Theory and computation highlights in April, 2021
(Contribution to the Director's Monthly Report to JSABOD)
May 7, 2021

Members of the Theory Group attended and presented at the APS meeting and the GHP Topical meeting. David Richards gave a plenary talk at the GHP Meeting where he received his APS Fellowship award sponsored by the GHP. In particular, Dr. D. Richards gave a plenary talk at the GHP Meeting where he received his APS Fellowship award sponsored by the GHP.

Members of the Theory Group and the CST division attended the Exascale Computing Project Annual User's Meeting. Members of CST presented posters on development of the software infrastructure for the Exascale computing systems. Dr. R. Edwards of Theory also attended the USQCD All-Hand's Meeting and made presentations about the new JLab "21g" computing system as well as the NP/LQCD computing facility initiative.

The production of eta-pion and eta'-pion pairs constitute two of the golden channels to search for hybrid, exotic mesons. Understanding the dynamics of the production of such pairs above the resonance region is required to impose additional constraints to the resonance extraction, and is essential for the GlueX experimental program. Theorists at JPAC consider the reactions pion+proton to eta+pion+proton and eta'+pion+proton measured by COMPASS, and show that the data beyond the resonance region can be described by amplitudes based on double-Regge exchanges [arXiv:2104.10646]. The angular distribution of the meson pairs, in particular in the eta'-pion channel, can be attributed to flavor singlet exchanges, suggesting the presence of a large gluon content that couples strongly to the produced mesons.

The possible existence of a new kind of low mass particle (at the MeV scale) is a problem of current and intense theoretical and experimental interest, especially, in the content of a broad effort to identify possible candidate for dark matter (DM). Recently, an excess has been observed in the angular distribution of electron-positron pairs at backward angles in the processes 7Li(p,e+ e-)8Be and 3H(p,e+ e-)4He, which has led to speculations that this anomaly may be originating from the decay of an unknown particle. Dr. R. Schiavilla of Theory and collaborators provided a state-of-the-art treatment, within chiral effective field theory, of e+-e- pair production in the four-nucleon system and a comprehensive analysis of the impact that the existence of such a particle would have on the cross section for the processes 3H(p,e+ e-)4He and 3He(n,e+ e-)4He [arXiv:2104.07808].

The chromodynamic gluon fields in the nucleon not only generate the mass and spin, but also mediate the nucleon's response to the violation of fundamental symmetries of the Standard Model. Recent theoretical work by Dr. C. Weiss [arxiv.2103.13471] has calculated the "dimension-6" gluon density in the nucleon, which governs the electric dipole moment of the neutron induced by a possible violation of CP-symmetry. The calculation employs an approximate description of the gluon fields in terms of instantons, which is similar to the lattice QCD formulation but permits analytic calculations with much less computational effort.

New theory work by Dr. N. Sato and collaborators presents a parton shower algorithm that allows for the calculation of leading-jet cross sections where logarithms of the jet radius and threshold logarithms are re-summed to next-to-leading logarithmic accuracy [arxiv.2103.16573]. Unlike for inclusive jets, the leading jets lead to normalized probability densities, which allow one to establish a well-defined notion of jet energy loss at the cross section level. The results are expected to be

relevant for quantifying the energy loss of quark and gluon jets that propagate through hot or cold nuclear matter.

Drs. W. Melnitchouk, N. Sato of Theory and colleagues reported results of a new Monte Carlo global QCD analysis of unpolarized PDFs <https://arxiv.org/abs/2104.06946>, including for the first time constraints from ratios of 3He to 3H structure functions recently obtained by the MARATHON experiment. The simultaneous analysis of nucleon PDFs and nuclear effects in A=2 and A=3 nuclei revealed the first indication for an isovector nuclear EMC effect in light nuclei. While the MARATHON data yielded relatively weak constraints on the neutron to proton structure function ratio and the d/u PDF ratio, they suggested a strongly enhanced
nuclear effect on the d quark PDF in the bound proton.