Theory and computation highlights in February, 2023
(Contribution to the Director's Monthly Report to JSABOD)
March 11, 2023

The JAM Collaboration reports [arxiv:2302.01192] the first simultaneous extraction of parton collinear and transverse degrees of freedom from Drell-Yan data in order to compare the transverse momentum dependent (TMD) parton distributions of the pion and proton. The analysis demonstrates that the transverse separation of the quark field encoded in TMDs of the pion is more than 5σ smaller than that of the proton. Additionally, the study finds that the transverse separation of the quark field decreases as its longitudinal momentum fraction decreases, and observes clear evidence for a transverse nuclear EMC effect.

The gravitational form factors furnish information on the mechanics of the nucleon. It is essential to compute the generalized isovector-vector form factors to examine the flavor structure of the gravitational form factors. The up quark dominates over the down quark for the mass and spin of the nucleon, whereas the down quark takes over the up quark for the D-term form factor. The flavor-decomposed form factors reveal the internal structure of the nucleon. Dr. Kim of JLab Theory and collaborators investigated for the first time the isovector cosmological constant term of the nucleon and its physical implications [arXiv:2302.02974]. The flavor-decomposed cosmological constant terms of the nucleon unveil how the up-quark contribution is exactly canceled by the down-quark contribution inside a nucleon within the framework of the pion mean-field approach. While the nucleon cosmological constant term does not contribute to the nucleon mass, its flavor structure sheds light on how the strong force fields due to the cosmological constant term characterize the stability of the nucleon.

A new global QCD analysis has been performed [arXiv:2302.11126] by the JAM Collaboration and researchers from the University of Adelaide, including a coupling to a dark photon that augments the standard model electroweak coupling via kinetic mixing with the hypercharge B boson. Including the most recent measurement of the anomalous magnetic moment of the muon as a constraint, the analysis finds a significant reduction in the combined $\chi 2$, favoring the inclusion of a dark photon, with improvements in the theoretical predictions spread across a wide range of kinematics. The best fit yields a value of g-2 which significantly reduces the disagreement with the latest experimental determination, with best fit values of 4.2 - 6.2 GeV for the dark photon mass and a mixing parameter of order 0.1.