Mass and Regge Trajectories for Heavy Pentaquarks

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Abstract: In the present work masses of higher states of heavy pentaquarks have been evaluated in the framework of mass loaded flux tube model where one heavy quark (c or b) and the two diquarks are connected by a flux tube with diquark as composite fermion. The Regge trajectories of charm and bottom pentaquarks have also been investigated. The masses of the ground states of heavy pentaquarks have been extracted from (M^2, L) plot. The masses are found to be in good agreement with other estimates.

1. Introduction:

The concept of multiquark state is as old as the conventional quark model of hadrons [1]. In an analogy with the θ^+ pentaquark, theoretical prediction of heavy pentaquarks (θ_c^0, θ_b^+) was initiated by Jaffe and Wilczek [2] and others [3-6]. The masses of higher states of heavy pentaquarks have been evaluated considering diquark-diquark-antiquark configuration in the framework of mass loaded flux tube model with diquark as composite fermion.

2. Composite Fermion (CF) Model of Diquark:

Following the work of ref.[7] the expression for the quasi particle mass in a gauge invariant system starting from the Hamiltonian of a composite fermion with a momentum cut off Λ can be expressed as:

$$\frac{1}{m_D^*} = \frac{1}{m_{q_1} + m_{q_2}}(1 + \frac{\Lambda^4}{2p_F^4}) \qquad (1)$$

Where m_D^* is the mass of the diquark, m_{q_1}, m_{q_2} are the constituent masses of the quark flavours constituting the diquark, p_F is fermi momentum and Λ is a cut off parameter. The diquark masses have been estimated using the expression (1).

3. Mass loaded flux tube and Regge trajectories:

In semi-classical mass loaded flux tube model The mass formula runs as [8]:

$$E = M_{c,b} + \sqrt{\frac{\sigma L}{2}} + 2^{\frac{1}{4}} k L^{-\frac{1}{4}} \mu_D^{\frac{3}{2}} + a\mathbf{L}\cdot\mathbf{S} \qquad (2)$$

The energy of the heavy pentaquark system have been estimated for different J^P states using (2). The results are displayed in Fig 1.

The orbital excitation of the particle can be described by the Regge trajectories and has been expressed by:

$$E^2 = \alpha J \qquad (3)$$

where E is the energy at the higher states for different value of L and J is the total angular momentum. Regge slope (α) can be expressed as:

$$\alpha = \frac{1}{2\pi\sigma} \qquad (4)$$

4. Discussions:

The Regge slope (α) of charm and bottom families are found to deviate from linearity condition with $\alpha_{average} \neq 1GeV^2$, the universal accepted value. The string (σ) have also been studied and results are given in Table I.. The ground state masses of the pentaquarks have been extracted from (M^2, L) RT plot (Fig 2) and given in Table II. Results are found to be in good agreement with results available in literature.

Acknowledgement

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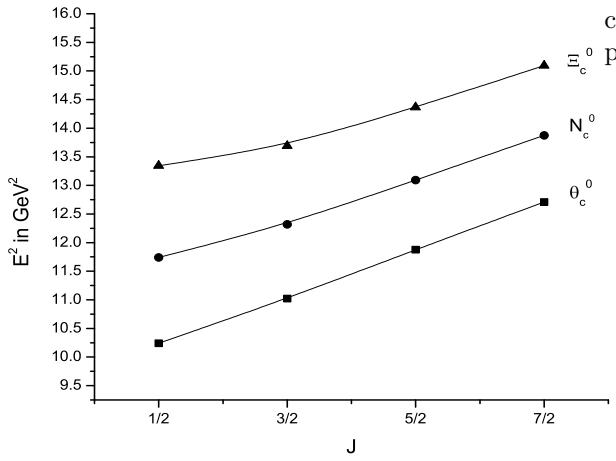

Figure 1: The Regge trajectories ($J - E^2$) for charm pentaquarks

Table I: Regge slope (α), string tension (σ) for charm pentaquarks extracted from Fig-1 and similar plot done for bottom, results shown in Table-I.

Heavy pentaquark	α (GeV^2)	σ (GeV^{-2})
θ_c^0	0.831	0.191
N_c^0	0.783	0.203
Ξ_c^0	0.726	0.219
θ_b^+	1.46	0.109
N_b^+	1.349	0.118
Ξ_b^+	1.228	0.129

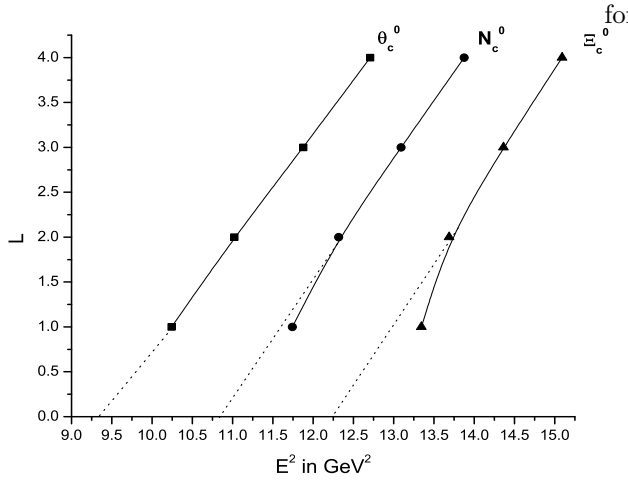

Figure 2: Energy variation (E^2) with angular momentum (l) for charm pentaquark

Table II: Ground state (L=0) mass of charm pentaquarks extracted from Fig.2 and similar plot done for bottom, results shown in Table-II .

Heavy pentaquark	*Our − work inGeV*	*Otherworks inGeV*
θ_c^0 $([ud][ud]\overline{c})$	3.061	$2.710^2, 2.990^3$ $2.902^5, 2.938 - 2.997^6$
N_c^0 $[ud][us]\overline{c}$	3.297	$2.870^2, 3.165^3$ $3.161^5, 2.860^4$
Ξ_c^0 $[us][us]\overline{c}$	3.5	$3.135^2, 3.340^3$ $3.403^5, 3.014^4$
θ_b^+ $[ud][ud]\overline{b}$	5.733	$6.050^2, 6.400^3$ $6.176^5, 6.370 - 6.422^6$
N_b^+ $[ud][us]\overline{b}$	5.958	$6.210^2, 6.570^3$ $6.442^5, 6.199^4$
Ξ_b^+ $[us][us]\overline{b}$	6.164	$6.351^2, 6.740^3$ $6.683^5, 6.351^4$