Selective Laser Ionization of N ≥ 82 Indium Isotopes: The New r-Process Nuclide ^{135}In

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Production yields and β-decay half-lives of very neutron-rich indium isotopes were determined at CERN/ISOLDE using isobaric selectivity of a resonance-ionization laser ion-source (RILIS). Beta-delayed neutron multiscaling measurements resulted in improved half-lives for $^{132-134}$In, as well as a first measurement of ^{135}In [1].

The region around the neutron-rich, double-magic ^{132}Sn has been the subject of intensive experimental investigations in recent years. The reason for this interest is the N=82 r-process "waiting-point" area, where the r-matter flow climbs up along the shell closure from ^{125}Tc (Z=43) to ^{130}Cd (Z=48). The r-process is able to escape from this region in the In (Z=49) isotopic chain at the "break-out points" ^{131}In and ^{133}In and speeds up again towards the rare-earth region.

Production and ionization of In isotopes

Neutron-rich medium-mass nuclei are normally produced at ISOLDE by high-energy (1 or 1.4 GeV) proton-induced spallation of ^{238}U. The disadvantage of this method is, that also proton-rich isobars of surface-ionized Rb and Cs will be produced to a large extent. The use of a so-called „neutron-converter" avoids this problem.

Indium (with an ionization potential of 5.79 eV) is already surface-ionized, but a further enhancement of the ionization efficiency was obtained by using the RILIS. The excitation scheme of In consists of two steps (from the ground state $^2P_{1/2}$ to $^2D_{3/2}$ and finally non-resonantly into the ionization continuum). For the first step, a frequency-doubled dye-laser beam of 303.9 nm is used, and for the ionization of In a copper vapor laser (510.6 nm and 578.2 nm) [2]. With this use of the RILIS, the yields of In were increased by a factor of seven compared to pure surface ionization. For a detailed description of these techniques, see [1].

Half-life measurements

After laser ionization and mass separation, the isotopically clean beams of In nuclides were transported to the beam line equipped with the Mainz moving tape station. Beta-delayed neutron data were collected by multi-scaling measurements (see Fig. 1) using the high-efficiency Mainz 4π ^{3}He neutron long counter. This detector consists of 64 ^{3}He proportional counters arranged in three concentric rings.

Table 1: Comparison of experimental β-decay half-lives for $^{132-135}$In with literature values and QRPA predictions for GT decay.

Nuclide	$T_{1/2}$(exp) [ms]	$T_{1/2}$(Lit) [ms]	$T_{1/2}$(QRPA) [ms]	$T_{1/2}$(cQRPA) [ms]
^{132}In	206 (6)	201 (13)	96	212
^{133}In	165 (3)	180 (20)	141	245
^{134}In	141 (5)	138 (8)	99	190
^{135}In	92 (10)	-	90	251

The resulting half-lives are summarized in Table 1, together with two predictions from Quasi-Particle Random-Phase Approximation (QRPA) models. The first one is in principle a "deformed" QRPA [3] for Gamow-Teller (GT) decay, which takes the ground-state shape of the β-decay daughter isotopes as predicted by the Finite-Range Droplet Model (FRDM) [4]. This model uses experimental nuclear masses, as far as they are available, otherwise FRDM predictions. The second model is the so-called continuum QRPA (cQRPA) [5], which is limited to spherical nuclei. It uses nuclear mass predictions from the ETFSI model [6].

Table 1 shows a satisfactory agreement within a factor of 2. The differences between QRPA and cQRPA predictions mainly reflect the effects from the different pairing models (Lipkin-Nogami and BCS, respectively) and Q_β values.

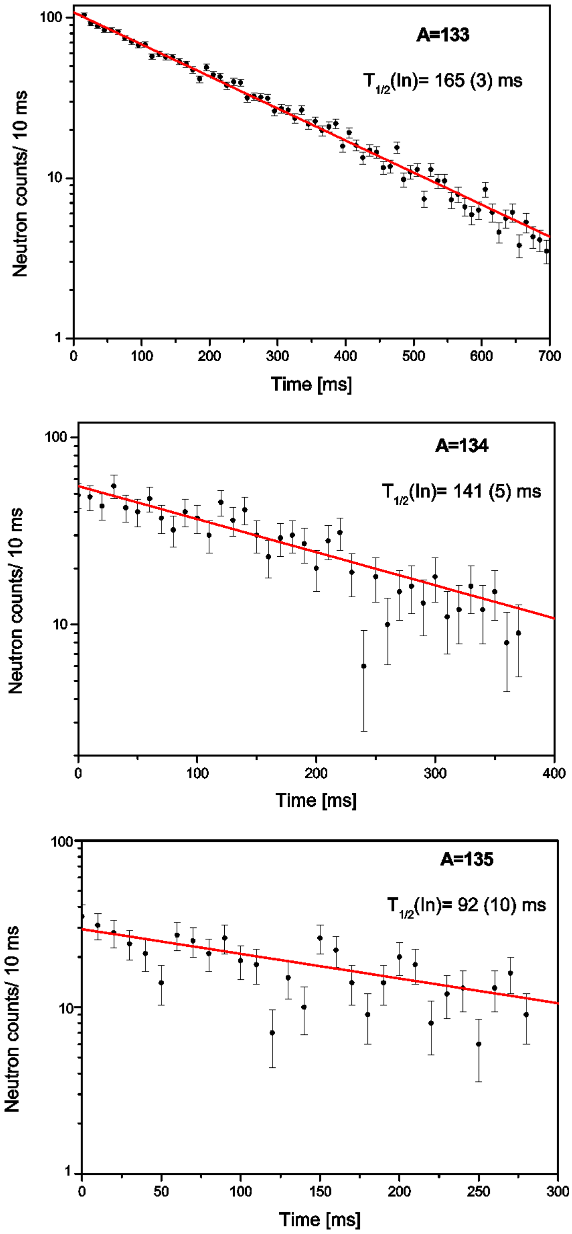

Fig. 1: Half-life measurements of $^{133-135}$In by multi-scaling of β-delayed neutrons, after correction for βdn-daughter activities and neutron background.

References

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