# Regge Trajectories of $\Xi_{bb}$ baryon in (n, $M^2$) and (J,$M^2$) planes

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## Introduction

During the last few years, there has been significant experimental progress on the spectroscopy of the heavy baryons. Doubly heavy baryons are made of two heavy and one light quark. No experimental evidences for the ground as well as excited doubly heavy baryon ($\Xi_{bb}$) states are observed yet [1]. Therefore, it would be interesting to present reliable theoretical predictions of these baryons. There have been several approaches to deal with the doubly heavy baryon masses, such as non-relativistic [2], relativistic [3], Semi relativistic quark model[4], QCD sum rules [5, 6], Lattice QCD [7], etc.

In present work, we have calculated mass spectra of $\Xi_{bb}$ baryon for 1S-3S, 1P-3P, 1D-3D and 1F states in Hypercentral constituent quark model with coloumb plus linear potential. From that, we obtained regge trajectories of the baryon in (n, $M^2$) and (J,$M^2$) planes. One can test linearity, parallelism and equidistant from these graphs. Here, $n_r$ is radial quantum number and n=$n_r$-1, M is baryon mass and J is the baryon spin. We are also able to assign $J^P$ values for particular states.

## The Hypercentral model

$\Xi_{bb}$ baryon is made of three constituent quarks ($bbd$). $m_b = 4.67$ and $m_d = 0.350$ are taken. The relevant degrees of freedom for their motion are related by the Jacobi coordinates ($\vec{\rho}$ and $\vec{\lambda}$). The Hamiltonian of three body baryonic system with different constituent quark masses for the hCQM [8–11] is written as

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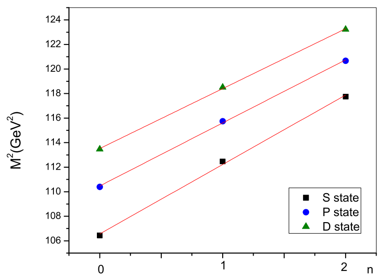


FIG. 1: Regge Trajectory of $\Xi_{bb}$ baryon in (n, $M^2$) plane for S($\frac{1}{2}^+$), P($\frac{1}{2}^-$) and D($\frac{5}{2}^+$) states (from bottom to top)

$$H = \frac{P_x^2}{2m} + V(x). \quad (1)$$

Where, $m = \frac{2m_\rho m_\lambda}{m_\rho + m_\lambda}$, is reduced mass. For the present study we consider the hypercentral potential V(x) as the color coulomb plus linear potential with spin interaction,

$$V(x) = \frac{\tau}{x} + \beta x + V_{SD}. \quad (2)$$

Here, $\tau = -\frac{2}{3}\alpha_s$ related to strong coupling constant; $\frac{2}{3}$ is the color factor for baryon, $\beta$ corresponds to the string tension of the confinement. The baryon spin average mass in this hypercentral model is given by $M_B = \sum_{i=1} m_i + BE$. $V_{SD}(x)$ contains three types of the interaction terms, such as the spin-spin term $V_{SS}(x)$, the spin-orbit term $V_{\gamma S}(x)$ and tensor term $V_T(x)$ given by [12],

$$V_{SD}(x) = V_{SS}(x)(\vec{S_\rho}.\vec{S_\lambda}) + V_{\gamma S}(x)(\vec{\gamma}\cdot\vec{S}) + V_T(x)\left[S^2 - \frac{3(\vec{S}\cdot\vec{x})(\vec{S}\cdot\vec{x})}{x^2}\right]. \quad (3)$$

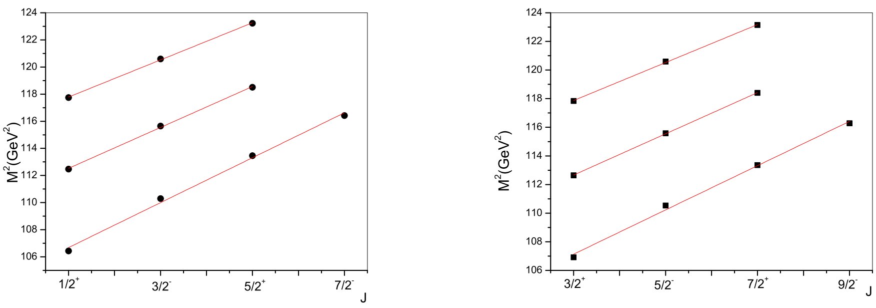


FIG. 2: Parent and daughter $(J, M^2)$ Regge trajectories for $\Xi_{bb}$ baryons with natural(left) and unnatural(right) parities.

## Conclusions

By using hCQM model, we obtained mass spectra of doubly heavy baryon $\Xi_{bb}$ are shown in Table I. We plotted regge trajectories with the help of these masses (See Figs. 1- 2). We have performed $\chi^2$ fitting, so that, all graphs are linear, parallel and equidistant. From the outcome of the figs., we assigned $J^P$ values to particular states. We have done calculations for S state($J^P{=}\frac{1}{2}^+$ and $\frac{3}{2}^+$), P state ($J^P{=}\frac{1}{2}^-$, $\frac{3}{2}^-$ and $\frac{5}{2}^-$), D state($J^P{=}\frac{5}{2}^+$ and $\frac{7}{2}^+$) and F state($J^P{=}\frac{7}{2}^-$, $\frac{9}{2}^-$). Such calculations are useful to the experimental groups as well as various approaches to find the mass spectra and other properties of doubly heavy $\Xi_{bb}$(dbb) baryon in future.

TABLE I:

| State | $J^P$ | Mass(GeV) | State | $J^P$ | Mass(GeV) |
|---|---|---|---|---|---|
| 1S | $\frac{1}{2}^+$ | 10.316 | 1S | $\frac{3}{2}^+$ | 10.316 |
| 2S | $\frac{1}{2}^+$ | 10.605 | 2S | $\frac{3}{2}^+$ | 10.605 |
| 3S | $\frac{1}{2}^+$ | 10.85 | 3S | $\frac{3}{2}^+$ | 10.8511 |
| 1P | $\frac{3}{2}^-$ | 10.502 | 1P | $\frac{5}{2}^-$ | 10.514 |
| 2P | $\frac{1}{2}^-$ | 10.754 | 2P | $\frac{1}{2}^-$ | 10.751 |
| 3P | $\frac{1}{2}^-$ | 10.981 | 3P | $\frac{1}{2}^-$ | 10.978 |
| 1D | $\frac{5}{2}^+$ | 10.652 | 1D | $\frac{7}{2}^+$ | 10.646 |
| 2D | $\frac{5}{2}^+$ | 10.886 | 2D | $\frac{7}{2}^+$ | 10.881 |
| 3D | $\frac{5}{2}^+$ | 11.100 | 3D | $\frac{7}{2}^+$ | 11.097 |
| 1F | $\frac{7}{2}^-$ | 10.790 | 1F | $\frac{9}{2}^-$ | 10.784 |

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