INTRODUCTION

Static and dynamic electromagnetic moments are of key importance to better assess the nuclear structure because of their high sensitivity to the details of the involved state wave functions. Several techniques have been developed to determine the transition probabilities and $g$-factors depending on the expected lifetime of the state of interest. We will focus here on the Recoil Distance Doppler-Shift method (RDDS) based on the utilization of a plunger device [1], to measure lifetimes in the range from few up to several hundreds of picoseconds. Different plunger devices have been developed in the last decades to be used with high efficiency $\gamma$-ray arrays and with complementary detectors such as the large acceptance spectrometers: PRISMA [2] and VAMOS [3]. Recently, a new plunger device for the $\gamma$-ray array GALILEO [4] has been developed in collaboration with the Cologne Institut für Kernphysik (IKP).

MECHANICAL DESIGN

The design of a new plunger device has to overcome several constrains such as:

- the possibility to vary the distances between target and stopper foil from a few micrometers to some tens of millimetres with a sub-micrometer precision,
- the $\gamma$-transparency of the device in order to minimize the absorption of the $\gamma$ rays emitted by the de-exciting nuclei,
- the positioning and alignment of the plunger device in the existing target chamber,
- a mechanism to stretch both target and stopper foils,
- an active feedback system to compensate for changes in the target-stopper foil distance induced by the target-beam interaction,
- and specifically for the GALILEO array, the coupling to existing complementary detectors, such as EUCLIDES [5].

Several options have been considered and the final design of the plunger device is presented in Fig. 1. We decided to design for a compact design where the motor is directly placed below the target and the stopper foils. In this configuration, a good transparency can be achieved for all GALILEO HPGe detectors except one detector located at 90 degrees with respect to the beam axis, that however is not usable for RDDS measurements. The target, placed on the sliding rail of the motor, can be moved with a sub-micrometric precision ($\sim 40$ nm) with respect to the fixed stopper. The movement of the target is ensured by the high resolution piezoelectric linear drive LPS-24 from Physik Instrumente. This piezo-motor has a travel range of about 15 mm and has the advantage of having a very compact design of 24 mm x 33 mm x 20 mm.

The target and stopper foils are stretched using stretcher cones pressing directly on the foils. The stretching of the foils is controlled manually by three screws, as shown in Fig. 2. The parallelism of the two foils, which is of key importance for the distance measurement and its correction during experiment, is also ensured by three screws between the target stretcher cone and the target cone support structure. The parallelism of the two foils is adjusted step by step by bringing the two foils to electrical contact and correcting it using the parallelism screws. The stopper cone
is placed at a fixed position.

The distance fluctuation induced by the target and stopper due to the beam interaction, is corrected via software using a capacitance measurement between the two foils. The LPS-24 motor is controlled by the PI E-861 Controller connected to a control PC accessible from outside the experimental hall in order to remotely change the target-degrader distance. All the control software was developed under LabVIEW by IKP staff.

### PLUNGER COMMISSIONING

The plunger was first commissioned at IKP to check the stability of the device in vacuum and in-beam using a $^{12}$C and a $^{32}$S beam impinging on a Cd target. After the first test, the plunger was transported and mounted inside the GALILEO reaction chamber in order to validate its mechanical construction. 15 $E - \Delta E$ telescopes from the EUCLIDES array were mounted together with the plunger to check the mechanical compatibility of the two devices.

A first in-beam commissioning of the plunger at LNL was performed using a $^{32}$S beam at $E_{lab} = 183$ MeV impinging on a 1mg/cm$^2$ $^{154}$Sm target deposited on Ta support of 2 mg/cm$^2$ and a 10 mg/cm$^2$ Au stopper foil. 25 HPGe Compton-Suppressed detectors of the GALILEO spectrometer, distributed over 4 rings at 152 (5 detectors), 129 (5 detectors), 119 (5 detectors) and 90 (10 detectors) degrees were used in this experiment. The projections of the $\gamma$-$\gamma$ matrix constructed using the rings at 129 and 159 are presented in Fig. 3 for several plunger distances between 5 and 100 $\mu$m with a gate on the in-flight component of the $8^+_1 \rightarrow 6^+_1$ transition of $^{180}$Pt.

### CONCLUSION

The new LNL plunger device, developed in collaboration with IKP, has been successfully commissioned. This device, combined with the GALILEO array, will allow to perform electromagnetic moment determination in exotic nuclei populated by nuclear reactions induced by both stable (Tandem-ALPI) and future radioactive beams (SPES).

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