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Onset of Constituent Quark Number Scaling in Heavy-Ion Collisions at RHIC

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One of the central goals of the RHIC Beam Energy Scan is to identify the transition from ordinary hadronic matter to the Quark–Gluon Plasma (QGP). Elliptic flow (v_2), which reflects the azimuthal anisotropy of particle emission, serves as a sensitive probe of collectivity and the active degrees of freedom of the medium. Over the past two decades, systematic studies of collectivity across quark flavors, from light to multi-strange hadrons and even charm hadrons, in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV have built a detailed history of partonic collectivity at RHIC. Systematic studies of v_2 across light, strange, and multi-strange hadrons have demonstrated partonic collectivity at top RHIC energies down to $\sqrt{s_{NN}}$ = 7.7 GeV, while results at $\sqrt{s_{NN}}$ = 3.0 GeV show that the system is dominated by hadronic interactions.

Recent STAR measurements reveal that at $\sqrt{s_{NN}}$ ≤3.2GeV, the Number-of-Constituent-Quark (NCQ) scaling is strongly violated, consistent with a hadronic equation of state. As the collision energy increases, a gradual emergence of NCQ scaling is observed, suggesting that parton-level collectivity develops in Au+Au collisions at 4.5 GeV. The breakdown followed by the onset of NCQ scaling provides direct evidence for the transition from hadronic to partonic dominance. These findings establish collectivity as a powerful tool to map the QCD phase structure, advance our understanding of the QGP as a new form of strongly interacting matter, and shed light on the conditions of
the early universe.

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