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Collision Energy and System Size Dependent Radial Flow Fluctuations at RHIC

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Understanding the expansion dynamics and transport properties of the quark–gluon plasma (QGP) is one of the central goals of heavy-ion collision experiments. The newly proposed observable $v_0(p_T)$ [1], which is directly sensitive to p_T-differential fluctuations of radial flow, has been measured by the LHC experiments [2,3] and has been suggested as a sensitive probe of the medium's bulk viscosity [4]. Extending these measurements to RHIC energies provides a unique opportunity to study the evolution of radial expansion dynamics and transport properties over a broad range of collision energies and system sizes.

In this work, we present measurements of $v_0(p_T)$ for charged hadrons and identified pions, kaons, and protons in Au+Au collisions at $\sqrt{s_{NN}} = 7.7$, 9.2, 11.5, 14.6, 19.6, 27, 54.4, and 200˜GeV, as well as in O+O collisions at $\sqrt{s_{NN}} = 200$˜GeV at STAR-RHIC. The characteristic mass ordering of $v_0(p_T)$ among identified hadrons at low p_T is studied for different collision energies and system sizes, and the analysis is extended to high p_T to investigate possible effects from jet quenching.

We also discuss the energy dependence of the p_T slope of $v_0(p_T)$ and the p_T value at which $v_0(p_T)$ changes sign, as they reflect the strength and fluctuations of the radial flow [5]. Particle and antiparticle results are compared across energies, highlighting the increasing role of baryon transport at lower energies. The results are compared with Pb+Pb data at $\sqrt{s_{NN}} = 5.02$˜TeV from the LHC to study the energy evolution of radial flow fluctuations from RHIC to LHC.

Finally, comparisons with state-of-the-art hydrodynamic calculations allow us to assess the sensitivity of $v_0(p_T)$ to key transport properties of the medium, including bulk viscosity, the speed of sound, and jet energy loss. These measurements provide new constraints on initial conditions and transport coefficients, and offer unique insights into the nature of radial flow fluctuations across a wide range of collision energies and system sizes.

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