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On the way to a realistic description of hadron resonances*

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We are in the course of developing a coupled-channel relativistic constituent-quark model (CC RCQM). Thereby it should become possible to describe hadron reactions more realistically. In particular, we focus on strong hadron resonance decays, where we want to include the coupling to the mesonic decay channels explicitly.

In this regard, promising results have already been obtained before in a toy model for quark-antiquark systems with a scalar interaction neglecting spin and flavor degrees of freedom [1, 2]. There we calculated the decay of a meson resonance into the ground state by emitting a pion in a fully relativistic manner. The RCQM was constructed in a coupled-channel formalism along Poincaré-invariant quantum mechanics in the point-form. It leads to the interacting mass operator in matrix form comprising the two channels

1. the confined quark-antiquark system, depending on the valence-quark degrees of freedom, described by the mass operator $\hat{M}_{\text{val}}$ and
2. the decay channel, containing in addition the π as the decay product, described by the mass operator $\hat{M}_{\text{val},\pi}$:

$$\hat{\mathcal{M}} = \begin{pmatrix} \hat{M}_{\text{val}} & \hat{K}^\dagger \\ \hat{K} & \hat{M}_{\text{val},\pi} \end{pmatrix} . \tag{1}$$

Here, the operator $\hat{K}$ provides the coupling to the decay channel by producing the π at an elementary quark/antiquark-π vertex. For simplicity, the mass operator in the first channel is assumed to be the free mass operator plus a confinement interaction of harmonic oscillator type. The mass operator $\hat{M}_{\text{val},\pi}$ in the second channel contains in addition the kinetic energy of the π.

We solved the eigenvalue problem of the matrix mass operator in Eq. (1) after a Feshbach reduction leading to the complex eigenvalue problem

$$\left[\hat{M}_{\text{val}} + \hat{K}^\dagger \left(\mathcal{M} - \hat{M}_{\text{val},\pi} + i0\right)^{-1} \hat{K}\right] |\psi_{\text{val}}\rangle = \mathcal{M}\,|\psi_{\text{val}}\rangle \ . \tag{2}$$

The results for the mass eigenvalues are shown in Fig. 1 as a function of the coupling strength to the decay channel. For the definite value of $g^2/4\pi$=1.19, marked

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by the vertical line, we obtained the ground state corresponding to a model ρ meson with real mass eigenvalue m and the first excitation as a true resonance with complex mass eigenvalue $\mathcal{M}$. The decay width of the latter is $\Gamma = 2\,\mathrm{Im}\,\mathcal{M} = 26$ MeV.

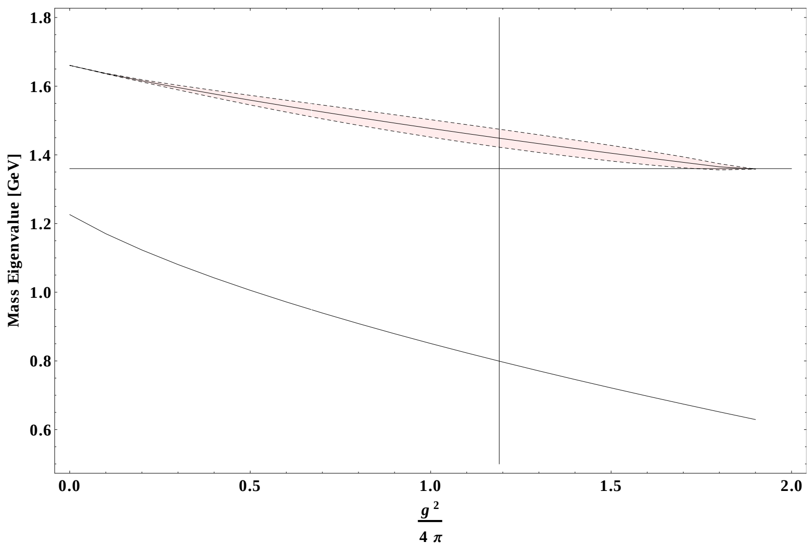

Fig. 1. Dependence of the mass-operator eigenvalues of the ground state (lower solid curve) and the first excited state (upper solid curve) on the coupling constant between the constituent (anti)quarks and the meson. For the resonant state it is also shown, how the decay width Γ – whose value is multiplied by a factor of 4 for better visibility – develops (shaded area). The vertical line indicates the particular coupling strength, where the mass eigenvalues of a model ρ ground state and an ω^* resonance are reproduced. The horizontal line marks the energy, where the decay width Γ vanishes; it is just the energy of the $Q\bar{Q}$ ground state with only confinement plus the π mass.

Beyond describing the spectrum more realistically, our model also allows to deduce meson vertex form factors from a microscopic approach. This has been done in ref. [3].

Currently, we are applying our approach to mesons, including spin and flavor degrees of freedom. At the same time we are improving the dynamics entering the valence and decay channels. Subsequently, the whole formalism will be extended to baryons. We expect that the notorious shortcomings of single-channel models, producing hadronic decay widths generally too small [4], will thereby be remedied.

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