Beta-decay studies of very neutron-rich indium isotopes

The β decay of the indium isotopes ^{133}In, ^{134}In, and ^{135}In was investigated experimentally with the aim of providing new insights into the nuclear structure of neutron-rich nuclides from the ^{132}Sn region. Better understanding of these exotic nuclides is required for accurate modeling of the rapid neutron capture nucleosynthesis process (r process), due to the $A \approx 130$ peak in the r-process abundance pattern being linked to the $N = 82$ shell closure. Because a vast number of nuclei involved in the r-process are β-delayed neutron (βn) emitters, new experimental data that can verify and guide theoretical models describing βn emission are of particular interest. The effects of nuclear structure strongly affecting the competition between neutron emission and γ-ray deexcitation in the decay of neutron-unbound states were recently observed in the region southeast of ^{132}Sn. The capability of γ-ray deexcitation to compete with neutron emission well above the neutron-separation energy calls for further investigation, primarily due to its consequences for astrophysical r-process modeling. Neutron-rich indium isotopes constitute excellent cases to address this problem owing to their large β-decay energy windows for the population of neutron-unbound states in daughter nuclei (>10 MeV), as well as the simplicity of their structure within the shell model. In particular, ^{134}In and ^{135}In – being rare instances of experimentally accessible nuclides for which the β-delayed three-neutron decay is energetically allowed – constitute representative nuclei to investigate the competition between β-delayed one- and multiple-neutron emission as well as the γ-ray contribution to the decay of neutron-unbound states.

The β-delayed γ-ray spectroscopy measurement was performed at the CERN-ISOLDE facility. The indium isotopes were produced in neutron-induced fission of the uranium carbide target. Laser-ionized beams of ^{133}In, ^{134}In, and ^{135}In were on-line mass separated and transported to the ISOLDE Decay Station. Isomer-selective ionization provided for ^{133}In enabled two β-decaying states in this nucleus to be studied separately for the first time. Transitions following the β decay of indium isotopes were identified based on $\beta\gamma$ and $\beta\gamma\gamma$ coincidence data. Decay schemes of ^{135}In and two β-decaying states of ^{133}In were established for the first time, while the decay scheme of ^{134}In was expanded with two β-decay branches. Two indium isotopes, ^{134}In and ^{135}In, were identified to be β-delayed two-neutron emitters. The population of neutron-unbound states decaying via γ rays was identified in ^{134}Sn and ^{133}Sn at excitation energies exceeding the neutron separation energy by 1 MeV. The β-delayed one-neutron decay was observed to be the dominant β-decay branch of ^{134}In and ^{135}In even though the Gamow-Teller resonance is located substantially above the two-neutron separation energy of the daughter nucleus. The observed dominant one-neutron emission from these nuclei is predicted only by theoretical models, which, apart from the inclusion of first-forbidden transitions, also consider all possible decay paths of neutron-unbound states. Experimental level schemes of ^{133}Sn, ^{134}Sn, and ^{135}Sn are compared with shell-model predictions, including calculations considering particle-hole excitations across the $N = 82$ shell gap. Neutron-unbound states corresponding to the couplings of the valence particles to the neutron-core excitations were found to be an important component of the deexcitation pattern observed in daughter nuclei following the β decay of neutron-rich indium isotopes.