

Theory and computation highlights in July, 2021  
(Contribution to the Director's Monthly Report to JSABOD)  
August 6, 2021

Understanding the physics of the double-Regge region is very crucial for providing theory support to the on-going experimental search of exotic hadrons from GlueX data at JLab. A new JPAC paper with JLab theorists on  $\pi^- p \rightarrow \eta(\prime) \pi^- p$  production in the double-Regge region was published in The European Physics Journal, C81, 647 (2021). In the paper, they showed that the double Regge model fits very well the COMPASS data. This is very important for analysis of exotic meson production which are expected to decay to eta-pi pairs.

As part of its outreach and education effort, the Theory Center hosted six undergraduate students this summer from across the country, sponsored by the SULI (Science Undergraduate Laboratory Internships) and REU (Research Experience for Undergraduates, through Old Dominion University) internship programs. The students (Cordie Aldridge/Washington and Lee U., Ajah Harris/James Madison U., Henry Mills/U. Mary Washington, Taylor Powell/ODU, Richard Whitehill/Wichita State U.) worked on various nuclear theory projects with Drs. Raul Briceno, Wally Melnitchouk, and Nobuo Sato involving lattice QCD calculations and developing new analysis techniques for extracting quantum correlations functions from experimental data. Typically the research with the theory summer students is of high quality and is expected to be published in refereed journals.

A recent article [Phys.Rev.Lett. 126 (2021) 012001 as an Editor's Suggestion] describing the first calculation of the energy dependence of a three-particle scattering amplitude is appearing as a JLab highlight to DOE. The lead author of the publication, Dr. Maxwell Hansen, also a member of the HadSpec collaboration, was awarded the Kenneth Wilson Lattice Award at the Lattice 2021 conference. This is a prestigious award in the community, named after the Nobel Prize winner who founded the field. Max gave a presentation at the meeting that highlighted his work with JLab theory members.

The HadStruc collaboration completed and posted on arXiv two new papers. In the first [C.Egerer et al., arXiv:2107.05199], a new study of the isovector parton distribution function (PDF) of the nucleon was performed within the short-distance/pseudo-PDF framework. By using the "distillation" method developed by the HadSpec collaboration for excited-state spectroscopy, they were able to sample the gauge configurations more fully, and thereby compute the lattice matrix elements to high precision. They then exploited that precision to separate the leading twist PDF from the higher-twist and lattice-discretization contributions, and study the DGLAP evolution of the PDF. In the second [T.Khan et al, arXiv:2107.08960], the computationally highly demanding gluon contribution to the nucleon PDF was computed within the short- distance/pseudo-PDF framework. The team exploited both distillation and the variational method to provide the needed precision, and the so-called gradient-flow method to control the short-distance fluctuations. The resulting gluon PDF was compared to the phenomenological determinations, included those of the JAM Collaboration of the Theory Center

On July 22, 2021, one of our graduate students, Yiyu Zhou (William & Mary) successfully defended his Ph.D. thesis titled "Proton Spin Structure from Simultaneous Monte Carlo Global QCD Analysis," in which he presented a comprehensive analysis of the gluon helicity parton distribution function (PDF) extracted from world data on polarized deep-inelastic scattering and jet production in polarized proton-proton collisions. Using the JAM Monte Carlo global QCD analysis framework, the

thesis focused in particular on the dependence of the extracted gluon polarization on various theoretical inputs, such as the assumption of SU(3) flavor symmetry and positivity of PDFs. After completing his Ph.D., which was done under the supervision of Dr. Wally Melnitchouk and Dr. Nobuo Sato, Yiyu will next move to a postdoc position jointly with UCLA and South China Normal University.

July was a busy month for meetings and conferences. The annual lattice symposium, hosted by MIT, took place virtually during the last week of July. The progress made within the lattice hadron structure effort of the Theory Center was described in several presentations by members of the Theory Center, with the emphasis on the work of early career researchers. Furthermore, the work was highlighted in the invited review talk on lattice hadronic structure. The biannual international conference on hadron spectroscopy and structure (hadron2021) was virtually hosted by Universidad Nacional Autonoma de Mexico also during the last week of July with over 500 registered participants. In addition to presentations, members of Theory Center served on the IOC, LOC and as conveners for conference.

The SciDAC-4 meeting was also held in July 2021. Lattice QCD was one of four projects selected to give a highlight on past successes, focusing on the impact on the hadron spectroscopy theory and experimental programs at JLab and DOE/NP at large.