular Electron-Ion Collider (EIC) that will be constructed in Brookhaven National Laboratory (BNL).

Currently available and future data can not be considered as a practical realizations of the aforementioned limit, where the probe (here, virtual photon) has an infinite momentum. This suggests the need for corrections somehow inversely proportional to this momentum, which in QCD are referred to as *higher-twist corrections.* At present the GPD phenomenology avoids higher-twist corrections with a rejection of kinematic domains where these corrections may be significant. In practice, it means that a fraction of experimental data is not analyzed and interpreted to access a valuable information about the nucleon structure. This kind of suppression of data, somehow arbitrary, could be avoided with higher-twist corrections taken into account. To address this problem, we present a work plan consisting of three main tasks:

Task 1: *Phenomenology of DVCS for current and future experiments.* We will analyze the existing DVCS data with the inclusion of higher-twist corrections. Those corrections, already known for DVCS, will be implemented in PARTONS open-source platform, which is a versatile C++ framework dedicated to GPD-related studies. On top of this, we will study the effect of higher-twist corrections for future experiments, like EIC.

Task 2: *Kinematical higher twist corrections for TCS.* We will derive the analytical expressions for the higher-twist corrections for TCS process. Then, we will carefully compare these corrections with those for DVCS, in particular to study the analytical structure of amplitudes for both processes. We aim in checking to which extent one can prove the universality (independence on the process) of GPDs by only comparing DVCS and TCS processes.

Task 3: *Phenomenology of TCS for current and future experiments.* Results obtained in Task 2 will form a basis for the phenomenological analysis of data expected from the current TCS experiments. As a first step we will implement results obtained in Task 2 in the PARTONS framework. Then, we will analyze the JLab data. We will check the consistency of multi-channel (DVCS and TCS) description by taking into account higher-twist corrections. In the same manner as in Task 1, we will provide the predictions for measurements of TCS observables by EIC experiments.