The science case for a small system scan at RHIC

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Abstract

The observation of multi-particle azimuthal correlations in high-energy small-system collisions has led to intense debate on its physical origin between two competing theoretical scenarios: one based on initial-state intrinsic momentum anisotropy (ISM), the other based on final-state collective response to the collision geometry (FSM). To complement the previous scan of asymmetric collision systems (p+Au, d+Au and He+Au), we propose a scan of small symmetric collision systems at RHIC, such as C+C, O+O, Al+Al and Ar+Ar at 0.2 TeV, to further disentangle contributions from these two scenarios.

Motivation

System scan of intermediate AA collision systems provides unique insights on
• Whether flow harmonics reflect initial geometry from small to large systems
• At what system size the initial-state effects become sub-dominant
• Turn-on of jet-quenching and Heavy Flavor “thermalization” with system size

Symmetric vs Asymmetric systems

For systems with approximately same \(N_{\text{part}}\), the symmetric system has a flatter shoulder than that for the asymmetric system, which thus is expected to be less sensitive to experimental centrality resolution effects.

\[ v_2 \text{ & } v_3 \text{ for different systems} \]

- Symmetric systems: \( v_2 \) increases and then decrease with increasing \( N_{\text{part}} \), the peak positions also increase slightly for larger systems.
- Asymmetric systems: \( v_2 \) increase with increasing \( N_{\text{part}} \).
- \( v_3 \) for all systems follow common increasing trend as function of \( N_{\text{part}} \).

\[ \text{RHIC & LHC synergy} \]

An O+O run at RHIC right after BES-II would provide a timely comparison of small system at very different collision energies to study systems with nearly identical nucleon geometry but different sub-nucleon fluctuations and particle production mechanism with different saturation scale and min-jet production in the initial state.

\[ \text{STAR Beam User Request Proposal} \]

Precise measurements of key observables can be made with proposed statistics
• \( \Phi \) meson \( v_2 \) in central collisions
• \( v_3 \) from multi-particle correlations

Summary

A scan of small A+A systems at RHIC top energy 200 GeV has been proposed to understand the timescale for the emergence of collectivity and early thermalization mechanisms in nucleus-nucleus collisions. Comparing to asymmetric systems with similar \( N_{\text{part}} \), the symmetric systems have different initial geometry fluctuations and less bias on the centrality selection. A scan of both symmetric and asymmetric systems provide an opportunity to disentangle contributions to collectivity from initial momentum anisotropy, pre-equilibrium and late-time dynamics.