Theory and computation highlights in July, 2023

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AI-supported generative models for supporting data analysis in nuclear physics. In a new paper [arXiv:2307.04450], JLab theorists demonstrated for the first time that generative adversarial networks (GANs) can be used in high-energy experimental physics to unfold detector effects from multi-particle final states, while preserving correlations between kinematic variables in multidimensional phase space. They performed a full closure test on two-pion photoproduction pseudodata generated with a realistic model in the kinematics of the Jefferson Lab CLAS g11 experiment. The overlap of different reaction mechanisms leading to the same final state associated with the CLAS detector's nontrivial effects represented an ideal test case for AI-supported analysis. Uncertainty quantification performed via bootstrap provided an estimate of the systematic uncertainty associated with the procedure. The test demonstrated that GANs can reproduce highly correlated multi-differential cross sections even in the presence of detector-induced distortions in the training data sets, and provided a solid basis for applying the framework to real experimental data.

Gauge invariant spectral analysis of quark hadronization dynamics. In a new paper [arXiv:2307.10152], JLab theorists studied the Dirac decomposition of the gauge invariant quark propagator, whose imaginary part describes the hadronization of a quark as this interacts with the vacuum, and related each of its coefficients to a specific sum rule for the chiral-odd and chiral-even quark spectral functions. Working at first in light-like axial gauge, they obtained a new sum rule for the spectral function associated to the gauge fixing vector, and showed that its second moment is in fact equal to zero. Then, they demonstrated that the first moment of the chiral-odd quark spectral function is equal in any gauge to the so-called inclusive jet mass, which is related to the mass of the particles produced in the hadronization of a quark. In addition, they presented a gauge-dependent formula that connects the second moment of the chiral-even quark spectral function to invariant mass generation and final state rescattering in the hadronization of a quark.

Synchronization effects on rest frame energy and momentum densities in the proton. In a new paper [arXiv:2307.11165], JLab theorists and collaborators derived two-dimensional relativistic densities and currents of energy and momentum in a proton at rest. These densities were obtained at surfaces of fixed light front time, which physically corresponds to using an alternative synchronization convention, using tilted light front coordinates, which consist of light front time and ordinary spatial coordinates. In this coordinate system, all sixteen components of the energy-momentum tensor (when written in the mixed representation) receive clear physical interpretations, and the nine Galilean components reproduce results from standard light front coordinates. They foud several optical synchronization effects that are absent in instant form densities, indicating motion within the target. Spin-zero and spin-half targets both exhibit an internal longitudinal energy flux related to the D(t) form factor of energy-momentum tensor (EMT), and transversely-polarized spin-half targets exhibit an energy dipole moment, which evaluates to $-1/4$ for all targets if the Belinfante EMT is used, but which is target dependent and vanishes for pointlike fermions if the asymmetric EMT is instead used.