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β-decay studies of N=Z nuclides at NSCL

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We have performed an experiment at NSCL to study the β-decay of N=Z isotopes ^{96}Cd, ^{98}In and ^{100}Sn using the β-Counting system (BCS) and the Segmented Germanium Array (SeGA). The nuclei of interest were implanted into a double-sided silicon strip detector and properties from both implantations and the subsequent β-decays were recorded on an event-by-event basis. The newly constructed Radio Frequency Fragment Separator (RFFS) was used to reduce the overall implantation rate due to low momentum tails of less neutron-deficient contaminants. The study of the doubly magic ^{100}Sn along with its neighbors is essential to understand single-particle structure and proton-neutron interaction close to the proton drip-line. The measured half-life of ^{100}Sn, $0.55^{+0.70}_{0.31}$ s, is consistent with a previous measurement. The presence of two $\beta-$decaying states in ^{98}In was also confirmed and the improved obtained half-lives are 47(13) ms and 0.66(40) s. The half-life of ^{96}Cd was measured to be $1.03^{+0.24}_{0.21}$ s.

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The experimental properties of the doubly magic nucleus ^{100}Sn and its closest neighbors are of great interest for nuclear astrophysics and nuclear structure considerations. Since the β-decay of ^{100}Sn is predicted to be concentrated in one single 1^+ level in ^{100}In with an almost pure $\pi g^{-1}_{9/2} \nu g^{1}_{7/2}$ configuration [1], shell model calculations should well describe the decay. This makes the β-decay of ^{100}Sn an ideal candidate to study the apparent reduction of the GT strength compared to theoretical expectations. Because the production and separation of ^{100}Sn has proven to be an experimental challenge over the years, projectile fragmentation using 1 GeV/A ^{124}Xe and ^{112}Sn along with 60 MeV/A ^{112}Sn have produced only a handful of identifications [2, 3, 4]. So far, the only ^{100}Sn half-life measurement is based on 7 total events. Improving the precision of the half-life measurement would help resolve a piece of the puzzle in the determination of the GT strength. The region near ^{100}Sn is also important for nuclear astrophysics, since improved half-life values would better determine the abundances of the rp-process. Among the rp-process waiting points, ^{96}Cd has the last experimentally unknown half-life and therefore uncertainties in its value directly affect the final abundances of ^{92,94}Mo and ^{96,98}Ru, which astrophysical origin is currently unclear [5].

At NSCL, a secondary beam containing the N=Z nuclei ^{96}Cd, ^{98}In and ^{100}Sn was produced from a 120 MeV/A ^{112}Sn primary beam impinging on a 195 mg/cm^2 ^{9}Be target placed at the entrance of the A1900 Fragment Separator. Fragments were transported through the A1900 for separation using a 40.6 mg/cm^2 Kapton wedge at the A1900 dispersive plane. Since the rate at the dispersive plane of the A1900 was too high to allow for momentum tracking of the fragments, the momentum acceptance was limited to 1%. The materials and the thicknesses of target and wedge were selected to maximize the yield of ^{100}Sn and to minimize the losses due to the production of charge states. A high level of contamination existed at the exit of the A1900 due to low momentum tails of higher rigidity fragments that overlap with the fragments of interest, and the RF Fragment Separator (RFFS) was used as a second purification stage. The RFFS applies a transverse radio-frequency electric field, which produces a vertical deflection of the fragments according to their phase difference with the primary beam. The phase was adjusted to transmit only N=Z fragments and closest neighbors. Because some of the low Z contaminants have a phase difference close to 2π with respect to the fragments of interest, they were also transmitted. The average transmitted rate was about 50 counts per second after a reduction by a factor of 200 using the RFFS. The particle identification spectrum after the RFFS is shown in Fig. 1.

Nuclei of interest were implanted into the NSCL Beta Counting System (BCS), which was surrounded by 16 detectors from the Segmented Germanium Array (SeGA). The BCS includes a 1 mm thick 40x40 (1600 pixels) Double Sided Strip Detector (DSSD) where nuclei were implanted. The β-decay was studied by correlating the decay event in the implantation pixel and its nearest neighbors for 10 seconds after each implantation. Three Si PIN detectors were used as active degraders upstream the DSSD. Six 1 mm thick Single-Sided Silicon Strip Detectors (SSSD) and a 1 cm thick planar Ge detector were placed downstream the DSSD. The experimental apparatus allowed for the measurement of β-decay half-lives, prompt and β-delayed γ-spectroscopy and the study of proton emission branching ratios. Analysis of the data is still in progress [6].

The average ^{112}Sn intensity was 10.7 pnA resulting in 274(24), 216(21) and 14(5) ^{96}Cd, ^{98}In and ^{100}Sn respective implants over 11.5 days. The number of counts and error bars are deduced from fits to the mass spectra for each element. The measured cross sections, after accounting for trans-

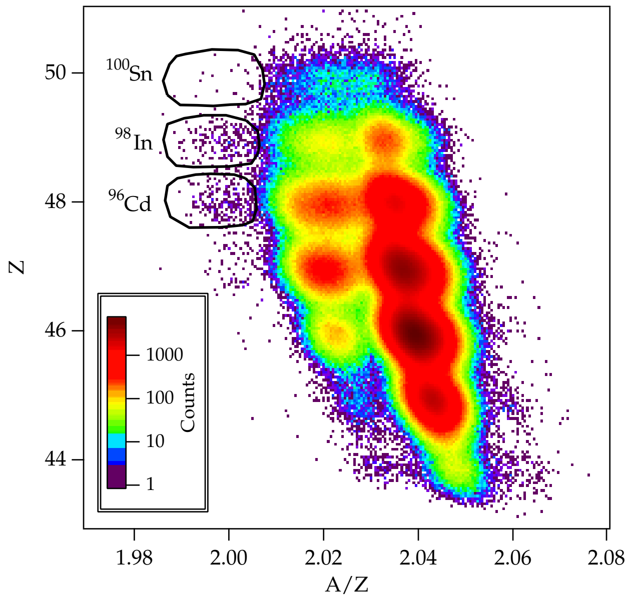

Figure 1: Particle identification spectrum of nuclei transmitted through the RFFS. Low-Z contaminants are not shown in the figure. Gates indicate N=Z nuclei. Taken from [7].

mission and charge state loss, were 5.5(14), 3.8(12) and 0.25(15) pb for ^{96}Cd, ^{98}In and ^{100}Sn, respectively. The observed cross sections for N=Z nuclei are between a factor of 10 and 30 below EPAX cross section predictions, while the experimental cross sections for N=Z+1 nuclei were found to agree with EPAX predictions. For comparison, the ^{100}Sn cross sections at 1 GeV/u ^{112}Sn and ^{124}Xe primary beams on a Be target are 1.8 pb (1 count) and 11 pb respectively [2, 3]. A 120 pb lower limit for the cross section of a 60 MeV/A ^{112}Sn primary beam on a Ni target was also reported in [8].

The β-efficiency of the DSSD was 37% as determined from fitting the decay curves of more abundant isotopes. Since the implantation history is recorded as a function of time and pixel, the induced activity level and the corresponding β-background were calculated as a function of time and pixel location. A maximum likelihood method (MLH) was used to minimize the error in the determination of the half-lives. Efficiency, background and a confidence level assigned to each implant based on the fit of the mass distribution of each element are inputs of the MLH method. The large number of implantations for ^{96}Cd also allowed a conventional fitting method to be used and the results compared favorably with those from the MLH analysis. The β-decay spectra along with the calculated contributions and the maximum likelihood curve are shown in Fig. 2 as a function of logarithmic time. The decay spectra of ^{98}In shows an extra component from a previously observed isomer [9].

The half-life results are shown in Fig. 3. The measured ^{100}Sn half-life is $0.55^{+0.70}_{-0.31}$ s which is in agreement with a previous measurement [2]. By combining both measurements an improved $0.86^{+0.37}_{-0.20}$ s is obtained. The number of ^{100}Sn events is too low by at least an order of magnitude for the detection of β-delayed γ-rays, which are necessary to study branching ratios to excited states and thus the GT strength. The decay of ^{98}In shows a long-lived isomeric component and a

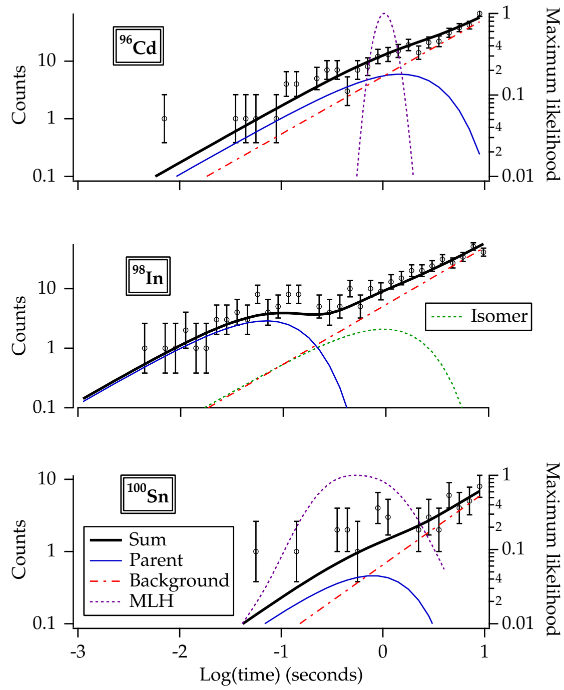

Figure 2: Decay spectra and calculated contributions from the parent and background as a function of time. Also included are the maximum likelihood curves for the ^{96}Cd and ^{100}Sn decay. Taken from [7].

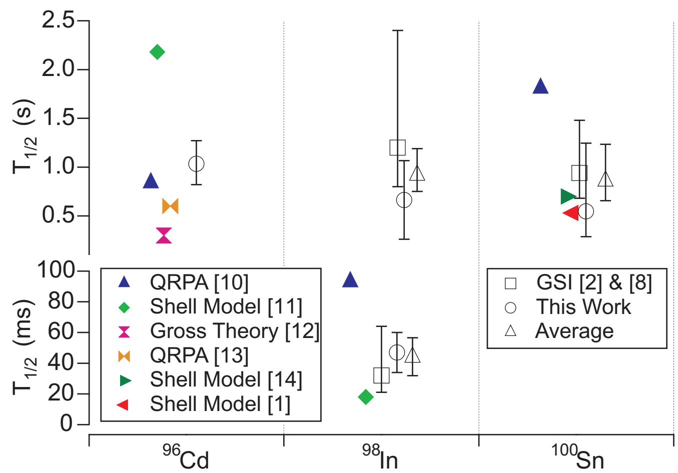

Figure 3: Half-lives obtained in this and previous experiments. Theoretical predictions are also shown.

short half-life attributed to the super-allowed Fermi decay from a 0^+ ground state. The improved measured values, 47(13) ms and 0.66(4) s, are in agreement with a previous experiment [9]. The half-life of ^{96}Cd was measured for the first time and the impact of our measurement in the origin of ^{96}Ru is described in [15].

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