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β-delayed proton emission in the ^{100}Sn region

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β-decay nuclides in the immediate neighborhood of ^{100}Sn were studied at the NSCL using the β-Counting System (BCS) and the Segmented Germanium Array (SeGA). The nuclei of interest were implanted into the BCS and properties from both, implantations and subsequent β-decays, were recorded on an event-by-event basis, allowing for the direct observation of half-lives, β-delayed proton emission branching ratios, and β-end point energies. In addition the use of SeGA in conjunction with the BCS allows the observation of the prompt γ radiation from implantations and as well as photons emitted following β and β-delayed proton decay.

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1. Introduction

The area around the doubly magic nuclide ^{100}Sn is a unique testing ground for nuclear structure physics in many respects. Due to the closed shells at N = Z = 50 detailed comparison between experimental results and shell model calculations are feasible.
Interesting phenomena such as decays with large energy release, β-delayed proton emission (βp), and spin-gap isomerism, also occur in this region. Thus, experiments in this region provide excellent conditions to study the role of core excitation and proton-neutron interaction in identical orbits.
Moreover, nuclear structure data in this part of the chart of nuclei provide valuable input data for models of the astrophysical rapid proton capture process [1].
In this paper, preliminary observations of β-delayed proton activity are reported for nuclei in the region of ^{100}Sn. For a discussion of the determination of the half-lives of these nuclei, see [2].

1.1 Experimental procedure and setup

Nuclei in the vicinity of ^{100}Sn were produced at NSCL by fragmentation of a 120MeV/u ^{112}Sn beam impinging on a 195mg/cm^2 Be target. The reaction products were selected in the NSCL A1900 fragment separator on the basis of their magnetic rigidity. A 40.6 mg/cm^2 thick Kapton wedge was placed at the intermediate image of the A1900 and used to provide a selection of the nuclear charge. Further purification of the secondary beam from the A1900 was based on the velocity selection achieved with the NSCL RF Separator [2].
After separation the nuclei of interest were implanted into the NSCL Beta Counting System (BCS) [3], which was surrounded by 16 detectors from the NSCL Segmented Germanium Array (SeGA) [4]. The BCS employs one double-sided silicon strip detector (DSSD) for implantation. The DSSD was 985μm thick and had 1600 pixels. Three PIN diodes were located upstream of the DSSD and provide beam diagnostics and energy loss information necessary for particle identification. β-decay was studied by correlating a decay event in the implantation pixel or its nearest neighbors for up to 20 seconds after each implantation.
Six single-sided silicon strip detectors (SSSD) and a planar Ge detector located downstream of the implantation detector constituted the β calorimeter, which allowed the measurement of the total energy of β particles emitted in the downstream direction to energies greater than 14 MeV. The experimental apparatus allowed for the measurement of β-decay half-lives, study of βp branching ratios, and prompt and β-delayed γ-ray spectroscopy.

1.2 Studies of β-delayed protons

In Fig. 1 are shown the energy spectra of decay events recorded in the DSSD for the several isotopes of interest. The energy loss contribution from positrons from β-decay and electrons from internal conversion occurs in the lower energy region of the spectra and is clearly distinguished from higher-energy events where β-decay is likely followed by proton emission. Since the proton emission is almost simultaneous with the β-decay, the energy deposited in the DSSD is the sum of the full proton energy and the small (~ few hundred keV) energy loss signal of the outgoing β particle, which largely escapes the detector.

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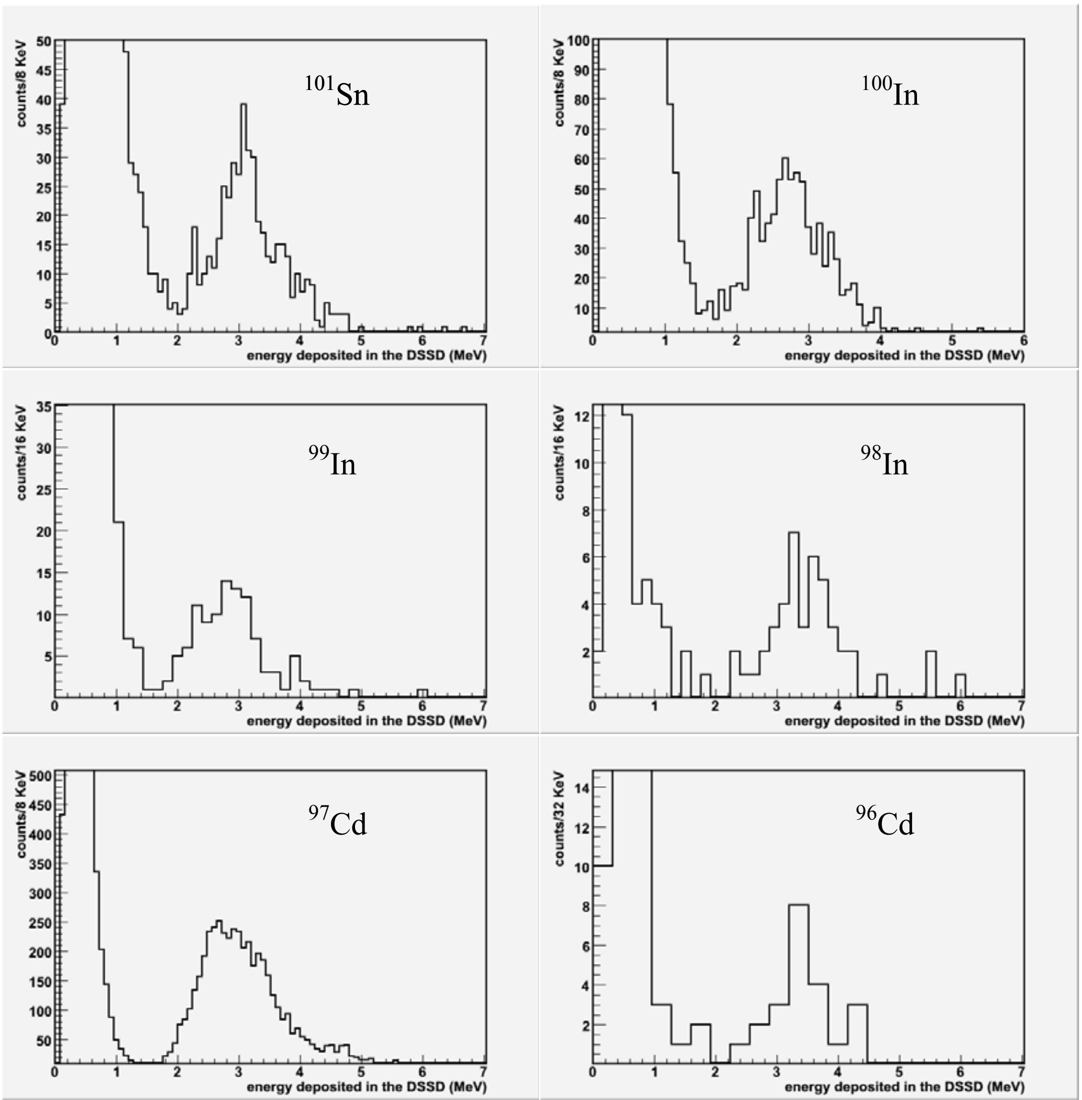

Fig. 1. Preliminary spectra of the energy deposited in DSSD for several implanted isotopes.

The background for the decay events of β-delayed proton emission was evaluated by studying how these events are correlated in time with implanted isotopes. In Fig. 2 is shown the decay curve for high-events recorded in the DSSD correlated with ^{97}Cd implantations. The random nature of the background results in a constant component, while the real decays are exponentially distributed, following the decay constant of the parent. It is possible to extract the βp branching ratio b_p from an exponential fit to the decay curve, since the βp decay rate is related to the number of implanted isotopes N_{imp}, the correlation time t_0, the decay constant λ, and the efficiency of detecting βp events ε_p, by the following equation:

$$\beta\text{-delayed proton decay rate}(t) = N_{imp}\,(1 - e^{-\lambda t_0})\,\varepsilon_p\, b_p\, e^{-\lambda t} + a,$$

where a is the background rate. The fit has only two free parameters b_p and a, since ε_p can be determined by studying the cases where γ rays are detected from the de-excitation of the granddaughter nucleus produced by βp emission. In those cases, the efficiency is simply determined for a specific γ-ray transition as the ratio between the number of pγ coincidences and the total number of γ rays. Such an analysis was completed for the known βp emitters ^{97}Cd, ^{93}Pd, and ^{96}Ag. The ε_p values are depicted in Fig. 3. An efficiency of 90(5)% was deduced based on a weighted average of these values.

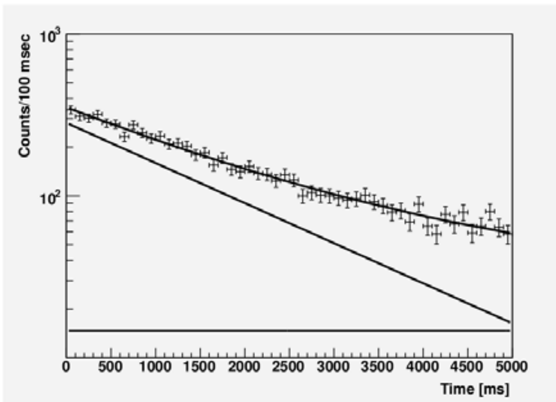

Fig. 2. Time distribution of events with proton emission for ^{97}Cd. The three components shown are the constant background, the contribution of the β-delayed proton emission, and their sum.

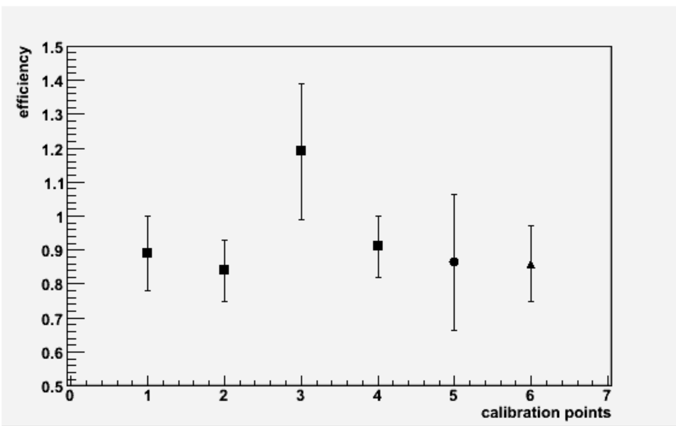

Fig. 3. Deduced ε_p values of the DSSD, calculated as described in the text using the γ rays 325, 684, 1253, and 1415 keV from the β-delayed proton emission of ^{97}Cd into ^{96}Pd (squares), the γ ray 773.8 keV from ^{93}Pd into ^{92}Ru (circle), and 1350 keV from ^{96}Ag into ^{95}Rh (triangle).

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1.3 Summary

We have performed an experiment at NSCL to study β-decay properties of nuclei in the ^{100}Sn region. We have observed for the first time β-delayed proton emission from nuclei $^{98,\ 99}$In and ^{96}Cd. ^{100}In, ^{97}Cd, and ^{95}Ag were found to be proton precursors as previously reported [5-7]. The data will allow us to determine for the first time the proton branching ratio of all the above nuclei.

Finally, β-decay proton emission of ^{101}Sn was also observed with higher statistics than in the previous observation [8].

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