Research Group for Reactions Involving Heavy Nuclei

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Shell structure of nuclei has substantial effects on their masses, decay modes and reactions. One of the research objectives of the group is to study the evolution of shell structure in exotic nuclei by measuring their decay properties, which enables us to establish a universal shell model. Our group is also pursuing fission studies for neutron and proton-rich nuclei in the region from mercury to very-heavy elements produced by heavy-ion induced reactions. For experiments, we exploit the JAEA tandem facility and other facilities inside and outside Japan.

Recently our group has published 2014 edition of the JAEA chart of nuclides [1], which is widely used in the nuclear physics and related communities over the world. In addition to the known data, the chart includes extensive theoretical predictions for yet unobserved nuclei.

Single-neutron orbits near the doubly-magic nucleus ^{78}Ni: Spectroscopy of the *N*=49 isotope ^{79}Zn

To understand the evolution of shell structure in exotic regions of the nuclear chart, single-particle properties of doubly-magic nuclei and their neighbours are essential to create theoretical models of nucleus. In our recent work [2], neutron single-particle states in the Z=30, N=49 isotope ^{79}Zn have been populated using the ^{78}Zn(d,p)^{79}Zn transfer reaction at REX-ISOLDE, CERN. A radioactive ^{78}Zn beam accelerated to 2.9 MeV/u impinged on a 100 μg/cm^2 deuterated polyethylene target. The Miniball Ge array was used to measure γ rays in coincidence with proton ejectiles detected by the T-REX segmented Si array. The first excited 5/2$^+$ and 1/2$^+$ states, corresponding to neutrons occupying the lowest orbits above the N=50 shell gap, could be identified. The analysis of angular distributions in fact provides evidence for a strong $\nu d_{5/2}$ and $\nu s_{1/2}$ single-particle strength in these states, which lie around E*~1 MeV. The new data were compared with state-of-the-art shell-model calculations, which reproduce the measured energy of the 5/2$^+$ state (in blue in Fig. 1) and also the evolution of the N=50 gap (revealed by 2-neutron separation energies) in N=49 isotones. This agreement supports the picture of a large N=50 gap at ^{78}Ni (~4.7 MeV), and of a robust magicity of ^{78}Ni.

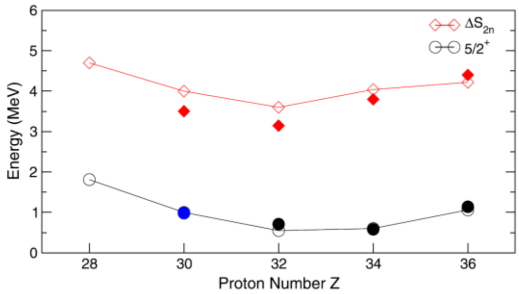

Fig. 1 Experimental (filled symbols) and calculated (empty symbols) N=50 gap sizes (red) and energy of the first 5/2$^+$ state in ^{79}Zn (blue) and N=49 isotones (black).

Identifying the origin of exotic isomeric states in neutron-rich sulfur isotopes

Neutron-rich sulfur isotopes are known to have several isomeric states whose configulations have not been well understood. The most exotic case among them is strongly hindered E2 $4^+_1 \rightarrow 2^+_1$ decay in ^{44}S, since in most deformed nuclei E2 transitions between low-lying yrast states (the lowest state for a given angular momentum) are much enhanced compared to single-particle estimate. It should be noted that ^{44}S is known to have significant quadrupole collectivity in spite of being an N=28 semimagic nucleus. In the study [3], we perform a novel analysis of nuclear shell-model wave functions based on the variation after angular-momentum projection (AM-VAP), which allows to extract wave functions in the intrinsic frame. As shown in Fig. 2, the strong E2 hindrance in ^{44}S is reproduced by the AM-VAP, as well as by the full shell-model calculation. In particular, the AM-VAP analysis demonstrates that the 4^+_1 state in ^{44}S is dominated by the K=4 wave function. This result is rather unexpected because such so-called high-K isomers have been so far identified only in some medium-heavy- and heavy-mass regions (A>100) where K value becomes an approximately good quantum number due to the development of axially symmetric deformation.

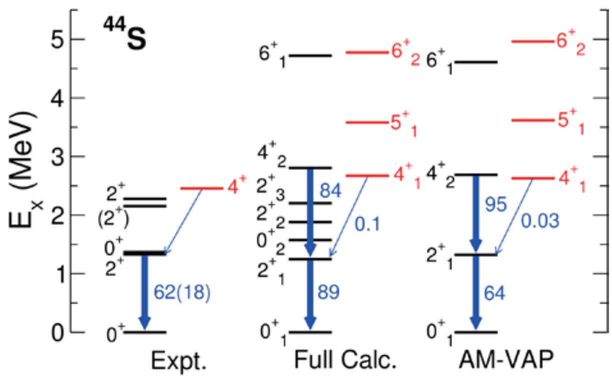

Fig. 2 Comparison of experimental energy levels and $B(E2)$ values in ^{44}S with full shell-model calculations (Full Calc.) and AM-VAP approach. The numbers next to the arrows denote the $B(E2)$ values in e^2fm^4.

References

[1] H. Koura *et al.*, *Chart of the Nuclides 2014*, JAEA (2015).
[2] R. Orlandi *et al.*, Phys. Lett. B. **740**, 298 (2015).
[3] Y. Utsuno *et al.*, Phys. Rev. Lett. **114**, 032501 (2015).