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Searching for the QCD critical point along the pseudo-critical/freeze-out line using Pade-resummed Taylor expansions of cumulants of conserved charge fluctuations

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One of the central goals in QCD with non-vanishing conserved charge densities is to find evidence for the existence of the so-called critical end point (CEP) in the QCD phase diagram. Lattice QCD calculations at smaller than physical quark masses, combined with our model based understanding of the QCD phase diagram, suggest that this critical point, if it exists, needs to be searched for at temperatures below $T \sim 140$ MeV. Following the rather small decrease of the QCD pseudo-critical temperature with increasing baryon chemical potentials (μ_B), it is expected that such low temperatures will only be reached for $\mu_B \geq 400$ MeV. These large values of μ_B and low temperatures are reached at freeze-out in heavy ion collisions only for beam energies less than 10 GeV.

In this low temperature, high density regime studies of QCD thermodynamics with straightforward Taylor expansions are likely to fail. We extend our Taylor series expansion down to temperatures of 125˜MeV and use the high statistics results for conserved charge cumulants up to 8th order, obtained by the HotQCD collaboration, to resum Taylor expansions of the logarithm of the QCD partition function. We will construct resumed results for cumulants of conserved charge fluctuations at low temperature and high density and show that the diagonal Pade-approximants for 8th order Taylor series in all three conserved charge chemical potentials can have real poles, signaling the occurrence of a phase transition, only at temperatures below 140 MeV. This gives further support for a CEP at low temperatures.

We will use these Taylor expansions and their Pade resummations for a determination of freeze-out conditions through QCD calculations of the mean, variance as well as the ratio of mean and variance of conserved charge fluctuations. We compare these calculations with experimental determinations of freeze-out parameters obtained
by STAR in the BES at RHIC. In particular, we find good agreement between QCD results and the STAR measurement
of the ratio of strangeness and baryon chemical potentials. We point out that this ratio of chemical potentials combined with the statement that freeze-out occurs close to the pseudo-critical temperature $T_{pc}(\mu_B)$ determined by ALICE and STAR is consistent with HRG model calculations only when additional strange baryon resonances
are included in the spectrum used for HRG model calculations.

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