Theory and computation highlights in December, 2021

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The last two decades have witnessed the discovery of a myriad of new and unexpected hadrons and we expect the future to hold more surprises, in large part thanks to JLab and EIC experiments. Understanding the signals and determining the properties of the new states requires a dedicated theoretical effort. JPAC submitted an invited paper [arXiv:2112.13436] to be published in the journal of Progress in Particle and Nuclear Physics which reviews the contributions made by the group to the field of hadron spectroscopy.

Extracting parton distribution functions (PDFs) from what can be calculated in lattice QCD requires a well-controlled matching between PDFs and the lattice data. Detailed results have been presented in a new Theory Center paper [arXiv:2111.06797] by I. Balitsky, A. Radyushkin and student W. Morris that form the basis for extracting the unpolarized gluon PDFs from lattice QCD calculations using the pseudo-PDF method, developed at Jefferson Lab. The results may be used in future extractions of gluon PDFs from different matrix elements calculated on the lattice. The formalism has also been extended to polarized gluon pseudo-PDFs [arXiv:2112.02011], including the calculation of the correlator of gluonic fields at one-loop level, which gives matching relations necessary for the extraction of the polarized gluon PDF from lattice data.

W. Melnitchouk and collaborators at NCSU and Duke U. presents a comprehensive analysis of baryon masses and σ-terms using high-precision lattice QCD data and chiral SU(3) effective theory with finite range regularization [arXiv:2112.03198]. The study finds for the pion-nucleon σ-term, $\sigma_{\pi N}$ = 44(3)(3) MeV, that is consistent with direct lattice simulations, but smaller than some recent estimates from pionic atom scattering, while the strange σ-term, σ_{Ns} = 50(6)(1) MeV, is found to have a much smaller uncertainty than in previous analyses. The trace anomaly and quark/gluon energy contributions to the baryon masses are found to decrease for strange baryons due to their larger strange σ-terms.

The JLab Theory QIS LDRD project is working with the AMO group at UVA to adapt their quantum computing systems for calculations relevant for nuclear physics. As a first step, the project has been investigating using the system for simulations of a simple boson quantum field. For such calculations, the application of gates to the evolving states that are non- gaussian in the fields. The first practical implementation of a cubic gate is under development based on photon-number resolving measurements. For this implementation to realize a cubic interaction, a large number of photons must be resolved. The project has demonstrated the reliable determination of up to 24 photons. The most recent progress in December has shown the reliable extraction of up to 50 photons, and it appears possible to resolve 100 photons which appears to be sufficient for a cubic interaction application.

One side benefit of this development is that the photon-number resolving measurements can act as a very clean random number key generator, sufficient for data encryption. The group is exploring turning this result into a journal publication.