Contribution ID : **19** Type : **not specified**

Finite Volume Hamiltonian method for two-particle system

We propose a systematic method to block-diagonalize the finite volume effective Hamiltonian for two-particle systems with arbitrary spin in both the rest and moving frame. The framework is convenient and efficient for addressing the left-hand cut issue arising from long-range potential, which are challenging in the framework of standard L\"uscher formula. Furthermore, the method provides a foundation for further extension to three-particle systems. We first benchmark our method by examining several toy models, demonstrating its consistency with standard L\"uscher formula in the absence of long-range potential. In the presence of long-range potential, we investigate and resolve the effects and issues of left-hand cut. As a realistic application, we calculate the finite volume spectra of isoscalar $D\bar{D}^*$ system, where the well-known exotic state $\chi_{c1}(3872)$ is observed. The results are qualitatively consistent
with the lattice QCD calculation, highlighting the reliability and potential application of our framework to the study of other exotic states in hadron physics.

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