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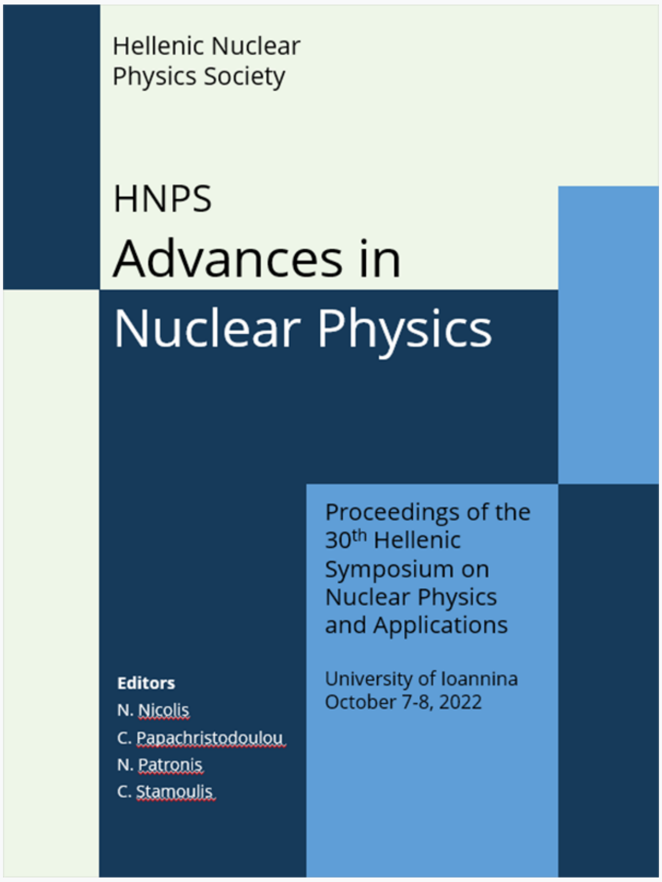


# Recent upgrades at the Tandem Laboratory of NCSR "Demokritos"

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# Recent upgrades at the Tandem Laboratory of NCSR "Demokritos"

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**Abstract** The infrastructure of the Tandem Accelerator Laboratory (TAL) underwent a major upgrade aiming at expanding its analytical capabilities by introducing new experimental setups in order to provide the scientific community with better quality beams. Moreover, through the acquiring of two new accelerators, a 17 MeV Cyclotron and an AMS Tandetron, TAL aims at broadening its multidisciplinary research interests with a wide spectrum of new techniques in the areas of material science, cultural heritage studies, biomedicine, etc. A short description of the upgrades and the new capabilities are presented.

**Keywords** Tandem accelerators, MC-17 cyclotron, AMS Tandetron

## INTRODUCTION

The Tandem Accelerator Laboratory (TAL) is a unique Research Infrastructure in Greece. The facility comprises the Tandem accelerator hall and two "target rooms", where the experimental setups are installed, a machine workshop, a target preparation room, an X-Ray Fluorescence (XRF) spectrometry laboratory, the control room, workspaces and offices. In 2016, the Tandem laboratory was included in the National Roadmap for Research infrastructures with the aim to be fully upgraded and establish the "Cluster of Accelerator Laboratories for Ion Beam Research and Applications" (CALIBRA) Research Infrastructure. The CALIBRA project is funded with ~3.42 M€ by the Partnership Agreement for the Development Framework 2014-2020 (PA 2014 - 2020) constituting the main strategic plan for growth in Greece with the contribution of resources originating from the European Structural and Investment Funds (ESIF) of the European Union.

## RECENT UPGRADES

Through the CALIBRA project, the Tandem Accelerator Lab has undergone a number of upgrades aiming at maximizing the beam producing capabilities of the Tandem Accelerator, as well as expanding to novel techniques and applications by installing two new accelerators: an MC-17 cyclotron and an AMS Tandetron accelerator. In the following sections a brief presentation of the new features of the laboratory will be discussed.

### *Tandem Accelerator Upgrades*

In 2020, the old oil-based pumping stations of the accelerator were replaced with new turbomolecular ones. Moreover, new full-range vacuum gauges were installed in the accelerator beam

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lines that are connected to the main control computer. This upgrade permitted the design of a new interlock system for vacuum safeguarding, while the vacuum in the accelerator tube is kept under $10^{-7}$ mbar.

In the framework of ion source upgrading, the old ion sources were removed along with their associated power supplies and the pre-acceleration tube. They were replaced with a TORVIS and a SNICS sputter source. They were both accompanied by their fiber-optics controlled power supplies enclosed in their own safety cage. Each source operates at a 55 kV pre-acceleration potential. Moreover, the TORVIS source is equipped with an ion exchange Rubidium exchange canal. Extensive testing on the performance of the TORVIS ion source produced a beam of 100 μA with low angular divergence for both $H^-$ and $D^-$ beams. Helium-producing tests are scheduled for the summer of 2023. The SNICS source has already successfully produced ion beams of Carbon and Oxygen at an intensity of 40 μA. The list of available beams will be constantly updated.

The main goal of the upgrade was the replacement of the accelerator charging system and the stripper canal along with their associated electronics (Fig. 1). The old electrostatic belt was replaced with three Pelletron© chains in order to maintain the maximum charging capability of the terminal. Moreover, two new stripping systems were installed in the terminal: a carbon foil one, capable of hosting 80 foils, and a gas stripper one, operated with nitrogen. The electronic modules responsible for operating the stripping systems are situated in the terminal above the central accelerator tube. The system is remotely controlled by the main control computer through fiber optical links. The stabilization of the terminal voltage is achieved with the aid of four separate systems that can work in a synergistic way: a Capacitive Pick-Off plate, a Generating Voltmeter, a Corona probe and the analyzing slits.

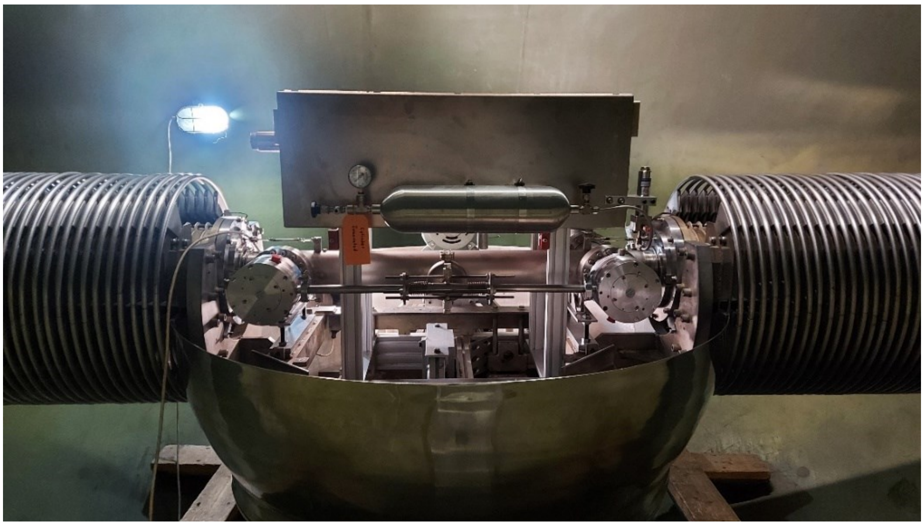

**Figure 1.** *The new stripping canal*

Finally, the control system of the accelerator was completely renovated. Two ACT crates were installed in the accelerator hall hosting a number of Analog and Digital Input/Output cards. The power supplies of the magnets, of the optical elements, the vacuum valves and gauges, as well as the accelerator terminal are interfaced through these ACT crates to a local main computer running the AccelNet© program. This computer is connected through an underground optical fiber cable to a remote computer situated at the control room (Fig. 2). The new control system is fully customizable and offers three main advantages: ease of use, capability of saving/restoring running parameters and remote access. Moreover, various interlock features (radiation levels, vacuum valves, e.tc.) are integrated to the control system.

**Figure 2.** *The computer controlled console*

*Scanditronix MC-17 Cyclotron*

Among the objectives of the TAL is the development of a new facility that will combine cyclotron unit operation with automated units to produce radioisotopes for research and industrial applications. The facility will be based on a MC-17F SCANDITRONIX cyclotron, a unit donated to NCSR "Demokritos" by the University Medical Center Groningen (UMCG), the Netherlands. The cyclotron accelerates protons and deuterons of energy 17 MeV and 8.5 MeV, respectively. The unit was used at UMCG to produce $^{18}F$, $^{11}C$, $^{15}O$ and $^{13}N$ for medical applications. After modifying the target, the unit can produce the isotopes $^{64}Cu$, $^{86}Y$, $^{89}Zr$, $^{123}I$ and $^{124}I$, which are of great biomedical and industrial interest.

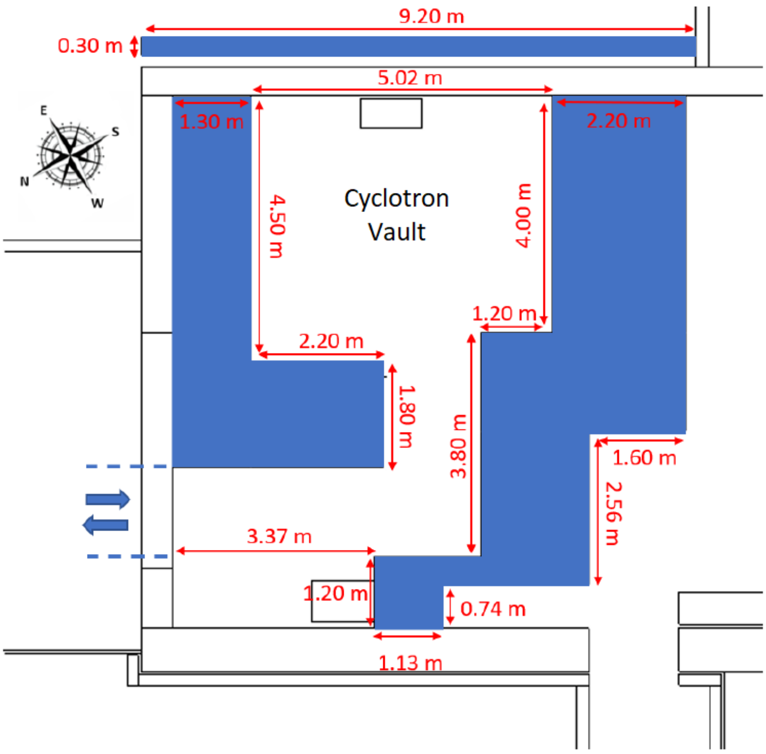


**Figure 3.** *The proposed cyclotron shielding configuration*

The unit is planned to be installed in the hall area of the TANDEM accelerator. The installation of the cyclotron unit will meet all the specifications regarding the radiation protection and safety of personnel, the public and the environment from the dangers of ionizing radiation, as described in the National Radiation Protection Regulation and the relevant guidelines of the International Atomic Energy Agency. The shielding was designed in collaboration with the Division of Technical Works and Research support in order to meet radiation protection requirements and to comply with the manufacturer's technical suggestions. The design (Fig. 3) was guided by Monte-Carlo calculations (MCNP 5) to estimate the ambient dose equivalent H*(d) in and around the chamber areas. The proposed design, comprising mainly barytes concrete (blue), re-enforced the pre-existing ordinary concrete (white) shielding of the building, so that the cyclotron unit is capable to operate independently and uninterruptedly from the TANDEM accelerator. The optimal shielding designed allowed for the ambient dose equivalent levels in the areas around the unit to be below the regulatory limits for occupationally exposed personnel and the public, and as low as possible according to the ALARA optimization principle. The proposed design accounted for a future connection to a control room (adjacent to the cyclotron chamber) and to a PET radioisotope production laboratory.

*The AMS Tandetron Accelerator*

In 2021, the School of Archaeometry of the Oxford University donated to NCSR "Demokritos" a fully functional AMS Tandetron accelerator (Fig. 4). The AMS is equipped with two ion sources: one for solid and one for gas samples. The analysis of the samples is fully automatized through a computer-controlled system. In late 2021 – early 2022, the accelerator was disassembled and packaged at the University of Oxford premises. Since last September, the AMS machine is stored at the ground floor of the Tandem Laboratory. In the next few months, the room that will host the new system will be prepared by properly reinforcing the ground plate of the building and by installing the necessary electrical and cooling subsystems.

**Figure 4.** *The donated AMS accelerator*

## CONCLUSIONS

In CALIBRA Phase-1, at the end of 9/2022, the existing 5.5 MV Tandem was completely upgraded with new components including a Pelletron© charging chain, new ion sources, new injection beamline, new voltage stabilizers, new foil and gas strippers, beam profile monitors, and a fully computer-controlled operation system. In addition, a 2.5 MV Tandetron for Accelerator Mass Spectrometry, donated by the University of Oxford will be installed. Also, a donated 17 MeV PET Cyclotron, already transferred from the Netherlands, will be used to establish a PET radioisotope production laboratory (subject of implementation of CALIBRA's Phase-2).

## Acknowledgments

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