Research Group for Heavy Element Nuclear Science

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Studies of the chemical properties of the heaviest elements, and determination of the limits of nuclear stability, are the most interesting, but also most challenging, topics in modern chemistry and nuclear physics. The research conducted in our group strongly focussed toward addressing these fundamental questions.

In nuclear physics, our core program is on fission, which is a unique physical process observed only in nuclear matter, and which provides the basis for numerous atomic energy applications. Our experimental and theoretical programs include nuclear structure and reaction studies of exotic neutron- and proton-rich nuclei, as well as super-heavy nuclei. For nuclear chemistry, our work is concentrated on the heaviest elements, whose chemical properties are crucially determined by relativistic effects. Atomic and chemical properties of exotic atoms and molecules are studied via an atom-at-a-time chemistry approach.

Measurement of high-energy prompt γ-rays in thermal-neutron induced fission of ^{235}U

Prompt fission γ-ray spectra (PFGS) are important as they allow us to study the structure and de-excitation process of neutron-rich nuclei. Also, it is required as a nuclear data for a design of new types of reactors, such as the Generation-IV reactors. For spontaneous fission of ^{252}Cf, the PFGS show a hump structure associated with a giant dipole resonance (GDR) observed in fission fragments around 15 MeV [1]. For thermal neutron-induced fission, the PFGS data are limited up to about 7 MeV, even in recent experiments for ^{235}U(n_{th},f). This prompted us to extend the measurement up to energies as high as 20 MeV, enough to observe the GDR in ^{235}U(n_{th},f).

The measurement was carried out using a cold-neutron beam from the high-flux reactor (PF1B line) of the Institut Laue-Langevin (ILL), Grenoble, France. In the present measurement, we used two multi-wire proportional counters (MWPCs) to detect both fission fragments in coincidence, and two $LaBr_3$(Ce) scintillators to measure the γ-rays in fission. The improved sensitivity of our detector setup revealed the PFGS up to ~20 MeV as shown in Fig. 1 [2]. The hump structure associated with the GDR is seen.

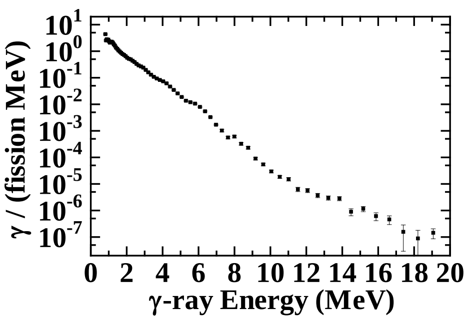

Fig. 1. The PFGS for ^{235}U(n_{th},f) obtained in the present measurement.

We also observed a local structure around 4 MeV and 6 MeV, which were also reported in ^{252}Cf(SF) [3]. From the correlation between the fission fragment mass and the γ-ray spectrum, it is found that they are emitted from the fragments in the vicinity of doubly-magic nucleus ^{132}Sn.

Improvement of the gross theory for the description of β^- decay half-lives

β^- decay is the dominant decay mode of neutron-rich nuclei and plays an important role in an astrophysical nucleothynthesis and/or nucler reactor technologies. The gross theory [4], based on the macroscopic concept, can predict a global trend for the β^- decay half-lives and delayed-neutron yields over the chart of nuclides, which have been a guide for β^--decay measurement and associated structure studies. Due to its statistical treatment the model does not take into account the microscopic properties, characterized by the spin and parity of a nuclear level, and their effects on β^--decay. This results in a local disagreement from the experimental data, particularly for nuclei in the vicinity of closed-shell nuclei.

To give a higher accuracy in our model, the microscopic effects are included, where a possible change in the parities between the parent and daughter nuclei significantly suppresses the nuclear matrix elements. The calculated results are shown in Fig. 2. A better agreement is found in the half-lives of the neutron-rich tin, indium and cadmium isotopes beyond the neutron magic number of N = 82.

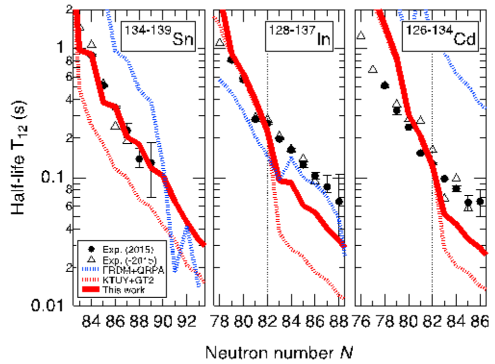

Fig. 2. β^--decay half-lives for tin, indium and cadmium isotopes in the neutron-rich region. Thick solid red lines are from the improved gross theory [5], which is compared with a previous model [4] (red dotted curve) and FRDM + Quasi-RPA calculation [6] (blue dotted curve). Location of the neutron magic number N=82 is shown by the vertical bar.

References

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