Options for the SELEX state $D_{sJ}^+(2632)$

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We consider possible assignments for the $D_{sJ}^+(2632)$, which was recently reported in $D_s^+\eta$ and D^0K^+ final states by the SELEX Collaboration at Fermilab. The most plausible quark model assignment for this state is the first radial excitation (2^3S_1) of the $c\bar{s}$ $D_s^*(2112)$, although the predicted mass and strong decay branching fractions for this assignment are not in agreement with the SELEX data. The reported dominance of $D_s\eta$ over DK appears especially problematic. An intriguing similarity to the $K^*(1414)$ is noted. 2^3S_1–$^3D_1$ configuration mixing is also considered, and we find that this effect is unlikely to resolve the branching fraction discrepancy. Other interpretations as a $c\bar{s}$-hybrid or a two-meson molecule are also considered, but appear unlikely. Thus, if this state is confirmed, it will require reconsideration of the systematics of charmed meson spectroscopy and strong decays.

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I. INTRODUCTION

The SELEX Collaboration [1] recently reported evidence for a new charm-strange meson, known as the $D_{sJ}^+(2632)$, in the final states $D_s^+\eta$ and D^0K^+. The strongest evidence for the state is in $D_s^+\eta$, from which SELEX quote a mass of M= 2635.9 ± 2.9 MeV. The D^0K^+ channel shows weaker evidence for a similar state, with a mass and total width upper limit of M= 2631.5 ± 1.9 MeV, $\Gamma < 17$ MeV, 90% *c.l.* These results led SELEX to a combined mass and total width limit of

$$M = 2632.6 \pm 1.6 \text{ MeV} \quad (1)$$

and

$$\Gamma < 17 \text{ MeV}, \quad 90\%\ c.l. \quad (2)$$

The estimated branching fraction ratio for the two observed modes is

$$\text{B.F.}(D_{sJ}^+(2632) \to D^0K^+/D_s^+\eta) = 0.16 \pm 0.06\ . \quad (3)$$

Assuming that the observation of a state decaying strongly into at least one of these modes is correct, this implies the existence of a relatively narrow resonance with a minimum quark content of $c\bar{s}$ and natural spin-parity.

If we restrict our initial consideration to conventional $c\bar{s}$ quark model states which were predicted by Godfrey and Isgur [2] to lie within 200 MeV of the reported $D_{sJ}^+(2632)$ mass, we find only one possible assignment which does not currently have an experimental candidate, the 2^3S_1 radial excitation of the $c\bar{s}$ $D_s^*(2112)$. (The 2^1S_0 state is excluded by parity. The $^3P_2$ state is consistent with the signal seen by SELEX at 2570 MeV in D^0K^+, which is absent in their $D_s\eta$ data; this is in accord with expectations from phase space for such a state.) Our rather generous mass constraint is motivated by the recent observation of the $D_{sJ}^+(2317)$ [3], which lies about 150 MeV below quark model expectations. The SELEX state is similarly about 100 MeV below the Godfrey-Isgur prediction of 2.73 GeV for the 2^3S_1 $c\bar{s}$ state. Other quark model predictions for the 2^3S_1 $c\bar{s}$ mass are in the range 2.71-2.76 GeV [4, 5, 6, 7], with one prediction of 2.81 GeV [8]. The next closest natural spin-parity $c\bar{s}$ state with no experimental candidate is the $^3D_1$, which is predicted at 2.90 GeV by Godfrey and Isgur, about 270 MeV above the $D_{sJ}^+(2632)$. Thus 2^3S_1 $c\bar{s}$ appears to be the most plausible quarkonium assignment for the $D_{sJ}^+(2632)$. (This conclusion has been reached independently by Chao[9].) The decay pattern of this state could also in principle be significantly modified by 2^3S_1–$^3D_1$ configuration mixing, which we will consider in our discussion.

Although the predicted Godfrey-Isgur mass of 2.73 GeV for the 2^3S_1 $c\bar{s}$ state is somewhat higher than observed for the $D_{sJ}^+(2632)$, we note that several recent candidates for light $q\bar{q}$ radial excitations also have rather lower masses than predicted by this model. Examples include the 2P $n\bar{n}$ ($n = u, d$) candidates $a_1(1640)$ and $a_2(1700)$ [10], which were predicted to be at 1820 MeV. It may be that this model overestimates the energy gap for radial excitation of mesons with small reduced $q\bar{q}$ mass; these states may be displaced in mass by additional non-valence effects such as mixing with the two-meson continuum.

In the following discussion we will consider the impli-

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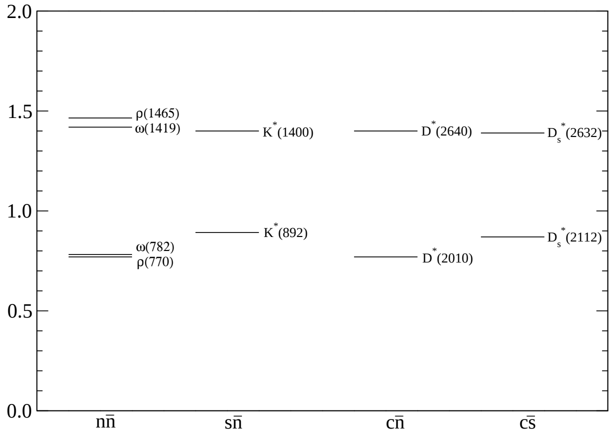

FIG. 1: The experimental spectrum of 1S and 2S vector quarkonium candidates, contrasting states with n and c quarks combined with $\bar{n}$ and $\bar{s}$ antiquarks. The charmed spectrum is shifted downwards by 1.238 GeV for comparison. Note that the 2S strange candidates $K^*(1414)$ and $D^+_{sJ}(2632)$ are roughly degenerate with their nonstrange partners.

cations of 2^3S_1 $c\bar{s}$ quark model, hybrid, and molecular assignments for the $D^+_{sJ}(2632)$ in more detail. We will find that the mass and peculiar strong branching fractions reported for this state appear inconsistent with any of these assignments.

II. THE $D^+_{sJ}(2632)$ AND THE $K^*(1414)$

It is notable that the $D^+_{sJ}(2632)$ shares several common features with the problematic excited strange vector $K^*(1414)$ [11]. The mass of the $K^*(1414)$ appears too light for a strange partner of the 2S $n\bar{n}$ candidates $\omega(1419)$ and $\rho(1465)$; these states are all roughly degenerate, unlike the 1S $K^*(892)$, $\omega(782)$ and $\rho(770)$. This is illustrated in Fig.1, which shows the striking similarity between the $n\bar{q}$ and $c\bar{q}$ spectra. The strong decay modes of the $K^*(1414)$ are also in disagreement with theoretical expectations. The $^3P_0$ decay model (see section III) predicts comparable branching fractions to πK, πK^*, ηK and ρK [11]. The LASS Collaboration [12] however reports a dominant πK^* mode, a weak πK mode (B.F. ca. 7%), and only an upper limit for ρK, $\Gamma(\rho K)/\Gamma(\pi K) < 0.17$, 95% *c.l.*. The weak ρK mode is especially surprising, since this branching fraction should equal πK^* modulo phase space differences.

Although these discrepancies do not explain the nature of the $D^+_{sJ}(2632)$, they do suggest that the $K^*(1414)$ and $D^+_{sJ}(2632)$ may be closely related; both are lighter than expected given their nominal nonstrange 2S partner radial excitations, and both show patterns of strong decays that differ considerably from the expectations of the $^3P_0$ model. Thus, what is learned about one state may be useful in understanding both.

III. QUARK MODEL $c\bar{s}$ INTERPRETATION

As stated in the introduction, the only plausible $c\bar{s}$ assignment for the $D^+_{sJ}(2632)$ is $n^{(2S+1)}L_J = 2^3S_1$, which has a predicted mass in the Godfrey-Isgur model of 2730 MeV. Allowed open-flavor decay modes for this state, assuming the SELEX mass of 2632 MeV, are DK, $D_s\eta$ and D^*K. The first two modes have two 1S pseudoscalars in the final state, and hence are related by flavor matrix elements. This relation is $\mathcal{A}(D_s^+\eta) = \sin\theta\,\mathcal{A}(D^0K^+)$, where $\mathcal{A}$ is a strong decay amplitude and $\sin\theta \approx -1/\sqrt{2}$ is the amplitude of the $s\bar{s}$ component of the η. Assuming the $^3P_0$ decay model and identical D and D^* spatial wavefunctions, the decay amplitude to D^*K is also proportional to the same function, $\mathcal{A}(D^*K) = -\sqrt{2}\,\mathcal{A}(DK)$. Thus, one expects *reduced* relative strong decay widths (summed over charge modes, but divided by the momentum-dependent decay amplitude squared) of $D^*K : DK : D_s\eta = 4 : 2 : 1$.

As a simple initial estimate of physical branching fractions, since these are all P-wave decays we may assume a p_f^3 threshold dependence for all modes, which gives expected relative branching fractions (again summed over all charge modes) of

$$\text{B.F. } (D^*K \ : \ DK \ : \ D_s\eta) \ = \ 4.2 \ : \ 7.0 \ : \ 1 \ . \qquad (4)$$

This is clearly in disagreement with the SELEX result (assuming equal D^0K^+ and D^+K^0 modes) of

$$\text{B.F. } (DK \ : \ D_s\eta) \ = \ 0.32 \pm 0.12 \ : \ 1 \ . \qquad (5)$$

These simple phase space arguments can sometimes be misleading, especially for radially excited states. A familiar example is provided by the relative branching fractions of the 3^3S_1 $c\bar{c}$ meson $\psi(4040)$ to $D\bar{D}$, $D\bar{D}^*+$h.c. and $D^*\bar{D}^*$. Spin counting rules lead to expected relative branching fractions of 1:4:7 for these modes. This simple estimate however is invalidated by a node in the $^3P_0$-model $D\bar{D}$ decay amplitude near the physical point [13], which strongly suppresses the $D\bar{D}$ width, in agreement with experiment.

In view of the possible complication of nodes in the strong decay amplitudes of radially excited vector mesons, we have evaluated these amplitudes for the $D^+_{sJ}(2632)$ in the $^3P_0$ decay model [13, 14, 15, 16, 17, 18, 19], given a 2^3S_1 $c\bar{s}$ assignment. The $^3P_0$ model, which assumes that strong decays proceed through local $q\bar{q}$ pair creation with vacuum quantum numbers, is the standard quark model approach for estimating strong decay widths. It has proven quite successful in describing a wide range of meson [11, 20] and baryon [21, 22] decays.

The pair creation strength used here is $\gamma = 0.4$, which gives reasonable numerical strong widths for a wide range of $n\bar{n}$, $n\bar{s}$, $s\bar{s}$ and $c\bar{c}$ mesons [11, 20]. We use simple nonrelativistic SHO wavefunctions for all mesons. The wavefunction width parameter β is fixed separately for each

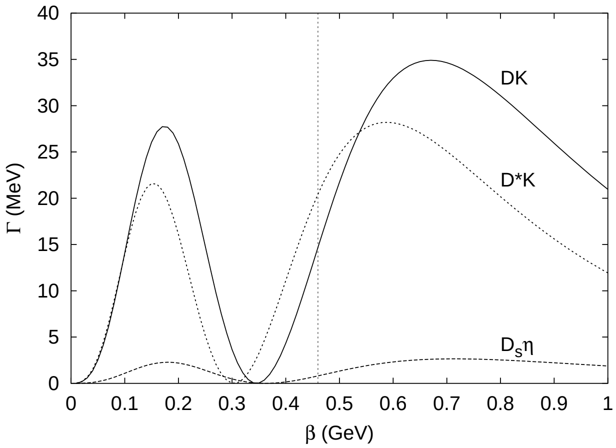

FIG. 2: Theoretical partial widths of the $D^+_{sJ}(2632)$ into D^*K, DK and $D_s\eta$ final states in the $^3P_0$ decay model, assuming a 2^3S_1 $c\bar{s}$ assignment. The widths are shown as functions of the $D^+_{sJ}(2632)$ SHO width parameter β ($\beta \approx 0.46$ GeV is preferred theoretically). See text for other parameter values.

meson to give the RMS radius predicted for that state by the Godfrey-Isgur relativised quark model [2]. This gives the values $\beta(\eta_{s\bar{s}}) = 0.64$ GeV, $\beta(\mathrm{K}) = 0.61$ GeV, $\beta(\mathrm{D}) = 0.60$ GeV, $\beta(\mathrm{D_s}) = 0.65$ GeV and $\beta(\mathrm{D}^*) = 0.52$ GeV. This procedure gives $\beta(D^+_{sJ}(2632)) = 0.46$ GeV, which is our preferred value. In the following we will treat this as a free parameter, to explore the sensitivity of our results to wavefunction variation. Masses of 330 MeV, 550 MeV, and 1600 MeV have been used for the up, strange, and charm quarks respectively.

The resulting partial widths as functions of the $D^+_{sJ}(2632)$ width parameter β are shown in Fig.2. For width parameters near our preferred physical value of $\beta = 0.46$ GeV we find the branching fraction hierarchy $\Gamma(\mathrm{D^*K}) \gtrsim \Gamma(\mathrm{DK}) \gg \Gamma(\mathrm{D_s}\eta)$. This conclusion is complicated somewhat by the presence of nodes near $\beta = 0.30 - 0.35$ GeV, where there is a small total width and rapidly varying branching ratios. At our preferred value of β the $D^+_{sJ}(2632)$ total width is 36 MeV, and the ratio $\Gamma(\mathrm{DK})/\Gamma(\mathrm{D_s}\eta)$ is about 9. It is clear that the reported ratio of $\Gamma(\mathrm{DK})/\Gamma(\mathrm{D_s}\eta)$ in Eq.(3) is not consistent with the expectations of the $^3P_0$ decay model for $D^+_{sJ}(2632)$ wavefunction width parameters near our preferred β.

The prediction of comparable couplings of a 2^3S_1 $c\bar{s}$ quark model state at 2632 MeV to DK and D^*K near our preferred β is also evident in Fig.2. A search for the D^*K mode and an accurate determination of the relative branching fractions of the $D^+_{sJ}(2632)$ to D^*K, DK and $D_s\eta$ should provide very useful tests of the 2^3S_1 $c\bar{s}$ assignment.

It is possible that 2^3S_1–1^3D_1 quarkonium mixing may significantly alter the ratio of DK and $D_s\eta$ branching fractions. Such mixing may be generated by coupling to shared virtual meson-meson states. We investigate this scenario by assuming a simple mixed state

$$|\mathrm{D_{sJ}}(2632)\rangle = \cos\theta|2^3\mathrm{S}_1\rangle + \sin\theta|1^3\mathrm{D}_1\rangle \qquad (6)$$

and examining the resulting ratio of DK to $D_s\eta$ widths. Direct computation in the $^3P_0$ model reveals that $\mathcal{A}(^3\mathrm{D}_1 \to \mathrm{DK})/\mathcal{A}(2^3\mathrm{S}_1 \to \mathrm{DK})$ is very close to $\mathcal{A}(^3\mathrm{D}_1 \to \mathrm{D_s}\eta)/\mathcal{A}(2^3\mathrm{S}_1 \to \mathrm{D_s}\eta)$. This may be expected since the same amplitude drives the DK and $D_s\eta$ modes. Thus the ratio of DK to $D_s\eta$ widths is very nearly independent of the mixing angle θ. The exception is a narrow band around

$$\theta = \tan^{-1}\left(-\frac{\mathcal{A}(2^3\mathrm{S}_1 \to \mathrm{DK})}{\mathcal{A}(^3\mathrm{D}_1 \to \mathrm{DK})}\right) \approx 0.86\,\pi\ , \qquad (7)$$

due to slightly offset nodes in the DK and $D_s\eta$ amplitudes. Suppression of the DK mode relative to $D_s\eta$ therefore requires a mixing angle of $\theta \approx 155^\circ$ or -25°. The near equality of the $^3D_1$ to 2^3S_1 ratios mentioned above implies however that the absolute partial widths to DK and $D_s\eta$ are both very small near these specific mixing angles. Thus one can only achieve a small DK to $D_s\eta$ branching fraction ratio at the expense of considerably suppressing the absolute partial widths to these modes. It therefore appears unlikely that 2^3S_1–1^3D_1 $c\bar{s}$ mixing can explain the reported SELEX DK/$D_s\eta$ branching fraction ratio.

One might also consider searches for radiative transitions from the $D^+_{sJ}(2632)$. An estimate of the E1 radiative partial widths of a 2^3S_1 $c\bar{s}$ $D^+_{sJ}(2632)$ to P-wave D_s states may be extracted from the results of Ref.[23]. These rates are found to be quite small, typically $\lesssim 1$ keV, so the $D^+_{sJ}(2632)$ should not be visible in these radiative modes with current statistics if it is indeed dominantly a 2^3S_1 $c\bar{s}$ state.

Similarly one can consider searches for closed-flavor dipion hadronic transitions of the $D^+_{sJ}(2632)$. Following Ref.[24], we estimate a partial width of $\Gamma(2^3\mathrm{S}_1(c\bar{s}) \to \mathrm{D}^*_s + \pi\pi) \simeq 220$ keV, which for $\Gamma_{tot.} < 17$ MeV implies a B.F. of $\gtrsim 1\%$. It may therefore be possible to observe the $D^+_{sJ}(2632)$ in this channel. The analogous width of a 1^3D_1 state at this mass is estimated to be $\Gamma(1^3D_1(c\bar{s}) \to \mathrm{D}^*_s + \pi\pi) \simeq 13$ keV which is probably too small to be observed.

IV. HYBRID ASSIGNMENT

Hybrid mesons, in which the gluonic degree of freedom is excited, should give rise to an "overpopulation" of the hadron spectrum relative to the expectations of the naive quark model. In the meson spectrum hybrids may be identified by their exotic J^{PC} quantum numbers, provided that the mesons have definite C-parity. The D_s sector however does not have definite C-parity, so the spectrum of hybrids must be identified through the overpopulation of states and the anomalous properties of these additional excitations. The quantum numbers of the lightest $c\bar{s}$-hybrid multiplet in the flux-tube model are $\mathrm{J}^{\mathrm{P}} = 0^{\pm}, 1^{\pm}, 2^{\pm}$ which implies that overpopulation of the natural-J^{P} D_s spectrum should first be evident in the 0^+, 1^- and 2^+ sectors.

As the $\mathrm{D}^+_{\mathrm{sJ}}(2632)$ is reported to have strong decay branching fractions that differ from ${}^3\mathrm{P}_0$ decay model expectations for the only likely $c\bar{s}$ candidate, it is natural to consider whether a $c\bar{s}$-hybrid assignment is plausible for this state. Unfortunately this interesting possibility does not appear to be consistent with recent mass estimates for hybrids. Although the unequal q and $\bar{q}$ mass case has not been considered in detail in the literature, $c\bar{s}$ is intermediate in quark mass between $c\bar{c}$ and light $n\bar{n}$ hybrids, which have been studied using lattice gauge theory (LGT) and various models. The flux-tube model [25] finds a hybrid mass gap of $\mathrm{M_H}$ - $\mathrm{M_{1S}} \approx 1.3$ GeV for light $n\bar{n}$ quarks and ≈ 1.1 GeV for $c\bar{c}$. This is roughly consistent with LGT studies [26, 27, 28, 29], which typically find hybrid mass gaps of $\mathrm{M_H}$ - $\mathrm{M_{1S}} \approx 1.3$ GeV for both $c\bar{c}$ and $n\bar{n}$ systems. Apparently the hybrid gap has little dependence on quark mass, which leads to an expected $c\bar{s}$-hybrid mass of 3.2 – 3.4 GeV.

There are however experimental candidates for hybrids at rather lower masses, the best established of which is the $\pi_1(1600)$ [30]. A recent quenched LGT study with light quarks [31] also finds a somewhat smaller $n\bar{n}$ hybrid mass gap, consistent with the $\pi_1(1600)$ being a hybrid. This suggests a hybrid mass gap of 1.0 GeV for light quarks, and a $c\bar{s}$-hybrid mass of ca. 3.1 GeV.

In either case the expected hybrid mass is sufficiently far above the $\mathrm{D}^+_{\mathrm{sJ}}(2632)$ mass to make this a very speculative possibility, which in our opinion does not merit further consideration without evidence that the hybrid mass gap is much lower than current theoretical expectations.

V. MOLECULAR ASSIGNMENT

The possibility that loosely bound states of mesons may exist in the charm sector was first suggested many years ago [32, 33] in response to the reported anomalous strong decays of the $\psi(4040)$. Such "molecular" meson bound states are allowed in principle in QCD; whether they actually do form in a given channel is a question of detailed dynamics. Unfortunately, our current understanding of interhadron forces is not sufficiently well developed to allow reliable predictions of the spectrum of hadronic molecules in general, and the existing predictions tend to be rather model dependent. Examples of hadron interaction models that anticipate molecular bound states in various channels are pion-exchange models [34, 35], the constituent quark model [36, 37], and multiple gluon exchange models [38].

Since the residual interhadron forces that can lead to molecular bound states are relatively weak, one would expect hadronic molecules to form most easily as S-wave bound states just below threshold. Examples include the $f_0(980)$ and $a_0(980)$ just below $\mathrm{K\bar{K}}$ threshold, which may be $\mathrm{K\bar{K}}$ molecules [36]; the $\mathrm{D_s}(2317)$, which may be an analogous DK molecule [39, 40]; and the X(3872), which may be a $\mathrm{D\bar{D}^*}$ $+\,h.c.$ bound state [41, 42, 43, 44]. In all cases these states have the quantum numbers of the two-meson pair in S-wave, and are at most 10s of MeV below threshold.

A plausible meson molecule assignment for the $\mathrm{D}^+_{\mathrm{sJ}}(2632)$ would similarly require a two-meson threshold at most 10s of MeV above the resonance mass, with S-wave quantum numbers consistent with the $\mathrm{D}^+_{\mathrm{sJ}}(2632)$. The only two-meson system with the required quantum numbers of I = 0, natural J^{P}, and quark content $c\bar{s}q\bar{q}$ that is within 100 MeV of the $\mathrm{D}^+_{\mathrm{sJ}}(2632)$ is $\mathrm{D}^*_{\mathrm{s}}\eta$, at a mass of 2660 MeV. Unfortunately this system does not appear plausible for a molecular bound state with $\mathrm{D}^+_{\mathrm{sJ}}(2632)$ quantum numbers, since natural J^{P} would require the $\mathrm{D}^*_{\mathrm{s}}\eta$ pair to be in a P-wave. This also applies to all pseudoscalar-pseudoscalar and pseudoscalar-vector pairs. A vector-vector pair would give the lightest possible S-wave natural parity molecules, but the lightest such systems with $\mathrm{D}^+_{\mathrm{sJ}}(2632)$ quantum numbers are $\mathrm{D}^*_{\mathrm{s}}\omega$ and $\mathrm{D^*K^*}$, which are both close to 2.90 GeV. The required binding energy of 270 MeV appears implausibly large for a two-meson molecule.

We conclude that there are no two-meson systems with $\mathrm{D}^+_{s\mathrm{J}}(2632)$ quantum numbers sufficiently nearby in mass to admit an S-wave molecular bound state as a possible assignment for this resonance.

VI. MULTIQUARK ASSIGNMENTS

More exotic possibilities can be considered for the $\mathrm{D}^+_{s\mathrm{J}}(2632)$, such as a $cq\bar{s}\bar{q}$ multiquark state [45, 46, 47, 48]. Of course a multiquark system that is above a fall-apart decay threshold would be expected to be extremely broad or nonresonant, and if the $\mathrm{D}^+_{s\mathrm{J}}(2632)$ is a $cn\bar{s}\bar{n}$ or $cs\bar{s}\bar{s}$ multiquark (for example) one would have to explain why the fall-apart modes DK, $\mathrm{D^*K}$ and/or $\mathrm{D}_s\eta$ do not make this an extremely broad state.

One should note that there is a qualitative difference between molecule and multiquark assignments, despite the fact that they share the same sector of Hilbert space. Thus one might argue from quark content alone that the $\mathrm{D}^+_{s\mathrm{J}}(2317)$ sets a scale of 2.32 GeV for the $c\bar{s}(u\bar{u}+d\bar{d})$ sector, and with an increase of 150 MeV for each s quark one could accommodate a $c\bar{s}s\bar{s}$ system near the mass of the $\mathrm{D}^+_{s\mathrm{J}}(2632)$. A $c\bar{s}s\bar{s}$ multiquark state might *a priori* have the large coupling to $\mathrm{D}_s\eta$ reported for the $\mathrm{D}^+_{s\mathrm{J}}(2632)$. However, this is misleading because the mass of the $\mathrm{D}^+_{s\mathrm{J}}(2317)$ is actually determined by the DK threshold if it is largely a DK molecular state, and there is no analogous S-wave threshold that could explain the $\mathrm{D}^+_{s\mathrm{J}}(2632)$.

VII. SUMMARY AND CONCLUSIONS

In this paper we have considered several possible assignments for the $D_{sJ}^{+}(2632)$ resonance recently reported by the SELEX Collaboration. Given the mass and allowed quantum numbers for this state, the most plausible conventional $q\bar{q}$ quark model assignment is a 2^3S_1 $c\bar{s}$ radial excitation of the 1S vector $D_s^*(2112)$. The mass reported by SELEX however is rather lower than predicted for this state, and the decay branching fractions disagree strongly with expectations. Theoretically, for a 2^3S_1 $c\bar{s}$ state at this mass one predicts a small $D_s\eta$ mode and comparable DK and D*K modes, with a total width of ≈ 36 MeV. The SELEX Collaboration instead report a much larger branching fraction to $D_s\eta$ than DK, contrary to expectations. For this reason we find that it is difficult to accommodate the $D_{sJ}^{+}(2632)$ as a conventional $q\bar{q}$ mesons.

Although the reported properties of the $D_{sJ}^{+}(2632)$ do not agree with quark model expectations for a radially excited 2^3S_1 $c\bar{s}$ vector, we noted that some of the unusual aspects of this state are reminiscent of the strange vector meson $K^*(1414)$, which is also a 2^3S_1 candidate. If the $D_{sJ}^{+}(2632)$ is confirmed, a comparison of these two resonances may prove enlightening.

We also considered two other possible interpretations for the $D_{sJ}^{+}(2632)$, a $c\bar{s}$-hybrid and a two-meson charm-strange molecule. Both of these assignments appear very unlikely, given the mass and quantum numbers reported for this resonance. We conclude that either our understanding of meson spectroscopy and especially strong decays is inadequate to explain this state, or it is simply an experimental artifact.

Future experimental studies will be crucial for understanding the $D_{sJ}^{+}(2632)$. The most important measurement (provided that the state is confirmed) will be the determination of the J^P quantum numbers, through the angular distributions of $D_{sJ}^{+}(2632)$ final states; this could support or eliminate our preferred 1^- (2^3S_1) assignment. A large branching fraction to the D*K final state is another important prediction of the 2^3S_1 assignment, which should be searched for. An accurate determination of the relative branching fractions to D*K, DK and $D_s\eta$ is clearly of great importance, since this is where there is currently evidence of disagreement with strong decay predictions for the 2^3S_1 $c\bar{s}$ assignment. A 2^3S_1 $c\bar{s}$ state should also have a closed flavor dipion decay to $D_s\pi\pi$ with a branching fraction of $\approx 1\%$, analogous to the decay $\psi' \to J/\psi\pi\pi$. This may also be observable, especially in the high statistics environment of the B-factories. If the 2^3S_1 $c\bar{s}$ assignment is correct, there should be a second 1^- $c\bar{s}$ state ($^3D_1$) approximately 200 MeV higher in mass; observation of this state would provide additional evidence in favor of a conventional $c\bar{s}$ interpretation that does not rely on the predictions of strong decay models. The observation of two new D_s states in B meson decay and the fact that the 1^3S_1 D_s^* state is produced in B decay with a branching fraction of several percent suggests that the 2S D_s^* radial excitation should also be produced with a sizable branching fraction. We therefore expect that the $D_{sJ}^{+}(2632)$ should also be evident in B decays, provided that it is indeed the 2^3S_1 $c\bar{s}$ state.

In view of the surprising properties reported for the $D_{sJ}^{+}(2632)$, if confirmed it will require reconsideration of theoretical expectations for both the spectrum and the strong decay systematics of charmed mesons. Confirmation (or refutation) of the $D_{sJ}^{+}(2632)$ is clearly an important priority for meson spectroscopy.

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