Contribution ID: **112** Type: **Oral**

Exploring QCD Matter: Phase Transitions, Critical Endpoints, and Rotation Effects in Pure Gluon and Multi-Flavor Models

Monday, 25 November 2024 15:00 (30 minutes)

We employ the non-perturbative gauge/gravity duality approach to study the phase structure of Quantum Chromodynamics (QCD) under finite temperature, baryon chemical potential, and rotational effects. Our models include the SU(3) pure gluon system, 2-flavor QCD, and 2+1-flavor QCD, all calibrated with the latest lattice data to analyze their thermodynamic properties and predict the location of the critical endpoint (CEP). For the 2-flavor model, we find the CEP at ($\mu_{\rm CEP}$,$T_{\rm CEP}$) = (219, 182) MeV. We also compute critical exponents associated with the CEP and find that they almost coincide with the critical exponents of the quantum 3D Ising model. In addition, by introducing angular velocity via a local Lorentz boost, we investigate the impact of rotation on the pure gluon and 2+1 flavor QCD systems, finding that the critical temperature and baryon chemical potential decrease as rotation increases. We construct a 3D phase diagram incorporating temperature, baryon chemical potential, and angular velocity for 2+1 QCD system, as well as a 2D phase diagram for the pure gluon system. Our findings reveal several interesting phenomena near the CEP. This study provides theoretical insights into the phase structure of QCD matter under various rotational conditions.

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Session Classification: Parallel-2