

**Project Title:**

**Structure and dynamics of nuclear large amplitude collective motion**

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Nucleus-nucleus interaction potential in heavy-ion collision gives important information on reaction dynamics, especially on the synthesis of superheavy elements and exotic nuclei. Various approaches, including phenomenological models and microscopic methods, have been employed to investigate nucleus-nucleus interaction potentials. Among these methods, the microscopic time-dependent Hartree-Fock (TDHF) with density-constraint is one of the successful approaches in a sense the nuclear structure and nuclear dynamics are treated in a unified framework and there is no free parameters in the description of nuclear dynamics.

Our study aims at investigating some alternative methods to deduce internuclear potential in the framework of TDHF theory. One way is to employ the time-even TDHF hamiltonian, the other with the boost-invariant TDHF hamiltonian, and another within the energy density functional theory with the frozen density approximation.

By using RICC system, the nucleus-nucleus interaction potential in heavy-ion collisions have been calculated with the three methods stated above. We solve TDHF equation in three-dimensional coordinate space and the numerical codes are parallized with message passing interface (MPI). The full three dimensional TDHF calculations will shed light on more realistic dynamics in heavy ion collisions. However the numerical calculations are quite time-consuming, especially for the calculation of nucleus-nucleus interaction potential. The high speed and available CPU cores of MPI parallization in RICC system provided essential support for the studies of the research project.

The nucleus-nucleus interaction potential for  $^{16}\text{O}+^{16}\text{O}$  has been calculated with the three methods stated above. The potential obtained from time-even

overlap of the two densities is small so that the comparison between EDF method and other methods is applicable.

In the next usage term, I will continue my present research project in the following three directions. First, the nucleus-nucleus interaction potential for heavy system will be investigated in order to understand the reaction mechanism of extra-push dynamics. Second, the study of extra-push dynamics for heavy systems leading to superheavy elements in heavy ion fusion reactions will be done with TDHF theory, e.g. the reactions leading to superheavy elements,  $^{70}\text{Zn}+^{208}\text{Pb}$ ,  $^{48}\text{Ca}+^{238}\text{U}$ , and  $^{96}\text{Zr}+^{132}\text{Sn}$ . Third is to investigate 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  $^{16}\text{O}$ ,  $^{40}\text{Ca}$  and  $^{48}\text{Ca}$  to  $^{90}\text{Zr}$ ,  $^{100}\text{Sn}$ ,  $^{132}\text{Sn}$  and  $^{208}\text{Pb}$  so on. All these studies need a lot of numerical calculations and RICC system will provide essential and important supports to these numerical calculations.

TDHF and boost-invariant TDHF method reproduce well the density-constraint TDHF results in the approaching process until Coulomb barrier. When approaching further until the first touch, the potential from time-even TDHF calculation also reproduces well the density-constraint TDHF results, while the potential from boost-invariant TDHF calculation becomes larger than density-constraint TDHF owing to the underestimate of the instantaneous collective kinetic energy. Since EDF method with frozen density approximation did not consider Pauli principle, the binding of the colliding system is overestimated. Near the Coulomb barrier,

## RICC Usage Report for Fiscal Year 2011

### **Fiscal Year 2011 List of Publications Resulting from the Use of RICC**

#### **[Publication]**

Kosuke Nomura, Takaharu Otsuka, Noritaka Shimizu, and Lu Guo, Microscopic formulation of the interacting boson model for rotational nuclei, Physical Review C 83, 041302(R) (2011), published 25 April 2011.

I am very sorry to forget to acknowledge RICC in the paper. I guarantee that I will not make the same mistake in future.

#### **[Proceedings, etc.]**

Kosuke Nomura, Takaharu Otsuka, Noritaka Shimizu, and Lu Guo, Derivation of IBM Hamiltonian for deformed nuclei, Journal of Physics: Conference Series 267, 012050 (2011).

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#### **[Oral presentation at an international symposium]**

#### **[Others]**