# Mass-spectroscopy of hidden bottom tetraquarks

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## Introduction

Since 2003, a significant number of unconventional states that do not fit in the conventional quark model have been detected in experiments and predicted theoretically are called exotic hadrons or simply exotics [1–7]. The recent discovery of all-charm tetraquarks X(6900) and the study of all-bottom tetraquarks $[bb][\bar{b}\bar{b}]$ (which we will refer to as $T_{4b}$), are among the heaviest tetraquarks, were crucial in understanding the quark confinement within tetraquarks [8–12].

The CMS collaboration discovered $\Upsilon(1S)$ pair formation in pp collisions at $\sqrt{s}$ = 8 TeV in 2017, and an excess at 18.4 GeV in the $\Upsilon(1S)l^-l^+$ decay channel was proposed in a subsequent preliminary study [13] whereas RHIC reported a similar observation at 18.2 GeV in Cu+Au collisions [14]. The LHCb collaboration, on the other hand, has not found any evidence in the $\Upsilon(1S)$ $\mu^-$ $\mu^+$ invariant mass spectrum [15]. In the invariant mass distributions $e^+e^- \to \Upsilon(nS)\pi^+\pi^-$, $n = 1, 2, 3$ and $e^+e^- \to h_b(mP)\pi^+\pi^-$, $m = 1, 2$, the Belle collaboration reported two charged bottomonium-like resonances $Z_b(10610)$ and $Z_b(10650)$,(hence referred to as $Z_b$ and $Z'_b$) [16, 17].

This article's primary emphasis is on investigating the mass-spectra of all-bottom tetraquark states $[bb][\bar{b}\bar{b}]$, which we will refer to as $T_{4b}$, as well as the double bottom tetraquark states $bq\bar{b}\bar{q}$, (q=u,d) in a non relativistic model. The detail analysis of this work can be found in our recent article [11].

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## Theoretical Approach

Tetraquarks are made up of a diquark $[QQ]$ and an antidiquark $[\bar{Q}\bar{Q}]$ in color antitriplet $\bar{\mathbf{3}}$ and triplet $\mathbf{3}$ configurations respectively, that are held together by colour forces [18–20]. The diquark $[QQ]$ and antidiquark $[\bar{Q}\bar{Q}]$ are made up of two quarks (antiquarks) in antitriplet (triplet) color states [21].
We have utilized the cornell-like potential $V_{C+L}(r)$, which consists of a coulomb term governing gluonic interaction and a linear term governing quark confinement [18].

$$V_{C+L}(r) = \frac{k_s\alpha_s}{r} + br \tag{1}$$

The central potential also includes the non-perturbative form of relativistic mass correction $V^1(r)$ which is not yet known, but leading order perturbation theory [22–25] and yields term;

$$V^1(r) = -\frac{C_F C_A}{4}\frac{\alpha_s^2}{(r)^2} \tag{2}$$

where $C_F = \frac{4}{3}$ and $C_A = 3$ are the Casimir charges of the fundamental and the adjoint representation respectively [22]. The spin-spin interaction is included pertubatively in the central potential [18], which gives;

$$V_{SS}(r) = C_{SS}(r) S_1 \cdot S_2, \tag{3}$$

The mass-spectra of $T_{4b}$ and $bq\bar{b}\bar{q}$ tetraquarks states have been calculated by;

$$M_{QQ\bar{Q}\bar{Q}} = m_{QQ} + m_{\bar{Q}\bar{Q}} + E_{[QQ][\bar{Q}\bar{Q}]} + \langle V^1(r)\rangle \tag{4}$$

## Results and Discussion

The masses of low-lying S-wave $T_{4b}$ and $bq\bar{b}\bar{q}$ states are anticipated to be in the range of 18-20 GeV and 10-11 GeV, respectively [26], in

TABLE I: The mass-spectra of S-wave hidden bottom tetraquarks. Parameters are taken from recent updated PDG [27].

| $N^{2S+1}L_J$ | $J^{PC}$ | $M_{bb\bar{b}\bar{b}}$ | $M_{bq\bar{b}\bar{q}}$ |
|---|---|---|---|
| $1^1S_0$ | $0^{++}$ | 18749 | 10429 |
| $1^3S_1$ | $1^{+-}$ | 18764 | 10454 |
| $1^5S_2$ | $2^{++}$ | 18792 | 10505 |
| $2^1S_0$ | $0^{++}$ | 19914 | 10987 |
| $2^3S_1$ | $1^{+-}$ | 19416 | 10995 |
| $2^5S_2$ | $2^{++}$ | 19421 | 11009 |

the current study, the masses are also found to be in this range. The masses of S-wave heavy-light bottom tetraquark states $bq\bar{b}\bar{q}$, are in good agreement with $B^{\pm}B^{\pm}$, $B^{\pm}B^{*}$, and $B^{*}B^{*}$ meson thresholds [27], with a difference of less than 200 MeV between the two meson thresholds and the model's mass ($m_i^f$). The two most discussed bottom resonances, $Z_b(10610)$ and $Z_b(10650)$, both with ($1^{+-}$), may be recognised as possible candidates for $bq\bar{b}\bar{q}$ states [17], which have a mass variation of 150 MeV from the model's mass ($m_i^f$).

Due to the fact that fully bottom tetraquark states $bb\bar{b}\bar{b}$ are heavier than heavy-light tetraquark states ($bq\bar{b}\bar{q}$), and they are likely to be recognised below two meson thresholds [27], namely $2\eta_b$, $2\Upsilon$ or $\eta_b\Upsilon$ with masses ranging from 18.7 GeV to 19 GeV. Our findings are in excellent accord with other non-relativistic models and other studies cited in the literature [19, 28, 29].

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