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DESPEC Phase-0 campaign at GSI

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Summary. — This paper reports preliminary results of the DESPEC campaign at GSI, focused on the study of neutron-deficient nuclei approaching ^{100}Sn. The results presented show the isomeric decays of excited states with $I^{\pi} = 14^{+}$ and 8^{+} in ^{96}Pd and ^{94}Pd, respectively. The detailed characterisation of the DESPEC set-up and analysis methodologies, proven in this experimental run, are crucial for the future campaigns.

1. – Introduction

The HISPEC-DESPEC Collaboration aims at investigating the nuclear structure of exotic nuclei formed in high-energy projectile-fragmentation reactions by performing decay spectroscopy measurements at GSI, as part of the Phase-0 GSI-FAIR experiments.

^{100}Sn, having $N = Z = 50$, is the heaviest self-conjugate doubly magic nucleus that is stable with respect to particle emission. Therefore, nuclei in the south-west region of ^{100}Sn are subject to extensive experimental and theoretical studies [1]. In particular, the structure of ^{94}Pd is an excellent case for understanding the effects of proton-neutron pairing, suggested to explain structural properties in the intermediate $N = Z$ nuclei ^{96}Cd [2, 3] and ^{92}Pd [4]. The triplet ^{92}Pd, ^{94}Pd and ^{96}Cd is predicted to show a sharp reduction in $B(E2)$ values for the yrast $8^{+} \rightarrow 6^{+}$ transition. A measurement of the $B(E2)$ transition strength in ^{94}Pd following population of the yrast cascade through the $I^{\pi} = 14^{+}$ isomer will allow a stringent test of state-of-the-art shell model calculations for $N \sim Z$ nuclei approaching ^{100}Sn and prove the role of p-n pairing in their structural evolution. The aim of this experiment was to study excited states in ^{94}Pd and several proton emitters along the $N = Z$ line between $A = 90$ and $A = 100$. A second aim of this experimental run is the search for direct evidence of proton emission in ^{89}Rh and ^{93}Ag as an important input for the modeling of the astrophysical rp-process. The prediction of the composition of rp-process ashes is important for the understanding of neutron-star crusts [5] and of the origin of the nuclei ^{92,94}Mo and ^{96,98}Ru, found in large quantities in the Solar System [6].

2. – Experiment and preliminary results

The experiment was performed at the GSI accelerator facility, where the nuclei of interest were produced in fragmentation reactions induced by a ^{124}Xe beam at an energy of 850 MeV/A impinging on a 4 g/cm^2 thick ^{9}Be target. The selection and transport of the ions of interest was performed using the FRS magnetic spectrometer (the FRagment Separator) through the $B\rho$-ΔE-$B\rho$ method. The ions were identified using the ToF-$B\rho$-ΔE method, with a measurement of the mass number over ionic charge (A/Q) and the atomic number Z. The study of the structure of the nuclei of interest was performed using γ-ray spectroscopy following the internal decay of metastable isomeric states. The same set-up allows to measure lifetimes of excited states populated by β decay through ion-β and $\beta - \gamma$-ray correlations. These measurements can be performed using a composite detector array. Fragments are implanted in the Advanced Implantation Detector Array (AIDA) [7], composed of three layers of high-pixellated DSSSDs, used also to detect β particles. Timing measurements of β particles are performed by sandwiching

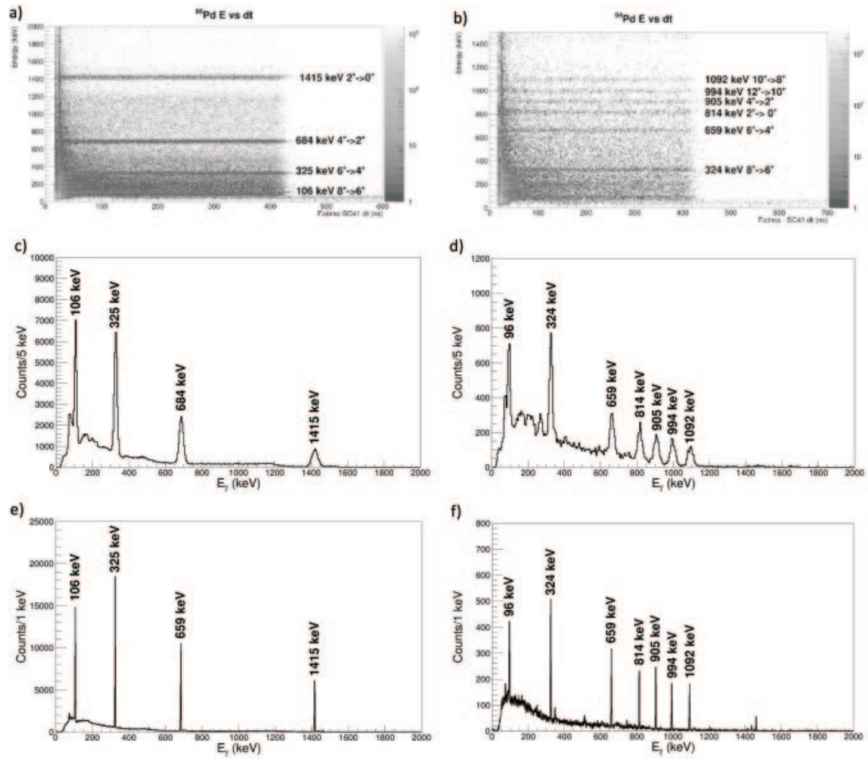

Fig. 1. – Panels (a), (b): Two-dimensional histograms of the energy spectrum from FATIMA *vs.* the time difference between a γ-ray detected in FATIMA and an ion signal in the last scintillator of the FRS. Panels (c), (d), (e), (f) give γ-ray energy spectra for FATIMA and Galileo. The panels are for ^{96}Pd (left) and for ^{94}Pd (right).

the AIDA detector between two fast plastic scintillators, the bPlast detectors. The detection of the emitted γ-rays is performed using a hybrid array designed for HPGe detectors (Galileo Triple Clusters (GTC) [8] and DEGAS [9]) arranged in 6 triple clusters, and 36 $LaBr_3$(Ce) detectors (FAst TIming Array (FATIMA)) [10, 11]. The GTC and FATIMA detectors are placed at 280 mm and 160 mm from the centre of AIDA, respectively. In this configuration, the full-energy peak efficiency is 1.7% for FATIMA and 1.4% for the 6 GTC detectors (after add-back) at 1.4 MeV. An investigation of the single subsystems' deadtime and trigger schemes was performed.

The previously reported yrast isomeric states, with half-lives 499(13) ns and 2.2(1) μs in ^{94}Pd and ^{96}Pd, respectively [12, 13], were identified using particle-id gated γ-ray spectra using both $LaBr_3$(Ce) and the HPGe detectors. The individual, discrete transitions which are emitted in the decay of these isomeric cascades are characterised by horizontal lines in the 2D matrix of particle gated γ-ray energy *vs.* the time difference between γ-ray emission and the ions passing through the final scintillation detector at the focal plane of the FRS (SC41). The energy *vs.* time plot gated on ^{94}Pd and ^{96}Pd ions for the FATIMA detectors is show in fig. 1. Transitions following the decay of the $I^\pi = 8^+$ isomer in ^{96}Pd and $I^\pi = 14^+$ in ^{94}Pd are clearly seen in the energy spectra shown in fig. 1. Results from this experiment were exploited to tune a GEANT4 [14] simulation of help for future proposals and experiments preparation. In fig. 2 we report a comparison of simulated and measured spectra relative to the isomeric decay in ^{96}Pd for FATIMA and

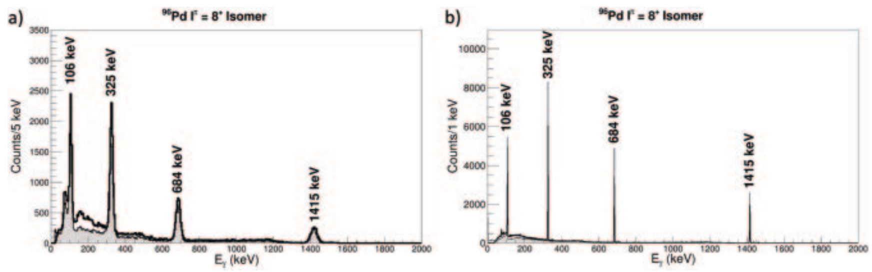

Fig. 2. – Comparison between simulations and experimental data for ^{96}Pd for FATIMA (a) and Galileo (b). The experimental spectra are shown in bold with the corresponding simulated spectra shown in greyscale.

GTC systems. Further analysis of the data is ongoing to extract level lifetimes of states below the isomer in ^{94}Pd and surrounding nuclei. The β decay of the other species produced in the fragmentation reaction is also currently being studied.

3. – Conclusions

This paper reports the preliminary results of the first experiment of the DESPEC Phase-0 campaign, focused on the study of proton-rich nuclei in the ^{100}Sn region. In particular, the isomeric lines of ^{94,96}Pd are identified. These results are intended as a proof of the correct functioning of the detector system and analysis techniques employed and will be used in future campaigns with the DESPEC set-up.

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