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Detecting critical points from Lee-Yang edge singularities in lattice QCD

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A new approach is presented to explore the singularity structure of lattice QCD in the complex chemical potential and fugacity plane [1, 2, 3]. Our method can be seen as a combination of the Taylor expansion and analytic continuation approaches. Its novelty lies in using rational (Padé) approximants for studying Lee Yang edge singularities, which provide valuable insights to the occur- rence of critical phenomena in the thermodynamic limit. Several numerical experiments have been performed to test and demonstrate its accuracy and stability.
We present a calculations of the densities of conserved charges as well as chiral condensates as a function of imaginary baryon number chemical potential, obtained with highly improved staggered quarks (HISQ) at temporal lattice extent of $N_\tau = 4, 6, 8$. We construct various rational function approximations of the lattice data and discuss how the closest singularities in the complex plane can be determined from them. We confirm stability of our results under conformal mappings. We discuss the universal scaling behavior of the Lee-Yang edge singularity and its role as a brunch-cut singularity in the order parameter. We apply the scaling in the vicinity of the Roberge-Weiss and chiral phase transitions. We find a temperature scaling that is in accordance with the expected power law behavior and determine some previously unknown non-universal constants. Finally we discuss the possibility to detect also the QCD critical end-point, if it exists, by this new method.

References

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