1$^{-+}\pi_1 (1400)$ cannot be hybrid meson

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Abstract

We expose arguments concerning the $\pi_1 (1400)$, observed decaying into $\eta \pi$ and claimed to be an exotic meson. We conclude that this object cannot be a $q\bar{q}g$ hybrid meson.

1 Introduction

From experimental efforts at IHEP, KEK, CERN and BNL, several isovector $J^{PC}=1^{-+}$ exotic mesons have been identified. In this note we focus on the resonance $\pi_1 (1400)$ claimed to be decaying into $\eta \pi$. More detailed data are summarized in table 1[1]. This discovery would be the first resonant state with really exotic quantum numbers since no $q\bar{q}$ system can have $J^{PC}=1^{-+}$.

No glueball interpretation can be retained when the resonance has isospin 1. Thus, we are left with two possibilities: the hybrid state $q\bar{q}g$ or the diquonium $qqq$. Hybrids have been studied, using the quark model with constituent gluon[2−6], the flux-tube model[7], using many body Coulomb gauge Hamiltonian[8], QCD sum rules[9], the MIT bag model[10], and lattice-QCD[11]. These models predict that the lightest hybrid mesons will be $J^{PC}=1^{-+}$ meson, in 1.4-2.1 GeV mass range. Decay process of the hybrid meson is studied in the framework of the first four models.

Diquonium was the subject of several works[3,12,13].

2 $\pi_1 (1400)$ cannot be hybrid meson

Indeed, several arguments support this idea:

i) One difficulty with interpreting this state as a hybrid is the $\sim 500$-$600$ MeV mass difference between the $\pi_1 (1400)$ mass and flux tube, LGT and MBCGH estimates of mass $\sim 1.9$-$2.1$ GeV. In other hand, it appears difficult to

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accommodate the \( \pi_1(1400) \) as hybrid state in the context of recent QCD sum rules calculations, the lightest hybrid in this case being approximately with mass 1.6 GeV. Although the range mass values 1.3-1.7 obtained from bag models are believed to suffer from parameter uncertainties\cite{14}.

\( ii) \) The studies of the decay mechanism\cite{7,9} predict the suppression of \( 1^- \text{(hybrid)} \rightarrow \eta\pi \). This selection rule was generalized in a quite model independent way\cite{4}. In spite of our calculations of hybrid masses which yield exotic \( 1^- \) mesons with mass around 1.4 GeV (QE hybrid)\cite{6} consistent with the experimental \( \pi_1(1400) \) the selection rule cited above excludes interpreting this resonance as QE-mode hybrid.

3 The \( q\bar{q}q\bar{q} \) possibility

The quantum numbers of \( \pi_1(1400) \) states is rather typical for P-wave \( q\bar{q}q\bar{q} \) states, so it is possible to interpret them as light \( q\bar{q}q\bar{q} \).

But here are some difficulties:

\( i) \) Mass results of \( 1^- \) \( q\bar{q}q\bar{q} \) are around 1.7 GeV and Bag model does not predict the low-laying P-wave \( q\bar{q}q\bar{q} \) states with \( I=1 \) as \( \pi_1(1400) \).\cite{13}

\( ii) \) The selection rule prevents the decay of the P-wave \( q\bar{q}q\bar{q} \) into \( \eta\pi \).\cite{3}

4 An alternative solution!

Authors of \cite{15} exploit the possibility to construct quark bilinear operator which have \( J^{PC}=1^- \) exotic numbers. A numerical solutions of Bethe-Salpeter equation yield two exotic \( 1^- \) mesons with masses of 1.439 and 1.498 GeV in good agreement with the experimental \( \pi_1(1400) \). Their approach does introduce explicitly gluon degrees of freedom. This may provide additional decay channels for exotic mesons, such as \( \pi_1(1400) \rightarrow \eta\pi \), that would normally be suppressed according to OZI rule\cite{4}.

But the odd-time-parity amplitudes associated with the exotic mesons corresponding to bound states whose BS amplitudes has negative normalizations. The authors claim that this is not enough to disregard the BS equation in these channels.

5 Do \( \pi_1(1400) \) really an exotic resonance?

In the work \cite{16}, since the attempts to describe the mass dependence of the amplitude and phase motion with respect to the D wave as Breit-Wigner resonance are problematic; the authors propose an alternative description of the mass dependent P-wave amplitude and phase that does not require the existence of an exotic meson but is consistent with \( \eta\pi \) re-scattering. In other hand, ”there are possibility that the structure observed by Crystal Barrel at 1400 is due to the rapid opening of the threshold for the process \( \eta\pi \rightarrow b_1\pi \) (or \( f_1\pi \)), since that the threshold for \( b_1(1235)\pi \) is about 1370 MeV. On the Agrand diagram, the
\( \eta \pi \) amplitude will turn rapidly though 90° if this channel opens, and will look as resonance"\(^{[17]} \).

6 Conclusion

Taking into account the arguments cited above, \( \pi_1(1400) \) (if it has really exotic quantum numbers) could not be an hybrid meson.

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7 References

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Table 1: detailed data for resonance $\pi_1(1400)^{(1)}$