Usage Report for Fiscal Year 2020

Project Title:

Properties of highly excited nuclei

Name:

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1 - It is shown, for the first time, how the exotic shapes due to cluster formation at high excitation energy and angular momentum are manifested through giant dipole resonance (GDR) strength function under the framework of the extended quantum molecular dynamics (EQMD) model. The results of EQMD calculation are compared with the existing experimental data of 32S and 28Si formed in the reactions 20Ne + 12C and 16O + 12C, respectively, at high angular momenta. It is found that the EQMD predicts the general trend of the experimental GDR strength functions for 32S and 28Si by considering the ring or toroidal configuration, whereas the linear chain configurations with α clusters can reproduce the higher-energy peak in 32S and 28Si. Thus, the direct signature of the cluster formation at high temperature and angular momentum is the observation of a GDR peak ≈25 MeV which cannot be predicted within the mean-field calculations. The present result highlights the role of α cluster states above the decay threshold, which is still an open field of investigation.

2- A fully microscopic model for the description of nuclear level density (NLD) in spherical nuclei is proposed. The model is derived by combining the partition function of the exact pairing solution plus the independent-particle model at finite temperature (EP+IPM) with that obtained by using the collective vibrational states calculated from the self-consistent Hartree-Fock mean field with MSk3 interaction plus the exact pairing and random-phases approximation (SC-HFEPRPA). Two important factors are taken into account in a fully microscopic way, namely the spin cut-off and vibrational enhancement factors are, respectively, calculated using the statistical thermodynamics and partition function of the SC-HFEPRPA without any fitting parameters. The numerical test for two spherical 60Ni and 90Zr nuclei shows that the collective vibrational enhancement is mostly dominated by the quadrupole and octupole excitations. This is the first microscopic model confirming such an effect, which was phenomenologically predicted long time ago and widely employed in several NLD models. In addition, the influence of collective vibrational enhancement on nuclear thermodynamic quantities such as excitation energy, specific heat capacity and entropy is also studied by using the proposed model.

3 - The enhancement of radiative strength function (RSF) in the region of low γ-rays energy ($E_\gamma \leq 12$ MeV), which is caused by the pygmy dipole resonance (PDR), is treated within the phonon damping model (PDM) plus exact thermal pairing (EP) without adding any extra PDR strength function. The numerical calculations performed for $^{161\text{-}163}$Dy show that, because of the effect of EP, the EP+PDM can describe reasonably well the total RSF data in both low- and high-energy regions of γ-rays. Consequently, as compared to the conventional description within the phenomenological generalized Lorentzian (GLO) and standard Lorentzian (SLO) models, the EP+PDM calculations are free from at least eight free parameters. This indicates the

important role of microscopic approaches towards the precise description of the RSF. In particular, temperature is found to have significant contributions to the RSF below the neutron separation energy, questioning again the validity of the Brink-Axel hypothesis in this energy region.

Future plan:

- Study of the effect of exact pairing on nuclear structure, level densities and radiative strength functions.
- Study of nucleon-nucleon and nucleon-nuclear elastic scattering in the low-energy region.

No job was executed because we managed to carry out all the calculations in this FY on the personal PC. However we would like to keep our account of Quick Use for the FY2021 in case of need, as my colleagues are planning to visit RIKEN to work with me on the spot after the coronavirus pandemic is over. Thank you.