Fluctuations of the Polyakov loop in the heavy quark regime.*

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The first-order deconfinement phase transition in SU(3) pure gauge theory is directly connected to the global Z(3) center symmetry and its spontaneous breaking. The transition is eventually washed out by the explicit symmetry breaking induced by dynamical quarks. The strength of the breaking increases as the quark mass decreases. It is thus expected that the transition remains discontinuous in the heavy-quark region and becomes a continuous crossover at some critical value of quark mass. This defines the critical end point (CEP) of the deconfinement phase transition.

Details of the phase structure of the deconfinement transition are revealed by examining the fluctuations of the Polyakov loop. Lattice results on these quantities exist for both pure gauge theory [1] and (2+1)-flavor QCD [2, 3]. However, the theoretical understanding of these quantities remains incomplete. It is therefore important to explore the properties of the Polyakov loop susceptibilities for different number of flavors, as functions of the quark mass in the heavy-quark region, thus bridging the gap between pure gauge theory and QCD.

In SU(3) gauge theory, the Polyakov loop is a complex-valued operator. One can therefore define the fluctuations of the order parameter along the longitudinal (real) and transverse (imaginary) directions. In the figures we show the temperature dependence of the susceptibilities computed within an effective model [4].

While both susceptibilities change with the value of quark mass, only the longitudinal one shows an enhancement near the CEP [4]. The transverse susceptibility decreases monotonically with decreasing quark mass. Thus, for a given N_f, the CEP can be located by finding the global maximum of $\chi_{\rm L}$. For different N_f, the following values of the critical quark masses are obtained:

$$m_{\rm CEP} = 1.10,\ 1.35,\ 1.48\,{\rm GeV}, \quad \text{for } N_f = 1, 2, 3. \qquad (1)$$

This trend, increasing $m_{\rm CEP}$ with N_f, is consistent with lattice results. Moreover, the critical mass is found to be increasing with quark chemical potential μ. Consequently, the first-order region of the deconfinement phase transition shrinks with increasing density. Conversely, within the model the critical temperature of the CEP is almost independent of μ.

We conclude that the CEP can be uniquely identified by a singularity of the longitudinal Polyakov loop susceptibility. In the critical region, the longitudinal fluctuation is enhanced. The transverse susceptibility, on the other hand, remains finite at the CEP.

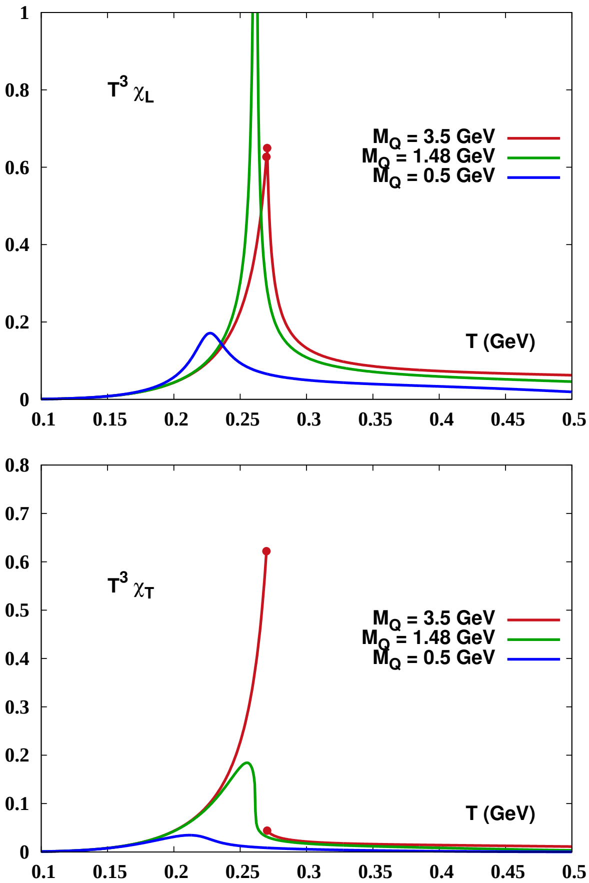

Figure 1: The temperature dependence of the longitudinal $\chi_{\rm L}$ and transverse $\chi_{\rm T}$ Polyakov loop susceptibilities for $N_f = 3$ and quark masses, $m = 0.5, 1.48$, and 3.5 GeV.

References

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