

NEW DEVELOPMENTS AT THE TANDEM ACCELERATORS LABORATORY AT IFIN-HH

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Abstract

The upgrade of the 9 MV Tandem accelerator at IFIN-HH started in 2006. Remarkable work was done in the last 6 years that can be seen in the improved performance and reliability of the machine. Using original preparation techniques, some new beam species were tested for the first time in our laboratory. This opened the door to new experiments. A major improvement for the laboratory is the installation of 1 MV Tandetron accelerator dedicated to ultra-sensitive accelerator mass spectrometry (AMS) measurements of ^{14}C , ^{10}Be , ^{26}Al and ^{129}I , and 3 MV Tandetron accelerator dedicated to ion beam analysis (IBA). The main directions of the research activity in the laboratory will be shortly presented.

INTRODUCTION

The Bucharest FN Tandem accelerator was commissioned in 1973. The accelerator was produced by High Voltage Electrostatic Corporation - HVEC USA. The first upgrade of the machine was done in 1983 when a new negative Cs sputtering ion source was installed [1] and the maximum accelerating voltage on the terminal was increased from 7.5 to 9 MV by installing new accelerating tubes with stainless steel elements and inclined field and introducing of SF_6 into the insulating gas mixture. In 1977 the accelerator column was destroyed and in 1986 it was partially damaged by two major earthquakes. Following these two events a second major upgrade was done, thus the earthquake protection system was installed [2].

Starting with 2006 a major upgrade program is ongoing. The upgrade works from 2006 to 2009, which include the installation of the pelletron charging system, a new sputtering ion source, a dedicated sputter ion source for AMS measurements, installation of titanium, spiraled field accelerator tubes, a lithium charge exchange alpha source, nanosecond pulsing system, new power supplies for the major ion optics elements, and refurbishment of the vacuum system were already reported in Ref. [3].

Nevertheless the upgrade program of our main accelerator continued and other two major experimental facilities are already installed. The upgrade of the electrical system of the main ion optic elements on the tandem accelerator continued with renewal of the power supplies of the beam deflection elements. The old stabilization system of the ac-

celerator functioning since 1973 was also replaced with an in house version, improving the stability of the accelerated beam. The alpha source installed in 2006 was upgraded to a more stable and reliable version. In order to ease the operation of the main power supplies of the bipolar magnets and beam deflectors, automated control system of the power supplies was realized. One important improvement of the accelerator is the installation of a new gas transfer system (made by DILO [4]). Compared with the old system using oil vacuum pumps and compressor, the new system is a state-of-the-art system specially customized to work with our machine. The new gas plant will improve the quality of insulating gas due to its oil free pumps and compressors and will diminish the gas losses at each transfer to an acceptable level. For the safety of the stripping foils and for protecting the accelerating tubes of accidental migration of carbon stripping foils inside them, a fast closing valve [5] was installed on the high energy section after the analyzing magnet. With this occasion, all the beam lines were replaced before and after the analyzing magnet with new beam lines having vacuum treated surfaces, thus improving the vacuum in that area.

One of the most important achievements for the research studies done at the tandem accelerator in this period were the new delivered beams that opened the possibility for new physics experiments in fields of basic and applied research.

Starting with 2010 two new HVE Tandetron accelerators [6] were installed in IFIN-HH with the support of an infrastructure grant [7] funded by the National Authority for Scientific Research [8]. The 1 MV Tandetron accelerator, along with its chemistry laboratory is dedicated for ultra-sensitive accelerator mass spectrometry measurements of C, Be, Al and I elements. The 3 MV machine, presently under commissioning, is dedicated for ion beam analysis techniques. Both machines are aimed to continue the long tradition in the applied physics research, currently being done at the 9 MV tandem accelerator.

MAIN UPGRADES OF THE 9 MV FN PELLETRON TANDEM ACCELERATOR

Upgrade of the Beam Steering System Power Supplies

The beam deflection system of the accelerator is an important part in the operating procedure. The beam quality and stability was often affected by the defective operation

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of the old poorly stabilized power supplies. The operation of the power supplies for the electrostatic deflectors was also not advantageous, pairs of power supplies being connected to the deflecting plates, both being polarized to an identical bias voltage in order to obtain the non-deflected accelerated beam.

The old beam deflection system power supplies of the tandem accelerator were replaced by new high voltage, bipolar output and continuous zero crossing power supplies (made by FuG-Germany [9]). The new devices were extremely stable, having a residual ripple smaller than $5 \times 10^{-4} pp + 10 mV pp$. The whole operation procedure for the electrostatic deflectors was also changed. Each pair of plates of an electrostatic deflector requires only one power supply whose output is connected to one of the plates while the second one is grounded. So a much more stable beam was obtained and the machine operation is eased. The power supplies for the double x and the double y deflection system of the LE part of the FN tandem are showed in Figure 1.



Figure 1: Bipolar power supplies block with continuous zero crossing capability for an electrostatic deflection system

New Beam Stabilization System

The stability of the beam was often affected by malfunction of the old and obsolete, but complex beam stabilization system of the FN tandem. The user request of beam time was also often affected. Thus, the work on a new, in-house built system was one of the main goals for our team. The work started with redesigning two preamplifiers for the slit

signal based on modern logarithmic integrated circuits, capable to measure on a wide range of currents (from 100 pA up to 3.5 mA) [10]. The improvement was continued by redesigning the comparator circuit giving the error signal as a result of the variation of the beam on the two image slits of the accelerator. The error signal was fed into the core circuit of the stabilization system, also completely rebuilt using a combination of analog and digital electronic circuits which replaced the electromechanical devices of the old stabilization system. This core circuit is making use of both signals coming from the GVM and slit error circuits, adjusting the voltage on the grid of the corona system vacuum tube and thus stabilizing the high voltage on the terminal. This upgrade improved the stability of the system, reducing the ripple on the terminal by about 20%. Due to its sensitivity the system allowed to decrease the lower limit for stable accelerating voltages from 1.5 MV to 0.8 MV.

Upgrade of the Helium Negative Ion Beam Source

The homemade helium source (a duoplasmatron ion source followed by a lithium vapor charge exchange unit [3]) commissioned in 2006 opened a new range of nuclear physics experiments in our laboratory [11]. The original design proved to obtain good results, but was not able to deliver stable beam for long periods of time, its operation being interrupted very often for cleaning and lithium refill. The design of the lithium oven placed at the ground potential surrounded by high voltage optical elements was not very reliable. Another drawback was that the lithium reservoir was not sealed and the lithium vapours were migrating in the whole source chamber, destroying the insulation of the accelerating elements. In order to solve all the problems, many elements were redesigned. The new layout of the source is presented in Figure 2 a) and the source itself is presented in Figure 2 b). The main modification was in the design of the lithium oven and reservoir. The reservoir was redesigned to be sealed and easy to remove without misaligning the adjacent electrodes. Another improvement consisted in connecting the lithium oven to the HV charge exchange unit and transmitting the low voltage supply through a separating transformer. This design made it more compact and efficient. In order to avoid the contamination of the surrounding accelerating elements with lithium vapors, more efficient condensation elements were designed at the ends of the lithium reservoir. The negative helium source is now very reliable and it can deliver beams for long periods of time with less lithium consumption and higher beam stability.

Computer Control System for Power Supplies

A program to change the old analogic control of the tandem by a computer control was started some years ago, beginning with the computer control of the sputter ion source [3]. This year the computer control of the bipolar magnets

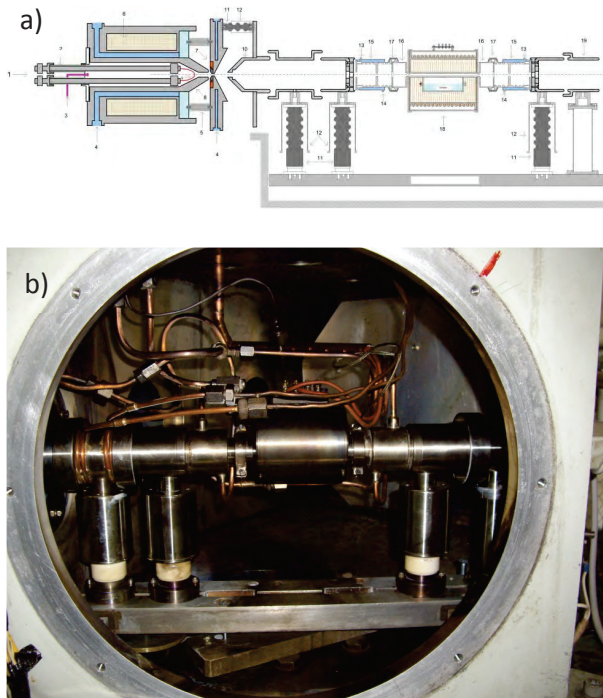


Figure 2: a) The layout of the new design of the helium source, b) The fully functional helium source

(see Figure 3) and the electrostatic and magnetic beam deflectors (see Figure 4) was achieved.

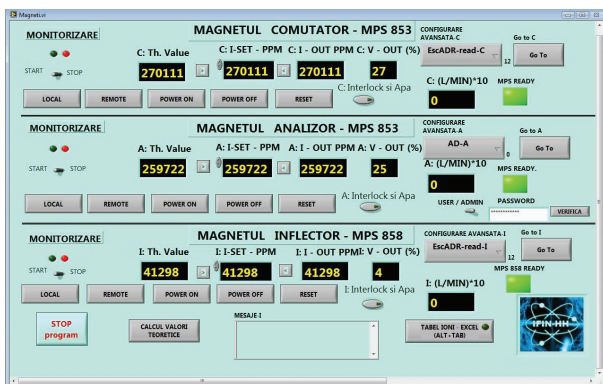


Figure 3: The computer control system for the three bipolar magnets on the accelerator (inflection, analyzing and switching magnet.)

The interesting feature of the control for the magnets is that the operator has to input only the beam specie, the energy and the desired charge state after stripping, and the fields in the magnets will be automatically set to a coarse value. The fine tuning will be done afterwards by the operator.



Figure 4: The computer control system for all the electrostatic and magnetic deflectors on the accelerator.

New Gas Transfer System

The insulating gas used now in the accelerator tank is a mixture of SF₆ and nitrogen. Two main problems regarding the gas were encountered. First is the problem of gas losses during every transfer to the storage tanks and back to the accelerator tank, and second is the quality of the gas, mainly from the point of view of the moisture, which can damage the nylon links of the pelletron chain, and the oil vapors coming from the pumps and compressors of the old gas system.

As a consequence the complete replacement of the old system by a new one was decided. The gas transfer plant was custom built by DILO [4] in Germany. When designing the system we took into account all the particularities our system has (for example different final pressures for the three storage tanks). A picture of the new installed system can be seen in Figure 5.

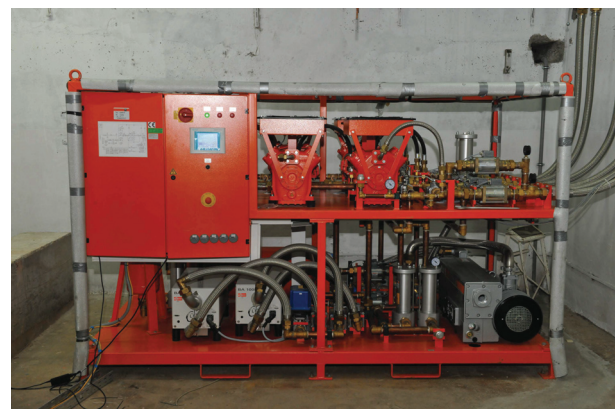


Figure 5: The new gas transfer system of the tandem accelerator.

The main advantages of this new system is that it has virtually no gas losses, has very good filtering capacity, being capable to remove moisture and corrosive products resulted from the SF₆ in the moment of sparks in the tank, and it has oil free compressors and vacuum pumps for SF₆ recovery and recirculation. This will ensure much more stable running at high voltage on the terminal.

Fast Closing Valve

The most serious problem that may occur during an experimental campaign is that someone accidentally breaks the vacuum in the beam line of the accelerator threatening the integrity of the turbomolecular vacuum pumps along the accelerator and destroying the carbon stripping foils in the terminal. The worst situation can occur when the carbon foils migrate into the accelerating tubes, and that can lead to the destruction of that tube. The best solution for that was a fast closing valve from VAT [5] with sensors and controller, having a closing time of less than 20 ms. The vacuum sensors were installed as close as possible to the experimental setups. An photo of this valve can be seen in Figure 6.



Figure 6: Fast closing valve designed to protect the vacuum pumps and the stripping carbon foils of the accelerator from accidental input of air

New Accelerated Beams

One of the main achievements of the last two years was the acceleration of new particle beams. One of the first cases of such a beam was the ${}^6\text{Li}$ which was used in one of the first plunger experiments in Bucharest [12] using a ${}^{40}\text{Ca}({}^6\text{Li}, \text{pn}){}^{44}\text{Ti}$ reaction to measure subnanosecond lifetimes in ${}^{44}\text{Ti}$. Another success was the ${}^{18}\text{O}$ obtained from the sputtering ion source using LiOH cathode made from lithium and water enriched in ${}^{18}\text{O}$. The beam was first time used in a lifetime measurements experiment in ${}^{34}\text{P}$ using the $\text{LaBr}_3:\text{Ce}$ array in IFIN-HH [13]. The ${}^{15}\text{N}$ beam was also used for depth profiling of hydrogen in nanomaterials. ${}^{13}\text{C}$ was used extensively for fast timing measurements in many experiments in our laboratory. One last successful experiment took place few month ago using ${}^{36}\text{S}$ beam on a lithium target. The aim of the experiment was to determine the beta-gamma branching ratios from the decay of the 5^- isomeric state in ${}^{38}\text{Cl}$ using an inverse reaction. The cathode material for the sputtering ion source was the silver sulfide obtained from very small amount of isotopically

enriched sulfur. A list of new beams, energies and their intensities after the analyzing magnet is presented in Table 1. Note that the presented parameters are not the maximum limits, but parameters extracted from the log book of the accelerator.

Table 1: New beams accelerated at the 9 MV tandem accelerator in the last two years. Examples of the energies and intensities are extracted from the log book of the accelerators and are not the maximum achievable parameters.

Particle	Energy MeV	Intensity of the analyzed beam nA
${}^6\text{Li}$	32	150
${}^{18}\text{O}$	34	90
${}^{15}\text{N}$	14	10
${}^{13}\text{C}$	42	50
${}^{36}\text{S}$	80	50

1 MV TANDETRON ACCELERATOR DEDICATED TO AMS MEASUREMENTS

A new facility dedicated for accelerator mass spectrometry (AMS) measurements was commissioned in IFIN-HH [14]. A general layout of the 1 MV machine manufactured by HVEE-Netherland as it is now installed is presented in Figure 7. The AMS system is designed to measure the C, Be, Al and I elements.

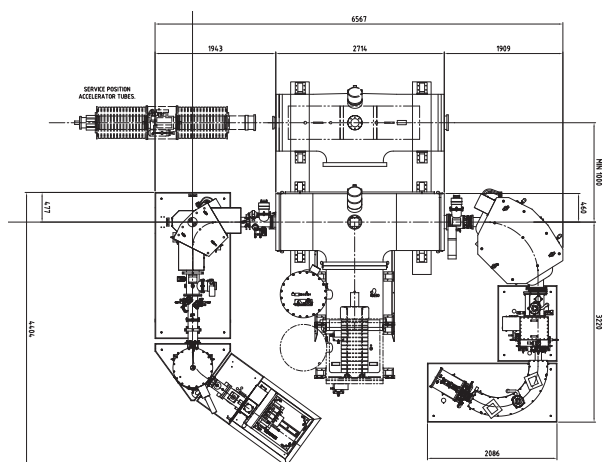


Figure 7: The layout of the 1 MV Tandatron accelerator dedicated for AMS measurements

The accelerator uses a multiple cathode Cs sputter ion source with 50 samples/cathodes. This allows the user to change the sample without breaking the vacuum. After the ion source an electrostatic deflector allows to use several ion sources. A key component of the system is the 90° analyzing magnet equipped with a bouncer system. The bouncer system consists of an insulated chamber on which



Figure 10: The hall of the 3 MV Tandatron accelerator

beamlines at the 9 MV tandem accelerator. In order to expand the research in the applied direction and because in this region of Europe this is the only laboratory having the dedicated equipment for this, we invested in this direction.

Besides the development of the accelerator infrastructure there is a big effort in the development of the research infrastructure around these accelerators. Two major breakthroughs were accomplished this year: the commissioning of the mixed detection array consisting of 25 HPGe detectors with anti-Compton shields and the 12 LaBr₃:Ce fast timing detectors called ROball, which will be used for nuclear structure physics studies at the energies delivered by the 9 MV tandem accelerator [15, 16, 17], coupled with the plunger device dedicated for ps timing measurements.

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