Regge Trajectories of Singly Heavy Non-strange Baryons in $n - M^2$ Plane

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Introduction

In recent years, many bottom baryon states are listed by Particle Data Group (PDG) [1] as the resonances are observed by various experimental facilities [2–5]. Till now, $\Lambda_b^0(5619)$, $\Lambda_b^0(5912)$, $\Lambda_b^0(5920)$, $\Lambda_b^0(6070)$, $\Lambda_b^0(6146)$, $\Lambda_b^0(6152)$, $\Sigma_b^+(5810)$, $\Sigma_b^-(5815)$, $\Sigma_b^{*+}(5830)$, $\Sigma_b^{*-}(5834)$ states are published with three star status by PDG. The possible J^p values are assigned to these states in our previous work [6]. The mass spectra of Λ_b and Σ_b baryons are enumerated using Hypercentral Constituent Quark Model (hCQM) and properties like magnetic moment, radiative decay, strong decay are also studied using the calculated masses [6].

In present study, the Regge trajectories of Λ_b and Σ_b baryons are plotted in $n-M^2$ plane using the mass spectra enumerated in Ref. [6]. Regge trajectories can be utilized for assigning the possible quantum number of the further hadronic states which can be identify the higher excited states of the baryon.

The Regge trajectories in (n, M^2) plane,

$$n = \alpha M^2 + \alpha_0 \tag{1}$$

where, α and α_0 are the slope of linear fitting line and interception on the y-axis respectively. The square of calculated masses for particular J^P values are indicated by various symbols in (n, M^2) plane for particular baryonic system.

The higher excited states can be predicted by extending the Regge lines. And J^p value can be assigned for the particular ressonance mass, which have no confirmed J^p value. Other than this application, the masses of the particular baryonic state can be derive using Regge phenomenology [7].

Theretical Framework

To explain the constituent quark interaction, Jacobian coordinates are employed; which can be expressed as given below [6, 8–11]:

$$\vec{\rho} = \frac{\vec{r_1} - \vec{r_2}}{\sqrt{2}} \quad and \quad \vec{\lambda} = \frac{\vec{r_1} + \vec{r_2} - 2\vec{r_3}}{\sqrt{6}}. \tag{2}$$

The Hamiltonian of the three quark bound system is given by [12],

$$H = \frac{P^2}{2m} + V(x) \tag{3}$$

Here, P is conjugate momentum, m is reduced mass [13] and $V(x)$ is non-relativistic interaction potential inside the baryonic system. The constituent quark masses are: $m_u = 0.350 GeV, m_d = 0.350 GeV, m_b = 4.670 GeV$.

The screened potential is considered as a confining potential with the color-Coulomb potential [14].

$$V_{conf}(x) = a\left(\frac{1 - e^{-\mu x}}{\mu}\right) \tag{4}$$

where, a is the string tension and the constant μ (= 0.07) is the the screening factor. After defining the confining potential and other parameters, the Schrödinger equations [15] of the Λ_b^0 and $\Sigma_b^\pm$ baryons can be solved using Mathematica notebook [16].

Regge Trajectories

For baryons, Regge trajectories are suppose to be linear. The nature of $n - M^2$ plot of

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singly heavy non-strange baryons is linear as shown in figure 1-3. The mandetory thing to notice in these plots is, the Regge lines are crossing each other. Regge Trajectories are plotted by Ref. [15] and [17] using linear potential and quasipotential approach respectively; which are linear and parallel also. The reason of intersecting Regge lines is the confining potential used in model. The screening potential has been considered as confining potential in calculation of mass spectra. As one go for higher excited states, the masses are screened due to the confining potential, which is called screening effect.

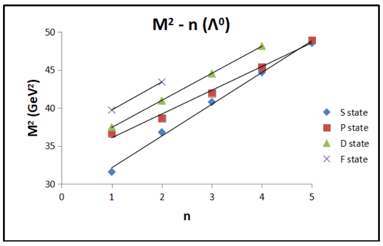

FIG. 1: Regge trajectory of Λ_b^0 in $n - M^2$ plane

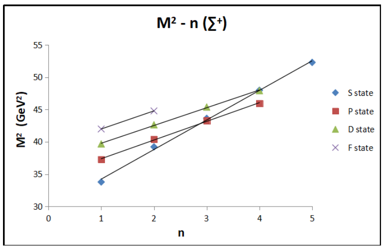

FIG. 2: Regge trajectory of Σ_b^+ in $n - M^2$ plane

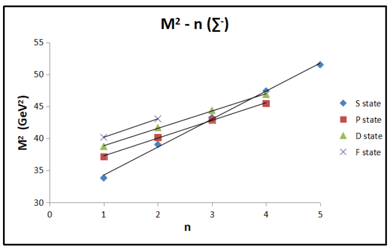

FIG. 3: Regge trajectory of Σ_b^- in $n - M^2$ plane

Conclusion

Our Regge lines are intersecting each other due to screening effect. Though they are obeying the nature of Regge lines for baryon, they are intersecting at excited states, which indicates that the mass spectra got screened at higher excited states and the screening is caused by the confining potential.

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