Commissioning of the 'Reversed Plunger Configuration' with AGATA at LNL

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INTRODUCTION

The lifetimes of nuclear-excited states provide useful information on the nuclear structure. Several techniques have been developed to measure these lifetimes, such as the Recoil Distance Doppler-Shift technique (RDDS) [1]. This technique consists of two foils parallel to each other, the target and the degrader/stopper. The reaction products move with a given velocity from the target towards the degrader. Being γ decay a statistical process, the decay of the particle may take place in flight or after being slowed down/stopped in the degrader. Varying the distance between the two foils one obtains the decay curve of the state of interest.

During the first campaign of AGATA at LNL [2], the AGATA γ-ray detector array [3] was coupled to the PRISMA spectrometer [4] (for the identification of the reaction products) and mainly multi-nucleon transfer (MNT) reactions will be used to populate low-lying excited states [2]. Using a plunger device [5, 6] with this setup in the standard configuration (i.e., a target followed by a degrader), as described above, gives the opportunity to perform lifetime measurements for a large number of nuclei with their mass in the region where the PRISMA spectrometer has a good nuclear charge resolution ($\Delta Z/Z \approx 1/60$) and a good mass resolution ($20<A<150$) [7]. This means that the lifetimes of nuclei heavier than Xe can not be measured since they have to pass through a degrader foil and the Z resolution in PRISMA does not allow an effective identification.

In the case of binary reactions, the isotope identification provided by PRISMA can be used to perform spectroscopic studies for the other partner. The kinematics of the undetected isotope can be reconstructed based on the angle and the velocity measured by PRISMA for the binary partner. This technique has been successfully exploited in the past and allowed the first measurement of γ rays linked to excited states of ^{196}Os and ^{200}Pt [8].

Taking advantage of the kinematics of the MNT reactions and the binary identification, these limits can be pushed forward and measurements can be performed for heavy nuclei that PRISMA can not detect with sufficient resolution. This technique requires the use of the plunger device in the so-called "reversed plunger configuration". In this configuration, the degrader is facing the beam as shown in Fig.1. The beam passes through the degrader, loses part of its energy, and then interacts with the target. The beam-like reaction products enter PRISMA, placed at the grazing angle, and the target-like particles are stopped in the degrader foil. A reaction channel selection is made by binary partner characterization. As understood, also in this configuration of the plunger device, similar to the standard configuration, the nucleus of interest travels with a given velocity from the target toward the degrader foil.

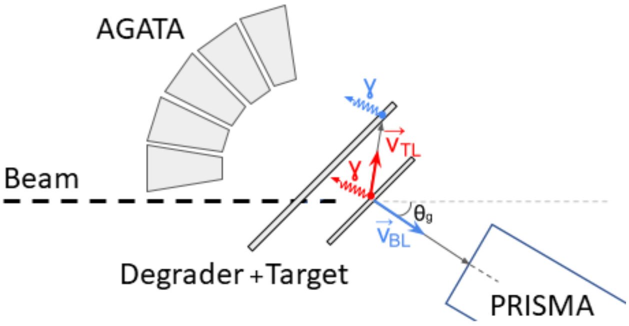

Fig. 1. Schematic representation of the AGATA + PRISMA coupled with the plunger device in the reversed configuration

EXPERIMENTAL DETAILS AND PRELIMINARY RESULTS

To validate the use of the plunger device in such a configuration, an experiment was performed in LNL with the aim of remeasuring the lifetime of the 4_1^+ state of ^{92}Zr. The 102(5) ps half-life of this state is known from the measured $B(E2) = 4.04(12)$ W.u. value in a Coulex experiment [9].

Excited states of ^{92}Zr were populated via MNT reaction. A beam of ^{34}S with the energy of 180 MeV, provided by the Tandem accelerator, impinged into a self-supporting target of ^{93}Nb with thickness around 1 mg/cm^2. A Ta foil with thickness 3 mg/cm^2 was used as a degrader, thick enough to stop the target-like reaction products. The target and the degrader foil, mounted in the plunger device, were tilted at 45° with respect to the beam direction. Beam-like reaction products enter PRISMA at 44° with the energy around 3.1 MeV/u. Meanwhile, the target-like reaction products travel towards the degrader at 62° with respect to the beam direction with $\beta \approx 3\%$. Gamma rays were measured with AGATA composed of 32 encapsulated detectors.

Measurements were performed at three distances between the target and the degrader, 100, 200, and 700 μm. The energy of the γ rays of ^{92}Zr, measured from AGATA in coincidence with PRISMA, is plotted as a function of the angle between the photon and the reconstructed direction of the emitting ^{92}Zr fragments as shown in Fig.2. As seen from the figure, the in-flight and the stopped components are both present and separated from each other. Their separation is dependent on the relative angle, with an overlap that corresponds to 90°.

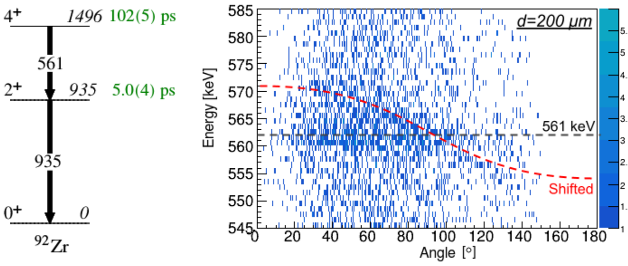

Fig. 2. (Left) Partial level scheme of ^{92}Zr. (Right) The energy of the γ rays of ^{92}Zr as a function of the angle between the emitting particle and the photon. The data correspond to a Plunger distance of 200 μm.

To better distinguish the two components, the γ-ray spectrum of ^{92}Zr measured from the AGATA array (from 0° to 60° ring) for different distances between the target and the degrader is shown in Fig. 3. The stopped component, the 561-keV peak ($4^+ \rightarrow 2^+$ transition of ^{92}Zr) is indicated with a red line. As can be seen from the figure, the intensity of the Doppler-shifted peak rises as increasing the distance.

SUMMARY

The lifetime of the 4^+ state of ^{92}Zr was measured using the plunger device in the so-called ”Reversed Plunger Configuration”. The preliminary analysis shows that the two γ-ray components in the spectrum emerging from the decay of the nucleus in flight or stopped can be separated as one expects with the plunger in the ”standard configuration”. This technique creates new possibilities for performing lifetime measurements of nuclear excited states in heavy ions produced via MNT reactions that can not be identified in the magnetic spectrometer, allowing one to reach nuclei in regions of the nuclear chart yet to be explored.

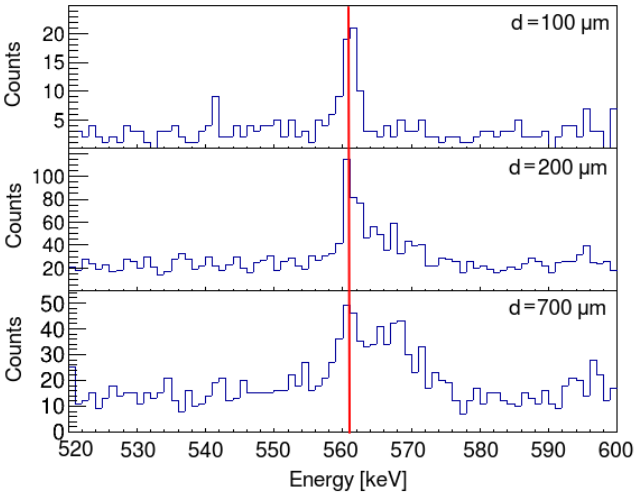

Fig. 3. The experimental γ-ray spectrum of ^{92}Zr measured from AGATA (from 0 to 60 degrees ring) in coincidence with PRISMA for different distances between the target and the degrader. The stopped component of the $4^+ \rightarrow 2^+$ 561-keV transition of ^{92}Zr is indicated with the red line.

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