Theory and computation highlights in September, 2019
(Contribution to the Director's Monthly Report to JSABOD)
October 9, 2019

High performance computing is an important component of the Nuclear Physics research program, and we are increasingly looking to the Exascale era for substantial increases in computing resources. The Exascale Computing Project (ECP) is leading the way for software development as well as co-design for this new generation of hardware. JLab is a member of the LQCD computing sub-project within ECP. In Sept. 2019, the sub-project underwent an annual review at the Univ. of Chicago. Members at JLab attended the review. While we have not seen a final report, the review did appear to go well. These reviews are important for the ECP project as they prepare for their own CD-2 review in December.

Lattice simulations of scattering of three particles have recently started to emerge. There is a large number of resonances that decay to three particle and such studies are of great importance for hadron spectroscopy. Theorists at JPAC developed a formalism for analysis of three particle reactions in the infinite volume and most recently extended it for description of three particle scattering in the finite volume to calculate spectrum of three of three positive pions in a [arXiv:1909.05749[hep-lat]]. The results are in good agreement with recent lattice simulations.

Photo production of eta-pi pairs is the golden reaction in searches for exotic, hybrid mesons. The GlueX Collaboration is expected to soon measure moments of the eta-pi0 angular distribution. Since the exotic meson decays in the P-wave, its presence will affect the angular distribution. Anticipating these results, theorists at JPAC generalized the formalism of moment extraction developed in the past for studies of vector meson production to the case when two or more resonances are produced, with a linearly polarized beam and build a model for the full process gamma + proton -> eta + pi0 + proton. The paper has recently been published in Phys. Rev. D. [Phys. Rev. D100, 054017].

This past summer the Theory Center hosted several undergraduate students conducting research into theoretical nuclear physics topics with members of the group. Several of the students worked with the Jefferson Lab Angular Momentum (JAM) Collaboration, which extracts the quark and gluon momentum and spin distributions in hadrons from global QCD analysis. **Jake Bringewatt**, from the University of Maryland, worked on the first ever combined analysis of high-energy scattering data and recent results from lattice QCD simulations of parton quasi-distributions, with the aim of better determining the anti-down/anti-up quark asymmetry in the proton. **Nina Cao**, from Harvard University, extended a previous analysis of pion PDFs to include transverse momentum dependent Drell-Yan cross section data, which have greater sensitivity to the pion's gluon PDF at large x. **Marston Copeland**, from Clemson University, calculated self-energies of flavor SU(3) octet and decuplet baryons within a relativistic chiral effective theory, comparing finite-range regularization with other regularization schemes. **Ben Slimmer**, also from Clemson University, has been working on implementing a formalism for studying photo/electro-production amplitudes from lattice QCD for kinematics where multiple channels may be kinematically open. **Alex Sturzu**, from New College of Florida, explored the possibility of determining purely hadronic scattering amplitudes using real-time lattice calculations, with preliminary results suggesingt that such calculations may be overwhelmed by

systematics associated with the truncation of the spacetime. And **Luisa Velasco**, from the University of Dallas, worked on an LDRD project to develop machine learning tools for constructing a universal Monte Carlo event generator that will allow fast and accurate predictions for femtometer scale reactions. All of the students are continuing their research this Fall at their home institutions, with publications summarizing the results expected in the next few months.