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Prospects of exploring nucleon and nucleus structures in hadronic collisions with the STAR experiment in 2022 and beyond

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The exploration of the fundamental structures of nucleon and nucleus has always thrived on the complementarity of lepton scattering and purely hadronic probes. With the Electron Ion Collider (EIC) on the horizon, it becomes more urgent than ever to complete key measurements in this regard with high precision in hadronic $p+p$ and $p+Au$ collisions during the final years of RHIC running. When combined with future data from the EIC, these measurements will be essential to establish the validity and limits of factorization and universality.

To carry out these measurements, the STAR collaboration is planning to collect data from transversely polarized $p+p$ collisions at $\sqrt{s} = 510$ GeV in 2022 and transversely polarized $p+p$ and $p+Au$ collisions at $\sqrt{s_{NN}} = 200$ GeV in 2024. A full suite of forward detectors will be installed at STAR prior to the $p+p$ run in 2022, providing excellent charged-particle tracking at high pseudorapidity ($2.5 < \eta < 4$) for the first time, coupled with both electromagnetic and hadronic calorimetry. In addition, detector upgrades realized for the Beam Energy Scan II program further extend and improve STAR's tracking and particle identification capabilities beyond those existed for previous $p+p$ and $p+Au$ runs. The planned two years of running and detector upgrades will allow STAR to measure fundamental proton properties, such as the Sivers and transversity distributions, over nearly the entire range of $0.005 < x < 0.5$. By exploiting these new capabilities, STAR will determine fundamental proton properties such as the Sivers and transversity distributions over nearly the entire range of $0.005 < x < 0.5$. We will also probe fundamental properties of heavy nuclei including non-linear low- x gluon dynamics, nuclear PDFs, nuclear fragmentation functions, and spin-dependent hadronization.

In this talk, we will outline prospects for key measurements envisioned to be carried out in 2022 and 2024, as well as briefly reporting on the progress of the STAR forward upgrade preparations.

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