$\bar{B}^0$ and $\bar{B}_s^0$ decays into J/ψ and $f_0(1370)$, $f_0(1710)$, $f_2(1270)$, $f_2'(1525)$, $K_2^*(1430)$

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We make predictions for the ratios of branching fractions of $\bar{B}^0$ and $\bar{B}_s^0$ decays into J/ψ and the scalar mesons $f_0(1370)$, $f_0(1710)$ or tensor mesons $f_2(1270)$, $f_2'(1525)$, $K_2^*(1430)$. The theoretical approach is based on results of chiral unitary theory where these resonances are shown to be generated from the vector meson–vector meson interaction. Eight independent ratios can be predicted, and comparison is made with the recent data on $\bar{B}_s^0$ decay into $J/\psi f_2'(1525)$ versus the $\bar{B}_s^0$ decay into $J/\psi f_2(1270)$.

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I. INTRODUCTION

While there is growing support for the low-lying scalar mesons $f_0(500)$, $f_0(980)$, $a_0(980)$, $\kappa(800)$ to be generated dynamically from the interaction of pseudoscalar mesons, forming some kind of composite meson-meson states [1–6], the case of the next set of scalar resonances at higher energies, $f_0(1370)$, $f_0(1710)$, $K_0^*(1430)$ is more a question of debate. So is the case of the tensor resonances $f_2(1270)$, $f_2'(1525)$, $K_2^*(1430)$. Concerning the latter ones there is some support for these resonances to be plain $q\bar{q}$ states belonging to a nonet of $SU(3)$ [7,8]. The case of the scalar resonances is more varied—the $f_0(1370)$ is also sometimes assumed to be a $q\bar{q}$ state, although in Refs. [7,8] it is also suggested that it could correspond to a $\rho\rho$ molecule based on phenomenological properties (the decay widths into $\rho\rho$ and $\eta\eta$). However, in Ref. [9], based on a study of decay properties within the chiral linear sigma model, the $f_0(1370)$ is suggested to be a $q\bar{q}$ state while the $f_0(1500)$ would correspond to the glueball. In Ref. [10] a study is conducted on the effects in some decay widths of assuming quarkonium, tetraquark, and gluonium components in the context of a nonlinear chiral Lagrangian for the $f_0(500)$, $f_0(1370)$, and $f_0(1500)$. There are even doubts about the existence of the $f_0(1370)$, but a strong case in favor is made in Ref. [11]. In Ref. [12] the $f_0(500)$, $f_0(980)$, and $f_0(1370)$ are assumed to be admixtures of two- and four-quark components, with the $f_0(500)$ being dominantly a nonstrange four-quark state, and the $f_0(980)$ and $f_0(1370)$ having a dominant two-quark component. Similarly, $f_0(1500)$ and $f_0(1710)$ have considerable two- and four-quark admixtures, but in addition they have a large glueball component. In Ref. [13] solutions in which the $f_0(1710)$ would be a glueball, while the $f_0(1370)$ and $f_0(1500)$ are predominantly $q\bar{q}$ states, are found likely. On the other hand in Ref. [14] the $f_0(1710)$ is advocated as a glueball, while the $f_0(1500)$ is also assumed to have a large glueball component, while the $f_0(1370)$ would correspond to a simple $q\bar{q}$ state. This is just a sample of recent discussions on these issues; further information and discussions can be found in Refs. [7,8,15].

On the other hand, a new perspective on these states has been offered by the work of Ref. [16], where the $f_0(1370)$ and $f_2(1270)$ resonances were shown to be generated from the $\rho\rho$ interaction provided by the local hidden gauge Lagrangians [17–19] implementing unitarization. The work was extended to $SU(3)$ in Ref. [20] and 11 resonances were dynamically generated, some of which were identified with the $f_0(1370)$, $f_0(1710)$, $f_2(1270)$, $f_2'(1525)$ and $K_2^*(1430)$. The idea has been tested successfully in a large number of reactions. In Ref. [21] the two-photon decay of the $f_0(1370)$ and $f_2(1270)$ were studied and good rates were obtained compared with experiment. This latter work was extended in Ref. [22] to the study of the two photons and one photon–one vector decays of the $f_0(1370)$, $f_2(1270)$, $f_0(1710)$, $f_2'(1525)$, and $K_2^*(1430)$. In Ref. [23] a study of the $J/\psi \to \phi(\omega) f_2(1270)$, $f_2'(1525)$, and $J/\psi \to K^{*0}(892)\bar{K}_2^{*0}(1430)$ decays was also carried out from that perspective and good results were obtained. The radiative decay of J/ψ into $f_2(1270)$, $f_2'(1525)$, $f_0(1370)$, and $f_0(1710)$ was also studied in Ref. [24] and good results were obtained for the available experimental information. One also very interesting repercussion of this perspective was the reinterpretation in Ref. [25] of the peak seen in the $\omega\phi$ distribution close to threshold [26] as a manifestation of the $f_0(1710)$ resonance below the $\omega\phi$ threshold rather than a signal for a new resonance. It is clear that the idea of the nature of these states as vector meson–vector meson composite states has undergone a scrutiny that no other model has undergone. Yet, the permanent discussion of the issue demands that extra checks are done with the different models for other observables, and in this sense the weak decays that we exploit here bring a new source of valuable information that should serve to test the different models. This is the purpose of the present work.

In this paper we present results for the weak decay of $\bar{B}^0$ and $\bar{B}_s^0$ decays into J/ψ and $f_0(1370)$, $f_0(1710)$, $f_2(1270)$, $f_2'(1525)$, $K_2^*(1430)$. The experimental results show that the $\bar{B}_s^0$ has a pronounced peak for the decay into $J/\psi f_0(980)$ [27], while no appreciable signal is seen for the $f_0(500)$. These results have been also supported by Belle [28], CDF [29], D0 [30], and again LHCb [31,32] Collaborations. Conversely, in Ref. [33] the $\bar{B}^0$ into J/ψ and $\pi^+\pi^-$ is investigated and a clear signal is seen for the $f_0(500)$ production, while only a very small contribution from the $f_0(980)$ production is observed. These reactions have motivated theoretical work, estimating rates of production [34–36] or trying to extract the amount of $q\bar{q}$ or tetraquarks in the scalar mesons [37]. Related theoretical work is also done in Refs. [38–43]. From the perspective of the scalar mesons as being dynamically generated from the meson-meson interaction, work was recently completed in Ref. [44], where the elementary mechanism is J/ψ formation together with a $q\bar{q}$, which is hadronized to convert it into a meson-meson pair. The resulting meson-meson pairs are allowed to interact, using for this purpose the chiral unitary approach [45], and the desired final state is selected. This interaction is known to generate dynamically the low-lying scalar mesons [1–6] and then one has a mechanism to produce all these resonances in these decays up to a global normalization constant. The agreement found with experiment for the different decays modes in Ref. [44] is remarkable. We shall follow a similar path here, but taking into account the fact that the scalar and tensor resonances discussed above, $f_0(1370)$, $f_0(1710)$, $f_2(1270)$, $f_2'(1525)$, $K_2^*(1430)$, are now generated from the vector meson–vector meson interaction.

II. FORMALISM

Following the Ref. [37] we take the dominant mechanism for the decay of $\bar{B}_0$ and $\bar{B}_s^0$ into a J/ψ and a $q\bar{q}$ pair. Posteriorly, this $q\bar{q}$ pair is hadronized into vector meson–vector meson components, as depicted in Fig. 1.

The hadronization of the $q\bar{q}$ pair is done following the idea of Ref. [23]. The idea is depicted in Fig. 1. In the $\bar{B}^0$ ($\bar{B}_s^0$) decays, a $c\bar{c}$ state is created producing the J/ψ, together with a light $q\bar{q}$ pair, $d\bar{d}$ for $\bar{B}^0$ and $s\bar{s}$ for $\bar{B}_s^0$ decays. In order to produce a meson which comes from vector-vector interaction, this $q\bar{q}$ pair has to hadronize. We need four quarks to build this new structure and this is accomplished by creating an extra $\bar{q}q$ combination with the quantum numbers of the vacuum, which corresponds to a flavor structure $\bar{u}u + \bar{d}d + \bar{s}s$. In order to formulate the correspondence between the hadronized $q\bar{q}(\bar{u}u + \bar{d}d + \bar{s}s)$ structure and that of the vector-vector components one proceeds as follows. We introduce the $\bar{q}q$ matrix M

$$M = \begin{pmatrix} u\bar{u} & u\bar{d} & u\bar{s} \\ d\bar{u} & d\bar{d} & d\bar{s} \\ s\bar{u} & s\bar{d} & s\bar{s} \end{pmatrix}, \tag{1}$$

which has the property

$$M \cdot M = M \times (\bar{u}u + \bar{d}d + \bar{s}s). \tag{2}$$

In this sense the hadronized $d\bar{d}$ and $s\bar{s}$ states in Fig. 1 can be written as

$$d\bar{d}(\bar{u}u + \bar{d}d + \bar{s}s) = (M \cdot M)_{22}, \tag{3}$$

$$s\bar{s}(\bar{u}u + \bar{d}d + \bar{s}s) = (M \cdot M)_{33}. \tag{4}$$

But now it is convenient to establish the relationship of these hadronized components with the vector meson–vector meson components associated to them. For this purpose we write the matrix M of Eq. (1) in terms of the nonet of vector mesons,

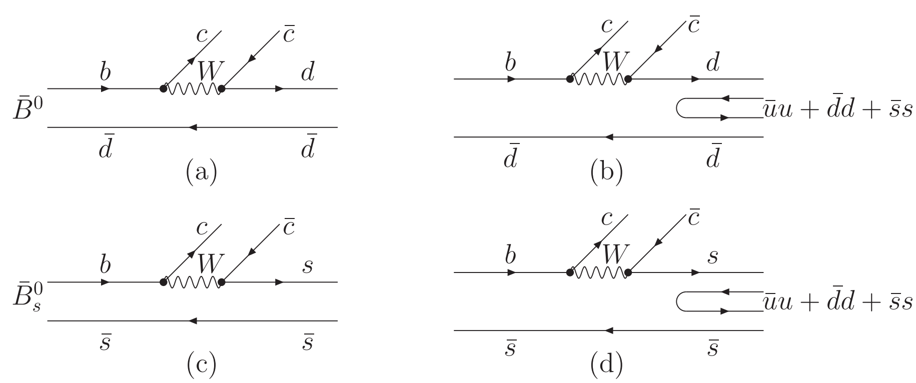

FIG. 1. Basic diagrams for $\bar{B}^0$ and $\bar{B}_s^0$ decay into J/ψ and a $q\bar{q}$ pair [(a) and (c)], and hadronization of the $q\bar{q}$ components [(b) and (d)].

$$V = \begin{pmatrix} \frac{\sqrt{2}}{2}\rho^0 + \frac{\sqrt{2}}{2}\omega & \rho^+ & K^{*+} \\ \rho^- & -\frac{\sqrt{2}}{2}\rho^0 + \frac{\sqrt{2}}{2}\omega & K^{*0} \\ K^{*-} & \bar{K}^{*0} & \phi \end{pmatrix}, \quad (5)$$

and then we associate

$$\begin{aligned} d\bar{d}(\bar{u}u + \bar{d}d + \bar{s}s) &\equiv (V\cdot V)_{22} \\ &= \rho^-\rho^+ + \frac{1}{2}\rho^0\rho^0 + \frac{1}{2}\omega\omega - \rho^0\omega + K^{*0}\bar{K}^{*0}, \end{aligned} \quad (6)$$

$$\begin{aligned} s\bar{s}(\bar{u}u + \bar{d}d + \bar{s}s) &\equiv (V\cdot V)_{33} \\ &= K^{*-}K^{*+} + K^{*0}\bar{K}^{*0} + \phi\phi. \end{aligned} \quad (7)$$

In the study of Ref. [20] a coupled channels unitary approach was followed with the vector meson–vector meson states as channels. However, the approach went further since, following the dynamics of the local hidden gauge Lagrangians, a vector meson–vector meson state can decay into two pseudoscalars, PP. This is depicted in Figs. 2(a) and 2(b). In Ref. [20] these decay channels are taken into account by evaluating the box diagrams depicted in Figs. 2(c) and 2(d), which are assimilated as a part, $\delta\tilde{V}$, of the vector-vector interaction potential $\tilde{V}$. This guarantees that the partial decay width into different channels could be taken into account when determining masses and widths of the resonances that the approach generates. However, the approach is not done by taking into account as coupled channels the VV and PP simultaneously. This means that one does not evaluate explicitly $VV \to PP$ transition matrices. Although the partial decay widths into PP are well evaluated, the fact that one does not have the $VV \to PP$ matrix elements forces us to take a path slightly different from the one taken in Ref. [44] to deal with the low-lying scalar resonances, which are generated from the PP interaction solely. Hence, rather than evaluating amplitudes and mass distributions for the pairs of pseudoscalars that are observed (the resonances that we get are usually bound in the vector-vector systems), we evaluate the amplitudes and rates for transition to the resonance itself.

Since the information of the PDG [46] is usually given in terms of rates for transition to specific resonances, the procedure that we follow allows direct comparison with these experimental magnitudes.

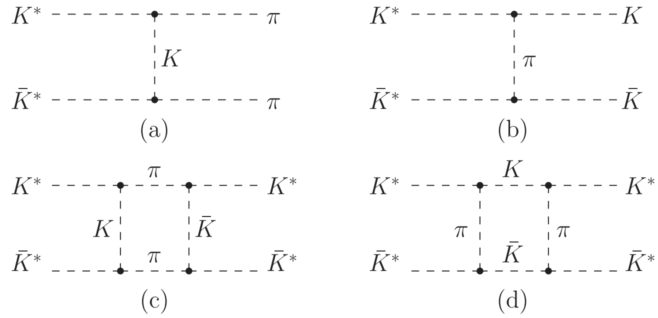

FIG. 2. Decay mechanisms of $K^*\bar{K}^* + \pi\pi$, $K\bar{K}$ [(a) and (b)] and box diagrams considered in Ref. [20] to account for these decays [(c) and (d)].

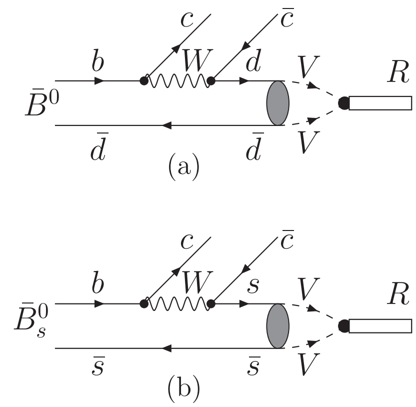

FIG. 3. Mechanisms to generated the vector-vector resonances through VV rescattering. The dot of the vertex RVV indicates the coupling of the resonance to the different VV components. (a) for $\bar{B}^0$ decay, (b) for $\bar{B}_s^0$ decay.

The vector-vector components of Eqs. (6) and (7) are produced in a first step and then they interact in coupled channels to produce finally the desired resonance. This propagation is taken into account by means of the two vector loop function G_{VV}, times the coupling of this vector-vector component to the resonance. Since we wish to have the resonance production and this is obtained through rescattering, the mechanism for J/ψ plus resonance production is depicted in Fig. 3.

The amplitudes for $J/\psi R$ production are then given by

$$t(\bar{B}^0 \to J/\psi f_0) = \tilde{V}_P V_{cd} p_{J/\psi} \cos\theta \left(G_{\rho^-\rho^+} g_{\rho^-\rho^+,f_0} + \frac{1}{2}\frac{1}{2} G_{\rho^0\rho^0} g_{\rho^0\rho^0,f_0} + \frac{1}{2}\frac{1}{2} G_{\omega\omega} g_{\omega\omega,f_0} + G_{K^{*0}\bar{K}^{*0}} g_{K^{*0}\bar{K}^{*0},f_0} \right), \quad (8)$$

$$t(\bar{B}_s^0 \to J/\psi f_0) = \tilde{V}_P V_{cs} p_{J/\psi} \cos\theta \left(G_{K^{*0}\bar{K}^{*0}} g_{K^{*0}\bar{K}^{*0},f_0} + G_{K^{*-}K^{*+}} g_{K^{*-}K^{*+},f_0} + \frac{1}{2} G_{\phi\phi} g_{\phi\phi,f_0} \right), \quad (9)$$

where G_{VV} are the loop functions of two vector mesons that we take from [20] and g_{VV,f_0} the couplings of f_0 to the pair of vectors VV, defined from the residues of the resonance at the poles

$$t_{ij} \simeq \frac{g_i g_j}{s - s_R}, \tag{10}$$

with t_{ij} the transition matrix from the channel $(VV)_i$ to $(VV)_j$. These couplings are also tabulated in Ref. [20]. The formulas for the decay amplitudes to $J/\psi f_2$ are identical, substituting f_0 by f_2 in the formulas and the factor $\tilde{V}_P$ by a different one $\tilde{V}'_P$ suited for the hadronization into a tensor. The magnitudes $\tilde{V}_P$ and $\tilde{V}'_P$ represent the common factors to these different amplitudes. In addition to the different weights of the several vector-vector channels in Eqs. (8) and (9) for the $\bar{B}^0$ or $\bar{B}^0_s$ decays into J/ψ and the same resonance, one also has the weight of different Cabibbo-Kobayashi-Maskawa (CKM) matrix element, V_{cd} for $\bar{B}^0$ decay, and V_{cs} for $\bar{B}^0_s$ decay. These matrix elements are given by

$$V_{cd} = -\sin\theta_c = -0.22534, \tag{11}$$

$$V_{cs} = \cos\theta_c = 0.97427. \tag{12}$$

Note that in the formulas we include a factor $1/2$ in the G functions for the $\rho^0\rho^0$, $\omega\omega$, and $\phi\phi$ cases to account for the identity of the particles. The factor $p_{J/\psi}\cos\theta$ is included there to account for a p wave in the J/ψ particle to match angular momentum in the $0^- \to 1^-0^+$ transition. The $\cos\theta$ dependence is the easiest one and we keep it, although it can be more complicated in the presence of vector mesons, but this does not matter for the ratios of rates. The factor $p_{J/\psi}$ can however play some role due to the difference of mass between the different resonances.

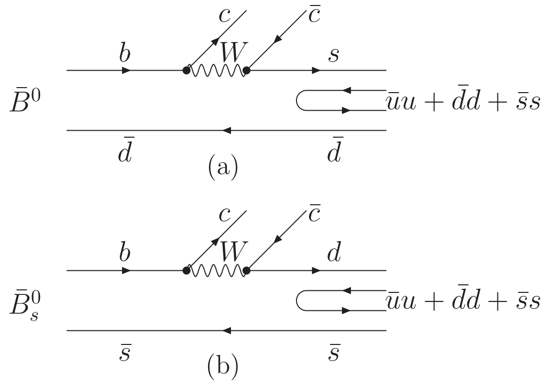

FIG. 4. Mechanisms for $\bar{B}^0 \to J/\psi \bar{K}^*_2(1430)$ (a) and $\bar{B}^0_s \to J/\psi K^*_2(1430)$ (b).

The case for $\bar{B}^0 \to J/\psi \bar{K}^*_2(1430)$ decay is similar. The diagrams corresponding to Figs. 1(b) and 1(d) are now written in Fig. 4.

In analogy to Eqs. (6), (7) we now have

$$s\bar{d}(u\bar{u} + d\bar{d} + s\bar{s}) \equiv (V\cdot V)_{32} = K^{*-}\rho^+ + \bar{K}^{*0}\left(-\frac{\rho^0}{\sqrt{2}} + \frac{\omega}{\sqrt{2}}\right) + \bar{K}^{*0}\phi, \tag{13}$$

$$d\bar{s}(u\bar{u} + d\bar{d} + s\bar{s}) \equiv (V\cdot V)_{23} = \rho^- K^{*+} + \left(-\frac{\rho^0}{\sqrt{2}} + \frac{\omega}{\sqrt{2}}\right)K^{*0} + K^{*0}\phi, \tag{14}$$

and the amplitudes for production of $J/\psi \bar{K}^*_2(1430)$ will be given by

$$t(\bar{B}^0 \to J/\psi \bar{K}^*_2) = \tilde{V}'_P p_{J/\psi}\cos\theta V_{cs}\left(G_{K^{*-}\rho^+} g_{K^{*-}\rho^+,\bar{K}^*_2} - \frac{1}{\sqrt{2}} G_{\bar{K}^{*0}\rho^0} g_{\bar{K}^{*0}\rho^0,\bar{K}^*_2} + \frac{1}{\sqrt{2}} G_{\bar{K}^{*0}\omega} g_{\bar{K}^{*0}\omega,\bar{K}^*_2} + G_{\bar{K}^{*0}\phi} g_{\bar{K}^{*0}\phi,\bar{K}^*_2}\right), \tag{15}$$

$$t(\bar{B}^0_s \to J/\psi K^*_2) = \tilde{V}'_P p_{J/\psi}\cos\theta V_{cd}\left(G_{K^{*+}\rho^-} g_{K^{*+}\rho^-,K^*_2} - \frac{1}{\sqrt{2}} G_{\bar{K}^{*0}\rho^0} g_{\bar{K}^{*0}\rho^0,K^*_2} + \frac{1}{\sqrt{2}} G_{\bar{K}^{*0}\omega} g_{\bar{K}^{*0}\omega,K^*_2} + G_{\bar{K}^{*0}\phi} g_{\bar{K}^{*0}\phi,K^*_2}\right). \tag{16}$$

One more step is needed since the couplings in Eqs. (8), (9), (15), (16) are given in charge basis while in the work of Ref. [20] they are given in isospin basis. For this we recall that in the unitary normalization used in Ref. [20] for convenience to deal with identical particles one has

$$|\rho\rho, I = 0 >= -\frac{1}{\sqrt{6}}(\rho^-\rho^+ + \rho^0\rho^0 + \rho^+\rho^-), \tag{17}$$

$$|K^*\bar{K}^*, I = 0 > = -\frac{1}{\sqrt{8}}(K^{*-}K^{*+} + K^{*0}\bar{K}^{*0} + K^{*+}K^{*-} + \bar{K}^{*0}K^{*0}), \tag{18}$$

$$|\omega\omega, I = 0 >= \frac{1}{\sqrt{2}}\omega\omega, \tag{19}$$

$$|\phi\phi, I=0>=\frac{1}{\sqrt{2}}\phi\phi. \tag{20}$$

Then we find

$$t(\bar{B}^0\to J/\psi f_0)=\tilde{V}_P p_{J/\psi}\cos\theta V_{cd}\left(-\frac{5\sqrt{6}}{12}G_{\rho\rho}g_{\rho\rho,f_0}+\frac{\sqrt{2}}{4}G_{\omega\omega}g_{\omega\omega,f_0}-\frac{\sqrt{2}}{2}G_{K^*\bar{K}^*}g_{K^*\bar{K}^*,f_0}\right), \tag{21}$$

$$t(\bar{B}_s^0\to J/\psi f_0)=\tilde{V}_P p_{J/\psi}\cos\theta V_{cs}\left(-\sqrt{2}G_{K^*\bar{K}^*}g_{K^*\bar{K}^*,f_0}+\frac{\sqrt{2}}{2}G_{\phi\phi}g_{\phi\phi,f_0}\right), \tag{22}$$

$$t(\bar{B}^0\to J/\psi \bar{K}_2^*)=\tilde{V}'_P p_{J/\psi}\cos\theta V_{cs}\left(-\frac{\sqrt{6}}{2}G_{\rho\bar{K}^*}g_{\rho\bar{K}^*,\bar{K}_2^*}+\frac{\sqrt{2}}{2}G_{\omega\bar{K}^*}g_{\omega\bar{K}^*,\bar{K}_2^*}+G_{\phi\bar{K}^*}g_{\phi\bar{K}^*,\bar{K}_2^*}\right), \tag{23}$$

$$t(\bar{B}_s^0\to J/\psi K_2^*)=\tilde{V}'_P p_{J/\psi}\cos\theta V_{cd}\left(-\frac{\sqrt{6}}{2}G_{\rho K^*}g_{\rho K^*,K_2^*}+\frac{\sqrt{2}}{2}G_{\omega K^*}g_{\omega K^*,K_2^*}+G_{\phi K^*}g_{\phi K^*,K_2^*}\right), \tag{24}$$

and for $\bar{B}^0(\bar{B}_s^0)\to J/\psi f_2$ the same as for f_0, but changing $\tilde{V}_P$ by $\tilde{V}'_P$. Note that $\tilde{V}'_P$ is then common to the decays into f_2 and $\bar{K}_2^*$.

The width for these decays will be given by

$$\Gamma=\frac{1}{8\pi M_{\bar{B}}^2}|t|^2 p_{J/\psi}, \tag{25}$$

with

$$p_{J/\psi}=\frac{\lambda(M_{\bar{B}}^2, M_{J/\psi}^2, M_R^2)}{2M_{\bar{B}}}, \tag{26}$$

with M_R the resonance mass, and in $|t|^2$ we include the factor $1/3$ for the integral of $\cos\theta$, which cancels in all ratios that we will study.

The information on couplings and values of the G functions, together with uncertainties, is given in Table V of Ref. [23] and Table I of Ref. [24]. The errors for the scalar meson production are taken from Ref. [24].

III. RESULTS

In the PDG we find branching fractions for $\bar{B}_s^0\to J/\psi f_0(1370)$ [31], $\bar{B}_s^0\to J/\psi f_2(1270)$ [31], and $\bar{B}_s^0\to J/\psi f'_2(1525)$ [47]. We can calculate ten independent rates and we have two unknown normalization constants $\tilde{V}_P$ and $\tilde{V}'_P$. As a consequence we can provide eight independent ratios parameter free. From the present experimental branching fractions we can only get one ratio for the $\bar{B}_s^0\to J/\psi f_2(1270)[f'_2(1525)]$. There is only one piece of data for the scalars, but we should also note that the data for $\bar{B}_s^0\to J/\psi f_0(1370)$ in Ref. [31] and in the PDG, in a more recent paper [32] is claimed to correspond to the $f_0(1500)$ resonance. Similar ambiguities stem from the analysis of Ref. [48].

The branching fractions for $f_2(1270)$ [31] and $f'_2(1525)$ [47] of the PDG are

$$\mathcal{B}(\bar{B}_s^0\to J/\psi f_2(1270))=(10^{+5}_{-4})\times 10^{-7}, \tag{27}$$

$$\mathcal{B}(\bar{B}_s^0\to J/\psi f'_2(1525))=(2.6^{+0.9}_{-0.6})\times 10^{-4}. \tag{28}$$

However, the datum for $\mathcal{B}(\bar{B}_s^0\to J/\psi f_2(1270))$ of the PDG is based on the contribution of only one helicity component $\lambda=0$, while $\lambda=\pm 1$ contribute in similar amounts.

This decay has been further reviewed in Ref. [32] and taking into account the contribution of the different helicities a new number is now provided,[1]

$$\mathcal{B}(\bar{B}_s^0\to J/\psi f_2(1270))=(3.0^{+1.2}_{-1.0})\times 10^{-6}, \tag{29}$$

which is about three times larger than the one already reported in the PDG.

We present our results in Table I for the eight ratios that we predict, defined as,

$$R_1=\frac{\Gamma[\bar{B}^0\to J/\psi f_0(1370)]}{\Gamma[\bar{B}^0\to J/\psi f_0(1710)]}, \tag{30}$$

$$R_2=\frac{\Gamma[\bar{B}^0\to J/\psi f_2(1270)]}{\Gamma[\bar{B}^0\to J/\psi f'_2(1525)]}, \tag{31}$$

[1]From discussions with S. Stone and L. Zhang. This new number has been submitted to the PDG by the authors of Ref. [32] and will appear in the next update of the PDG.

TABLE I. Ratios of $\bar{B}^0$ and $\bar{B}_s^0$ decays.

Ratios	Theory	Experiment
R_1	6.2 ± 1.6	...
R_2	13.4 ± 6.7	...
R_3	$(3.0 \pm 1.5) \times 10^{-2}$	...
R_4	$(7.7 \pm 1.9) \times 10^{-3}$	...
R_5	$(6.4 \pm 3.2) \times 10^{-1}$	...
R_6	$(1.1 \pm 0.3) \times 10^{-2}$	...
R_7	$(8.4 \pm 4.6) \times 10^{-2}$	$(1.0 \sim 3.8) \times 10^{-2}$
R_8	$(8.2 \pm 4.1) \times 10^{-1}$	...

$$R_3 = \frac{\Gamma[\bar{B}^0 \to J/\psi f_2(1270)]}{\Gamma[\bar{B}^0 \to J/\psi \bar{K}_2^*(1430)]}, \quad (32)$$

$$R_4 = \frac{\Gamma[\bar{B}^0 \to J/\psi f_0(1710)]}{\Gamma[\bar{B}_s^0 \to J/\psi f_0(1710)]}, \quad (33)$$

$$R_5 = \frac{\Gamma[\bar{B}^0 \to J/\psi f_2(1270)]}{\Gamma[\bar{B}_s^0 \to J/\psi f_2(1270)]}, \quad (34)$$

$$R_6 = \frac{\Gamma[\bar{B}_s^0 \to J/\psi f_0(1370)]}{\Gamma[\bar{B}_s^0 \to J/\psi f_0(1710)]}, \quad (35)$$

$$R_7 = \frac{\Gamma[\bar{B}_s^0 \to J/\psi f_2(1270)]}{\Gamma[\bar{B}_s^0 \to J/\psi f_2'(1525)]}, \quad (36)$$

$$R_8 = \frac{\Gamma[\bar{B}_s^0 \to J/\psi f_2(1270)]}{\Gamma[\bar{B}_s^0 \to J/\psi K_2^*(1430)]}. \quad (37)$$

Note that the different ratios predicted vary in a range of 10^{-3}, which means a big range, such that even a qualitative level comparison with future experiments would be very valuable concerning the nature of the states as vector-vector molecules, on which the numbers of the tables are based.

The errors are evaluated in quadrature from the errors in Refs. [23,24]. In the case of R_7, where we can compare with the experiment, we put the band of experimental values for the ratio to show that the theoretical results and the experiment just overlap within errors.

From our perspective it is easy to understand the small ratio of these decay rates. The $f_2(1270)$ in Ref. [20] is essentially a $\rho\rho$ molecule while the $f_2'(1525)$ couples mostly to $K^*\bar{K}^*$. If one looks at Eq. (9) one can see that the $\bar{B}_s^0 \to J/\psi f_0(f_2)$ proceeds via the $K^*\bar{K}^*$ and $\phi\phi$ channels, hence, the $f_2(1270)$ with small couplings to $K^*\bar{K}^*$ and $\phi\phi$ is largely suppressed, while the $f_2'(1525)$ is largely favored.

One should take into account that the rate of Eq. (29) is one of the smallest rates reported in the PDG. These numbers come from an elaborate partial wave analysis that, although rather stable against different assumptions, is not free of ambiguities. In this context, the agreement of theory with experiment in the only case that we can compare is very encouraging and shows the potential that the measurement of the other ratios has in learning about the nature of the set of resonances on which we have reported. This discussion should serve to encourage further experimental analysis in this direction.

IV. CONCLUSIONS

In this paper we have studied the decay of B^0 and B_s^0 into J/ψ and one of the resonances $f_0(1370)$, $f_0(1710)$, $f_2(1270)$, $f_2'(1525)$, $K_2^*(1430)$, which are generated dynamically from the interaction of vector mesons. The approach followed is rather simple and very predictive. We isolate the dominant mechanisms for the elementary decay of the B into the J/ψ and a $q\bar{q}$ component. This latter one is hadronized, giving rise to two vector mesons which are allowed to interact in coupled channels with a unitary approach, with the input obtained from the local hidden gauge approach, which extends chiral symmetry to the realm of the vectors. The approach allows us to get ten independent decay rates and we have two unknown factors in the theory. They are eliminated to give eight independent ratios of rates, which appear parameter free in the theory. We could only compare with one of the smallest ratios, the one between the B_s^0 into J/ψ $f_2(1270)$ and B_s^0 into J/ψ $f_2'(1525)$, and the agreement was good within errors. This small ratio has reasons purely dynamical in our theory. Indeed, we could see that the decay selected a $s\bar{s}$ pair that upon hadronization gets converted into $K^*\bar{K}^*$ and $\phi\phi$. On the other hand, in the underlying theory of these states as vector-vector molecules, the $f_2(1270)$ couples essentially to $\rho\rho$, while the $f_2'(1525)$ couples basically to $K^*\bar{K}^*$. Then it comes naturally that the $f_2(1270)$ is largely suppressed, while the $f_2'(1525)$ is clearly favored.

The potential of the ratios predicted to tell us about the dynamics of vector interaction and the nature of the resonances discussed here is great. This should serve to encourage further measurements and analysis of data. At the same time, to advance on the issue of the nature of resonances, it would be most advisable that other groups, with other theories, also make predictions for these rates that allow us to make comparisons and advance in our understanding of the nature of hadronic resonances.

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