Theoretical and Computational Physics highlights in October, 2023

NUCLEAR SCIENCE 2023 LONG-RANGE PLAN DOCUMENT

Drs. Dudek and Qiu completed their work on the 2023 NSAC Long Range Plan writing committee, with the publication of the document, "A New Era of Discovery – The 2023 Long Range Plan for Nuclear Science" [https://science.osti.gov/∼/media/np/nsac/pdf/202310/NSAC_LRP_2023.pdf]. Drs. Dudek and Orginos took a trip to Washington DC to promote its content to congressional staffers..

HIDDEN-CHARM SCALAR AND TENSOR RESONANCES FROM LQCD CALCULATIONS

Explaining the spectrum of the mysterious XYZ states observed experimentally in the charmonium region is a leading contemporary problem in QCD. In two new papers [arXiv:2309.14070; 2309.14071], Drs. Dudek and Edwards with their collaborators in Cambridge determined scalar (0^{++}) and tensor (2^{++}) resonances in charmonium from coupled-channel scattering using lattice QCD, and found that contrary to several other studies, only a single resonance in each J^{PC} is required. These results have implications for the XYZ states observed in high energy machines and the proposed study of these states at a possible future energy upgrade of CEBAF at JLab.

NEUTRON STRUCTURE FUNCTION FROM PROTON AND DEUTERON DIS DATA

The world-inclusive DIS data on proton and deuteron structure functions are leveraged in a new paper [arXiv:2309.16851] by Drs. Accardi, Melnitchouk and experimental colleagues to extract the free neutron structure function using the latest nuclear effect calculations in the deuteron. Special attention is devoted to the normalization of the proton and deuteron experimental datasets and to the treatment of correlated systematic errors, as well as the quantification of procedural and theoretical uncertainties. The extracted neutron dataset is used to evaluate the scale dependence of the Gottfried sum rule and an extraction of nonsinglet structure function moments for comparison with recent lattice QCD calculations.

CONTINUOUS VARIABLE QUANTUM COMPUTATION OF THE O(3) MODEL IN 1+1 DIMENSIONS

The O(3) nonlinear sigma model is a toy model of nuclear physics that shares several features with QCD, such as asymptotic freedom. A new paper by Dr. Ringer and colleagues [arXiv:2310.12512] describes the model in terms of the continuous variable approach to quantum computing based on photonic platforms, developing quantum simulation protocols for the time evolution and ground-state preparation. Continuous-variable quantum computing is well-suited for bosonic and gauge field degrees of freedom, and the results in this work represent an important steppingstone toward simulations of QCD and nuclear physics applications.

DIFFUSION MODEL APPROACH TO SIMULATING ELECTRON-PROTON SCATTERING

Generative artificial intelligence is a fast-growing area of research offering various avenues for exploration in high-energy nuclear physics. New work by Drs. Qiu, Ringer and Sato [arXiv:2310.16308] explores the use of diffusion models for simulating electron-proton collisions relevant to experiments such as those at Jefferson Lab and the future EIC. The results demonstrate that diffusion models can accurately reproduce relevant observables such as momentum distributions and correlations of particles, momentum sum rules, and the leading-electron kinematics, all of which are of particular interest in electron-proton collisions.