Comment on "Possibility of Deeply Bound Hadronic Molecules from Single Pion Exchange"

In Ref. [1], the possibility of deeply bound systems of a pair of two open charm mesons, for simplicity here called D_α and D_β, was discussed. One of the two constituents, here D_β, has to have a large width, dominated by the S-wave decay $D_\beta \to D_\alpha \pi$. Since this large width implies a large coupling to pions in the transition potential, the authors concluded [1,2] that in some channels the attraction in the $\bar{D}_\alpha D_\beta$ system could be sufficiently strong to produce *deeply* bound states. In this Comment, we present arguments that those states should not exist: If D_β has a significant $D_\alpha \pi$ decay width, this not only means that the $\bar{D}_\alpha D_\beta$ interaction via pion exchange should be strong, but also that in the dynamical equations for $\bar{D}_\alpha D_\beta$ scattering, the D_β width has to be included as well as the three-body cuts due to $\bar{D}_\alpha D_\alpha \pi$ intermediate states. That the former effect alone will already strongly distort the resonance shape was discussed recently in Ref. [3]. For the case at hand here, we found from an explicit calculation, which is consistent with the results of Ref. [2] once the approximations of that paper are imposed, that taking into account both aforementioned effects completely removes any signal of bound states—qualitatively, this possibility was already discussed in Ref. [2]. Thus, we find that as soon as the $D_\beta \to D_\alpha \pi$ coupling is sufficiently strong to produce a bound state it is at the same time *necessarily* sufficiently strong to provide the state with such a large width that it becomes unobservable. This connection is unavoidable, for the interplay of the various components is a consequence of unitarity [4].

In order to make the arguments given more quantitative, we now focus on the example of a possible bound $\bar{D}_1 D^*$ system in the isoscalar-vector channel. To visualize our findings we present the predicted $\bar{D}^* D^* \pi$ invariant mass distribution assuming all three particles to emerge from a point source. To do the calculation we convolute the resulting transition matrix element with the proper three-body phase space as well as the D_1 spectral function. For the latter quantity in the phase space integration for all calculations we use the correct expression, regardless of what approximations are used in the scattering equation. The parameters underlying the calculation are 2427 and 453 MeV for the mass and the width of the D_1, respectively, where the latter is consistent with the strength of the potential given in Ref. [2]. No form factors were used. In Fig. 1, we show as the dashed line the result of our calculation once all approximations of Refs. [1,2] are imposed. The spectral distribution clearly shows the lowest two states as very sharp peaks. The binding energies are 227 and 12 MeV, respectively, consistent with one of the results of Ref. [2], where, however, a large parameter space is studied. Then we add in the imaginary part of the potential as derived, but not used in Ref. [1], as well as a constant width for the D_1. This leads to the dot-dashed result in Fig. 1. As one can see, both resonance signals are completely gone. In addition, this simplified calculation is already very close to the full result, as given by solid line, which is obtained by solving the Lippmann-Schwinger–type equation for the $\bar{D}_1 D^*$ system including the full $\bar{D}^* D^* \pi$ dynamics (in particular, the $\bar{D}^* D^* \pi$ cut) with relativistic pions as well as the full energy dependence of the potential and of the D_1 width. Moreover, going to the full calculation does not introduce any new parameter, since all individual contributions are linked through two- and three-body unitarity. Thus, the deeply bound hadronic molecules advocated in Refs. [1,2] do not exist.

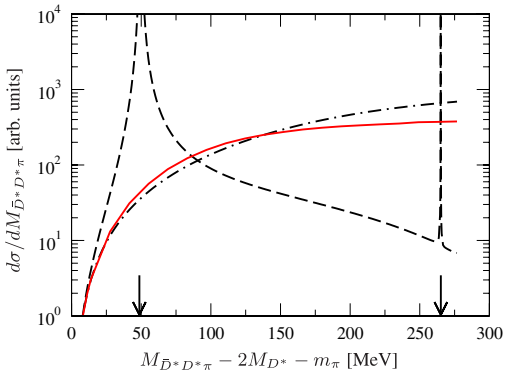

FIG. 1 (color online). Calculated $\bar{D}^* D^* \pi$ production cross sections with arbitrary relative normalization. Dashed line: Using all approximations of Refs. [1,2]. Dot-dashed line: Adding simplified imaginary parts. Solid line: Exact result. For details, see the text.

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[1] F. Close and C. Downum, Phys. Rev. Lett. **102**, 242003 (2009).
[2] F. Close *et al.*, Phys. Rev. D **81**, 074033 (2010).
[3] C. Hanhart *et al.*, Phys. Rev. D **81**, 094028 (2010).
[4] R. Aaron *et al.*, Phys. Rev. **174**, 2022 (1968).

