The Present and Future of Small-System Collectivity Search from STAR

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Abstract

The emergence and evolution of collective behavior in small collision systems remains a key area of interest in high-energy nuclear physics. To understand how collectivity evolves with system size RHIC has conducted a dedicated small system scans, including He^3+Au, d+Au, and p+Au collisions.

In 2021, the STAR collaboration expanded the scan by introducing a symmetric yet small system through O+O collisions at RHIC, offering a unqiue opportunity to study the interplay between initial-state geometry and fluctuations. In the same year, STAR revisited d+Au collisions at RHIC, utilizing the detector's extended pseudorapidity coverage ($|\eta| < 1.5$ and $2.1 < |\eta| < 5.1$) to systematically study azimuthal correlations, focusing on their dependence on relative pseudorapidity $\Delta\eta$.

The smallest system displaying collectivity observed at RHIC to date is p+Au. To examine even smaller systems, STAR has initiated a search for collectivity in photon-induced (γ+Au) processes by triggering on ultra-peripheral Au+Au collisions at $\sqrt{s_{NN}} = 200\,\text{GeV}$, corresponding to a maximum photon-nucleon center-of-mass energy of $W_{\gamma N}^{\max} \approx 34.7\,\text{GeV}$. Additionally, in 2024, STAR conducted its first dedicated effort to probe collectivity in high-multiplicity $p+p$ collisions, collecting high-statistics data at low luminosity at RHIC.

This talk will present STAR's latest measurements of azimuthal correlations in O+O and d+Au collisions, the status of the collectivity search in γ+Au processes.We will also discuss the challenges, prospects, and future directions for collectivity studies using high-statistics data from the 2023–2025 RHIC runs in various small systems such as γ+Au, $p+p$, and the anticipated p+Au collisions.