Confirmation of orbital excited (P) states of Bottomonia

Vikas Patel[1*] and Ajay Kumar Rai[2†]
[1] Department of physics, Uka Tarsadia University, Bardoli 394250, Gujarat, India. and
[2] Department of Physics, Sardar Vallabhbhai National
Institute of Technology, Surat 395007, Gujarat, India.

Introduction

Bottomonium system is believed to have non-relativistic nature and hence can be treated as two body system of heavy quark and antiquark. Recently, many X Y Z resonance states have been discovered, and they are still being examined using different relativistic and non-relativistic potential models[1]. Many other states above open flavour have also been observed experimentally in the bottomonium family but their association to a particular S,P or D state remains questionable[2]. The success of various of theoretical (phenomenological) model like relativistic quark model [3], Non- relativistic quark model [1, 4, 11] are help us for more calculation of Quarkonia. Non-relativistic models have been significantly successful in interpreting the heavy quarkonia spectroscopy [5–10].

In fermi lab by E288 collaboration discovered many bottomonia states:$\Upsilon(1S, 2S, 3S)$ using proton-nucleon collisions: $P+N \rightarrow \mu^+\mu^- + X$ [12]. In 2012, the Belle collaboration reported the first evidence of the $\eta_b(2S)$ with mass $9999 \pm 3.5^{+2.8}_{-1.9}$ MeV/c^2 [13]. Recently reported by LHCb new bottomoia states $\chi_{b1}(1P)$, $Z_b(10610)$ and $Z_b(10650)$ respectively [14]. $\Upsilon(1^3D_2)$ well established by BABER at low lying states $h_b(1P)$ and $h_b(2P)$ [15, 16]. The dipion transition width ($\Upsilon(5S) \rightarrow Z_b^{(')\pm}\pi^{\mp} \rightarrow \Upsilon(1D)\pi^{\pm}\pi^{\mp}$) between $\Upsilon(5S)$ and $\Upsilon(1D)$ devloped new three states $\Upsilon_1(1D)$, $\Upsilon_2(1D)$ and $\Upsilon_3(1D)$ of Z_b' [17].

Regge trajectory can also help in the assignment of experimentally observed highly excited $Q\bar{Q}$ meson state to a particular $b\bar{b}$ meson state and could also help in determining their quantum numbers [18]. In this paper we employ screening potential $V_s(r) = \frac{A}{\xi}(1 - e^{-\xi r})$ to study the mass spectroscopy and calculated orbitally and radially excited masses of $b\bar{b}$. In the present article we employ variational method with a single Gaussian trial wave function with one parameter; both in position space as well as momentum space; in a Cornell potential model to calculate the mass spectrum of the $b\bar{b}$ meson [5–7]. We incorporate corrections to the kinetic energy of quarks as well as the relativistic correction $\mathcal{O}(\frac{1}{m})$ of to the potential energy part of the Hamiltonian. Also establish the Regge trajectories in $n_r \rightarrow M^2$ planes of heavy-heavy and light-heavy flavoured mesons [5–10]. Regges linearity of tra- jectories represents a representation of strong forces at large distances between quarks (color confinement)[1].

Regge-trajectories

Regge spectroscopy plays a major role in determining the experimental state and confirming the quantum number for the specific state is given. Bottomonia masses calculated by our model are represented by the hollow symbol in the figure, while the experimentally available mass is represented by solid symbol with the corresponding term [5–10].The Regge trajectories for n_r = n - 1 principal quantum number in the$((n_r, M^2))$ plane are describe in Fig.

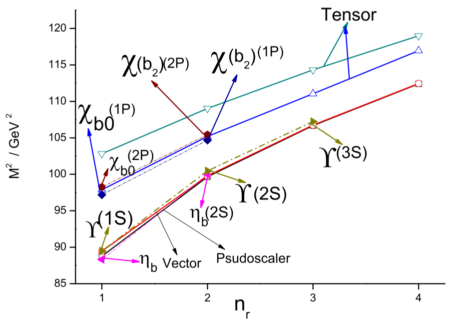
*Electronic address: `patelvikas2710@gmail.com`
†Electronic address: `raiajayk@gmail.com`

The (n_r, M^2) Regge trajectory:

$$n_r \equiv n - 1 = \beta M^2 + \beta_0; \qquad (1)$$

Where β, is the slopes and β_0, are the intercepts.The daughter trajectories, which involve both radially and orbitally excited states, turn out to be almost linear, equidistant and parallel whereas the parent Regge-trajectories, which start from ground states, are exhibiting a nonlinear behavior in the lower mass region in both planes [2]. The radial spectrum of bottomonia usually leads to powerful non linearities in the Regge phenomenology in the hadron string model system [19].

Results and Discussion



For the psuedoscalar and vector state, The $M^2 \rightarrow n_r$ Regge-trajectory of $b\bar{b}$ meson masses S state, excited of P and D states.

The Regge- trajectories reflects strong force between quarks at large distance by linearity. The curvature of the trajectory near the ground state is due to the contribution of the color Coulomb interaction, which increases with mass. Hence, the Regge-trajectories of the bottomonium are basically nonlinear and exhibiting a nonlinear behavior in the lower mass region. We compare slopes of linear Regge trajectory of $b\bar{b}$ meson obtained in this paper to about 0.160 GeV^{-2} with the slope of $b\bar{b}$ meson from previous work [18] which is 0.175 GeV^{-2} and would comment that the slope of the meson Regge-trajectory is mainly determined by and depends upon the mass of the quark. From the Fig. We conclude many tensor states in P wave are confirmed for bottomonia with help of J^{PC} quantum number. For E.g $\chi_{b1}(9892)$, $h_b(9899)$, $\chi_{b2}(9912)$, $\eta b_1(10255)$, $\eta b_2(10268)$ and $h_b(10259)$ with their respective $J^{PC} = 1^{++}, 1^{-+}, 2^{++}$,$1^{++}, 1^{-+}, 2^{++}$.

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