Study of t quarkonium system with energy dependent potential

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Introduction

In 2007 T. Altonen et al presented new measurement of top quark mass in all Hadronic Channel in $p\bar{p}$ collision at CDF II. In the standard model (SM) the top quark is a weak isospin partner of the b quark. The SM predicts the charge q the top quark to be +Ze/3 .As soon as toponium system becomes available it is however important to emphasize the interpretation of spectroscopic data of toponium. If $\Delta E_{2s\text{-}1s} \geq \Gamma_{t\bar{t}}$ then there is possibility of formation for the bound state.
As the experimental data are not yet available, our goal is to present a mass determination formula which can be directly used for top quark mass spectrum. In the present work an analytical method has been used to determine the eigen energies of bound states of the Schrodinger equation for heaviest self conjugate system $t\bar{t}$ using three dimensional harmonic oscillator with energy dependence plus inverse quadratic potential as quark interquark potential. Earlier energy dependence concept for same potential is applied for charmonium and bottonium system [2]. We set parameters ω , γ and g so as to fit predicted levels of triplet of s state w.r.t. 1s and average of 1p w.r.t. 1s [3]. By solving nonlinear energy eigen value analytically from equation (3), we get all parameters and shown in table 1.

Calculation Details

A toponium system, held together by spherically symmetric force, is described by the Schrodinger equation.

$$\left[-\frac{1}{2\mu}\vec{\nabla}^2 + V(r,E_{n,l},g)\right]\psi_{n,l,m}(r) = E_{n,l}\psi_{n,l,m}(r) \quad (1)$$

$$\mu = \frac{m_q m_{\bar{q}}}{m_q + m_{\bar{q}}}$$

The radial equation

$$u'' + 2\mu\left[E - V(r) - \frac{l(l+1)}{2\mu r^2}\right]u(r) = 0$$

Where u(r) = rR (r) is the radial wave function and l the orbital angular momentum quantum number. (Notation $\hbar = c = 1$ is considered)

The energy dependent interquark potential chosen is

$$V(r,E_{n,l},g) = \frac{1}{2}\mu\omega^2 r^2(1+\gamma E) + \frac{g}{r^2} \quad (2)$$

First term is the energy dependent harmonic oscillator and second term proportional to $1/r^2$ is added to improve the short term interaction. The analytical expression for the energy eigen values $E_{n,l}$ is obtained as

$$E_{n,l} = \frac{-a^2\omega^2\gamma^2}{8} + \frac{a\omega}{8}\sqrt{a^2\omega^2\gamma^2 + 16} \quad (3)$$

Where $a = 4n - 2 + \sqrt{(2l+1)^2 + 8\mu g}$

By solving nonlinear energy eigen value analytically from equation (3), we get all parameters and shown in **table1** for different mass of top quark. It is seen that γ and g are negative for all m_t.

The energy eigenvalues are dependent on three parameters α γ and g. Calculated level spacings for different s states w.r.t. 1s states ($E_{n,l}$) are plotted with the variation of mass in **fig 1** for energy dependent ($\gamma \neq 0$) and for independent case (γ=0) . Topponium spectroscopy is studied for several values of top quark mass
20 GeV< m_t<60 GeV.

Table1: Spectroscopic parameters for different m_t.

Mass (GeV)	α (fm^{-1})	γ (GeV^{-1})	g (GeV^{-1})
20	.299	- .432	-1.160×10^{-2}
30	.326	- .433	-7.825×10^{-3}
40	.350	- .434	-6.056×10^{-3}
50	.369	- .425	-4.883×10^{-3}
60	.379	- .411	-4.149×10^{-3}

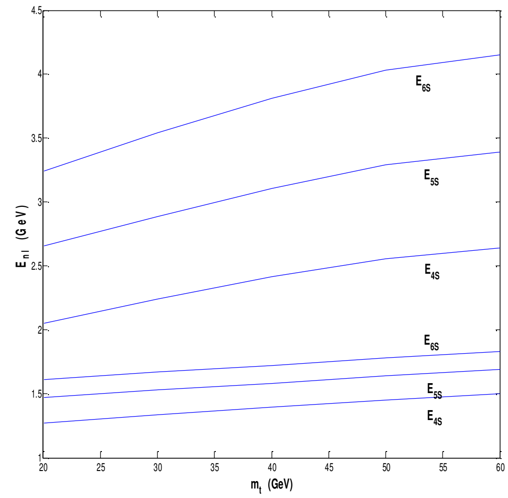

Fig1: t quark mass dependence of level spacing w.r.t. to 1s of $t\bar{t}$ system in the present potential. Solid lines refer γ=0 case and dashed line refers $\gamma \neq 0$ cases.

Conclusion

We predicted the yet to be observed hypothetical $t\bar{t}$ meson using new potential for variation of mass. Analytically solved energy levels are exhibited for energy dependent and energy independent case. We note that the energy dependence of the confining potential provides a natural mechanism for the saturation of the spectra. It is seen that on applying energy dependence we get level spacing becomes less as compared to energy independent case as already shown in charmonium and bottonium system [2].

References

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