

Strong Decays of Hybrid Mesons from the Heavy Quark Expansion of QCD

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Abstract

We calculate the strong decays of hybrid mesons to conventional mesons for all the lowest lying J^{PC} hybrids of flavour $u\bar{u}$, $d\bar{d}$, $s\bar{s}$, $c\bar{c}$ and $b\bar{b}$. A decay operator developed from the heavy quark expansion of quantum chromodynamics is employed. We show that the selection rule that hybrid mesons do not decay to identical S-wave mesons, found in other models, is preserved. We predict decays of charmonium hybrids, discuss decays of $J^{PC} = 1^{-+}$ exotic isovector hybrids of various masses, and interpret the $\pi(1800)$ as a hybrid meson.

As the Standard Model has successively been confirmed in recent years, one remaining area of ignorance is the interactions of the strong gluonic degrees of freedom. Particularly, quark–antiquark bound states where there is an explicit excitation of the gluon field of QCD, called “hybrid mesons”, have been predicted to exist, but have so far not been uncovered unambiguously in experiment.

In this talk we outline a new model for the decay of hybrid mesons into conventional mesons [1] to be reported in detail elsewhere [2].

Our description of hybrid mesons and conventional mesons is that of the non–relativistic flux–tube model of Isgur and Paton. We consider a connected decay of an initial hybrid

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A into final state mesons B and C. Isgur, Kokoski and Paton proposed a decay operator motivated from the strong coupling limit of the hamiltonian formulation of lattice gauge theory, which we shall refer to as the “IKP model” [3]. We propose a decay operator motivated from the heavy quark expansion of QCD in Coulomb gauge [1].

We uncover the selection rule that hybrid meson decays to two identical angular momentum $L = 0$ mesons vanish if the final state meson wave functions are identical. This is also found in the IKP model and has recently been proved to arise independent of detailed models [4]. However, in our model, the selection rule remains true even for mesons with general L [1].

We present some of the highlights of a calculation of the strong decays of hybrid mesons to conventional mesons for all the lowest lying J^{PC} hybrids of flavour $u\bar{u}$, $d\bar{d}$, $s\bar{s}$, $c\bar{c}$ and $b\bar{b}$. If the hybrid decays differs from that of the IKP model, we are able to ascertain model-dependence of predictions and hence can apply some caution to results. In areas where the two models coincide they provide robust predictions.

Caution has to be applied to the overall normalization of decays. The IKP model predictions calculated here can be up to 2 times larger than quoted, due to uncertainties in the pair creation strength [2] and correspondingly, our model’s predictions, since its normalization is fixed relative to the IKP model.

We firstly discuss charmonium hybrids. The widths of charmonium hybrids are sup-

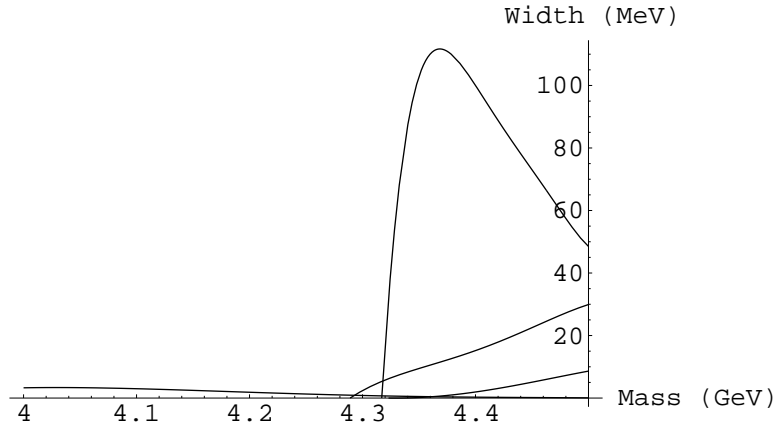


Figure 1: Dominant partial widths of a $1^{-+} c\bar{c}$ hybrid at various masses. The partial widths to $D^{**}(1_H^+)D$, $D^{**}(1_L^+)D$, $D^{**}(2^+)D$ and D^*D correspond to the highest to the lowest intersections with the vertical axis. $D^{**}(1_L^+)$ and $D^{**}(1_H^+)$ (denoted $D_1(2420)$ in the PDG) are the low and high mass 1^+ states respectively.

pressed below the $D^{**}D$ threshold (≈ 4.3 GeV), where only D^*D and $D_s^*D_s$ modes are allowed by the selection rule, since these are the only open charm combinations where the two final state wave functions are sufficiently different. However, when states are allowed to become more massive than the $D^{**}D$ threshold, the total widths increase drastically (see Fig. 1) to 15 – 160 MeV for 4.4 GeV hybrids.

Hybrids often have exotic quantum numbers not found for conventional mesons, e.g. $J^{PC} = 1^{-+}$ and 2^{+-} . Exotic J^{PC} immediately identifies the state as not being a conventional meson. The 4.4 GeV $c\bar{c}$ 2^{+-} exotic has a small width of 15 MeV in our model, but not in the IKP model. Fig. 1 indicates widths for the 1^{-+} exotic.

We now indicate results for the u, d quark isovector $J^{PC} = 1^{-+}$ hybrid. Our expectations for the widths of a 1^{-+} of mass 2.0 GeV are (in MeV)

	$b_1\pi$	$K_1(1400)K$	$\eta(1295)\pi$	$\rho\pi$	$\rho(1450)\pi$	$f_1\pi$	$a_1\eta$	$K_1(1270)K$
Our model	40	30	30	20	10	10	10	10
IKP model	60	80	20	20	10	40	10	20

where we have neglected K^*K , $f_2\pi$, $\pi(1300)\eta$, $K(1460)K$ and $K^*(1410)K$ which are predicted at ≤ 5 MeV in both models, and $\eta\pi$, $\eta'\pi$, $\rho\omega$, $a_2\eta$ and $K_2^*(1430)K$ with are 0 MeV in both models. Because of the substantial phase space available and the selection rule, $P + S$ channels are dominant. Our model has several modes which are suppressed

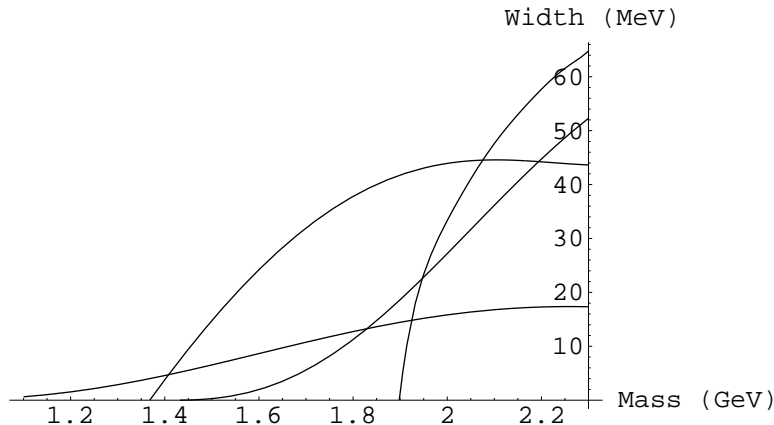


Figure 2: Dominant partial widths of a 1^{-+} isovector hybrid at various masses. The partial widths to $K_1(1400)K$, $\eta(1295)\pi$, $b_1\pi$ and $\rho\pi$ correspond to the highest to the lowest intersections with the vertical axis.

relative to the IKP model. In addition to the important $b_1\pi$ channel, $K_1(1400)K$ emerges as a prominent channel.

For a 1.6 GeV state the widths are

	$b_1\pi$	$\rho\pi$	$f_1\pi$	$\eta(1295)\pi$	K^*K	
Our model	20	10	5	2	1	MeV
IKP model	60	10	10	1	0	MeV

where both models predict $\eta\pi$, $\eta'\pi$, $\rho\omega$ and $f_2\pi$ widths to be 0 MeV. Superficially, the main effect of our model is to make the $P + S$ modes of a more similar size to the $S + S$ modes than they are in the IKP model. We emphasize the importance of searching for the hybrid in $\rho\pi$, as well as in the $b_1\pi$ and $f_1\pi$ channels qualitatively preferred by the selection rule. Also, both models concur that $b_1\pi$ should primarily be focused upon.

The decay modes in Fig. 2 demonstrate significant dependence on the hybrid mass.

Ref. [1] contains a calculation of the widths of the $\pi(1800)$ in our model which include below threshold decays to $K_0^*(1430)K$ of 85 MeV.¹ It is useful to correlate the decay modes to experimentally known ratios. Specifically, using the VES experimental branching ratios² [5] and correcting for decays of particles into the specific channels observed by VES [6], we obtain

	$K_0^*(1430)K$	$f_0(1370)\pi$	$\rho\pi$	K^*K	$\rho\omega$	$f_1\pi$
Experiment	1.0 ± 0.3	0.9 ± 0.3	< 0.36	< 0.06	0.4 ± 0.2	small
Our model	< 0.7	0.6	0.31	0.05	0	0.01

where we have scaled our model widths evaluated in ref. [1] by a common factor to compare to the experimental ratios deduced in ref. [6]. The correspondence is spectacular. Experimentally, significant couplings to $f_0(980)\pi$ and $a_0(980)\eta$ are also observed [5], which should arise due to final state interactions in our model. We emphasize that although $\rho\pi$ is suppressed in the data, we expect the resonance to have a non-negligible coupling to this channel.

¹Some of the $K_0^*(1430)K$ mode predicted in our model is expected to couple to $f_0(980)\pi$ via $K_0^*(1430)K \rightarrow (K\pi)K \rightarrow f_0(980)\pi$ final state interactions, so that our model estimate is actually less than 85 MeV.

²The experimentally measured $KK\pi$ ($\pi\pi$) in S-wave is assumed to arise solely from $K_0^*(1430)K$ ($f_0(1370)$).

One inconsistency with VES data appears to be the $\rho\omega$ mode. It is significant that the resonance in $\rho\omega$ has a mass of 1.732 ± 0.01 GeV [7], shifted downward from the usual $\pi(1800)$ mass parameters. There are also indications of the presence of a broad 0^{-+} wave [7]. This may signal the presence of the u, d quark conventional meson expected in this mass region, removing the apparent inconsistency with the hybrid interpretation of $\pi(1800)$.

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