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imaging nuclear modifications on parton distributions in proton-nucleus collisions

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Nuclear modifications to collinear parton distribution functions are conventionally quantified by the ratios $r_i^{\rm A}(x,Q^2) = f_i^{\rm A,proton}(x,Q^2)/f_i^{\rm proton}(x,Q^2)$. For a given nucleus A, these ratios generally depend on the parton momentum fraction x, the probing scale Q^2, and the parton species i. Determining these dependencies relies on a global analysis of diverse experimental data. However, in realistic observables, these dependencies are intricately intertwined, making their extraction challenging. In this paper, we propose a novel approach to effectively image the nuclear modification factors $r_i^{\rm A}(x,Q^2)$ at the observable level in proton-nucleus collisions at the Large Hadron Collider. Specifically, through a combined study of Z-boson production, Z+jet production, and $Z+c$-jet production, we separately enhance signals arising from light-quark, gluon, and heavy-flavor (charm) distributions in nuclei. This enables us to effectively image the $r_i^{\rm A}(x,Q^2)$ for specific parton species. The feasibility of this method is validated through perturbative calculations at next-to-leading order in the strong coupling constant, employing three sets of nuclear PDF parametrizations: EPPS21, nCTEQ15, and TUJU19. Future measurements of these observables are expected to provide better-motivated parametrization form of nuclear PDFs and yield new insights into the detailed partonic structures of nuclei.

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