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CLUSTER OF ACCELERATOR LABORATORIES FOR ION BEAM RESEARCH AND APPLICATIONS – CALIBRA: A NATIONAL RESEARCH INFRASTRUCTURE FOR ACCELERATOR-BASED SCIENCE AND ANALYTICAL SERVICES

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Abstract. *CALIBRA is the acronym for a National Research Infrastructure hosted by the Institute of Nuclear and Particle Physics (INPP) at the National Centre for Scientific Research "Demokritos" in Athens, Greece. It was established through the CALIBRA project, co-financed by Greece and the European Union. This project has enabled the development of open-access facilities equipped with state-of-the-art setups, which are now available to the scientific community for research and development activities. These facilities support high-level excellence and provide analytical services with significant socioeconomic impact. This article presents an overview of these setups and their achievements.*

Keywords: *ion-beam accelerator-based research infrastructures*

1. CALIBRA: A National Research Infrastructure

CALIBRA, which stands for "Cluster of Accelerator Laboratories for Ion-Beam Research and Applications," is a National Research Infrastructure hosted by the Institute of Nuclear and Particle Physics (INPP) of the National Centre for Scientific Research "Demokritos" in Athens, Greece.

The implementation of CALIBRA is a multi-phase process aimed at creating and operating a unique scientific environment for cutting-edge research and education, with a focus on excellence. It could also provide a broad range of irradiation and analysis services to both public and private sectors and act as an innovation platform. The first phase of CALIBRA was funded through the "CALIBRA project".

The CALIBRA accelerator cluster includes a 5.5-MV Van de Graaff Tandem accelerator, a 250-keV high-current proton and deuteron single-stage accelerator (PAPAP), a 2.5-MV Tandetron accelerator for Accelerator Mass Spectrometry (AMS) and a 17-MeV Cyclotron for producing PET and other radioisotopes, to support research and development in radiopharmacy.

2. CALIBRA: Accelerator-based Science for Greece

In Greece, the demand for accelerated ion beams is surprisingly high. A realistic estimate of the beam time required to meet local needs for ion beam irradiations is approximately 4000 hours per year. Over 70% of this demand is driven by applications related to analysis of cultural heritage objects (including radiocarbon dating), environmental studies, the development of new materials of technological interest, testing new detectors and sensors, and various other analytical services. This estimate does not include beam time required for research and development of new radioisotopes for medical use, nor does it account for beam time requested for services to the public or private sector.

Currently, the majority of the local demand for accelerated ion beams is met by TAL, the TANDEM Accelerator Laboratory [1], a unique research facility in Greece, located at "Demokritos". CALIBRA serves as an extension of TAL, with the goal of gradually fulfilling national beamtime needs. CALIBRA's vision is to support both the public and private sectors by offering irradiation and analytical services, while also facilitating the transfer of knowledge and expertise. Furthermore, a key component of CALIBRA's mission is to provide high-level education and training for young researchers.

3. The CALIBRA Project

The CALIBRA project was funded with ≈3.5 million Euros. It was implemented under the Action "Reinforcement of the Research and Innovation Infrastructures," which was financed by the Operational Programme "Competitiveness, Entrepreneurship, and Innovation" (NSRF 2014–2020) and co-financed by Greece and the European Union (European Regional Development Fund). The project aims to implement CALIBRA Phase 1, the first step towards the completion of the full-scale CALIBRA National Research Infrastructure.

The primary goals of Phase 1 include: (a) to fully refurbish and upgrade the existing 5.5-MV Tandem accelerator, (b) to transport the Cyclotron to "Demokritos," (c) to transport and install the 2.5-MV

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Tandetron AMS, and (d) to acquire state-of-the-art setups and scientific instruments. These goals were successfully achieved. Additionally, the project facilitated numerous Joint Research Activities (JRAs) and Networking Activities (NAs). CALIBRA is now an open-access, interdisciplinary research infrastructure, serving more than 50 users.

4. CALIBRA's Core Idea

CALIBRA was motivated by the numerous research opportunities of operating various types of ion-beam accelerators within a unique multidisciplinary scientific environment. This environment has been successfully established over the years at "Demokritos", where Biosciences, Material- and Nanoscience, Environmental and Cultural Heritage studies, Radiobiology and Radiopharmacy coexist with Nuclear Physics.

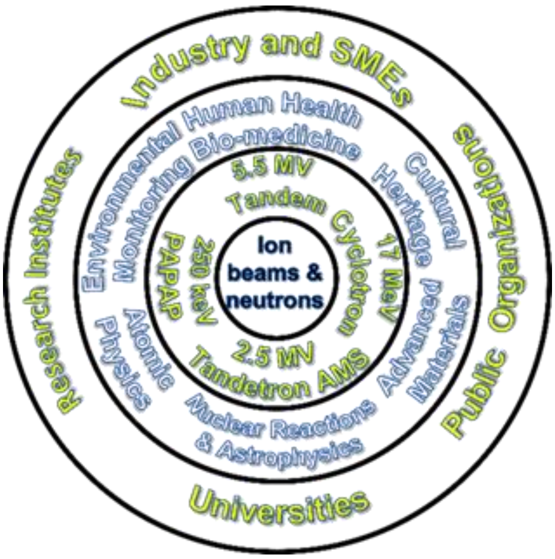

Figure 1. CALIBRA's core idea

In such a multi-multidisciplinary environment, the operation of a "Cluster of Accelerator Laboratories for Ion-Beam Research and Applications" could successfully contribute not only to the overall scientific program of "Demokritos" but also to that of the wider national and European scientific community. Using the CALIBRA accelerator cluster, front-line research programs at the level of excellence can be implemented and irradiation services can be offered using accelerated beams of charged atoms (ions) from the lightest (hydrogen) to one of the heaviest (gold), and secondary neutron beams.

5. Access to CALIBRA Facilities

CALIBRA provides access to its facilities for researchers from both Greece and abroad, enabling them to conduct R&D and implement educational activities in many areas including: (a) Nuclear Astrophysics, (b) nuclear reaction studies with ion beams and fast neutrons, (c) Atomic Physics, particularly high-resolution studies of Auger electrons from accelerated ions excited in ion–atom collisions, (d) radiation damage phenomena in materials, and (e) Ion Beam Analysis (IBA) of material surfaces altered by various physical or chemical processes or radiation hardening, as well as the analysis of cultural heritage objects, environmental air or soil samples, and toxic elements or heavy metals affecting human health and food quality. IBA techniques such as RBS, Channeling, PIXE/PIGE, NRA, and ERDA are commonly employed for these analyses.

CALIBRA's irradiation and analytical services are also available to the public and private sectors, thereby contributing to the increased competitiveness of the Greek economy. In the near future, CALIBRA will offer radiocarbon dating services for the first time in Greece, using Accelerator Mass Spectrometry (AMS). If fully funded and completed, the full-scale CALIBRA will also enable the production and distribution of PET radioisotopes for R&D and medical use.

Scientists from universities and research centers are welcome to submit beamtime requests at any time. Beamtime is granted following evaluation by an International Scientific-Technical Advisory Committee (ISTAC), which meets twice a year. Requests for irradiation and analytical services from state organizations, the private sector, startups, or funded projects can be directed at any time to CALIBRA's management via the email: calibra@inp.demokritos.gr. Depending on the scope, nature, and duration of the service request, fees may apply.

6. CALIBRA INFRASTRUCTURE

6.1. Accelerators

5.5 MV Tandem: Currently the workhorse of CALIBRA, it is a vertically T-shaped Van de Graaff electrostatic accelerator capable of generating a maximum accelerating voltage of 5.5 Megavolts. It houses two ion sources that produce beams of charged atoms (ions), ranging from the lightest hydrogen to iodine. Samples to be analyzed can be placed in analytical stations installed at eight beamlines.

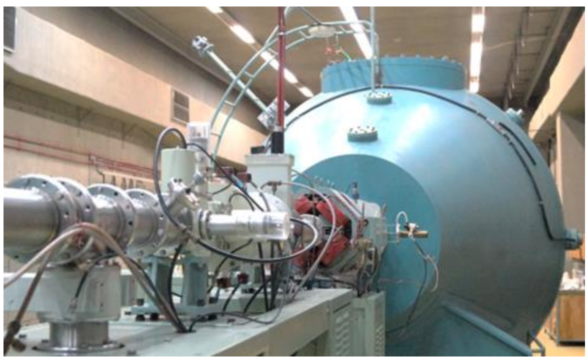

Figure 2. The tank of the 5.5-MV Tandem accelerator

The building that houses the Tandem laboratory was constructed in the early seventies. It ensures full radioprotection and shielding against ionizing radiation, particularly the production of secondary neutron beams. The laboratory is located on the ground floor and is enclosed by borated concrete walls. It covers an area of approximately 1900 m², of which ≈ 900 m² is occupied by the Tandem accelerator hall and the two 'target' rooms where the experimental end stations are installed. The remaining area includes: the accelerator control room, a 300-m² area where the AMS Tandetron is installed, a machine shop, a target preparation room, workspaces, and offices.

CALIBRA funds enabled a complete upgrade of the Tandem accelerator, including:

- Replacement of the ion sources with brand new ones: a state-of-the-art Sputter source for heavy ions and a high current TORVIS producing negative hydrogen, deuteron and helium ions.
- Replacement of existing charging belt with Pelletron® charging system to achieve excellent charging efficiency, longevity, durability and acceleration voltage stability.
- Replacement of the electron stripping devices in the high voltage terminal (tank) with two brand new ones; a gas and a foil stripper.
- Replacement of old voltage stabilizer with new one with one with Generating Volt meter (GVM), new corona probe and controller units.
- Installation of computer control system to operate the accelerator. All parameters of the accelerator are connected to the control console and can be adjusted using a computer. Parameters can be saved to an electronic log and restored. The system allows remote operation using the laboratory network or the web.
- Installation of beam profile monitors at selected points along the accelerator beam lines to provide continuous scope display of the shape and position of the beam cross section in both X and Y coordinates.

250-keV Single-stage Accelerator (PAPAP): PAPAP is a single-stage accelerator with a multi-cusp type source capable of delivering high-current (up to 0.5 mA) proton beams. Its construction was partially funded by the Inst. of Nuclear Physics of “Demokritos”.

PAPAP was built and installed at CSNSM, Université Paris-Sud Orsay, France, for the needs of a research program focusing on the solar neutrino problem. With the termination of this program, PAPAP was donated to the INPP, where it is now installed. It is equipped with an advanced chamber for material analysis capable of cooling samples down to liquid nitrogen temperatures.

Subject of further funding, PAPAP will be used as an intense neutron source capable to reach a neutron flux of approximately 10^{11} neutrons per second allowing for a wide spectrum of research, with emphasis on the study of materials relevant to fusion technology, as well as industrial applications.

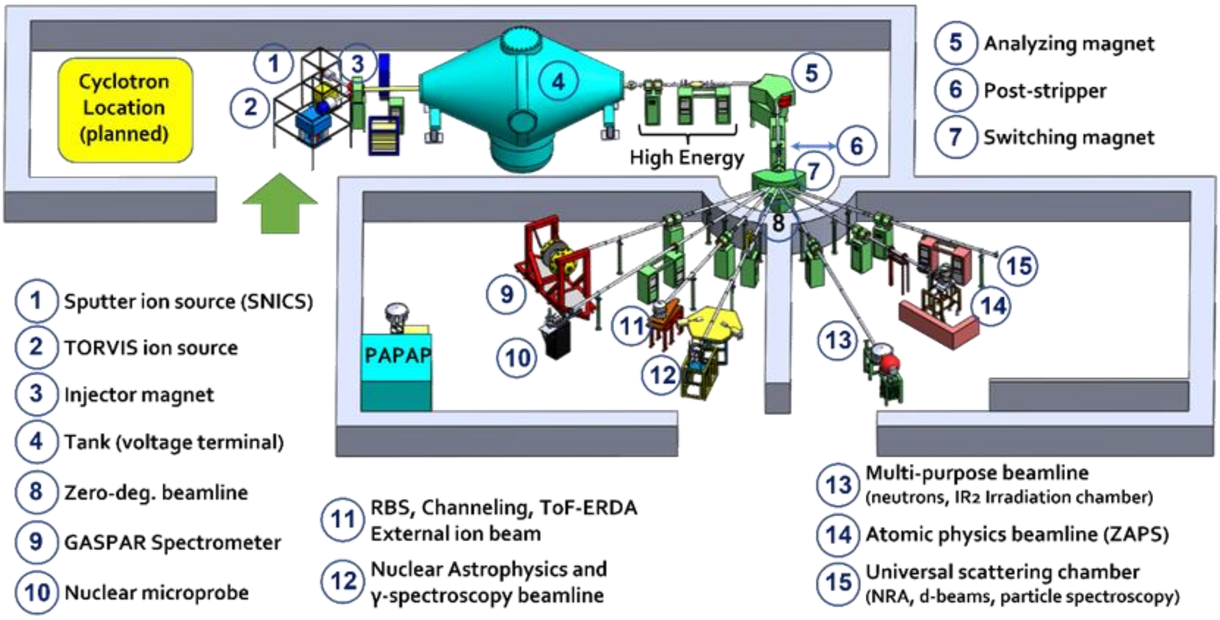

Figure 3. Layout of the 5.5 MV Tandem accelerator laboratory

Figure 4. The PAPAP 250-keV Single-stage accelerator

MC 17-MeV Scanditronix Cyclotron: A unique scientific tool for R&D in the country, it can deliver proton and deuteron beams with energies up to 17 and 8.5 MeV, respectively, and currents around 60 μA. With these projectiles, the positron-emitting radioisotopes ^{18}F, ^{11}C, ^{13}N, and ^{15}O can be produced and subsequently used for the preparation of widely used radio-pharmaceuticals, such as 11C-Methionine, 18F-FDG, etc., for diagnostic purposes in nuclear medicine. The cyclotron was donated by UMCG, the Dutch University Medical Center Groningen, together with an advanced target system for the production of all well-establish PET radioisotopes.

The main goal of its operation, which is subject of CALIBRA’s continuation, is the establishment of a research program aiming at the development of advanced radiopharmaceuticals by Greek scientists.

Figure 5. MC 17-MeV SCANDITRONIX Cyclotron

2.5 MV Tandetron AMS: Donated recently by the University of Oxford, UK, it offers for the first time in Greece radio-carbon dating possibilities of key importance to cultural heritage studies and archaeology. It will also cover local needs for analysis of samples relevant to environmental monitoring and climate change studies.

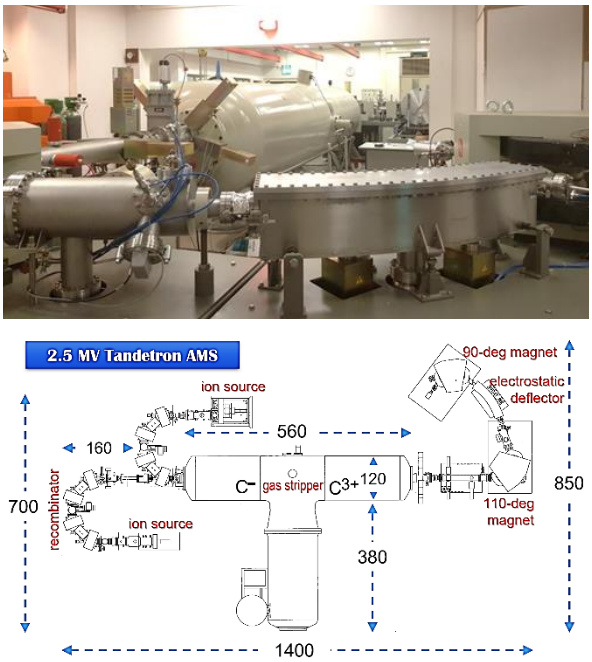

Figure 6. The 2.5-MV Tandetron AMS accelerator

6.2. Setups – End stations – Scientific Instruments

GASPAR BGO Ball: GASPAR stands for "GASP for Astrophysics Research", with "GASP", referring to the GAmma Spectro-meter previously operating at the Laboratori Nazionali di Legnaro (LNL), Padova, Italy. GASPAR is a 4π calorimeter composed of 80 Bismuth Germanate Oxide (BGO) crystals covering 80% of 4π solid angle. Each crystal is 65 mm-thick, sufficient to absorb 95% of 1-MeV γ-rays. The resulting total efficiency is 70%. When high multiplicity events are detected, the total BGO ball efficiency is ≈100%.

During GASP's utilization at LNL, its BGO ball was used as a multiplicity filter. With the replacement of GASP with the new GALILEO array at LNL, the BGO ball became available for other research topics and was loaned by LNL to the Tandem Accelerator Laboratory to be used for the study of nuclear reactions relevant to nuclear astrophysics and the dynamics of low-energy nuclear reactions. GASPAR was recently equipped with new digital electronics for signal processing using funds from the CALIBRA project.

Figure 7. The GASPAR BGO Ball

NEOPTOLEMOS γ-Summing Spectrometer: Capture reactions play a prominent role in nuclear astrophysics studies. Often, the cross sections of interest are very small making the use of highly efficient hyper-pure Germanium detectors (HPGe), even equipped with Anti-Compton shields, impractical in in-beam cross-section measurements.

The Nuclear Astrophysics Group of "Demokritos" developed a new technique [2,3] that enables measuring angle-integrated γ-spectra instead of time-demanding γ-angular distributions. This technique is based on the use of a large-volume NaI(Tl) detector with the highest possible absolute γ-ray detection efficiency.

NEOPTOLEMOS is a large-volume (14 inch X 14 inch) cylindrically-shaped NaI(Tl) detector with a borehole of 32 mm diameter along its axis. It is two-fold segmented (top and bottom halves) having an absolute efficiency better than 50%, for a two-fold cascade. Apart from Nuclear Astrophysics studies, NEOPTOLEMOS can also be used for applications, notably for hydrogen profiling of materials.

HELGA, the HELlenic Gamma Array: HELGA is a high-resolution detector array consisting of six hyper-pure Germanium (HPGe) detectors, three of which are equipped with Anti-Compton shields (BGO crystal detectors. The BGOs produce an electronic signal (veto) that prohibits the data acquisition system from registering the photons resulting from Compton scattering. This way, the unwanted background in the gamma-ray spectra can be decisively suppressed, often by a factor of 10 or higher, thus increasing the sensitivity of the measurements as the detection of very low intensity γ-rays is enabled.

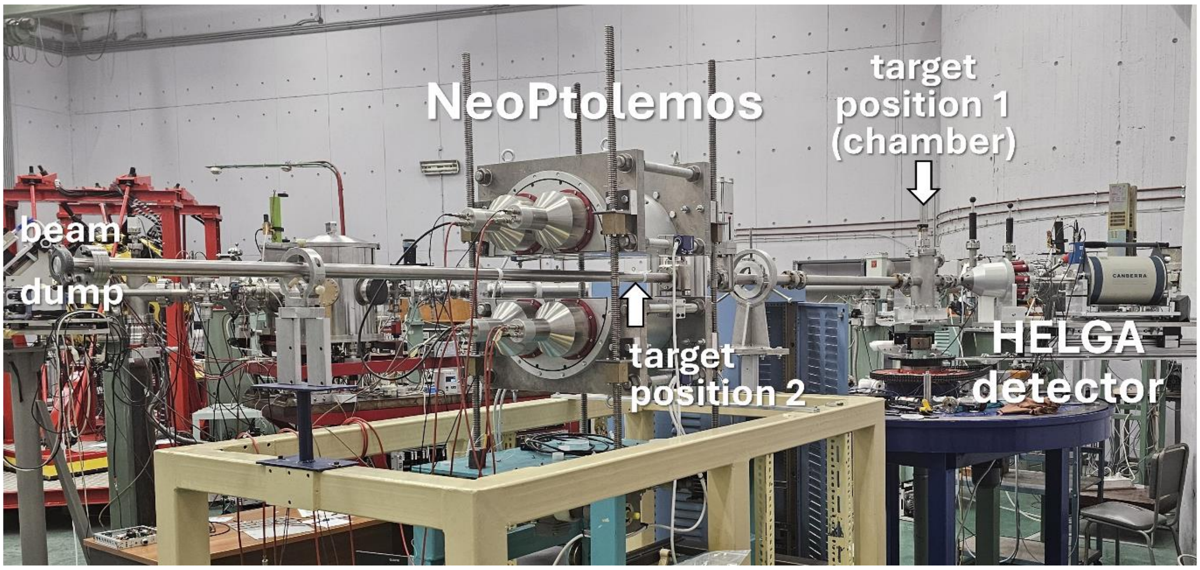

Figure 8. The Nuclear Astrophysics beamline at the Tandem Accelerator Laboratory. On the right, one HPGe detector of the HELGA array with its BGO Anti-Compton Shield is shown. The NeoPtolemos spectrometer is depicted in the center of the figure. Its top and bottom parts are hereby moved vertically. Depending on the type of experiment, the target of interest is located either in chamber surrounded by HELGA detectors (target position 1) or at the center of NeoPtolemos' axis (target position 2).

Figure 9. One of the HELGA HPGe detectors with its BGO shield on rotating table.

HELGA is a universal detector system for gamma spectroscopy for fundamental nuclear physics research as well as for many applications. HELGA's HPGe detectors are portable to allow for measurements outside the accelerator laboratory.

Universal Scattering chamber: The chamber is made of aluminum with an outer diameter of 80 cm and a height of 35 cm. It can host up to eight surface barrier detectors which are mounted onto aluminum rails so that their distance to the target can be adjusted.

Samples are mounted on a target holder at the center of the chamber that can move vertically. Samples can be cooled by a copper block attached on its back side. Between the sample and the block, a thin mica foil was placed to achieve electrical, but not thermal, insulation. The beam is collimated by two Ta collimators before entering the chamber.

Nuclear Microprobe: For the determination of the elemental composition of surfaces of solid materials a microbeam system was purchased from Oxford Microbeams Ltd. The arrangement of the beam-defining and focusing elements are shown in Figure 9.

The quadrupole triplet is mounted on an artificial granite plinth to eliminate vibrations that could affect the spatial resolution of the system. The chamber has 22 ports at several angles, where detectors and auxiliary equipment can be attached and is also equipped with a load lock chamber, which permits the change of samples without the need to vent the whole vacuum chamber, and a microscope just above the chamber entrance with a large focal length.

A CCD camera is installed at its eyepiece to remotely monitor the exact spot of the beam on the sample. The target holder is mounted on a high-precision multistage that can rotate by 360 degrees around the vertical axis and be translated across all three dimensions. All sample movements, apart from rotation, are motorized and computer controlled. The holder also has the possibility of heating or freezing the sample. The microbeam system can currently focus the beam down to ≈2 μm size.

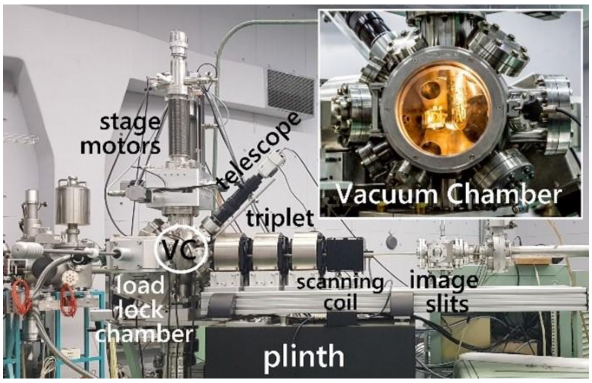

Figure 10. The Nuclear Microprobe

External ion beam: The setup has an ion-beam exit nozzle covered by a 100-nm-thin Si3N4 foil. It allows for the detection of X rays with energies down to 1 keV. It is also equipped with a CCD camera, for visual inspection of the sample point under analysis, and lasers for the necessary alignment. The setup was developed to be used with ions heavier than protons.

The External Ion Beam setup was recently upgraded with CALIBRA funds to offer fast elemental analysis with a spatial resolution of ≈1 mm2 and examination of large areas on the investigated objects. It is now equipped with state-of-the art Silicon Drift detectors (SDDs) and a fast XYZ motorized stage allowing for the positioning of large objects and scanning over extended areas.

Figure 11. The External ion beam system

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ToF-ERDA Analytical End-Station: Among the widely used non-destructive analytical techniques, only a few are capable not only to detect light elements in heavy element matrices but also to quantify their concentration.

For this type of measurements, which are of paramount importance in many cases of materials analysis with key technological applications, a brand-new Time-of-Flight (ToF) Elastic-Recoil Detection Analysis (ERDA) system, currently under commissioning, was purchased with CALIBRA funds.

The addition of this setup provides more accurate results and allows for faster analyses, as the system can simultaneously detect several light isotopes, from hydrogen to calcium, contained in heavy element matrices. The ToF-ERDA setup is Figure 11. The ToF-ERDA analytical endstation.

Figure 12. The ToF-ERDA Analytical End-Station

RBS-Channeling chamber: Well-established Ion Beam Analysis (IBA) techniques are extensively used by CALIBRA for material characterization, surface analysis and environmental monitoring. Rutherford Backscattering Spectrometry (RBS), Channeling, Nuclear Reaction Analysis (NRA) and Particle-Induced X-ray Emission (PIXE) are the main applied techniques for which dedicated experimental setups are installed.

RBS-Channeling measurements are performed with the chamber shown in the figure. The chamber is made of stainless steel and is cylindrically-shaped with a 20-inch diameter. It contains a sample positioning manipulator. The samples are mounted on a cylindrical holder made of stainless steel or aluminum, which has a diameter of 5 cm and a thickness of 1.5 cm. The sample manipulator can position the samples with an accuracy of 1 μm for the translations and 0.01 degrees for rotations. The range of angles covered is from -45 to +45 deg. for rotations around the horizontal axis (tilting) and from -90 to +90 deg. for rotations around the vertical axis.

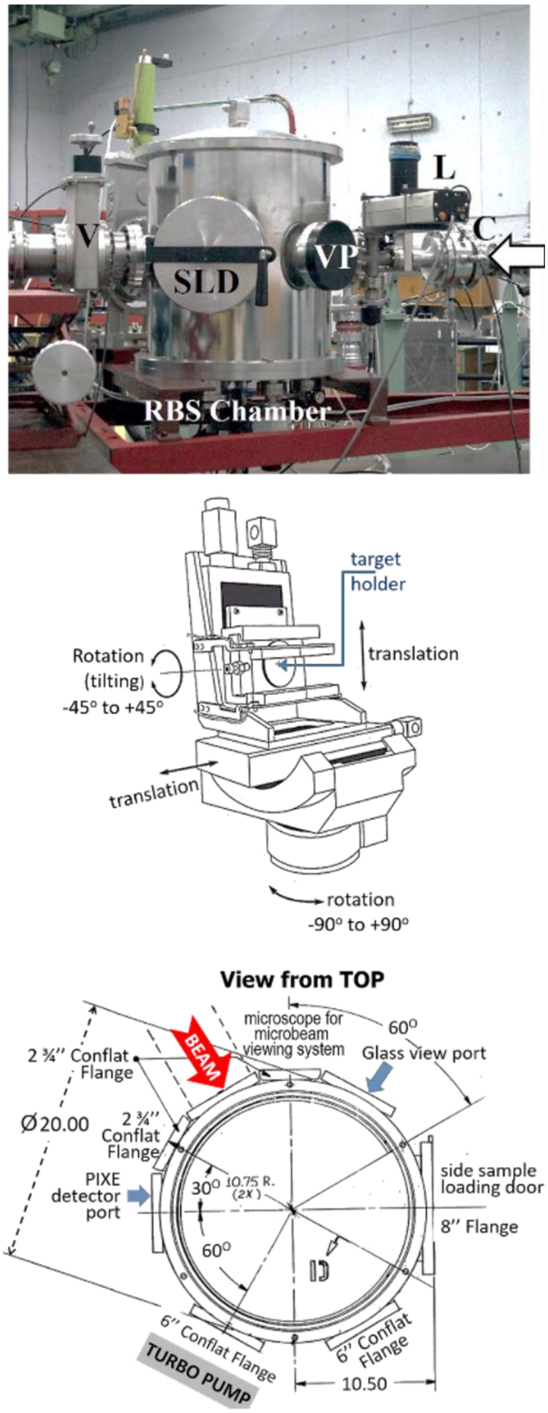

Figure 13. The RBS/Channeling chamber (top), its sample-positioning manipulator (middle) and cross section indicating its dimensions.

The incoming particle beam is collimated by means of one adjustable tantalum collimator and one double collimator that are mounted at 35 and 60 cm, respectively, from the entrance of the chamber. A laser (L) mounted outside the chamber is used for the placement of the detectors at the desired scattering angles and for beam alignment. Samples are loaded through a sample loading door (SLD).

A glass view port (VP) allows for visual monitoring of the chamber's interior, the sample's translations and rotations and the beam spot's location and shape. The target holder is being monitored by a CCD camera inside the chamber.

Universal Scattering chamber: The chamber is made of aluminum with an outer diameter of 80 cm and a height of 35 cm. It can host up to eight surface barrier detectors which are mounted onto aluminum rails so that their distance to the target can be adjusted.

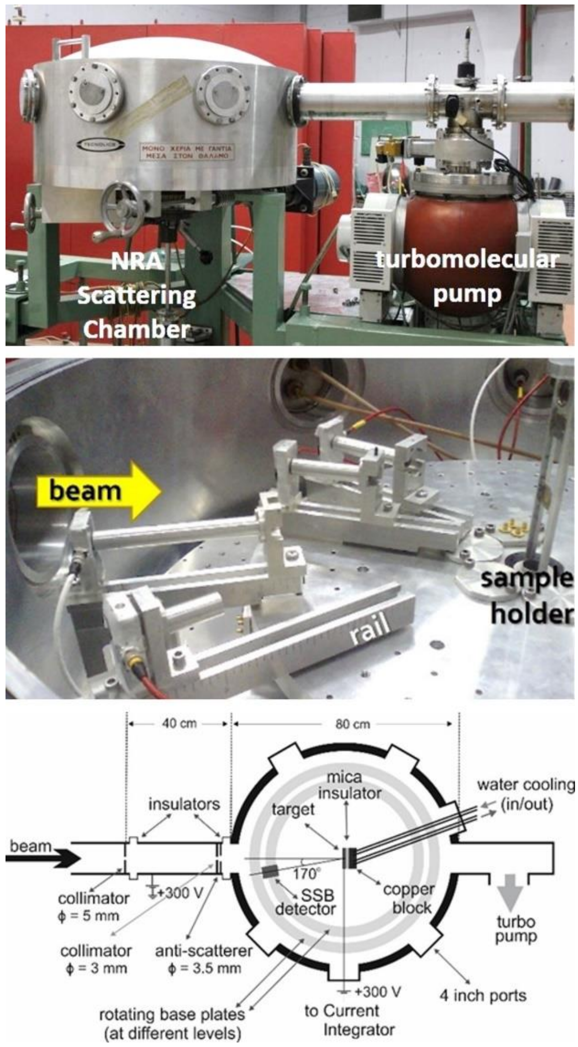

Figure 14. *Top:* The TECNOLICS large scattering chamber and its supporting turbomolecular pump; *Middle:* Interior of the chamber with its sample holder and the supporting bases of the surface barrier detectors; *Bottom:* Horizontal cross section of the chamber and its components.

Samples are mounted on a target holder at the center of the chamber that can move vertically. Samples can be cooled by a copper block attached on its back side. Between the sample and the block, a thin mica foil was placed to achieve electrical, but not thermal, insulation. The beam is collimated by two Ta collimators before entering the chamber.

HELLENA: The HELLEnic Neutron-Array: HELLENA is a 4π array of thermal-neutron detectors. It consists of 16 proportional counters filled with He-3 gas (sensitive length = 45.7 cm, Ø =2.54 cm, pressure = 4 bar), embedded in a cylindrical-shaped moderator made from polyethylene (length=1.00 m, Ø=35 cm) with a central bore hole (Ø = 7 cm) in the center of which is the target. At an inner circle of Ø=16 cm there are eight He-3 counters and at Ø=24 cm there are another eight He-3 counters, all embedded in holes of Ø=3 cm in the moderator.

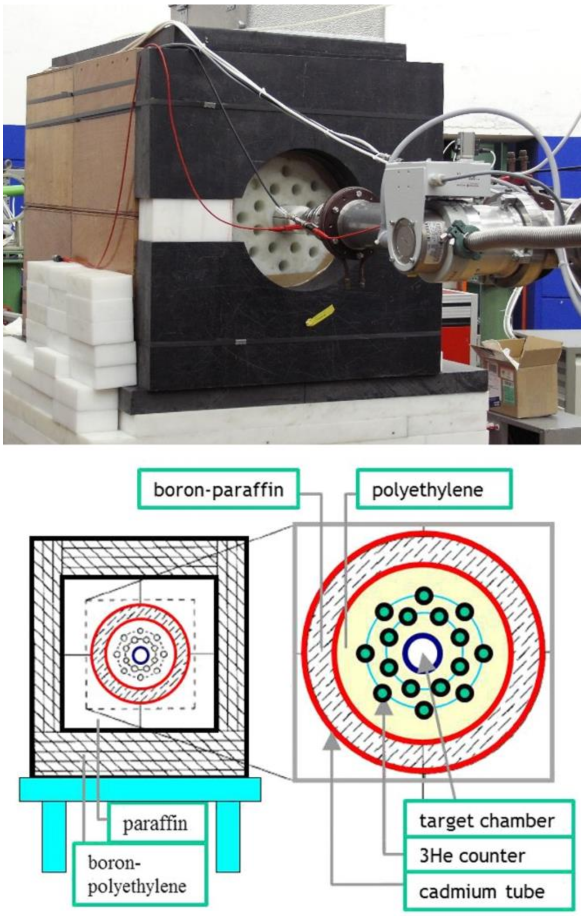

Figure 15. The HELLEnic Neutron-Array HELLENA

The inner and outer counters are positioned with a relative angle difference of 22.5 deg. To reduce the neutron background due to cosmic showers, several components for passive shielding (Cd, polyethylene, bor-polyethylene, bor-paraffin) are placed around the moderator leading to a background rate of about 0.25 counts/s. HELLENA is 85 cm high, 85 cm wide and 115 cm deep.

Neutron Facility: Quasi-monoenergetic neutron beams of different energies En are produced at the TANDEM laboratory using the reactions:

- ^{7}Li(p,n)^{7}Be En ≈ 120 – 650 keV
- ^{3}H(p,n)^{3}He En ≈ 2 – 5.3 MeV
- ^{2}H(d,n)^{3}He En ≈ 4.0 – 11.4 MeV
- ^{3}H(d,n)^{4}He En ≈ 16–20 MeV

In the latter three cases, a gas-cell is used filled with the corresponding isotope. The target assemblies are air cooled during the proton or deuteron beam irradiations. Two collimators of 5- and 6-mm diameter are used; beam currents are measured both at the collimators and the target and, prior to CALIBRA Tandem upgrades, were kept at the 0.7 to 1 μA range. To date, the accelerator can provide at least 10 times more intense beam currents.

The neutron flux variation is monitored by a BF3. Its spectra are stored at regular time intervals (~100 sec) during irradiation. The absolute flux of the beam is obtained with respect to the cross section reference reactions: ^{27}Al(n,α), ^{197}Au(n,2n) and ^{93}Nb(n,2n). Recently, the flux was found to range between 5 x 10^{6} and 10^{7} n/cm^{2}sec. The beam current on the target is also recorded during the same time intervals to test the reliability of the BF3 counter during long irradiation periods. A BC501A scintillator monitors the energy distribution of the neutron beam.

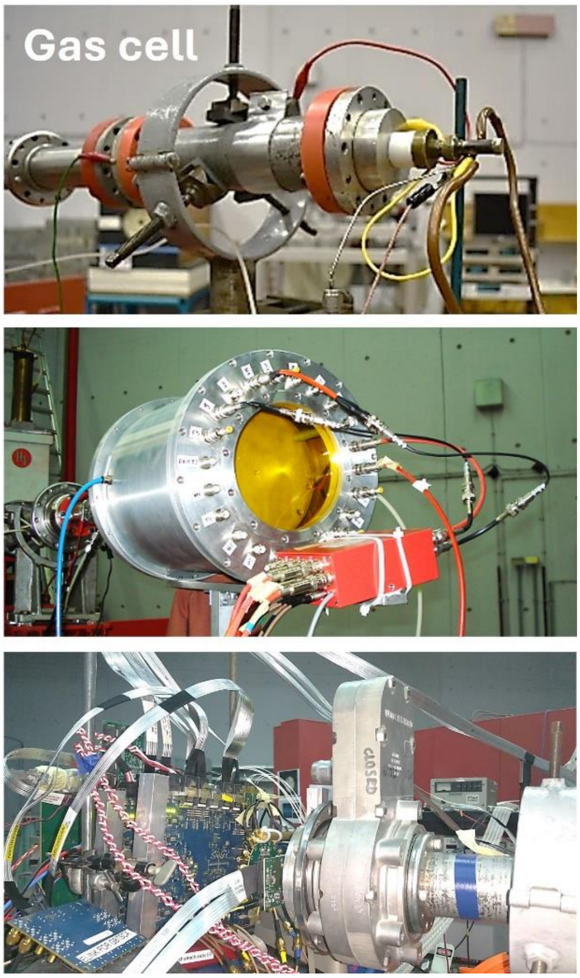

Figure 16. The gas cell used to produce neutron beams (top). The CERN/n_TOF Micromegas detector installed right after the gas cell (middle). Irradiation of electronic units used at the CERN ATLAS experiment (bottom). See also in Ref. [4].

ZAPS Spectrometer: ZAPS stands for "Zero-degree Auger Projectile Spectroscopy". The ZAPS spectrometer was installed by the collaborating Univ. of Crete to perform high-resolution studies of Auger electrons emitted from projectile ions excited in ion-atom collisions. The workhorse of the

ZAPS apparatus is a single stage hemispherical detector analyzer (HDA) combined with a 2D Position Sensitive Detector (PSD) and a 4-element injection lens. A doubly-differentially pumped gas target is utilized to allow for a vacuum of ≈10^{-7} Torr, even when the gas cell is loaded.

Figure 17. The ZAPS Spectrometer (see also in Refs. [5,6] for details).

The projectile ion beam from the accelerator goes through the target gas cell (where the collision takes place) and continues through the lens and on via the HDA. It exits from a hole in the back, where it is collected in a Faraday cup (FC), where its charge is integrated for absolute normalization. Auger electrons emitted from auto-ionizing projectile ion states excited in the collision, also exit along zero-degrees with respect to the ion beam.

After their last exit, the Auger electrons enter the spectrograph and are focused and decelerated by the lens to further improve energy resolution. Subsequently they enter the HDA where they are energy-dispersed and recorded at the exit of the HDA along the PSD.

The atomic structure and collision dynamics of multiple excited atomic states using high-resolution Auger electron spectroscopy has attracted a lot of scientific interest over the last decades. This interest results from the need to understand the collisional properties of highly stripped ions in various research domains, such as radiotherapy with light ions (hadron therapy), plasma physics and thermonuclear fusion research.

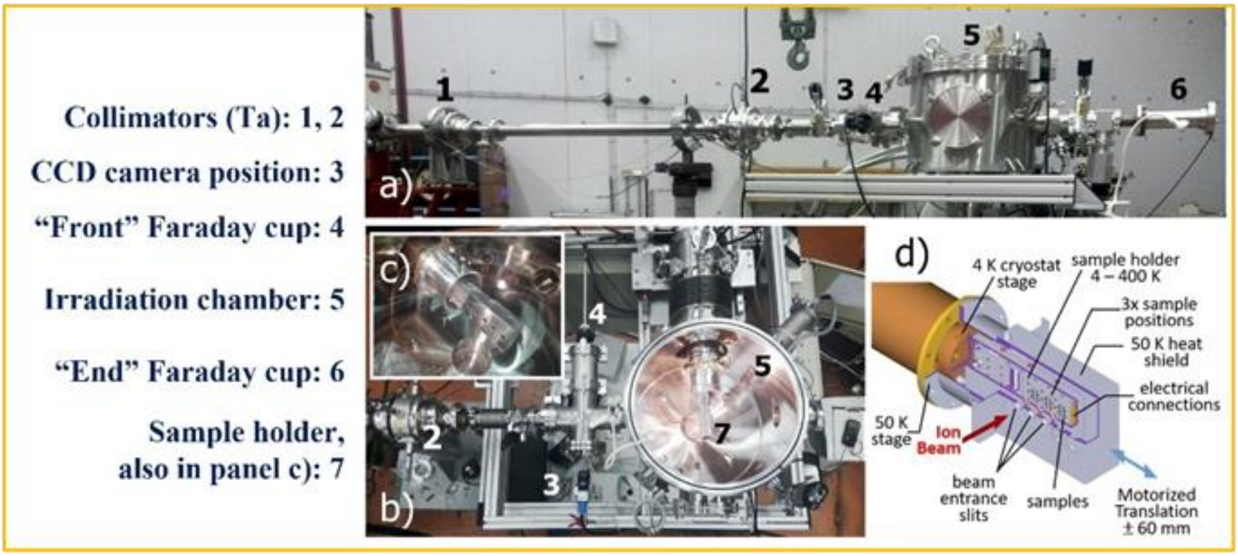

Figure 18. The IR² Materials Irradiation Setup (see also in Ref. [1] for details).

The IR² Materials Irradiation Setup: IR² stands for Ion iRradiation with In-situ electrical Resistivity measurements, a setup installed by the collaborating Fusion Technology Group of the INRASTES institute of “Demokritos”. IR2 is an irradiation facility dedicated to radiation damage studies of metallic materials at well controlled flux and temperature, from the cryogenic range (≲ 10 K) up to 700 K, by means of a dedicated cryo-cooler. Cryogenic temperatures are vital for the study of extreme mobile lattice defects generated by the irradiation, which then recombine promptly at room temperature and above making their observation extremely difficult. IR2 offers unique capabilities for the study of fundamental radiation damage processes in materials, which are of particular importance for the validation of new multiscale theoretical models and tools that are being developed with the aim of understanding the behavior of materials under fusion irradiation conditions.

7. Summary and Conclusions

CALIBRA plays a prominent role in the education and training of young researchers who develop highly specialized skills using the CALIBRA facilities. As of today, more than 20 theses (Diploma, Master and PhD) submitted to Greek Universities were completed using the CALIBRA facilities.

Through the CALIBRA project, two more accelerators, a PET Cyclotron and a 2.5-MV Tandetron for Accelerator Mass Spectrometry were added to the existing ones. They are both unique tools in Greece and could provide highly specialized services to the public and private sector.

CALIBRA is now a well-established open-access research infrastructure offering state-of-the-art setups to conduct research at the excellence level. CALIBRA is utilized by a large user group of more than 50 scientists, interested in basic nuclear physics research as well as in interdisciplinary applications of ion beams. Up to date, more than 60 high-quality publications in international peer-reviewed scientific journals were produced by using the CALIBRA setups.

Despite the adverse constrains imposed by the covid pandemic and other time-demanding bureaucratic procedures (tendering regulations etc.) required by the Greek legislation, all milestones of the CALIBRA project were successfully achieved.

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