Project Title:

Structure and dynamics of nuclear large amplitude collective motion

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The studies of dynamical fusion threshold in heavy-ion reactions have attracted great interest in recent years, especially with the experimental progress of the synthesis of superheavy elements and exotic nuclei. Both macroscopic model and simplified microscopic model predicted the need for an extra push over the Coulomb barrier in fusion reactions. The extra push is characterized by an additional bombarding energy over the barrier height in order to achieve a fused system.

Our study aims at investigating whether the microscopic time-dependent Hartree-Fock (TDHF) calculation quantitatively reproduces the extra-push energy for the fusion reaction, including the criterion for the mass combination of projectile and target above which the extra push is needed, and how much the extra push energy is. We study these issues in heavy-ion fusion reactions with TDHF theory employing the full Skyrme force and without any geometric symmetry restrictions. This study will give some guidance and information for the experimentalists.

By using RICC system, the systematic calculations have been done from the light to heavy nuclei with TDHF theory to investigate whether an extra push energy over Coulomb barrier is necessary for the fusion of heavy ion collision. We solve TDHF equation in three-dimensional coordinate space and the numerical codes are written in Fortran 95. The full three dimensional TDHF calculations will shed light on more realistic dynamics in heavy ion collisions. However the calculations require much computational times. The high speed and available CPU times of RICC system provided essential support for the studies of the research project.

We found that for light systems the TDHF fusion threshold, interaction barrier with frozen-density energy density functional (FD-EDF) method and experimental Coulomb barrier have a quite good agreement, which imply extra push is not needed for light systems. However for heavy system, the TDHF fusion threshhold is higher than the interaction barrier with FD-EDF method. One may make a conclusion that an extra push energy above the interaction barrier is needed in order to achieve the fusion for heavy systems. In order to give more confidential answers to those issues on the fusion dynamics, more systematic calculations for heavy systems are now under progress.

In the next usage term, I will continue my present research project in the following three directions. First, the study of extra push energy for heavy system in heavy ion fusion reactions will be done with TDHF theory. The heavy system includes the combinations of the projectile and target among the heavy nuclei, e.g., ^{100}Sn, ^{132}Sn, ^{208}Pb and so on. Second is to study the dissipation mechanism in nuclear Landau-Zener effect of heavy ion collisions with boost-invariant TDHF theory. Some deeper investigations will be performed to see whether a Landau-Zener transition clearly exist or not. Until now I have already calculated the collisions of light systems ^{4}He+^{16}O and ^{16}O+^{16}O. I plan to calculate some other systems, e.g. ^{40}Ca+^{40}Ca, ^{40}Ca+^{48}Ca and ^{40}Ca+^{90}Zr, to study the nuclear Landau-Zener effect. Third is to study the dissipation mechanism in nuclear giant resonance with boost-invariant TDHF theory. The nucleus will be excited with external fields, and some dissipation mechanism will be investigated from light to heavy nuclei, e.g. from ^{16}O, ^{40}Ca and ^{48}Ca to ^{90}Zr, ^{100}Sn, ^{132}Sn and ^{208}Pb so on. All these studies need a lot of numerical calculations and RICC system will provide essential and important supports to these numerical calculations.