Variation of Top Quark Mass (m_t) with Quantum Chromodynamics (QCD) Scale Parameter a and Down Quark (m_d)

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***Abstract*- Variation of top quark mass m_t with QCD scale parameter Λ = 0.1 GeV, Λ=0.15 GeV and Λ=0.3 GeV with down quark m_d (0.3285, 0.3286….0.3305) GeV. Variation of m_t and m_d was reported. The top quark is a member of the third generation quark doublet in standard model of particle physics. Although the standard model has shown incredible successes with regard to experiments, the top quark remained elusive for quite a long time and these were several predictions on top quark mass around 120 GeV or above. The central value extracted from precision electroweak measurement at LEP suggest that the top quark mass can be taken to be about 174 GeV. The purpose of the present work is to estimate discuss the top quark mass in QCD motivated potential model using the empirical result $M_V^2 - M_P^2$ is a constant (≈0.56 GeV²) for non-self conjugate mesons containing one light and one heavy quark.**

Keywords: Mass, QCD scale parameters.

INTRODUCTION

The top quark is a member of the third generation quark doublet model of particle physics. Although the standard model has incredible success with regard to experiments, the top quark remained elusive for quite a long time [1,2] and these were several predictions on top quark mass around 120 GeV or above [3]. The central value extracted from precision electroweak measurement at LEP [4] suggest that the top quark mass [5] can be taken to be about 174 GeV. It is interesting to see whether it is possible to obtain such a high value for the top mass with the QCD based potential. The purpose of the present work is to estimate discuss the top quark mass in quantum chromodynamics (QCD) motivated potential model using the emperical result [6] $M_v^2 - M_p^2$ is a constant $\left(\approx 0.56\, GeV^2\right)$ for non-self conjugate mesons containing one light and one heavy quark.

Mass of the basis of the empirical relation $M_V^2 - M_P^2 \approx 0.56,$ where M_V and M_P stand for mass of vector and pseudo-scalar meson, respectively. It is assumed that the mass of top quark should be much greater than that of *s* quark. This quantum chromodynamic potential (QCD) model consists of a colour coulomb potential and a linear potential with spin-dependent forces obtained from the reduction of the Bethe-Salpeter Kernel into Breit interaction. The confinement potential is assumed to be scalar-vector admixture with dominance of scalar interaction. The top quark mass comes out to be 179.991 GeV for the QCD scale parameter Λ=0.1 GeV, S. quark mass m_s=.450 Gev and $M_V^2 - M_P^2 = 0.45$ GeV².

The model consists of a linear and a colour-coulomb potential along with spin dependent potential obtained from the reduction of Bethe-Salpeter Kernel into Breit interaction. The model has been found to be successful in its application quarkonium spectroscopy [7]. This model is simple. It requires minimum number of parameters and has high correlative powers. We apply this model to the determination of top quark mass on the basis of the following assumptions:

(i) $M_V^2 - M_P^2 \approx 0.45$ GeV²

(ii) The top quark mass $\left(m_t\right)$ is very large compared to s-quark mass $\left(m_s\right)$, so that the reduced mass for $T\left(t\bar{s}\right)$ meson is approximately equal to $\left(m_s\right)$.

(iii) The spin dependent correction terms can be neglected in the sum $M_V + M_P$.

The top quark is the heaviest standard model (SM) particle found so far, with a mass m_t ~175 GeV ~ $V_H/\sqrt{2}$ (V_H is vacuum expectation of Higgs Field) and with a Yu-Kawa coupling very close to unity. This fact is probably related to a nature of the electroweak symmetry-breaking-mechanism. In the SM the top quark is very heavy but at the same time is assumed to be point like. Because of these and other unusual top quark properties, possible deviations from SM predictions might be first manifest in the top quark sector.

Top quark being produced singly through the electroweak interaction give a unique opportunity to investigate a number of delicate top quark properties.

THEORY

***Variation of top quark mass**:*

It is assumed that start with the expressions for the masses of vector and pseudo-scalar mesons given by [8].

$$M_V = m_1 + m_2 + C_1\,\bar{\mu}^{1/3} + \frac{1}{6m_1m_2}\left(\frac{16}{3}\pi\alpha_s\left|\Psi(0)\right|^2 + \frac{C_2}{10}\mu^{1/3}\right)$$

…(1)

and

$$M_P = m_1 + m_2 + C_1\,\bar{\mu}^{1/3} - \frac{1}{2m_1m_2}\left(\frac{16}{3}\pi\,\alpha_s\left|\Psi(0)\right|^2 + \frac{C_2}{10}\mu^{1/3}\right)$$

…(2)

Hence

$$M_V - M_P = \frac{2}{3m_1m_2}\left(\frac{16}{3}\mu\,\alpha_s\left|\Psi(0)\right|^2 + \frac{C_2}{10}\mu^{1/3}\right)$$

For a meson containg a very heavy quark like the top, it is a good approximation to neglect the spin dependent term in $M_V + M_P$, so that

$$M_V + M_P \approx 2\left(m_1 + m_2\right) + 2\,C_1\,\mu^{-1/3}$$

The assumptions above would not effect the result significantly but would simplify the calculations very much. A similar but rather crude approximation was adopted in the work of Frank and O' Donnel [9]. With $\left|\Psi(0)\right|^2 = ba\mu$ obtained from scaling (10) and by multiplying equation (4) by equation (3). It is assumed that obtained an expression for $M_V^2 - M_p^2$ which can written in the form –

$$\frac{2C_2}{15}\mu^{-2/3} + \frac{64\,C_1\,\pi\,\alpha_s\,ba}{9\,m_1\,m_2} + \frac{2C_1C_2\,\mu^{-1}}{15\left(m_1+m_2\right)} + \frac{64}{9}\pi\,\alpha_s ba - \left(M_V^2 - M_p^2\right) = 0$$

…(5)

For a meson containing *t* and *S* quarks. The assumptions $m_t >> m_s$ gives $\mu = m_s$. Hence for *T* meson, equation (5) becomes

$$\alpha\, m_t^2 + \beta\, m_t + \gamma = 0$$

The solution of which is

$$m_t = \frac{\beta \pm \sqrt{\beta^2 - 4\alpha\gamma}}{2\alpha}$$

where

$$\alpha = \frac{2C_2}{15}\left(m_s\right)^{-2/3} + \frac{64}{9}\pi\,\alpha_s\,ba - \left(M_V^2 - M_p^2\right)$$

$$\beta = \frac{2C_2}{15}\left(m_s\right)^{1/3} + \frac{64\pi\,\alpha_s\,ba\,C_1}{9}\times\left(m_s\right)^{-1/3} + \frac{2C_1\,C_2}{15}\left(m_s\right)^{-1}$$

$$+\left\{\frac{64\pi\,\alpha_s\,ba}{9} - \left(M_V^2 - M_p^2\right)\right\}m_s$$

…(9)

$$\gamma = \frac{64\pi\,\alpha_s\,ba\,C_1}{9}\left(m_s\right)^{2/3}$$

…(10)

The parameters required for this analysis are obtained from Ref. [8]. These are as follows- m_s=0.450, C_1= - 23.1265, C_2= - 2.12419, *b*=0.95388, $a = \frac{1}{5}$ (all in GeV units) and QCD scale parameter Λ 0.100 Gev α_s is calculated using the formula [7].

$$\alpha_s = \frac{12\pi}{\left(33 - 2\,n_f\right)L_n\left(Q^2/\Lambda^2\right)}$$

Here $Q = 4s$ and $n_f = 3$ [11]. Equation (7) in conjuction with equns (8-11) and the parameters given above give the value of m_t. …(3)

RESULTS AND DISCUSSION

The results of our calculations are presented in Table-1,

The variation of top quark mass with the QCD scale parameter Λ and m_s for $M_V^2 - M_p^2 = 0.45\,GeV^2$ are presented in 1. In the column first of the Table values of mass of s-quarks are presented which vary from 0.440 to 0.460 GeV. In column second, third, fourth calculated values of mass of top quarks are presented with QCD scale parameter Λ=0.1 GeV, Λ=0.15 GeV and Λ=0.3 GeV respectively. From table we find that the top quark mass is 179.991 GeV for s-quark mass equal to 0.450 GeV in the case of Λ=0.1 GeV, $M_V^2 - M_p^2 = 0.45\,GeV^2$. This value of top quark mass is in experimental agreement [12]. The table shows that the values 0.15 GeV and 0.3 GeV for Λ are not possible for m_s = 0.440 to 0.460 GeV. The Fermi lab experiments suggests that the value Λ=0.1 GeV and m_s = 0.450 GeV are possible choice. Thus, we fix the parameters like s-quark mass and QCD scale parameter. We find that using the standard value of the parameters like Λ, m_s and the experimental value of $M_V^2 - M_p^2$, the top quark mass estimated from the potential model matches well with the recently observed value. The value of the top quark mass comes out to be 179.991 GeV, which tallies with the value of obtained from experimental results [12,13]. Thus we find that it is possible to obtain the present fermilab prediction on top quark from a QCD based potential model.

…(4) …(6) …(7)

Table-1: Variation of top quark mass m_t with QCD scale parameter Λ and m_s. …(8)

S.No.	m_s (GeV)	m_t		
		Λ=0.1 GeV	Λ=0.15 GeV	Λ=0.3 GeV
1	0.440	194.502	84.601	49.506
2	0.441	192.785	84.329	49.453
3	0.442	191.313	84.092	49.400
4	0.443	189.876	83.885	49.339
5	0.444	188.246	83.683	49.285
6	0.445	186.847	83. 478	49.231
7	0.446	185.471	83.246	49.177
8	0.447	183.921	83.043	49.118
9	0.448	182.590	82.842	49.065
10	0.449	181.280	82.642	49.010
11	0.450	179.991	82.411	48.950
12	0.451	178.721	82.213	48.897
13	0.452	177.470	82.016	48.843
14	0.453	176.238	81.820	48.790
15	0.454	175.025	81.625	48.737
16	0.455	173.829	81.431	48.684
17	0.456	172.641	81.238	48.631
18	0.457	172.556	81.047	48.578
19	0.458	170.326	80.856	48.525
20	0.459	169.199	80.663	48.473
21	0.460	168.078	80.489	48.420

CONCLUSION

The quark mass are m_s = 0.450 GeV, m_t = 179.991 GeV.

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