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B-MESON MOLECULES MASS SPECTRUM

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Abstract. In this work, the structural properties of B-meson molecules have been calculated within the cluster model and harmonic oscillator representation method while the bound state properties have been calculated using quanto-molecular type potential, which is able to describe and calculate the mass and energy spectra of multi-cluster colored particles. From our results, the obtained mass spectra of hadron molecules show that the bonding states of meson-meson state is mainly contributed by two hadronic clusters like chemical molecule that contained two atoms. These hadronic clusters can be same and also can be different that partially formed by the meson-meson, baryon-baryon and meson-baryon. The obtained result calculations for BB-meson systems show an excellent agreement when compared with available experimental data and theoretical which have used different methods.

Keywords: mass spectrum, quanto-molecular potential, BB-mesonic states, exotic states.

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1. INTRODUCTION

The interactions binding the BB-hadron molecules are described by quanto-molecular type potential as these exotic states are been studied under framework of other model (Törnqvist, 1993),(L.Mainani, 2005), (Barnes, Close, & Swanson, 1995), (Weinstein & Isgur, 1983), (Isgur N., 1985). All of models are successful for BB-molecules' energy and mass spectra predictions at the different sectors and different type of hadron molecules. In this article the mass spectra BB-exotic hadron molecules are calculated by using oscillator representation and operator ladder methods(Schroeder, 2016), (Jahanshir, 2015), (Efimov, 1989).

2. THEORETICAL FRAMEWORK

The oscillator representation and operator ladder methods for the mass of bounding states are used here with the molecular type potential model for BB-hadron molecules.

Therefore, the mass spectra of BB-systems of meson-mesonic states are studied with the nonrelativistic Hamiltonian for the systems that was formulated in 198 9(Efimov, 1989).
The ground state masse of BB-hadron molecules is determined and calculated. Our start point for combining QCD and QFT is the asymptotic behavior of the loop function in the external scalar field theory with the strong interaction and transformation of tetrquark (Monemzadeh, Tazimi, & Sadeghi, 2015), (Meng, Li, & Ping, 2014) states to BB-mesons state(Angelo Esposito, 2013), (Zouzou, Silvestre-Brac, Gignoux, & Richard, 1986), (Kim, Cheoun, & Oh, 2014).

The mass of the BB-systems are defined through the asymptotic behavior loop function at the large distances, so if one finds the loop function then the mass of bound state and other characteristics may be defined easily with quark-molecular potential.

$$W_{B-B}(r) \cong -\frac{k_{mol}}{r} e^{-\frac{h^2 r^2}{2}} \qquad (1)$$

(k_{mol}) is the residual strength of the strong interaction coupling and (h) is the effective color screening parameters of confined gluon.

We found the energy spectrum of quark-molecular potential model. The mass spectrum of BB-systems with the masses $\left(m_B = m_{B_1} = m_{B_2}\right)$ are

$$M_{B-B} = 2\sqrt{m_B^2 + 0.3\frac{dh^2}{r^2}\frac{\Gamma(3r+1)}{\Gamma(3r)}} - \qquad (2)$$

$$-1.5hk_{mol}\frac{\Gamma(2r)\Gamma^{0.5}(3r+1)}{\Gamma(3r)\Gamma^{0.5}(r+1)} e^{-1.18h^4\frac{\Gamma^{0.5}(3r+1)}{\Gamma^{0.5}(r+1)}}$$

and the constituent mass (m) we get:(Yazarloo & Mehraban, 2017)

$$m = \frac{m_{B_1}.m_{B_2}}{m_{B_1} + m_{B_2}} \qquad (3)$$

Where

$$m_{B1} = \sqrt{m^2{}_{B1} + 0.052(r+1)e^{\frac{s^2 G(2r)}{r\, G(3r)}}}$$

$$m_{B2} = \sqrt{m^2{}_{B2} + 0.052(r+1)e^{\frac{s^2 G(2r)}{r\, G(3r)}}} \qquad (4)$$

and the binding energy (E_{bin}) of B-meson Molecules read

$$E_{bin} = M_{B-B} - m_{B_1} - m_{B_2} \qquad (5)$$

Theoretical presentation and predictions shown here are compared with the experimentally and theoretically other results known exotic molecular states (see *Table 1*). For BB-meson molecules the values of $(k_{mol} = 0.45)$ and $(h = 0.47GeV)$ are considered and the experimental masses of the mesons are(Yazarloo & Mehraban, 2017),(Nakamura, 2010),(Olive, 2014)

$$m_B = 5.280 GeV, \quad m_{B^*} = 5.324 GeV$$
$$m_{B_s^*} = 5.415 GeV, \quad m_{B_s} = 5.366 GeV$$

3. RESULTS AND CONCLUSION

In summary, we studied the structural and theoretical properties of hadron molecules (BB-mesons) underground states characteristic based QCD and QFT principles calculations. It is observed that muli clusters hadronic states show a molecular formation with the molecular hadronic type potential.

These data are useful to develop a continuum description and comparison which is suitable for tetraquark as a continuous/integrated system and two separated pairs of colored particles as two clusters i.e. meson-meson. It was found that the calculated masses of BB-hadron molecules just depend on the residual strength of the strong interaction coupling and the effective color screening parameters of confined gluon and the parameter (r) where the variable $\left(r = r(q^{2r})\right)$ and identify the transformed equation with a Schrödinger equation in the space with different dimension.

The transition in the radial Schrödinger equation to higher dimensions from the general point of view was considered earlier. Thus, the calculation of the wave function would be equivalent to the calculation of the ground state wave function of a modified Hamiltonian in another dimension. Moreover, the wave functions in this new auxiliary space should have the oscillator Gaussian asymptotic behavior.

Table 1: Masses of exotic hadron molecules (di-mesonic molecule)

B-meson molecules	M_{B-B}	$M_{theor.}$	$M_{exp.}$
$B - \bar{B}$	10.4236	10.577 Smruti Patel, Manan Shah, Arpit Parmar, 2013)	-
$B - \bar{B}^*$	10.4675	10.623 Smruti Patel, Manan Shah, Arpit Parmar, 2013)	10.607 (Bondar et al., 2012)
$B^* - \bar{B}^*$	10.5113	10.670 Smruti Patel, Manan Shah, Arpit Parmar, 2013)	10.652 (Bondar et al., 2012)
$B_s^* - \bar{B}_s^*$	10.6927	10.6502 (Rai, Shah, & Toshniwal, 2013)	10.680 (B.Silvestre-Brac & Semay, 1993)
$B_s - B_s^*$	10.6439	-	-
$B_s - B$	10.5951	10.6502 (Rai et al., 2013)	10.6502 (B.Silvestre-Brac & Semay, 1993)

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