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О возможности образования резонансов в системе 3 бозонов

На основе решения задачи Гильберта-Шмидта для ядра уравнения Фадеева показано, что в системе 3 бозонов, взаимодействующих посредством потенциала Ямагучи, возникает резонанс в состоянии с полным моментом $L=0$. Исследуется поведение положения резонанса в зависимости от параметров парного потенциала.

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On Possibility of Resonance Formation in Three-Boson System

By solving the Gilbert-Schmidt problem for the kernel of the Faddeev equation, it is shown that a resonance in a state with total angular momentum $L=0$ is formed in a 3-boson system with the Yamaguchi two body potential. The behaviour of the resonance position is studied as a function of parameters of the two-body potential.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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This note continues the search and analysis of the resonance properties in a system of three identical spinless particles interacting via the Yamaguchi two-body separable potential started in paper [1].

The discovery of narrow resonances is of especial interest: their study can help one to understand the formation and behaviour of resonances in real physical systems because just the narrow resonances can be rather reliably identified in experiment.

As in the previous paper [1], the existence of a resonance in a system is determined by the condition [2]:

$$\lambda_n(Z_{res.})=1, \qquad (1)$$

where $\lambda_n(Z)$ are eigenvalues of the kernel of the Faddeev equation, $Z_{res.}$ is the total energy of the 3-body system at which a resonance exists. The dependence of characteristics of the three-particle resonance (e.g., its width of the full decay and position) on properties of the two-body potential is not yet clear. At the same time, the three-particle resonance is a more rich system with respect to the independent physical characteristics than the bound state. Therefore it may be expected that the study of the dependence of these parameters on two-body interaction characteristics, on the one hand, gives a new information on the dynamics of motion of a 3-body system in the continuum, and, on the other hand, allows one to compare the properties of the two-body potentials.

This study can be performed in two ways.

The first method (we shall deal with here) is as follows: the varying parameter is quantity α related to the two-body potential in the form

$$V(k,k') = -\gamma g(k) g(k')$$

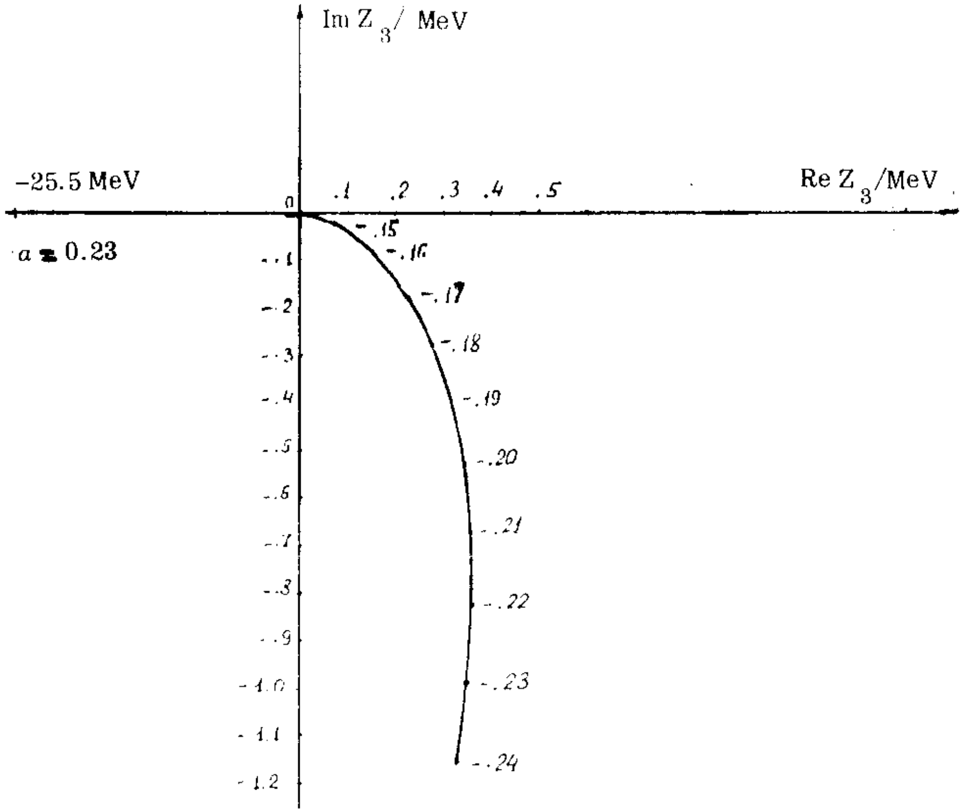
$$g(k) = (2\pi)^{3/2} (k^2 + \beta^2)^{-1} \qquad (2)$$

$$\gamma = \frac{1}{\pi^2} \beta(\beta+\alpha)^2 \qquad \alpha^2 = \frac{mE_d}{h^2} > 0,$$

where E_d is the binding energy in the two-body system. For $\alpha < 0$ there is no bound state in the subsystem.

The other method consists in the following: the scattering phase is put to be constant in a two-body system, and the resonance characteristics are studied as a function of the off-mass-shell behaviour of the potential. This method allows one to study the sensitivity of properties of 3-body systems to the changes of the two-body potential at short distances [3].

The figure represents the trajectory of a pole of the 3-body T-matrix (total angular momentum $L = 0$, $\beta = 1.45\ fm^{-1}$) versus parameter α. The position of poles was calculated in the following way: In ref. [1] it was shown that poles corresponding to resonances are concentrated on the unphysical in energy Z_3 sheet, and the eigenvalues on that sheet were proposed to find through the numerical analytic continuation of function $\lambda(Z_3)$ calculated numerically on the physical sheet. The main drowback of this method is that it gives



Numbers on the curve show the value α.

rather reliable values of λ on the unphysical sheet only nearby the physical sheet. Here, we calculated the poles by refined method from ref. [4] which gives eigenvalues just on the unphysical sheet via deforming the integration contour.

As is seen from the figure at $\alpha = 0.23\ fm^{-1}$ (the usual triplet interaction) the considered pole corresponds to the bound state with binding energy $Z_3 = -25.5$ MeV. With approaching zero, the two-particle bound state transforms into continuum while the three-particle bound state still exists. At $\alpha \approx -0.14\ fm^{-1}$ the latter also turns into continuum.

The observation of further motion of the pole shows that in the given system (i.e., in the state with $L=0$, $\ell_{ik}=0$, ℓ_{ik} is the moment in the subsystem) there are favourable conditions for the resonance formation.

The comparison of this result with the known behaviour of poles in the two-body case for the square well potential [5] leads to a very interesting conclusion. Indeed, in ref. [5] it was shown that the narrow resonances cannot be generated in S-state that is physically justified. Therefore, it could be expected that in the 3-body system with $L=0$ and $\ell_{ik}=0$ narrow resonances are absent, as well, because of the absence of centrifugal barriers. The existence of the narrow 3-body resonance in S-state leads us to assume that in the considered system there arises the effective repulsion. The existence of such a repulsion is supported also by negative eigenvalues of the Gilbert-Schmidt 3-body problem obtained for a separable two-body potential of type (2) in ref. [6]. A possible origin of the effective repulsion in the 3-body system can be attributed to known specific properties of the potential (2). Indeed, because of the nonlocality of the separable potential (2) there does not appear more than one level with increasing its depth. It is just this property of the nonlocal potential that seems to be natural to associate with the appearance of effective repulsion. To answer the above paradox, it is instructive to consider a possibility for appearance of the 3-body resonance with a two-body potential more close to the local one, e.g., which contains sevaral separable terms.

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