Theory and computation highlights in August, 2021
(Contribution to the Director's Monthly Report to JSABOD)
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A new global QCD analysis of the pion's quark and gluon (or parton) distribution functions (PDFs) was reported [arXiv:2108.05822] by the Jefferson Lab Angular Momentum (JAM) collaboration, using a Bayesian Monte Carlo framework and including for the first time effects of threshold resummation. Threshold resummation is a technique that accounts for logarithmic corrections in perturbative QCD calculations arising from kinematics thresholds, such as when a single parton carries a large fraction x of the pion's momentum. Exploring various treatments of resummation, the study, led by Theory Center postdoc Dr. Patrick Barry, found that the large-x behavior of the valence quark distribution ~ $(1-x)^b$ can differ significantly, with b ranging from ≈1 to > 2.5. Regardless of the specific implementation, however, the resummation-induced redistribution of the momentum balance between valence quarks and gluons boosts the total momentum carried by gluons to 40%, increasing the gluon contribution to the pion mass to ≈40 MeV.

A pioneering new factorized approach to semi-inclusive deep-inelastic scattering has been developed by Theory Center staff, which treats QED and QCD radiation on equal footing, and provides a systematically improvable approximation to the extraction of transverse momentum dependent parton distributions. The paper [arXiv:2108.13371] demonstrates how the QED contributions can be well approximated by collinear factorization, and illustrates the application of the factorized approach to QED radiation in inclusive scattering. For semi- inclusive processes, radiation effects prevent a well-defined "photon-nucleon" frame, forcing one to use a two-step process to account for the radiation. The utility of the new method is illustrated by explicit application to the spin-dependent Sivers and Collins asymmetries.

Deep-inelastic scattering (DIS) on the deuteron with spectator nucleon tagging represents a unique method for extracting the free neutron structure functions and exploring the nuclear modifications of bound protons and neutrons. The detection of the spectator (with typical momenta $\lesssim$ 100 MeV/c in the deuteron rest frame) controls the nuclear configuration during the DIS process and enables a differential analysis of nuclear effects. At the future electron-ion collider (EIC) such measurements will be performed using far-forward detectors. Theory Center staff and collaborators carried out a theory-experiment joint task to simulate deuteron DIS with proton or neutron tagging with the baseline EIC far-forward detector design. They generated DIS events with proton and neutron spectators by using the BeAGLE Monte Carlo generator. They quantified detector acceptance and resolution effects, and reconstructed the spectator nucleon momentum including these detector acceptance and resolution effects. They studied feasibility of free nucleon structure extraction using pole extrapolation in the spectator momentum, and performed the pole extrapolation under realistic conditions. In a recent paper [arXiv:2108.08314], they reported that proton and neutron spectator detection is possible over the full transverse momentum range $0<p_T<100$ MeV/c needed for pole extrapolation. Resolution effects on the distributions before corrections are ~10% for proton and ~30 for neutron spectators, and the overall accuracy of nucleon structure extraction is expected to be at the few-percent level. They concluded that free neutron structure extraction through proton tagging and pole extrapolation is feasible with the baseline EIC far-forward detector design. The corresponding extraction of free proton structure through neutron tagging provides a reference point for future studies of nuclear modifications.