Impact Of The String Tension Parameter On Several Characteristic Features Of QCD

N. Hothi* and S. Bisht
Department of Physics, Kumaun University, Nainital-263002, INDIA.
* email: hothi.navjot@gmail.com

Introduction

The string tension is a characteristic quantity in discussing confinement physics and we have investigated the relation and impact of string tension upon various distinctive features of Quantum-Chromodynamics (QCD) [1]. These include the behavioural implications of string tension correponding to varying temperatures under different QCD phases. The spatial string tension projects out as a classic non-perturbative probe for the convergence of weak coupling expansion at high temperatures. The behavioral implications of the Wilson loops at high temperature helped in probing the deconfinement physics and thereby proved useful in determining the temperature dependence of the spatial string tension under the gluon chain model and also under the AdS/QCD picture. From these pictures, we can easily conclude that the temperature dependence of spatial string tension is very soft below the deconfinement temperature (T_c) and sharp above it.

Futhermore, we determined the implications of the string tension parameter upon the glueball dynamics. The N_c=3 and N_c=2 limits display evident intimacy and they extensively stand apart from the N_c=1 limit. Clear intrinsic connection is visible between N_c=3 and $N_c=\infty$ limit and both the limits dispay proximity.

Spatial String Tension And The Gluon Chain Model

For temperatures T such that $T_0<T<T_c$, the spatial string tension behaviorism is implicitly dependent upon two prominent features that is the physical string tension and temperature parameter itself. This particular analysis exhibits the fact that spatial string tension variation pattern can be effectively determined by varying these two parameters within their specified range. We have varied the physical string tension within a range 0 to 0.2GeV^2. It may however be pointed out that for temperatures far above the critical temperature (more than a few 100 MeV), the spatial string tension displays a linear variation with the temperature. The spreadsheet for N_c=1 limit covers the entire available spatial dimensions, whereas the N_c=3 three dimensional plot is restricted within a smaller domain and the spreadsheet possesses an effective curvature. This analysis evidently provided a platform for demonstrating evident difference between the N_c=1 conjecture and the N_c=3 formalism.

Spatial String Tension Within AdS/QCD framework

The SU(N) gauge theories undergo a phase transition to a deconfined phase at high temperature. The pseudo-potential extracted from spatial Wilson loops does not exhibit quantative drastic change at deconfinement temperature T_c. This owes to the fact that certain confining properties survive in the high temperature phase. High temperature perturbation theory is helpful in determining the behaviorism of pseudo potential for temperatures well above T_c. However, near the phase transition point, the non-perturbative effects pose difficulties in the computation of the pseudo potentials. At this point, the AdS/QCD approach came to the rescue which deals with a string description of strong interactions.

The five dimensional AdS/QCD approach helps in exploring the temperature dependence of the spatial string tension. Spatial Wilson loops are studied which obey an area law and provide string tension.

Our analysis revealed the following expression relating T_c and σ and (here g ~0.94 and comes from the Cornell potential).

$$\frac{T_c}{\sqrt{\sigma}} = \sqrt{\frac{2}{e\pi g}}$$

The relation between T and σ_s was found to be

$$\frac{\sqrt{\sigma_s}}{T_c} = 1.44\frac{T}{T_c}exp\left\{\frac{1}{2}\left(\frac{T_c}{T}\right)^2 - \frac{1}{2}\right\}$$

A detailed analysis of the above expression revealed the fact that the temperature dependence of spatial string tension is very soft below T_c and sharp above T_c.

k-string tensions under the large N_c formalism

The naive QCD string is the flux tube that links heavy color sources in the fundamental representation. It is referred to as the fundamental string and the string tension corresponding to it is called the fundamental string tension. However, the large N_c visualizations have found a novel realization in the studies of the spectrum of k-strings in the SU(N) gauge theories. A k string is basically a flux tube generated between sources in the higher representation with non-vanishing N_c-ality. In the large N_c limit, the interactions between the flux tubes are suppressed in the powers of $1/N_c$ and therefore the lowest energy state of the system should be made of k fundamental flux tubes connecting the sources. This eventually lead to the expression

$$\frac{\sigma_k}{\sigma_f}\xrightarrow{N\to\infty} k\,,\ k\ fixed$$

String tension ratios for the large N_c limit were compared to Casimir scaling as well as the MQCD (sine scaling) inspired conjectures. Also, both these scaling were found to remain invariant under the replacement of k by (N-k), i.e. exchange of quarks by antiquarks. For both the scaling conjectures, the string tension ratios tend to approach the Casimir factor (=2) at large values of N_c. Thus we can say that as $N_c\to\infty$, the two approaches coherently reproduce similar behaviorism and this could substantially give boost to the validity of the effective emerging large N_c theory and also to the fact that $N_c=3$ limit is proximate to $N_c\to\infty$ limit.

String Tension Parameter And Glueball Dynamics

One of the main ingredients of the glueball dynamics is the adjoint string (or two fundamental strings) [2] occurring between the gluons in the two gluon glueballs. This adjoint string conjecture is inspired by the type two superconductor, which explores a new scenario of gluon-gluon interaction. Under this framework, the adjoint string is replaced by a pair of fundamental strings. The adjoint string is a natural extension of the fundamental string, which predicts a linear Regge trajectory:

$$\alpha'_{FT} = \frac{1}{8\pi\sigma}$$

However, when we consider the adjoint string model, it too predicts a linear Regge Trajectory

$$\alpha'_{AS} = \frac{1}{2\pi\sigma_a}$$

and this evidently turns out to depend upon N, through the N dependence on σ_a/σ.

$$\frac{\sigma_a}{\sigma} = \frac{C_A}{C_F} = \frac{2N^2}{N^2-1}$$

For large N values, the above ratio approaches the Casimir scaling factor (=2).

When the spectrum of the glueballs is computed [3] under the adjoint string model, it was found that

$$M_n = 4\sqrt{\frac{n\sigma_a}{2}}\quad n = 1{,}3$$

This equation is of particular interest because then the masses of the glueballs which otherwise depend upon σ_a can be connected to the fundamental string tension. The rotating glueballs lie entirely within a plane, therefore calculations in SU(3) gauge theory are identical to SU(2). The only prominent difference is that in SU(2) the adjoint string tension is $\sigma a=(8/3)\sigma(SU(2))$, whereas for SU(3) its value is $\sigma a=(9/4)\sigma(SU(2))$. These values of string tensions clearly demonstrate the fact that the SU(3) and the SU(2) gauge theories are clearly approximate to each other.

References

[1] N. Hothi and S. Bisht, to appear in the EJTP, (2011).
[2] F. Bigazzi, A. L. Cotrone, L. Martucci and L. A. Pando Zayas, Phys. Rev., **D71**, 066002 (2005).
[3] Yu. A. Simonov, Phys. Atom. Nucl., **70**, 44 (2007).