Theory and computation highlights in August, 2023

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The annual conference of the lattice gauge theory community, Lattice 2023, took place at FNAL the beginning of August. The work of the lattice hadron structure group was highlighted in several presentations: Joe Karpie, a post-doctoral researcher at the Theory Center, described progress at calculating Generalized Parton Distributions within the pseudo-PDF framework, Daniel Kovner, a William and Mary graduate student and former DOE-SCGSR recipient at JLab, presented his calculation of the pion distribution amplitude, and Chris Chamness, a William & Mary graduate student under the supervision of Kostas Orginos, presented work on so-called trivializing flow in certain two-dimensional models.

Exploring the 3-dimensional structure of hadrons with the conceptual framework of Generalized Parton Distributions (GPDs) is a central goal of the JLab 12 GeV and EIC physics programs. While such studies have so far focused on the structure of ground-state hadrons such as the nucleon, recent developments in theory and experiment make it possible to extend the concepts to excited hadron states and explore their 3-dimensional structure (so-called Transition GPDs). A recent workshop organized by JLab Theory staff member Weiss, hosted jointly by the European Center for Theoretical Studies of Nuclear Physics (ECT*) in Trento, Italy, and the Asia-Pacific Center for Theoretical Physics (APCTP), discussed the status and prospects of this emerging field and proposed a roadmap for further studies [Webpage: https://www.ectstar.eu/workshops/ect-apctp-joint-workshop-exploring-resonance-structure-with-transition-gpds/]. At this event new experimental results in Delta^{++} pi- production from CLAS12 were presented for the first time [JLab Press Release https://www.jlab.org/news/releases/ringing-protons-give-insight-early-universe] and shared with theorists for analysis and interpretation.

Emergence of hadrons from quarks and gluons is one of the key challenges for understanding QCD and hadron physics. Track functions are universal nonperturbative objects similar to fragmentation functions that describe the total momentum fraction carried by all charged hadrons originating from a quark or gluon. In contrast to inclusive fragmentation functions, these satisfy non-linear evolution equations and capture aspects of the multi-parton nature of the QCD hadronization process. In a new paper [arXiv:2308.00028], Dr. F. Ringer and collaborators derived relevant QCD factorization theorems for extracting track functions from jet measurements at the LHC and the future EIC, which will serve as input to a range of observables that are measured only on a subset of final state hadrons.

Understanding the dynamics of bound state forma5on is one of the fundamental ques5ons in confining quantum field theories, such as QCD, and one of the key ques5ons of the experimental program at Jefferson Lab and the EIC. A recent paper [arXiv:2308.03878], also by Dr. F. Ringer and collaborators, studied the real-5me dynamics of the string breaking mechanism and the formation of bound "meson" states in the Schwinger model, which has similarities with QCD. The analysis explored the modificatoon due to the presence of a thermal background and observed a delay of the process due to dissipative effects that is closely related to the von Neumann entropy of the bound state system.

A new paper [arXiv:2308.07461] by Drs. Wally Melnitchouk and Nobuo Sato and the JAM Collaboration analyzes world polarized inclusive and semi-inclusive deep-inelastic scabering data at low parton momentum fractions x, using small-x evolution equations for the helicity parton distribution functions (hPDFs). Improving on previous work by utilizing more realistic helicity evolution, and incorporating running coupling corrections, the analysis finds an anti-correlation between the signs of the gluon and quark hPDFs and the g1 structure function. While the existing low-x data are insufficient to constrain the initial conditions for the polarized dipole amplitudes in the evolution, future EIC data will allow more precise predictions for hPDFs and the g1 structure function for x values beyond those probed at the EIC.