A Phenomenological Understanding of QCD Phase Transition

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The QCD phase transition is one of the most interesting subjects in the quark-hadron physics. Since, at present, the RHIC experiment is being performed to observe the QGP at BNL, much progress is desired in the theoretical understandings of the nature of the QCD phase transition. In this paper, we study the nature of the QCD phase transition by using the closed packing model. This phenomenological model provides its own insights into the QCD phase transition. In this model, hadrons are treated in the bag model picture, and the QCD phase transition takes place, when these thermally excited bags cover the whole space region. This leads us to the following phenomenological relation among the critical temperature T_c, the mass and the radius of hadrons[1]:

$$\sum_n \frac{4\pi}{3} R_n^3 \lambda_n \int \frac{d^3k}{(2\pi)^3} \frac{1}{e^{\sqrt{m_n^2+\vec{k}^2}/T_c} - 1} \simeq 1, \tag{1}$$

where n labels the n-th hadronic mode, and m_n, R_n and λ_n denotes its mass, its radius and its degeneracy, respectively. In the ordinary context, the closed packing model is applied to full QCD, where the pion is the lightest physical excitation and is expected to play the dominant role in the QCD phase transition. By taking into account pionic degrees of freedom, and using m_π=140MeV, $R_\pi\sim$1fm and λ_π=3 as inputs, T_c of full QCD is estimated as $T_c\simeq$183MeV from Eq. (1), which should be compared with the $T_c\simeq$170MeV in full lattice QCD. Hence, the closed packing model seems to be working in full QCD. As for quenched QCD without quarks, however, the closed packing model fails to reproduce $T_c\simeq$260MeV as the result of quenched lattice QCD. In fact, in quenched QCD, the lightest physical excitation is the 0^{++} glueball with the mass $m_{\rm G}\simeq$1500–1700MeV, which we may expect to play the dominant role in the QCD phase transition. By taking into account this 0^{++} glueball, using $m_{\rm G}$=1.7GeV, $R_{\rm G}\simeq$1fm and $\lambda_{\rm G}$=1 as inputs into Eq. (1), we obtain $T_c\simeq$465MeV, which is too high. In Fig. 1, T_c is plotted against $m_{\rm G}$ for various $R_{\rm G}$. We see that, to reproduce $T_c\simeq$260MeV, either a drastic reduction in $m_{\rm G}$ as $m_{\rm G}$<0.5GeV or a tremendous expansion in radius as $R_{\rm G}\simeq$4fm is required in the vicinity of T_c. In this talk, we will consider this problem in connection with the recent lattice result of thermal glueball properties[2,3]. A careful consideration shows that this problem actually exists in full QCD also. Hence, this problem may be rather general for the QCD phase transition at finite temperature.

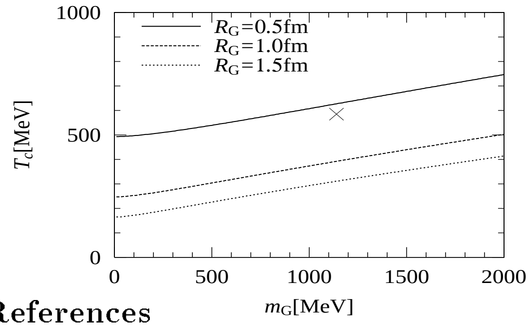

Figure. 1: The critical temperature T_c is plotted against the 0^{++} glueball mass $m_{\rm G}$ for various glueball radiuses $R_{\rm G}$. The cross ($\times$) indicates the recent lattice QCD result on the thermal glueball properties in the vicinity of T_c obtained in Refs[2,3].

References

[1] N.Ishii et al., in *Lepton Scattering, Hadrons and QCD*, (World Scientific, 2001) 252.
[2] N. Ishii et al., Nucl. Phys. **B** (Proc. Supple.) **106&107** (2002) 516.
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