Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics A 931 (2014) 238–245

NUCLEAR PHYSICS A

www.elsevier.com/locate/nuclphysa

Selected issues in thermal field theory

Chihiro Sasaki [a,b]

[a] *Frankfurt Institute for Advanced Studies, D-60438 Frankfurt am Main, Germany*
[b] *Institute of Theoretical Physics, University of Wroclaw, PL-50204 Wroclaw, Poland*

Received 3 August 2014; received in revised form 1 September 2014; accepted 1 September 2014

Available online 3 September 2014

Abstract

New developments on hot and dense QCD in effective field theories are reviewed. Recent investigations in lattice gauge theories for the low-lying Dirac eigenmodes suggest survival hadrons in restored phase of chiral symmetry. We discuss expected properties of those bound states in a medium using chiral approaches. We also examine the role of higher-lying hadrons near chiral symmetry restoration from the conventional and the holographic points of view.

Keywords: Chiral symmetry restoration; Deconfinement; Trace anomaly

1. Introduction

The interplay between dynamical chiral symmetry breaking and color confinement in a hot/dense medium has not been sufficiently understood, and remains one of the central subjects in QCD [1,2]. The chiral symmetry breaking and its restoration are well characterized by the quark–antiquark (chiral) condensate, whereas no reliable order parameter for the confinement–deconfinement phase transition is known. The Polyakov-loop expectation value, which plays the role of the order parameter in pure Yang–Mills (YM) theory, is disturbed seriously by dynamical quarks. Hence, even though the expectation value exhibits an inflection point at a certain temperature, it is not manifest that the system undergoes a transition from hadrons to quarks and gluons. A constructive way to identify the deconfined phase is to explore various fluctuations associated with conserved charges. In particular, the kurtosis of net-quark number fluctuations measures clearly the onset of deconfinement [3].

http://dx.doi.org/10.1016/j.nuclphysa.2014.09.003
0375-9474/

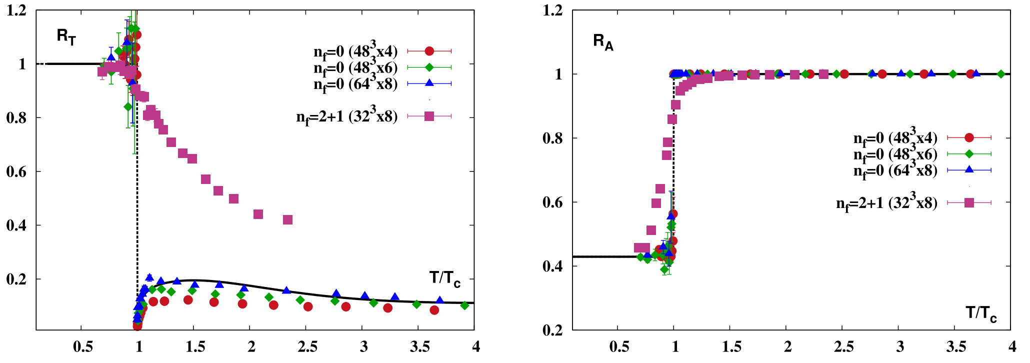

Fig. 1. Lattice results of the ratios of the Polyakov loop susceptibilities, $R_T = \chi_I/\chi_R$ and $R_A = \chi_A/\chi_R$ for pure YM and $N_f = 2+1$ QCD at vanishing chemical potential [5]. The temperature is normalized by the critical temperature in pure YM theory, and by the pseudo-critical temperature for the chiral symmetry restoration in full QCD.

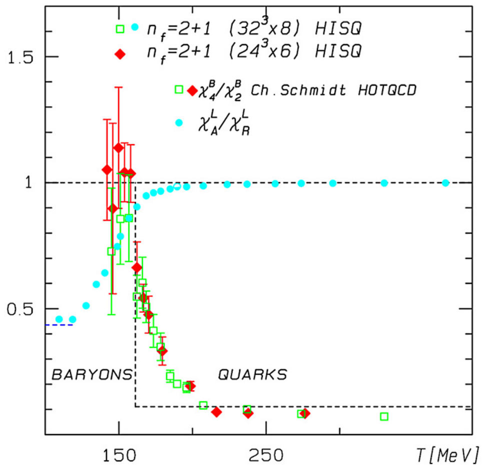

Fig. 2. The ratio of the Polyakov loop susceptibilities $R_A = \chi_A/\chi_R$ and the kurtosis of net quark number fluctuations. Lattice data points are taken from [5,6].

Recently, other fluctuations more addressing the gluon sector have been calculated in lattice gauge theory with light quarks [4,5], where two ratios, $R_T = \chi_I/\chi_R$ and $R_A = \chi_A/\chi_R$, are considered in terms of the susceptibilities associated with the modulus, real and imaginary parts of the Polyakov loop. Asymptotic values of those ratios are properly quantified within a $Z(3)$-symmetric model when there are no dynamical quarks (see Fig. 1). Once the light flavored quarks are introduced, the R_T becomes much broadened, similarly to the Polyakov loop expectation value. On the other hand, the R_A retains the underlying center symmetry fairly well even in full QCD with the physical pion mass. Also, ambiguities of the renormalization prescription can be avoided to large extent in the ratio. The R_A thus serves as a better pseudo-order parameter than the Polyakov loop by itself. In Fig. 2, the R_A is compared with the kurtosis of the quark number fluctuations. The quark liberation takes place evidently together with a qualitative changeover in R_A. Those abrupt changes in the Polyakov loop and quark number fluctuations appear in a nar-