Study of Regge Trajectories of Hexaquarks

D. G. Sindhu[1],* A. Ranjan[1], V. Sharma[2],† and H. Nandan[2,3]

[1]*Department of Physics, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, Karnataka-576104, India.*

[2]*Department of Physics, H. N. B. Garhwal University, Srinagar, Uttarakhand-246174, India. and*

[3]*Department of Physics, Gurukula Kangri (Deemed to be University), Haridwar, Uttarakhand 249404, India.*

Introduction

We report the study of Regge trajectories of Hexaquarks with various possible configurations as shown in Fig. 1. Some theoretical models suggest that the transition from quark-gluon plasma (QGP) to hadrons in the early universe also accounts for the production of Hexaquarks states in nature. Few combinations of such Hexaquarks also serve as potential dark-matter candidates (e.g., d*(2380))[1]. This possibility is supported by some recent experimental discoveries which resulted the emergance of new theoretical models for the study of such states. Although, in this report, we focus on the fully heavy hexaquark states. The mass spectra of these hexaquark states has also been investigated and the results are compared with other theoretical works [2]. In our calculations, we also account for the relativistic corrections in view of the high rotational speed of the quarks at the end of flux tube structure. Our findings are in close agreement with the calculations performed by the other researchers [2].

Formulation

The hadronic systems could be studied by using different models. The flux tube model in one of such successful models to explain the classical mass and angular momentum of a hadronic system. It has also an importance in explaining the color confinement mechanism. This model consists of a flux tube with quark and antiquark at opposite ends. There exists overall 31 configurations of hexaquarks, where one or two or three quarks could exist at one end of the string as depicted in Fig. 1(a, b, and c respectively). These quarks at the ends of the string are considered as massless so that they revolve at the speed of light. Due to the string tension, the mass of hardron changes into its potential energy. If the string is rotating about its middle point, the interrelationship of classical mass (M) and angular momentum (J) of a hadron is as follows:

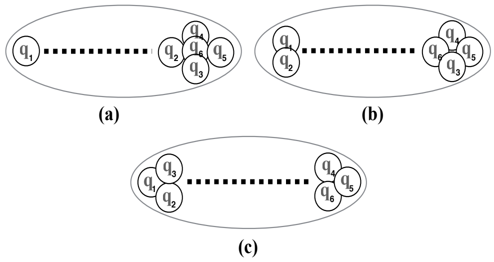

FIG. 1: Different configurations of hexaquarks with n =1 (a) ,2 (b), 3 (c) number of quark at one end of the string. There exixists several combinations (6, 15, and 10) within those quarks for each of these three cases (a, b, and c respectively).

$$J = \alpha M^2 + \alpha_o, \tag{1}$$

where, α_o accounts for the intrinsic spin of quarks and α is the Regge slope parameter. The modified mass expression for the mass and angular momentum generated due to mo-

*Electronic address: sindhudgdarbe@gmail.com

†Electronic address: vsharma.phys@hnbgu.ac.in

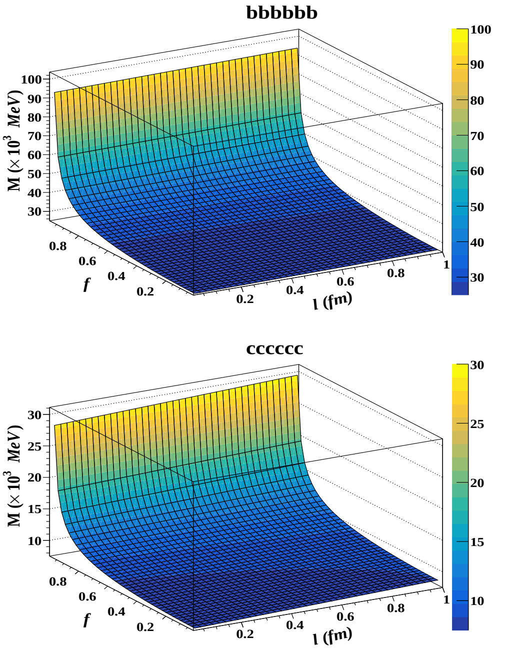

FIG. 2: Mass variation with change in string length and fraction rotational speed for (a) cccccc, and (b) bbbbbb hexaquark averaged for all possible (6+15+10) configurations of Fig. 1. Other hexaquarks also follows the similar pattern of gradual change in mass with change in string length.

tion of massive quarks is given by [3, 4]

$$M_n = \frac{Kl\mathcal{M}_n}{fM}\left\{\sin^{-1} f + \sin^{-1} \xi\right\} + \gamma_0 \sum m_{q_n} + \gamma_n \mathcal{M}_n, \tag{2}$$

$$J_n = \frac{kl^2}{f^2}\left(\frac{\mathcal{M}_n}{M}\right)^2 \left[\frac{1}{2}\sin^{-1} f - \frac{f}{2}\sqrt{1-f^2} + \frac{1}{2}\sin^{-1}\xi - \frac{1}{2}\xi\sqrt{1-\xi^2}\right] + \frac{\sum m_{q_n}}{M} fl\left(\gamma_0 \mathcal{M}_n + \gamma_n \sum m_{q_n}\right), \tag{3}$$

where, $M=\sum_{i=1}^{6} m_{q_i}$, $\xi=\left(\frac{\sum m_{q_n}}{\mathcal{M}_n} f\right)$, $\mathcal{M}_n=M$-$\sum m_{q_n}$, $\sum m_{q_n}=\sum_{n=1}^{n} m_{q_n}$, and n is the number of quarks at one side of string. Furthermore, $\gamma_0 = (1-f^2)^{-1/2}$, $\gamma_n = \left[1-\left(\frac{\sum m_{q_n}}{\mathcal{M}_n}\right)^2\right]^{-1/2}$, and f is the fractional rotational speed (with $\hbar$= 1 and c = 1). The actual mass and angular momentum must be averaged for all 31 configurations (see Fig. 1) of hexaquarks as each of them have equal probability of their occurance in the nature.

Results and Discussions

The quark masses are taken considered as in Ref. [5] whereas, the quarks or antiquark that make up q_1, q_2, q_3, q_4, q_5, and q_6 are not stated explicitly. It does not have any impact on the given formalism. We have observed that the present results are in good agreement with the other models [2]. The length l is considered different for different states. Its value is expected to be shorter for the heavy quark than the light quark, due to the relationship between quark mass, string tension, and string length in the flux tube model of hadrons. Furthermore, the higher angular momentum states are obtained with the increase in the string length as well as rotational speed. New theoretical research and experimental measurements will be required for deeper insights of the behaviour and characteristics of the Regge trajectories of hexaquark states. Future investigations needs careful attention to address several topics including breaking of string, relation of flux tube with quark confinement, and the possibilities of searching hexaquark dark matter candidates.

References

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