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Properties of highly excited nuclei

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○Nguyen Dinh Dang (1), Nguyen Quang Hung (2), Le Tan Phuc (2), A. K. Rhine Kumar (3)
Laboratory at RIKEN: (1) Quantum Hadron Physics Laboratory, RIKEN Nishina Center
(2) Institute of Fundamental and Applied Sciences, Duy Tan University, Ho Chi Minh City 700000, Vietnam
(3) Department of Physics, Cochin University of Science and Technology, Cochin, Kerala, India

This year the situation with the corona virus has caused significant difficulties for my collaborators in India and Vietnam, which were among the countries most affected by the pandemic.

Nevertheless, we managed to conduct a systematic study to understand the proton entropy excess ΔS_p obtained for different pairs of odd-even and odd-odd nuclei ranging from A = 90 to 238 (^{90}Y and ^{91}Zr, ^{196}Pt and ^{197}Au, ^{211}Po and ^{212}At, ^{231}Th and ^{232}Pa, ^{237}U and ^{238}Np). The proton entropy excess determined from the existing experimental nuclear level density (NLD) data has been compared with the microscopic calculation within the exact pairing plus independent particle model (EP+IPM). The latter has predicted an enhanced peak of ΔS_p at excitation energy E^* ≈1 MeV in near spherical nuclei (^{90}Y and ^{91}Zr, ^{211}Po and ^{212}At), indicating a possible signature of pairing reentrance in hot nuclei.

We found that the experimental value of ΔS_p as a function of E^* exhibits a strong fluctuation at $E^* < 1$ MeV and reaches saturation at high $E^* > 3 - 6$ MeV. The analysis within the microscopic EP+IPM calculations shows that the proton entropy excess is around $0.1 - 0.5\ k_B$ for the spherical systems and around $1.0 - 1.2\ k_B$ the deformed ones, in good agreement with the experimental data. This value of proton entropy excess is smaller than that of the neutron one due to the effect of Coulomb interaction and proton single-particle level density, which is less than the neutron one. Moreover, a peak-like structure, which is seen in the proton entropy excess obtained within the EP+IPM at low energy $E^* < 1$ MeV, is explained by the pairing reentrance phenomenon caused by the weakening of blocking effect of an odd nucleon.

This peak-like structure is found to be more pronounced in the spherical systems than in the deformed ones because the pairing reentrance is stronger in spherical nuclei than in deformed ones. However, this theoretical peak-like structure is not well supported by the experimental observation due to the strong fluctuations of the measured data. Therefore, more precise and direct experimental measurements in the low-energy region (E^* <1 MeV) are called in order to confirm our theoretical predictions.

Schedule and prospect for the future

In a recent test of the generalized BA hypothesis in heavy nuclei in the energy region below the neutron threshold [1], the authors compared the gamma-ray strength functions (GSFs) in $^{116;120;124}$Sn deduced from relativistic Coulomb excitation in forward-angle inelastic proton scattering and from Oslo-type experiments. Based on the agreement of the two sets of GSFs within experimental uncertainties in the energy region between 6 MeV and the neutron threshold, the authors claimed that the generalized Brink-Axel (BA) hypothesis holds for the studied cases in this energy region, and experiments based on ground-state photoabsorption indeed provide the same information on GSFs in nuclei as Oslo-type experiments. They also expect that this claim on the BA hypothesis may hold, in general, for heavy nuclei with ground-state deformation (and thus higher level densities), except for doubly magic cases. Future comparisons should explore the limits of ground-state photoabsorption experiments to extract the GSF as a function of γ energy, level density, and mass number.

As the BA hypothesis has been theoretically and experimentally proved to hold only approximately at high excitations energy for the giant resonances, we are planning to carry out the theoretical calculations of the gamma-ray strength functions for tin isotopes within the phonon-damping model at low excitation energies (temperature below 1 MeV) in the region of low gamma-ray energy to investigate the fulfillment of the BA hypothesis.

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[1] M. Markova et al., Phys. Rev. Lett. 127 (2021) 182501.

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 FY2022 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.