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Jost function method approach for study of unstable nuclei

We have developed the formalism of the Jost function method (JFM) to study unstable nuclei. The component of the unbound states becomes important in the field of quantum systems where open channels are included in the system, e.g. study of unstable nuclei. From the aspect of the few-body treatment, the position of the S-matrix pole is a crucial key to characterize the system. The pole position can be obtained very precisely by using the Jost function method (JFM). A practical recipe for the numerical treatment of JFM was given by S. A. Sofianos and S. A. Rakityanskiy. Inspired by this practical approach, we have developed the formalism of the Jost function method (JFM) to study the partial decay widths in coupled-channel systems, virtual (anti-bound) states, non-local kernels in the Hamiltonian and application to the Lagrange-mesh formalism. In this talk, we show the applications of JFM for studying the unstable nuclei.

First, we have shown the partial decay widths in a coupled-channel system can be determined by JFM under the assumption that the sum of the partial widths becomes the total width. We demonstrate how accurately we can determine the partial decay widths even for broad resonant cases and show that two different schemes to define the widths give exactly the same result using the JFM approach.

Next important progress on the study of unstable nuclei is the discussion of the virtual state pole within the other physical observables, i.e. scattering phase-shift and scattering length. We compare the two systems, 5He and 10Li, which are considered to be the subsystem of halo nuclei: 6He and 11Li. To understand the structure of 11Li, the position of the pole in s-wave state of 10Li is important. Because 11Li is a p-shell nucleus in the shell model point of view, and the valence neutrons are in the 0p1/2-orbit with respect to the 9Li core. Nevertheless, experiments indicate the strong s-wave component for the low-lying state of 10Li (9Li-n) system, and no s-wave bound states are observed. Hence, such the s-state can be considered as a virtual (anti-bound) state. For the theoretical approach to study of 11Li, we need to determine the potential strength of the 9Li+n system. The position of the S-matrix pole can be investigated by JFM even for the virtual states, and we discuss how the pole moves on the complex momentum plane by changing the potential strength. The results are connected to other physical observables such as the phase shift and scattering length.

The remaining issues for the JFM approach is to include non-local potentials or kernels into the formalism. We proposed a practical approach for solving an integro-differential equation of JFM.

Using this formalism, the virtual state of 10Li can be determined including the non-local Pauli projection operators under the orthogonality condition model. Recently, we apply JFM to the Lagrange-mesh approach. The prominent advantages of the Lagrange-mesh approach are follows. The mesh points of this method can be taken very small number compared to the conventional numerical integration for solving the differential equation, e.g. the Runge-Kutta method. The typical number of the mesh points is 20 to 100. Furthermore, the mesh points are defined as the zero-point of the Lagrange polynomials. Hence, the non-local potential which induces the integration in the differential equation can be reduced to a value to each mesh point.

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