Behaviour of Quantum Chromodynamics Near an Infrared Fixed Point

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Abstract

In perturbation theory, the QCD running coupling depends on the renormalization scheme or is parameterised by a physical process. The problem is that artefacts of this ambiguity may upset physical conclusions outside the asymptotically free region, in particular near an infrared fixed point. Thus, a non-perturbative definition for the QCD running coupling is required that should be a monotonic and analytic function of the space-like energy scale Q^2. The most physical coupling is Grunberg's definition for the running coupling as an effective charge $\alpha_G(Q^2)$. However, we find that it works only for sufficiently high energy scales. At some finite values of the energy scale, near the top of the resonance region, the β-function associated with $\alpha_G(Q^2)$ has a false zero below which $\alpha_G(Q^2)$ decreases.

We test this conclusion further by applying chiral perturbation theory to the running coupling based on the method of effective charges. We consider the Drell-Yan ratio $R(q^2)$ and Adler-function $D(Q^2)$ in the time-like and space-like domains, respectively. These quantities tend to a finite value in the both infrared and ultraviolet limits: $R(0) = D(0) = 0.5$ for $\pi^\pm,\ K^\pm$ and $R(\infty) = D(\infty) = 2$ for the light quarks. This means that the running coupling becomes negative in the infrared limit. Therefore, neither the time-like nor the space-like effective charges is a monotonic function over the whole energy scale.

We also try to cancel the space-like pole of the proposed exact β-function, using the property of renormalization scheme dependence. Our modified exact β-function is non-singular for all finite values of the running coupling α and has an infrared fixed point even for a small number of quark flavours.

Statement of Originality

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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List of workshop proceeding and future publication based on this thesis:

- G. O. Souadi, *When is an Infrared Fixed Point of QCD Physical?*, poster presented at workshop "Determination of the Fundamental Parameters of QCD", Nanyang Technological University, Singapore, March 18-21, 2013.
- R. J. Crewther and G. O. Souadi, *When is a QCD Infrared Fixed Point Physical?*, in preparation.

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