Progress Report on the activities of the National Technical University of Athens (NTUA) supported by ARIEL

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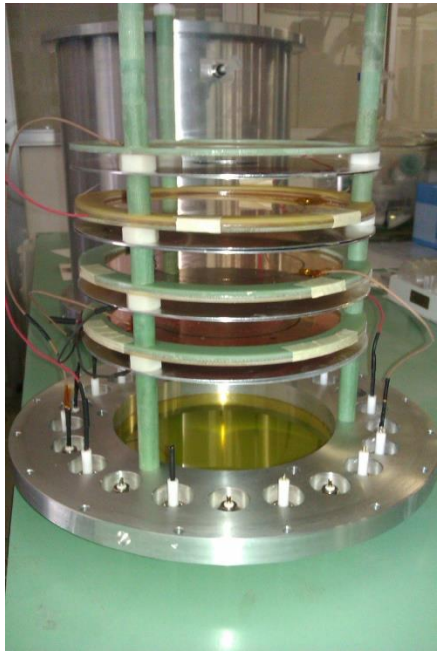
Second ARIEL progress meeting and scientific workshop, NPL, UK, 15-16 March 2023

Education and Training visits of early stage researchers

A. Nikolaos Kyritsis (PhD student) – support for 12 weeks



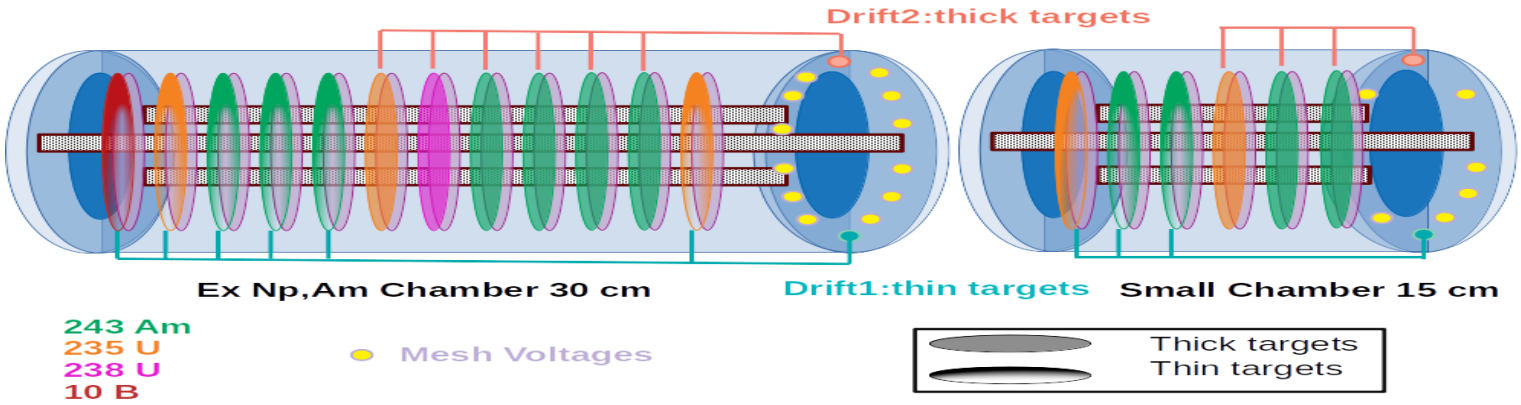
Preparations of the ^{243}Am(n,f) cross section measurements with Micromegas detectors at the CERN n_TOF facility

The goal of these measurements would be the accurate and consistent fission cross section of the ^{243}Am(n,f) reaction from thermal up to ~300 MeV neutron energy - very important reaction for the investigation of the fission process and for the new generation of nuclear reactors, which have several advantages with respect to radioactive waste management and nonproliferation, as compared with the conventional reactors.

The measurements of the ^{243}Am(n,f) reaction will be carried out in 2023 at both experimental areas EAR-1 and EAR-2 of the CERN n_TOF facility, taking advantage of the excellent energy resolution of EAR-1 to measure the high energy region and the higher neutron flux of EAR-2 to measure the lower energy region, where the cross-section is expected to be small.

Proposal approved by the INTC-CERN for **2 months of beam time**. Spokespersons of the proposal are: N.Patronis from the University of Ioannina and M.Diakaki from the National Technical University of Athens. **Subject of the PhD thesis of Nikolaos Kyritsis.**

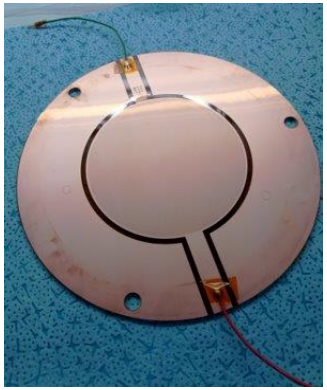
Education and Training visits of early stage researchers

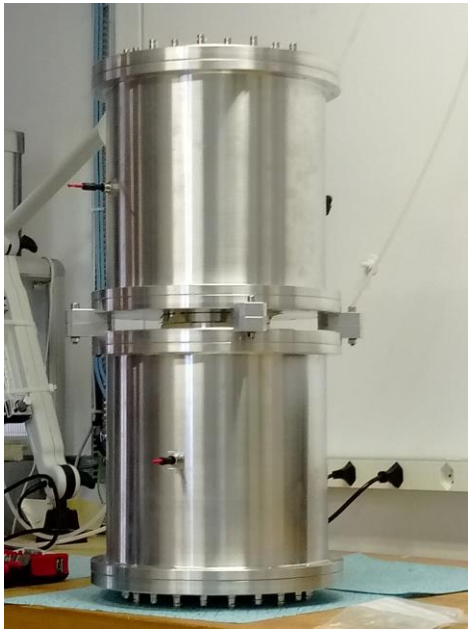


High purity ^{243}Am samples, will be prepared at JRC-Geel, along with the reference samples ^{235}U, ^{238}U and ^{10}B. Six **thick** (~150μg/cm^2 per sample) and five **thin** (~3μg/cm^2 per sample) ^{243}Am samples will be implemented in order to avoid pile-up issues and maintain high counting rates in all energy regions. Very complicated experimental setup!

Preparatory work – 12 weeks supported by ARIEL for N.Kyritsis in autumn 2022 at CERN - crucial for the final experimental configuration

- Ten new Micromegas detectors were received at n_TOF and tested.
- New chambers were constructed, assembled and tested at CERN.
- New preamplifiers delivered, assembled and tested at n_TOF.
- Safety manuals for the radioactive samples were prepared and the reference targets **^{235}U, ^{238}U and ^{10}B** arrived at CERN.





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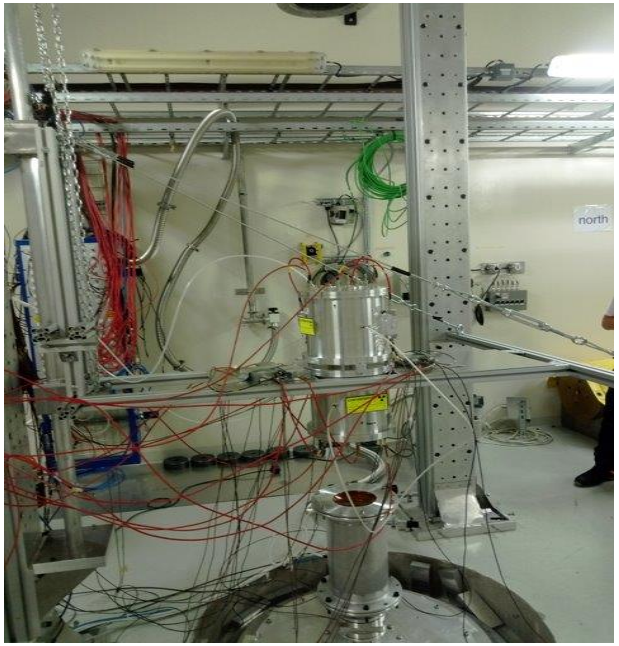
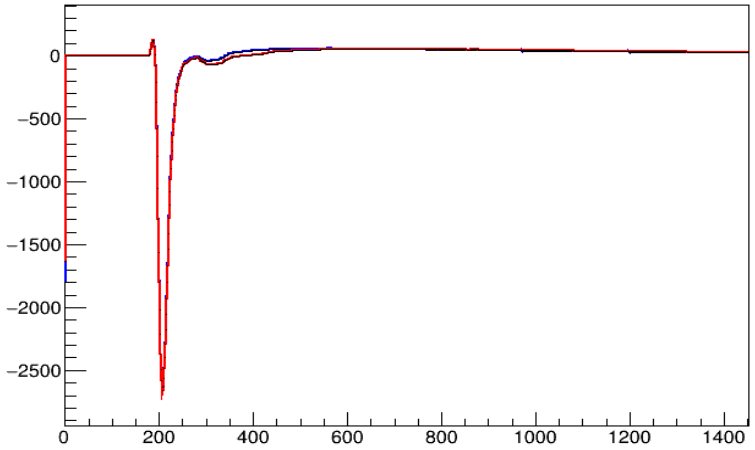
- A **test run** lasting 1 week was conducted at **n_TOF EAR-2 in November 2022**
- It included the new detectors, chambers and the reference targets that will be used in the ^{243}Am(n,f) experiment
- Purpose of the test : Check Micromegas response to the g-flash/g-flash tail with the new spallation target and the fission collimator (not tested during the commissioning) and get prepared for the real measurement in 2023
- Test of two different Gases and different drift gaps for the detectors



The analysis of the data from this test will help determine the ideal setup for the experiment in June and July of 2023. The analysis is currently ongoing – experience in data analysis – excellent communication/collaboration with the local team.



Average gamma-flash response of an empty cell for the two different gases used (Ar:CF_4 with 2% (blue line) and without (red line) isoC_4H_{10})

Any chance for accepting a new proposal for the experiment (2 months) in 2023?

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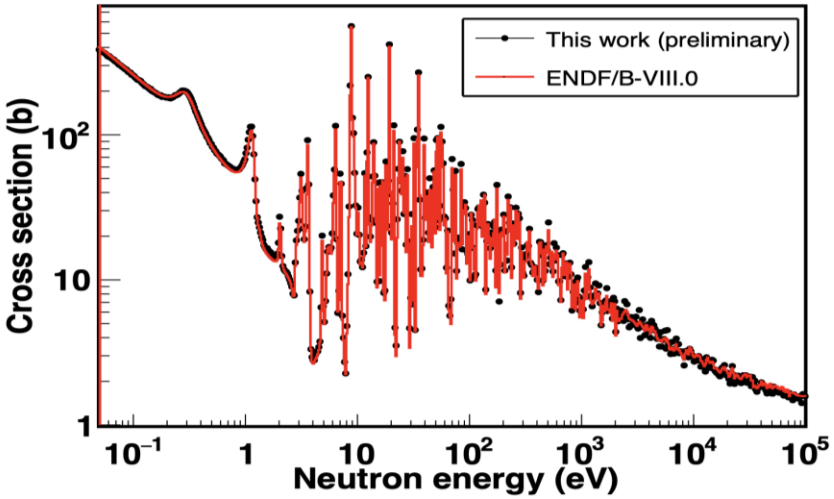
B. Dr Veatriki Michalopoulou (Post-Doc) – support for 6 weeks

^{235}U(n,f) cross section relative to the ^{10}B(n,α) reaction with Micromegas detectors at the CERN n_TOF facility

The **^{235}U(n,f)** cross section is widely used as reference reaction from thermal up to 1 GeV neutron energy and as a standard at thermal energies and from 150 keV to 200 MeV. High quality data are needed to improve the accuracy and extend the energy region of the standard. The **^{10}B(n,α)** reaction is used as reference reaction - from 0.0253 eV to 1 MeV- smooth cross section in the region of resolved and unresolved resonances.



^{235}U(n,f) data from EAR-1 data using **^{10}B(n,α)** as reference reaction

In 2018 at EAR-1 and EAR-2 of the n_TOF facility, during the ^{230}Th(n,f) campaign (PhD thesis of V. Michalopoulou), the data from the ^{235}U and ^{10}B reference targets were analysed for EAR-1. The EAR-2 data due to very high counting rates that could not recover with pile-up correction methods, it was not possible to extract any results.

Education and Training visits of early stage researchers

Final Decision : In the ^{243}Am(n,f) campaign in 2023 **repeat the EAR-2 measurements with a ^{10}B target of ~0.3 µg/cm^2** (instead of the ^{10}B target of 8 µg/cm^2 used before) - All samples have been prepared at JRC Geel.

- **1 week in October 2022** to prepare the Micromegas detectors, preamps, sample holders, gas system, gas, etc. for the in-beam test in November 2022
- **2 weeks in November 2022** to perform the test in EAR-2, with ^{235}U and ^{10}B samples in the chamber and check the γ-flash and response of the detectors with the new spallation target - alternative gas for the operation of the detector - the switch circuit to avoid the saturation from the g-flash.
- **3 weeks in 2023** when the ^{243}Am experiment will be performed, to help in the preparation and ensure the ^{10}B and ^{235}U targets are set in a way we can extract the **^{235}U(n,f)** cross-section using the **^{10}B(n,α)** as reference.

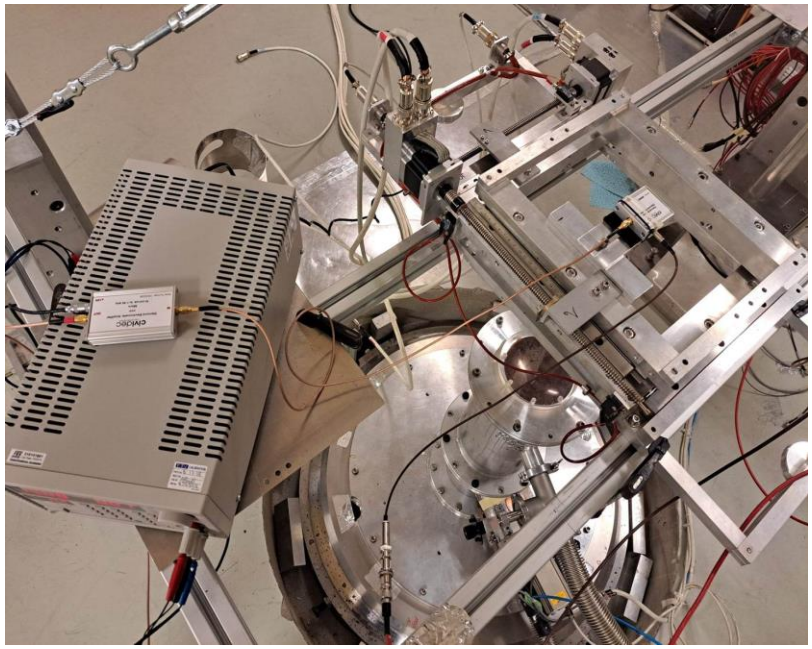
Education and Training visits of early stage researchers

C. Kalliopi Kaperoni (PhD student) – support for 12 weeks

Direct measurements of the n_TOF NEAR time of flight neutron fluence with diamond detectors

This research will be an important contribution to the n_TOF collaboration and will help improving the **diamond detector** system for in-beam measurements in harsh radiation conditions of the NEAR station, the new experimental area at n_TOF. Subject of K. Kaperoni's PhD thesis. First time of using active detector at NEAR in 2023!

The diamond detectors (4 mm x 4 mm x 50 μm) have been developed and produced by CIVIDEC Instrumentation. R&D for the electronics of diamond active detector to measure the neutron fluence at the n_TOF NEAR station.
6 weeks in autumn 2022 for the preparation and execution of the **diamond detector test in EAR2**, using various CIVIDEC amplifiers with fast response. Extract the detector current wrt ToF, compare with the simulations, prepare for the NEAR measurement in 2023. Work/collaboration with local team.



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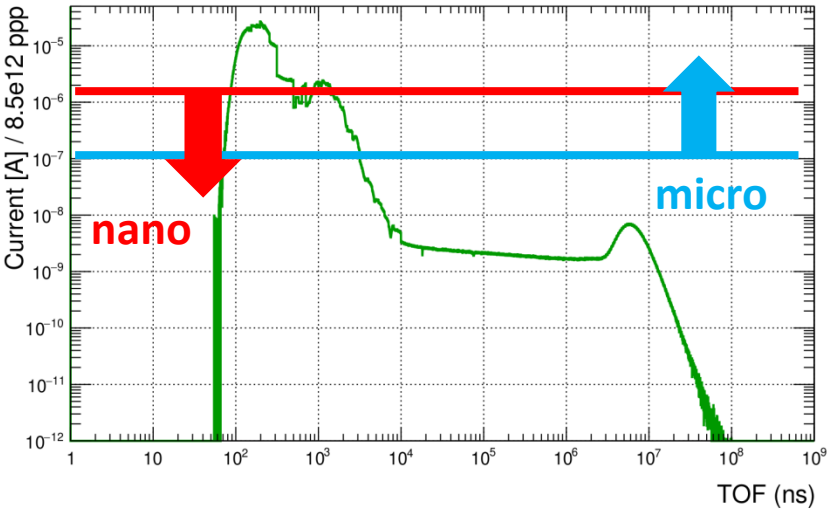
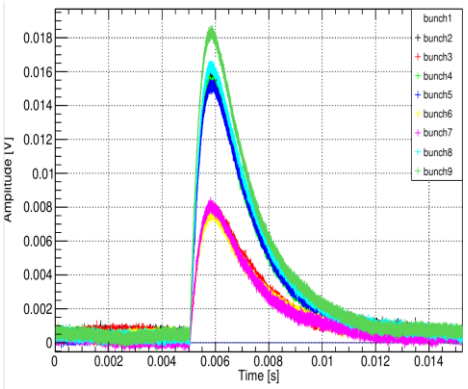
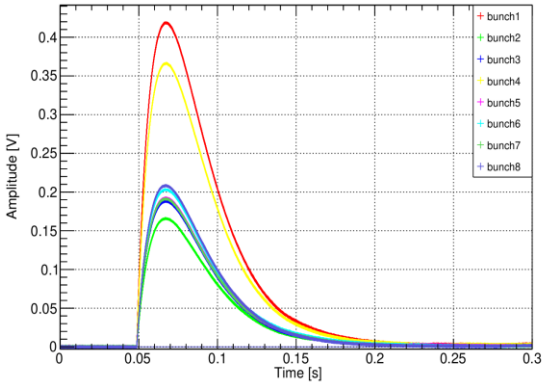
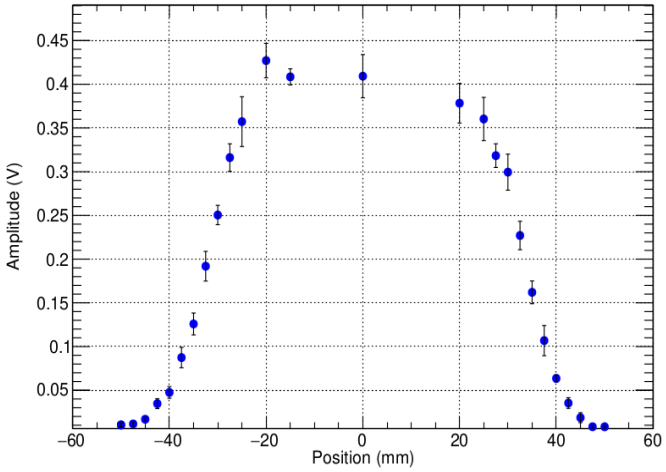
In the EAR-2 tests last November, two DC amplifiers were tried **Micro (10mV/µA)** and **Nano** (**10mV/nA)** to cover a large range of neutron energies. Nano amplifier is much slower than Micro







By moving the detector from 0cm to 40cm wrt the centre of the beam, the beam profile at EAR-2 was extracted



Need of faster amplifiers for NEAR, Under development at CIVIDEC.

6 weeks in 2023 for tests and measurements of beam fluence in the n_TOF **NEAR station**

Transnational Access for beam time at AMANDE facility in France

A. Sotirios Chasapoglou (PhD student) and Maria Diakaki (Ass. Professor) – 1 week at AMANDE facility (IRSN)

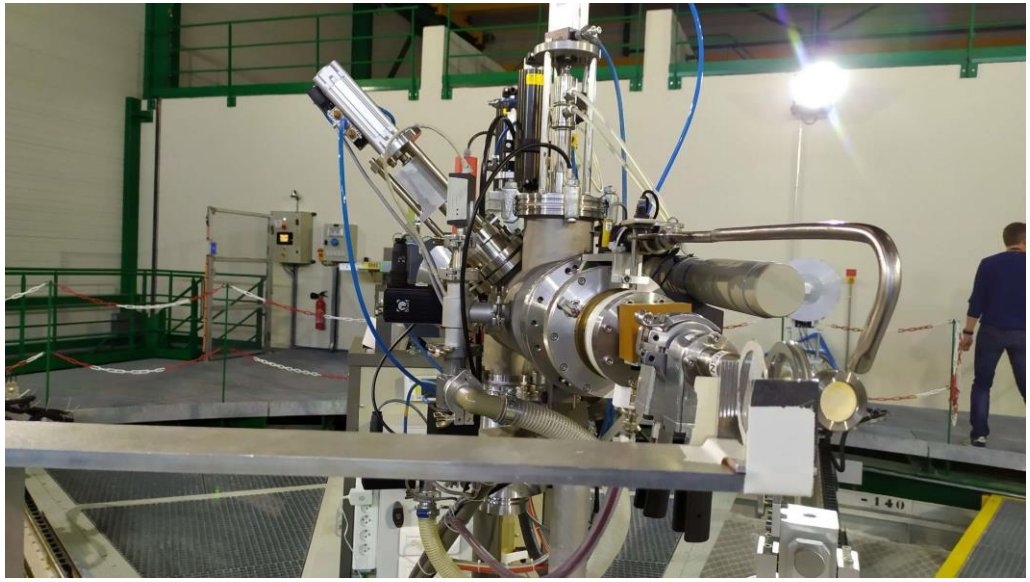
Neutron induced cross section measurements on Ge isotopes at the AMANDE facility using mono-isotopic targets

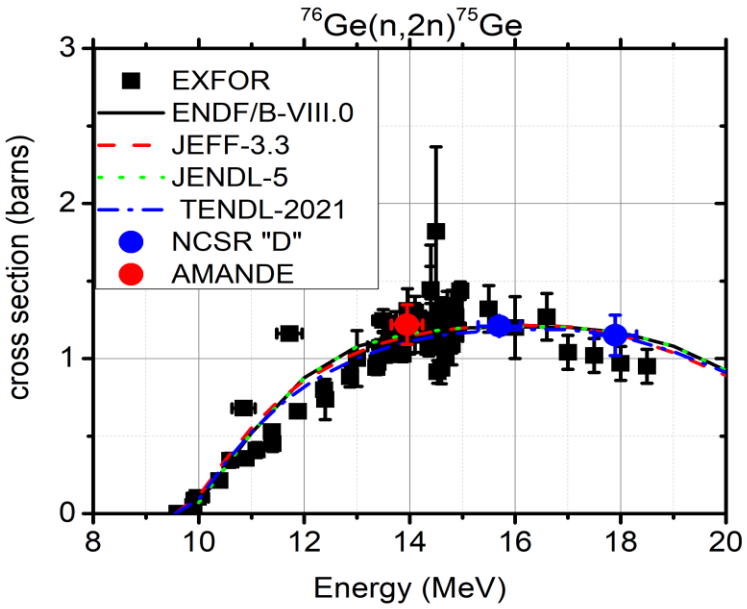
Of all isotopes contained in natural germanium (^{70,72,73,74,76}Ge), following neutron irradiation, only the ^{72,73}Ge(n,p)^{72,73}Ga, ^{72,74}Ge(n,α)^{69m,71m}Zn, ^{70,76}Ge(n,2n)$^{69,75m+g}$Ge, ^{73}Ge(n,nα)^{69m}Zn and ^{73,74}Ge(n,np)^{72,73}Ga reactions, can in principle be studied using the activation technique. Measurements at ~ 15-20 MeV have been carried out at our local neutron facility in NCSR Demokritos, Athens and a complementary measurement is needed at **13.9 MeV** and was **successfully performed at AMANDE**. Mono-isotopic targets are essential to accurately determine cross sections of these 9 reactions, as they will not be affected by interfering reactions with neighbouring isotopes.

Five samples of high purity pellets of ^{70}Ge, ^{72}Ge, ^{73}Ge, ^{74}Ge, ^{76}Ge in the form of GeO_2 and mass of 2g placed between **Al and Au reference foils** and exposed to the neutron beam, each of them separately, **in 30/1 - 3/2/2-23**. Thanks to the high flux (even at 100^0 wrt the beam axis) 2-5 hours of irradiation was sufficient for each of the Ge isotopes and their reference foils.

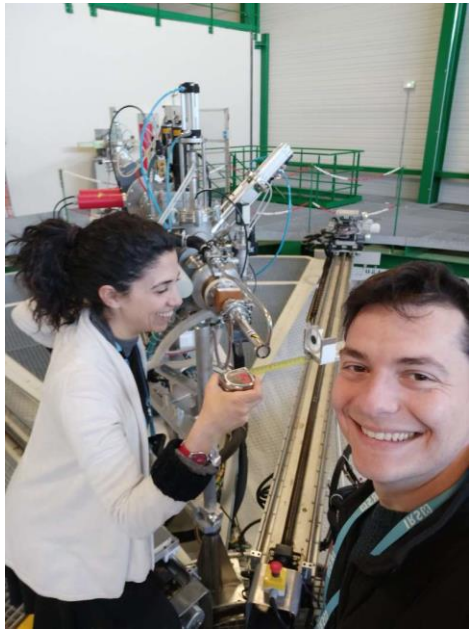
Transnational Access for beam time at AMANDE facility in France

Following the irradiations, the induced activity in the samples of interest and reference foils were measured by γ-ray spectroscopy, using HPGe detector available at the facility (13% of relative efficiency). Local team (Richard Babut & Nelson Magalotti) very helpful – Excellent collaboration both before and during the measurements. Preparation for target holders, detector etc.





Very successful experiment! Data are currently in the analysis process. Important contribution in the PhD thesis of S.Chasapoglou



Transnational Access for beam time at the CERN n_TOF facility

B. **R. Vlastou, V. Michalopoulou, M. Diakaki, S. Chasapoglou – 1 week** each of us to participate to the ^{243}Am(n,f) cross section measurement with Micromegas detectors at the CERN n_TOF facility that will be performed this summer, in June and July 2023 – seniors have to be present for the PhD data of Nikos (who will ask for another 2 months support from ARIEL)

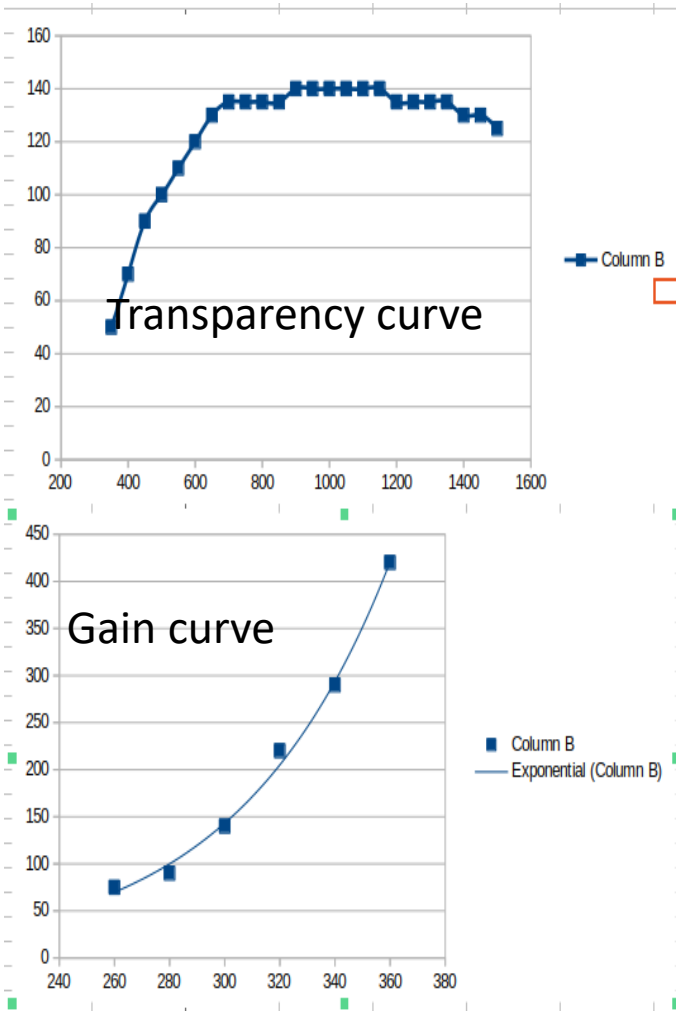
Participation in Summer Schools

The two PhD students Sotirios Chasapoglou and Nikolaos Kyritsis participated last September in the Summer School
"HiSPANoS Hands-on School on the production, Detection and Use of Neutron Beams" at CNA in Seville, Spain
GREAT EXPERIENCE!

Final results from all these activities will be presented by the actual beneficiaries (3 PhD students and 1 Post-Doc) in the next ARIEL meeting

Many thanks to ARIEL project for the support!
Very important for the progress of these projects

Thank you
for your attention



- **^{243}Am ($T_{1/2}$ = 7364 y) contributes to the long-term production of ^{239}Pu** via α- and subsequent β-decay
- **Accuracies of ~2%** for the development of Fast Reactors **are needed**
- Despite the excellent work of **F. Belonni** et al. (0.5 – 20 MeV) and **M. Mastromarco** et al. (… – 1.6 MeV) (FIC measurement) **there is space for improvement**
- **Special care for the contamination issues of the target** will be taken ("fresh" target) → improve the quality of the data in the low energy region
- New data **for En > 0.5 MeV** (fission threshold) with **improved statistical uncertainty** (smaller energy bin size) will improve the overall accuracy of the data
- **Data at En > 20 MeV can be obtained**