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Quantization conditions in the finite volume within the plane wave basis expansion

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The quantization of the energy levels of interacting two-particle system in a finite volume has been well considered in which the exponential suppressed finite volume effect was usually omitted. The partial waving mixing effect in the finite volume is also an obstacle to extracting the interacting information in the infinite volume. In this work, we propose a framework to calculate the energy levels of two-particle systems in the box with the plane wave basis expansion rather than the partial wave expansion. We can reduce the interacting matrices of operators into the irreducible representations of the corresponding point groups. We use a nonrelativistic toy model and a relativistic example, $\pi\pi$ scattering, to illustrate the framework for both static and moving systems. In this framework, the exponential suppressed effect and partial wave mixing effect are embedded naturally. Our results show that the exponential suppression effect and the partial wave mixing effect for NN interaction with typical range $1/m_\pi$ are important for the box with size L<5 fm. This framework could be used to obtain the two-body finite volume energy spectrum from the effective field theories, unitarization approaches and other theoretical models, which could be related to the lattice QCD raw data.

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