



Contribution ID: 100

Type: Oral Presentation

Lattice study on a tetra-quark state T_{bb} in the HALQCD method

Tuesday, 9 August 2022 14:40 (20 minutes)

We study a doubly-bottomed tetra-quark state ($bb\bar{u}\bar{d}$) with quantum number $I(J^P) = 0(1^+)$, denoted by T_{bb} , in lattice QCD with the NRQCD quark action for b quarks.

Employing $(2+1)$ -flavor gauge configurations at $a \approx 0.09$ {fm} on $32^3 \times 64$ lattices, we have extracted the coupled channel HAL QCD potential between $\bar{B}\bar{B}^*$ and $\bar{B}^*\bar{B}^*$, which predicts an existence of a bound T_{bb} below the $\bar{B}\bar{B}^*$ threshold.

By extrapolating results at $m_\pi \approx 410, 570, 700$ {MeV} to the physical pion mass $m_\pi \approx 140$ {MeV}, we obtain a binding energy with its statistical error as $E_{\text{binding}}^{(\text{single})} = 155(17)$ MeV and $E_{\text{binding}}^{(\text{coupled})} = 83(10)$ MeV, where “coupled” means that effects due to virtual $\bar{B}^*\bar{B}^*$ states are included through the coupled channel potential, while only a potential for a single $\bar{B}\bar{B}^*$ channel is used in the analysis for “single”.

A comparison shows that the effect from virtual $\bar{B}^*\bar{B}^*$ states is quite sizable to the binding energy of T_{bb} . We estimate systematic errors to be ± 20 MeV at most, which are mainly caused by the NRQCD approximation for b quarks.

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Session Classification: Hadron Spectroscopy and Interactions

Track Classification: Hadron Spectroscopy and Interactions