Spin-based Projective Imaging of Nuclei at the Electron-Ion Collider

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February 6, 2023

Abstract

A primary scientific goal of the Electron-Ion Collider (EIC) is to study the gluon structure in nuclei. It is predicted that high gluon densities lead to novel QCD phenomena, such as non-linear evolution and saturation. A mission-critical measurement is exclusive diffractive vector meson production in the scattering of electrons off heavy nuclei. The distribution of the momentum transfer ($|t|$) in coherent events reflects the spatial distribution of gluons inside the nucleus, while incoherent events (nucleus breaks up) are sensitive to fluctuations. Coherent and incoherent events, both interesting in their own rights, must be separated experimentally. Measurements of the $|t|$ distribution encounter two critical challenges: (i) the limited precision in $|t|$ due to beam effects that impact our knowledge of the momentum of the incoming electron as well as the finite experimental resolution of the outgoing electron momentum and (ii) the overwhelming incoherent background, which severely jeopardize the prospects of utilizing this process.

In this work, we propose to utilize the electron beam polarization in e+A collisions at the EIC and measure the $|t|$ distribution by applying a strategy which had been successfully employed in the quantum interference enabled nuclear tomography at RHIC. Specifically, we plan to investigate the projection of the vector meson momentum along the normal direction ($\hat{n}$) of the electron scattering plane, which eliminates the resolution contributions from the incoming and outgoing electron momenta. Furthermore, we propose to utilize the decay pattern of the vector meson with respect to $\hat{n}$, to precisely determine the fraction of coherently produced vector mesons. The spin of coherently produced vector meson aligns with the polarized photon direction inherited from the electron polarization direction. In cases where the incoming electron spin flips after scattering off the nucleus target, it also aligns with $\hat{n}$ resulting a non-trivial pattern, while such an alignment is absent for incoherently produced vector mesons. With this proposal, we will study the feasibility of the proposed strategy with model simulations of coherent and incoherent exclusive vector meson production in e+A collisions, and quantify the impact of the anticipated EIC detector performance on determining the electron scattering plane and measuring vector meson momentum. It is also critical to study the sensitivity of the projected $|t|$ distribution to gluon saturation and potential loss of information due to the projection. In the end, we aim to derive a standard analysis tool of spin-based projective imaging for future applications at the EIC.