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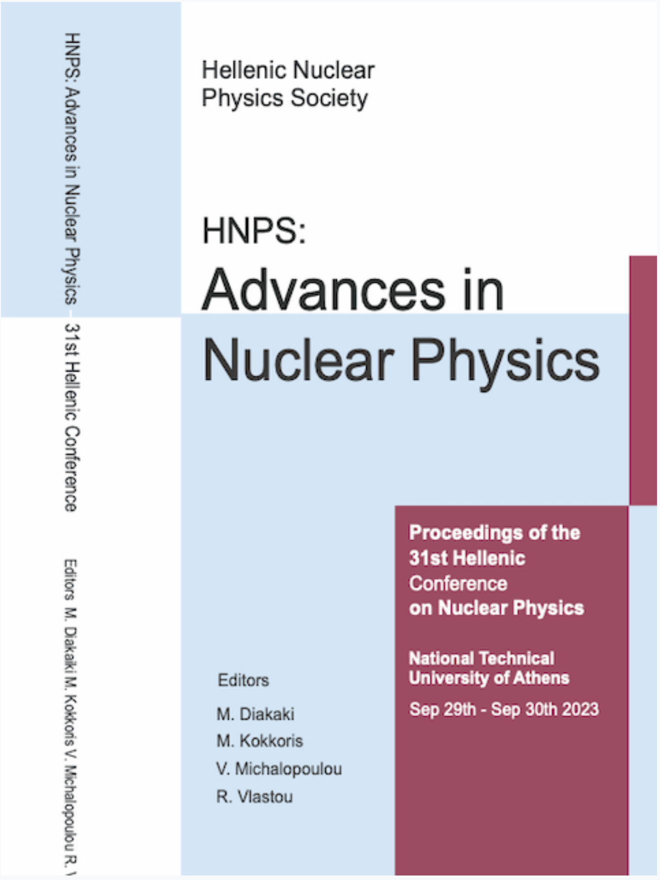

Fast-timing measurements of nuclear lifetimes in the Z ~ 50 region

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Fast-timing measurements of nuclear lifetimes in the Z ~ 50 region

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Abstract The neutron–deficient region around the Z=50 major shell closure provides fertile grounds for nuclear structure studies, as single–particle degrees of freedom compete with collective phenomena to form several of the observed spectroscopic properties. This work reports on the progress and the preliminary results of a recent experiment performed at IFIN–HH, in Magurele, Romania, focused around the measurement of lifetimes of excited states in neutron–deficient Te isotopes, by means of the Fast Electronic Scintillation Timing (FEST, or fast–timing) technique. A ^{11}B beam of E_{lab} = 35 MeV impinging on a 5 mg/cm^2 ^{nat}Ag target was used to populate excited states in $^{115-120}$Te. The γ rays de-exciting these levels were detected by the ROSPHERE array, in its mixed 15 HPGe + 10 $LaBr_3$(Ce) detector configuration. Additionally, the SORCERER particle detector array was coupled to ROSPHERE, enabling the study of p-γ and p-γ-γ coincident events. The combination of experimental findings and theoretical predictions from several models, including the newly developed proxy-SU(3), is anticipated to offer valuable insights into the dynamic shape evolution of the investigated isotopes.

Keywords $^{115\text{-}120}$Te, ^{106,108}Pd, nuclear lifetimes, FEST, B(E2) transition strengths

INTRODUCTION

The neutron–deficient region around the Z=50 major shell closure provides fertile grounds for nuclear structure studies, as single–particle degrees of freedom compete with collective phenomena to form several of the observed spectroscopic properties. Te (Z=52) and Pd (Z=46) isotopes, located two protons above and four protons below the aforementioned shell, respectively, have been the subject of numerous experimental investigations, as well as theoretical studies, employing different approaches, ranging from denstity functional theory (DFT), to shell model and interacting boson model (IBM) calculations, in an effort to gain insight into the dynamical shape evolution, and the onset of shape coexistence (SC) along these isotopic chains (see Ref. [1] for an overview of the experimental and theoretical findings regarding shape phase trasitions and SC for these isotopes). Still, for many of the members of the Pd and Te isotopic chains, there is a persistent scarcity of experimental data [2] pertaining to lifetimes and B(σL) transition strengths, quantities directly connected to various nuclear structure related phenomena appearing in these nuclei.

This work features preliminary results from our recent experimental campaign at the IFIN-HH laboratory, in Romania, aimed at measuring lifetimes of excited states in Te and Pd isotopes via the Fast Electronic Scintillation Timing (FEST, or fast-timing) [3] technique.

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EXPERIMENTAL DETAILS

The experiment was carried out at the 9 MV Tandem accelerator of IFIN-HH, in Magurele, Romania. A ^{11}B beam with a laboratory energy of E_{lab} = 35 MeV impinging on a 5.24 mg/cm^2 ^{nat}Ag (51.839% ^{107}Ag, 48.161% ^{109}Ag) target was used to populate states of interest in the tellurium isotopes via the ^{107,109}Ag(^{11}B,xn)$^{115\text{-}120\text{-}x}$Te reaction. In addition, excited states in ^{106,108}Pd were populated in the ^{107,109}Ag(^{11}B,^{12}C)^{106,108}Pd proton pick-up channel.

The ROSPHERE array [4], in its mixed 15 HPGe + 10LaBr$_3$(Ce) detector configuration was employed for the detection of the γ decays of product nuclei. The detectors were distributed over 5 rings (R1-5), at angles 37° (R1), 70° (R2), 90° (R3), 110° (R4) and 143° (R5) relative to the beam axis. R1,3,5 were loaded with HPGe detectors, with the LaBr$_3$(Ce) scintillators being mounted in R4,5. Coupled to ROSPHERE was the SORCERER [5] solar cell particle detector array, which allowed for the implementation of p-γ and p-γ-γ coincidence techniques to isolate the decays of interest. A picture of the detector array employed in the experiment is shown in Fig. 1.

Figure 1. *The ROSPHERE array*

ANALYSIS AND PRELIMINARY RESULTS

Lifetimes of excited nuclear states were determined via the fast-timing technique, by measuring the time-difference between two signals stemming from a populating and a depopulating transition. The master trigger condition for data acquisition was set to 1 HPGe + 1 LaBr$_3$(Ce) <OR> 2 HPGe, where the detector type signifies the γ ray(s) incident on it. A standard ^{152}Eu source was used for energy and efficiency calibration of the detectors. The same source was used to determine the energy-dependent time-walk of the experimental setup, in the range of 121 keV to 1408 keV, using well-known pairs of γ–γ coincidences resulting from the γ decay of ^{152}Sm and ^{152}Gd [2]. The process is described in detail in Refs. [3,6,7].

After applying all the necessary corrections, the data were sorted into $E^{\gamma}_{LaBr_3} - E^{\gamma}_{LaBr_3} - \Delta$t cubes. To better isolate transitions belonging to the ^{106}Pd decay, a gate was placed on the ^{12}C peak of the paricle spectrum, corresponding to the ^{107,109}Ag(^{11}B,^{12}C)^{106,108}Pd reaction channel (Fig. 2). Two-dimensional gates were placed on the energy-energy plane, selecting the populating and depopulating transition of the nuclear state of interest (in this case, the 2^+_1 state in ^{106}Pd). An additional gate was placed in an area around each 2D full-energy energy peak (Fig. 3, left), which was used for random coincidences and

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Compton-background corrections, leading to the construction of background-free delayed and anti-delayed time distributions (Fig. 3, right). The lifetime τ of the 2_1^+ state in ^{106}Pd was subsequently determined through the centroid difference method [8], as:

$$\Delta C = C_d - C_a = 2\tau \tag{1}$$

where ΔC denotes the difference between the delayed (C_d) and anti-delayed (C_a) time-distribution centroids.

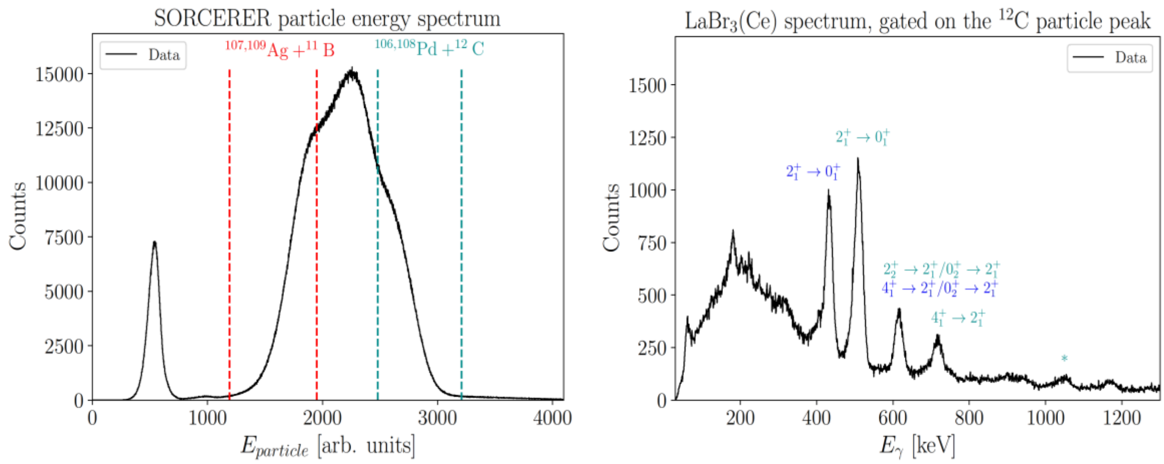

Figure 2. *Left: Particle spectrum recorded by SORCERER. The limits of the ^{11}B and ^{12}C peaks used in the particle gates are denoted by the red and cyan dashed lines, respectively. In the middle part of the spectrum there is an overlap between ^{11}B and ^{12}C (and thus, the corresponding ^{107,109}Ag and ^{106,108}Pd). Right: LaBr$_3$(Ce) spectrum corresponding to ^{106,108}Pd, obtained by placing a gate on the ^{12}C peak in the particle spectrum (cyan dashed line). Transitions in ^{106}Pd and ^{108}Pd are marked in cyan and blue, respectively.*

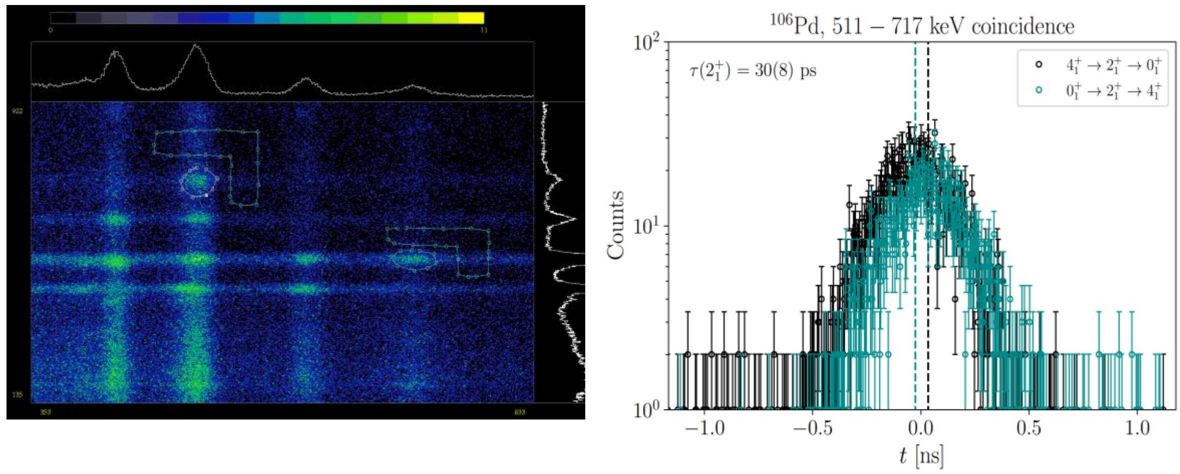

Figure 3. *Right: Preliminary results for the lifetime of the 2_1^+ g.s.b. level of ^{106}Pd, obtained with the centroid shift method, using (left) 2D energy-energy gates for the 511 − 717 keV delayed and anti–delayed coincidence peaks.*

DISCUSSION AND OUTLOOK

Preliminary results for the lifetime of the 2_1^+ state in ^{106}Pd are presented in Table 1. This transition, albeit having a known lifetime of τ = 17.50$\binom{+48}{-45}$ ps in literature [9], can serve as a validation of the experimental method (time walk correction, systematic errors, etc.).

Table 1. *Preliminary results for the 2_1^+ (E =511.850(23) keV) state in ^{106}Pd*

E_γ [keV]	τ [ps]	B(E2) [W.u.]	Ref.
511.842(28)	30(8)	26(7)	**This Work**
	$17.50(^{+48}_{-45})$	44.3(12)	Pritychenko et al. [9]

The extracted preliminary B(E2) value suggests a vibrational character for the 2_1^+ state of ^{106}Pd. As this work is still ongoing, further insight into the nuclear structure is expected from the lifetime measurements. As the analysis progresses, the rest of the populated levels in ^{106}Pd, along with ^{108}Pd and $^{115\text{-}120}$Te will be thoroughly investigated for lifetimes and B(E2) transition strengths. Complementary activation measurements performed in this experiment are expected to provide further information on the ground-state half-lives of members of the Te–Sb–Sn radioactive decay chains, updating the existing literature values [10,11].

In addition to the experimental results, theoretical predictions [12] using a variety of models (e.g. proxy-SU(3), IBM etc.) will be compared with the experimental results and are expected to shed more light on the structure and dynamical shape evolution of the isotopes considered, including shape coexistence, which is expected to be present in this region of the nuclear chart [1,13-15].

Acknowledgments

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