Theory and computation highlights in March, 2023
*(Contribution to the Director's Monthly Report to JSABOD)*
April 7, 2023

The HadStruc collaboration, lead by members and associate members of the Theory Center, has been awarded 1.2M node hours on Frontera at the Texas Advanced Computing Center, in a proposal rated "highly competitive". This substantial allocation will be essential to the Theory Center's program of first-principles calculation of GPDs, and flavor-singlet hadron structure.

A new paper [arXiv:2303.04921] by Dr. T. Rogers and colleagues solves the problems needed to consistently merge traditional transverse momentum dependent (TMD) factorization and evolution with nonperturbative descriptions of hadron structure in phenomenological applications. The paper illustrates the steps for semi-inclusive deep-inelastic scattering to demonstrate the improvement over conventional approaches. The new methods will be especially important for applications of TMD factorization at JLab and the EIC at moderate energies, where there is greater sensitivity to nonperturbative structures.

The CTEQ-JLab (CJ) collaboration has released [arXiv:2303.11509] a new set of parton distribution functions (PDFs), referred to as "CJ22." This includes constraints from new data for W-boson production in proton-proton collisions from the STAR collaboration at Brookhaven National Lab and lepton pair production in proton-proton and proton-deuteron collisions from the SeaQuest collaboration at Fermilab. The new data provide strong constraints on the light antiquark PDFs in the proton, leading to an excess of anti-down quarks over anti-up quarks over all the measured range up to a parton momentum fraction $x \sim 0.45$. The CJ22 analysis also identified an interesting correlation between the down to up quark ratio and the anti-down to anti-up quark ratio, which leads to a softer down to up ratio as $x \to 1$ compared with the previous CJ15 analysis.

Phenomena caused by higher-order electromagnetic interactions in electron scattering (two-photon exchange processes) present unique challenges to theory and experiment and mark the precision frontier in hadronic physics. A recent theoretical study has computed the target normal single-spin asymmetry produced by two-photon exchange in inclusive electron-nucleon scattering in the resonance region, using an effective field theory method ($1/N_c$ expansion) that provides a systematic treatment with controled uncertainties [arXiv:2303.12681]. Measurements of this spin observable and related two-photon exchange effects are planned in next-generation experiments at JLab with a positron beam.