RESEARCH ARTICLE

Possible Hexaquark Explanation for the X(2370)

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Abstract

The BESIII Collaboration performed a partial wave calculation for decays of the X(2370) into γ K_s^0 K_s^0 η'. The decays exhibit a resonance X(2370) that has a $J^\pi = 0^-$ assignment with a mass of 2395 MeV/c^2.

The X(2370) is modeled as a K_s^0 K_s^0 η' hexaquark state with minimal coupling between the three meson clusters. The model predicts the correct J^π value, and the calculated mass is about 15% less than the experimental value.

1. Introduction

Based on ~1x10^{10} J/Ψ events, The BESIII Collaboration performed a partial wave calculation for decays of the X(2370) particle into γ K_s^0 K_s^0 η'[1]. The decays exhibit a resonance X(2370) that has a $J^\pi = 0^-$ assignment with a mass of 2395 MeV/c^2. A statistical significance of the X(2370) is determined to be greater than 11.7σ. Ref. 1 notes that these results are in agreement with the characteristics of the lightest pseudoscalar glueball.

This paper investigates the X(2370) in terms of a K_s^0 K_s^0 η' hexaquark modeled as a three meson cluster. The meson masses are derived from the semiempirical model of Zel'dovich and Sakharov[2][3]. This model was previously used to describe other hexaquark states[4][5].

2. Model Formulation

Within the scope of the first-order mass formula, the X(2370) is modeled as three coupled meson clusters with zero angular momentum between the clusters. The total J^π of the hexaquark is

$$J^\pi = J^\pi(K_S^0) \times 0 \times J^\pi(K_S^0) \times 0 \times J^\pi(\eta') \qquad (1)$$

Inserting the spin and parity values[6] of the included states yields the final hexaquark value of 0^- that agrees with the experimental value[1]

$$J^\pi = 0^- \times 0 \times 0^- \times 0 \times 0^- = 0^- \qquad (2)$$

The meson mass formula is given by Zel'dovich and Sakharov[2][3]

$$M = \delta_m + m_1 + m_2 + b_m[(m_0)^2/(m_1 m_2)]\sigma_1 \cdot \sigma_2 \qquad (3)$$

where the labels 1 and 2 refer to the quarks comprising the meson, δ_m has the value 40 MeV/c^2, b_m is 615 MeV/c^2, and the product of the quark spin vectors ($\sigma_1 \cdot \sigma_2$) is -3/4 for pseudoscalar mesons[2][3].

Eq. 3 incorporates effective quark masses determined for d, u, s, c, b, and t quarks[7]. These quarks have the values 340, 336, 486, 1550, 4730, and 177000 MeV/c^2, respectively[7]. Incorporating the Standard Model convention[6][7], the quarks are grouped into three generations: [d(-1/3), u(+2/3)], [s(-1/3), c(+2/3)], and [b(-1/3), t(+2/3)][6][7]. The quark charges are given within the parentheses in terms of the unit charge e,

Eq. 2 assumes that the mesons reside in their ground state. If an excited state is included in the analysis, the difference between the excited and ground state masses must be considered.

Within the scope of the first order hexaquark model[4][8][9][5], the mass of the X(2370) is given by

$$M[X(2370)] = M(K_s^0) + M(K_s^0) + M(\eta) + \Delta(\eta' - \eta) + \Phi_1 + \Phi_2 \qquad (4)$$

where $\Delta(\eta' - \eta)$ is the difference between the η' and η masses[6]. In Eq. 4, $\mathbf{\Phi_1}$ represents the interaction between the K_s^0 mesons and $\mathbf{\Phi_2}$ is the interaction between the K_s^0 and η' mesons. The first-order model assumes the mesons are weakly bound and $\mathbf{\Phi_1}$ and $\mathbf{\Phi_2}$ are much less than the meson masses.

3. Results and Discussion

The first order mass formula of Eq. 4 yields a mass of 2051 MeV/c^2 for the X(2370). This result is about 15% less than the measured value of 2395 MeV/c^2[1].

The model also yields the correct spin and parity for the X(2370).

The model’s mass underestimate is expected because the photon’s energy in the final state is not included. In addition, there is considerable uncertainty in the assumed quark masses[6][7].

4. Conclusions

The 0^- X(2370) resonance was observed by the BESIII Collaboration in J/Ψ decays into γ K_s^0 K_s^0 η'. A first-order hexaquark model was utilized to describe this state. The first order mass formula yields a mass of 2051 MeV/c^2 for the X(2370). This result is about 15% smaller than the measured value of 2395 MeV/c^2. The model also yields the correct spin and parity for the X(2370).

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