Theoretical Nuclear Physics Laboratory
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1. Abstract

Nuclei are finite many-particle systems composed of protons and neutrons. They are self-bound in femto-scale (10^{-15}m) by the strong interaction (nuclear force) whose study was pioneered by Hideki Yukawa. Uncommon properties of the nuclear force (repulsive core, spin-isospin dependence, tensor force, etc.) prevent complete microscopic studies of nuclear structure. There exist number of unsolved problems even at present. In addition, radioactive beam facilities reveal novel aspects of unstable nuclei. We are tackling these old problems and new issues in theoretical nuclear physics, developing new models and pursuing large-scale calculations of quantum many-body systems. We are also strongly involved in research on other quantum many-body systems, to resolve mysteries in the quantum physics

2. Major Research Subjects

(1) Nuclear structure and quantum reaction theories
(2) First-principle calculations with the density functional theory for many Fermion systems
(3) Computational nuclear physics

3. Summary of Research Activity

(1) Large amplitude dynamics in shape coexistence phenomena

Shape coexistence phenomena in proton-rich ^{68}Se and ^{72}Kr have been studied with the adiabatic self-consistent collective coordinate method. The canonical collective variables, mass parameter, and potential were determined self-consistently. The calculation indicates importance of the triaxial degrees of freedom for the tunneling dynamics between two quasi-vacua at prolate and oblate shapes. The collective Hamiltonian was requantized to calculate excitation spectra and transition properties for the first time. The shape mixing is hindered by coupling to the rotational motion to localize collective wave functions around prolate and oblate minima.

(2) Time-dependent density funcitonal approach to nuclear photoabsorption

Nuclear photoabsorption cross sections were calculated with the finite amplitude method for the time-dependent density functional theory which we had proposed in 2007. We used the supercomputers at RIKEN, KEK, and University of Tsukuba to perform the large-scale calculations for cross sections from Be to Ni isotopes, from proton to neutron driplines. Detailed analysis is under progress.

(3) Nuclear matter density distributions and nuclear radii

We revisited the commonly accepted notion that the difference between interaction and reaction cross sections is negligible at relativistic energies. We show that the difference is clear especially in small mass number region. It could bring about uncertainties of the order of nuclear skin thickness of stable nuclei in estimates of nuclear matter radii

(4) Nuclear structure studies using nuclear reactions

We systematically studied total reaction cross sections of carbon isotopes with N=6–16 on a proton target for wide range of incident energies. The calculations include the reaction cross sections of $^{19,20,22}C$ at 40A MeV, the data of which had been measured at RIKEN. Our numerical results are consistent with the preliminary data, and suggest very small S_{2n} for ^{22}C.

(5) Neutron Cooper pair in deformed neutron-rich nuclei

Appearance of di-neutron correlation by neutron skin and continuum effects in neutron rich Mg and Cr isotopes is pointed out. By evaluating the moments of inertia, we show that the rotational excitations are qualitatively influenced by the di-neutron correlation and the systematic experimental information of the E2 properties can indicate the novel correlation.

(6) Molecular structure of ^{12}Be studied with the generalized two-center cluster model

We investigate the molecular structures in the unbound region and the reaction dynamics on their excitation. In this study, we employ the generalized two-center cluster model (GTCM) which can describe the atomic and molecular limits of the system with two inert-cores plus valence neutrons. We applied the GTCM to ^{12}Be and found that the various molecular configuration appear above the $\alpha+^{8}He$ threshold and they are strongly excited by the reaction of $\alpha+^{8}He \rightarrow {}^{6}He + {}^{6}He$.

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