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RESULTS OF DTAS CAMPAIGN AT IGISOL: OVERVIEW*

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The β decays of more than twenty fission fragments were measured in the first experiments with radioactive-ion beams employing the Decay Total Absorption γ-ray Spectrometer. In this work, we summarize the main results obtained so far from this experimental campaign carried out at the Ion Guide Isotope Separator On-Line facility. The advances introduced for these studies represent the state-of-the-art of our analysis methodology for segmented spectrometers.

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1. Introduction

The Decay Total Absorption γ-ray Spectrometer (DTAS) is a segmented NaI(Tl) detector composed of up to 18 crystals [1]. It will be a key instrument of the DESPEC experiment at FAIR [2]. DTAS was employed for the first time in a campaign of experiments at the Ion Guide Isotope Separator On-Line facility (IGISOL) [3] of the University of Jyväskylä. The fission ion guide allowed us to extract the nuclei produced by 25-MeV proton-induced fission on a natural uranium target. The radioactive nuclei were separated based on their mass-to-charge ratio by means of the IGISOL separator magnet. Further isobaric purification was achieved using the double Penning trap system JYFLTRAP [4]. After extraction from the trap, ions were implanted on a magnetic tape placed in front of a plastic β detector of 3 mm thickness located at the center of DTAS [5]. A tape transport system was employed to remove periodically the activity from DTAS during the measurements.

A coincidence between DTAS and the β detector was required in order to provide a spectrum free from the environmental background. The signals of the individual modules were employed to reconstruct off-line the total sum energy, as detailed in Ref. [6], where the complete characterization of DTAS with calibration sources is discussed for this experimental campaign.

The Total Absorption γ-ray Spectroscopy (TAGS) technique has been applied to determine the β-intensity distributions of the cases studied, following the analysis method developed by the Valencia group [7–10]. The TAGS technique allows one to determine the β-intensity distributions free from the Pandemonium effect [11] that impairs the results of high-resolution γ-spectroscopy approaches based on HPGe detectors.

2. Highlights

In the following, we summarize some of the most important achievements with DTAS during these first experiments with radioactive beams. They are important contributions for the consolidation and extension of our analysis methodology for segmented spectrometers. These advances set the grounds of what can be done in future experimental campaigns and have also been exploited in the first experiments with DTAS at fragmentation facilities [12].

2.1. Cases with decaying isomers

Many nuclei with β-decaying isomeric states are produced by means of fission. Some of them play a crucial role in nuclear reactors, as it is the case of neutron rich niobium and yttrium isotopes around $A = 100$. Challenging measurements of the decays of ^{96}Y and ^{98,100,102}Nb, each with an isomeric state (at 1540 keV, 84 keV, 313 keV, and 94 keV, respectively), were performed during this campaign at IGISOL. Different strategies were followed to study separately the β decay of the ground state and the decaying isomer for each case, as described in Refs. [13, 14], taking advantage of the JYFLTRAP purification capabilities and populating the low-spin states through the decay of the parent nucleus, when possible. A large impact of some of the present results on reactor summation calculations has already been reported [13, 15].

2.2. γ emission above S_n

The sensitivity of the TAGS technique to determine β intensity above the neutron separation energy (S_n) followed by γ emission was already proved in previous studies [16–19]. In the present campaign, we measured some β-delayed neutron emitters as ^{137}I and ^{95}Rb. A large competition between neutron emission and γ de-excitation above S_n was found for these two cases, as discussed in Ref. [20]. This hindrance for neutron emission could be explained due to the large angular momentum needed by the neutrons, given the spins and parities of the states involved. For these cases, we successfully tested a time discrimination approach to reject the γ rays produced by the interaction of neutrons with the scintillation material of DTAS. It will be of great interest for future measurements of β-delayed neutron emitters.

2.3. Ground-state feeding determination

Even though ground state-to-ground state transitions are characterized by the absence of γ emission, the TAGS technique allows for the determination of this branch thanks to the sensitivity of spectrometers like DTAS to the penetration of the corresponding β electrons. The response function associated with the population of the ground state is fitted as part of the deconvolution process in the TAGS analysis, giving satisfactory results, as reported in Refs. [13, 14, 21, 22]. A complementary method to determine the β feeding to the ground state was developed 30 years ago [23]. We have revised, corrected, and extended the formulation of this method, which relies on counting β particles and β–γ coincidences in the plastic β detector and DTAS, respectively. The results, applied to some cases of this campaign and discussed in Ref. [24], show the potential of this method to complement the TAGS results and improve the associated uncertainties, as well as the possibility to determine the ground-state branch in particular cases where TAGS has not enough sensitivity.

2.4. *Multiplicity studies*

The segmentation of our detector can be exploited to validate the results of the TAGS analyses by verifying the reproduction of extra experimental spectra. In this campaign, we have implemented the verification of the spectra of the individual modules and the TAGS spectra gated on the multiplicity of the events (the number of modules with a signal above the threshold) [13, 20]. Especially, the latter is a very stringent cross-check of the branching ratio matrix used for the analysis. In our most recent work, we have developed new tools for the direct TAGS analysis of the multiplicity-gated spectra [14]. This opens the possibility of studying mixtures of β decaying ground states and isomeric states with very different spin-parity values, due to the very different module-multiplicity patterns associated with them.

2.5. *E0 and pair production*

For two of the cases studied in this campaign, ^{96}Y and ^{98}Nb, the de-excitation of the daughter nuclei exhibits strong E0 transitions. The corresponding electrons have been found to affect significantly the β efficiency of the setup [14], an effect overlooked in other TAGS studies for these nuclei [25–27]. In addition, we have developed new tools to properly consider the competition between E0 and pair production for the case of ^{96}Y, which implies a dramatic change in the response function for the levels involved and was not taken into account in the other TAGS studies [25, 26].

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