Theory and computation highlights in May, 2019
(June 5, 2019)

The Lattice QCD projects centered around JLab rely on access to leadership computing resources, and the access to these new hardware platforms is essential to achieve milestones for the group. Software development strategies and access to new resources are coalescing around three similar systems. The first is the new Perlmutter system to go online at NERSC in 2020. The JLab group, along with the USQCD collaboration, has just received a NERSC Exascale Science Applications Program award (NESAP) that will allow us early access to the new system. Under the Exascale Computing Project (ECP), JLab and members of the LQCD application project are part of the Early Science Project on Aurora at ANL, deploying in 2021. The ECP LQCD team will also have access to Frontier at ORNL in 2023. Early science awards have not been allocated on this system, yet. Traditionally, Lattice QCD has received allocations about 15% of all leadership systems over the last 30 years. The announced Exascale systems are $1.1B for their machine contracts. Thus, the LQCD application projects are in a favorable position to have access to sustained allocations of about $150M worth of hardware over the next several years.

Explaining how the proton spin emerges from the motion of quarks and gluons is essential for understanding nucleon structure on the basis of QC5. In a recent work [arXiv:1905.02742], Theory Center staff, C. Weiss, and C. Granados of GWU (formerly JLab Theory) have computed the spin and orbital angular momentum densities in the proton at peripheral distances (of the order of the inverse pion mass), using systematic methods of chiral effective field theory. The results indicate that the proton's periphery contains mostly orbital angular momentum arising from pion-like fluctuations, and suggest a compelling physical picture of the proton's spin structure at large distances. The methods can be extended to other form factors of the QCD energy-momentum tensor and moments of the Generalized Parton Distributions.

Understanding the role played by strange quarks in the proton has been an ongoing quest of experimental programs at Jefferson Lab and worldwide. The JAM (Jefferson Lab Angular Momentum) Collaboration has recently completed [arXiv:1905.03788] the first simultaneous extraction of parton distributions and fragmentation functions from a Monte Carlo analysis of global high-energy scattering data, in an effort to place more robust constraints on the sea quark content of the proton. Inclusion of the semi-inclusive deep-inelastic scattering data in particular reveals a strong suppression of the strange quark distribution at parton momentum fractions $x > 0.01$, in contrast with the ATLAS observation of enhanced strangeness in W and Z boson production at the LHC. The study reveals significant correlations between the strange quark density and the strange to kaon fragmentation function needed to simultaneously describe semi-inclusive kaon production data from COMPASS and inclusive kaon spectra in electron-positron annihilation from ALEPH and SLD, as well as between the strange and light antiquark densities in the proton.

The JPAC collaboration has concluded a new study (arXiv:1905.12007) which shows that two seemingly different three-particle scattering formalisms are equivalent. While both formalisms have applications to lattice QCD studies of three-hadron spectra, their approaches differ in that one is an all-orders effective theory construction while the other is derived via S-matrix unitarity. It is proven that the physical content of the resulting scattering equations are identical, with the superficial difference lying in how rescattering contributions are organized.