Romanian Reports in Physics, Vol. 63, No. 4, P. 923–928, 2011

STATUS OF THE NEW AMS FACILITY IN MAGURELE: THE CENTER OF RADIOCARBON FOR ENVIRONMENT AND BIOSCIENCES*

A. OLARIU, C. IVAN, N. V. ZAMFIR

National Institute for Nuclear Physics and Engineering,
P.O.Box MG-6, RO-077125 Bucharest-Magurele, Romania, E-mail: agata@nipne.ro

Received March 4, 2011

Abstract. The new Center of radiocarbon for environment and biosciences, *Tandimed,* will be commissioned in Magurele, at IFIN-HH in mid of 2012. A state-of-the-art 1 MV tandetron AMS system will be installed in a new building. The center includes a chemistry laboratory for the preparation of the AMS samples.

Key words: accelerator mass spectrometry, 1 MV tandetron.

1. INTRODUCTION

In recent years compact accelerator mass spectrometry (AMS) systems with low terminal voltages and low dimensions have been developed. In the AMS technique the high sensitivity is reached by destroying the interfering molecules in a stripping process. The procedure until the middle of 1990's was using relatively large accelerators of 2.5–5 MV and charge state 3+ for which small molecules are unstable. In 1997, Suter and co-workers discussed the use of an 0.5–1 MV AMS accelerator, which would operate in the 1+ or 2+ charge state [1]. They made studies showing that molecular interference could be removed with a higher stripper gas pressure than previously used. Then the design of a prototype of a small 0.5 MV accelerator, CAMS (carbon accelerator mass spectrometer), a compact radiocarbon dating system that can use the 1+ charge state have been reported at the Institute of Particle Physics-ETH Zürich in cooperation with the National Electrostatic Corporation (NEC) [2], which can be regarded as an initial step towards a new generation of compact AMS systems. Even smaller AMS machine have been constructed like SSAMS (single stage AMS) [3] or MICADAS (mini radiocarbon dating system) [4], which operate at maximum voltages of 250 kV and 200 kV respectively and have proved that they are suitable for radiocarbon dating.

* Paper presented at the National Symposium of Archaeometry, 28–29 October 2010, Bucharest, Romania.

A new AMS facility is going to be set up in the summer of 2012 at IFIN-HH in Magurele: the 1 MV tandetron AMS system, model 4110Bo-AMS designed and manufactured by High Voltage Engineering Europa (HVEE), will be the heart of the new Center of radiocarbon for environment and biosciences, *Tandimed*. The facility is a multi-elemental accelerator system and is able to detect low-mass isotopes such as ^{10}Be, ^{14}C and ^{26}Al, but also heavy elements such as ^{129}I and Pu isotopes, remaining still small in size and cost-effective.

In the present paper we give a brief description of the status of Center of radiocarbon for environment and biosciences *Tandimed* at IFIN-HH with the new 1 MV tandetron AMS facility of IFIN-HH.

2. DESCRIPTION OF THE FACILITY

2.1. Location

The 1 MV tandetron AMS system will be located at the first floor of the new building which at present is in the phase of construction. The room of the accelerator occupies an area of 144 m^2. A special concrete pad was designed and cast to sustain the load of all component parts of the accelerator system and also has a special cast for a cable duct and holes through the basement, where the main utilities, like distilled water, and compressed air devices will be located. There is a separate room for the computer control system which allows for automated and unattended operation 24 hours a day.

2.2. Accelerator system

The schematic drawing of the 1 MV tandetron AMS system model 4110Bo-AMS, which in the construction phase at HVEE is presented in Fig. 1. The background information about the facility is described in ref. [5–6]. The system has the overall dimension of 4.7 m × 7.9 m and is equipped for ^{14}C measurements and also for ^{10}Be, ^{26}Al, ^{129}I and Pu measurements.

The Ion Source, model SO-110-50 is a negative sputter ion source and has a carrousel for 50 targets (or cathodes) with a carrousel exchange time of about ~ 30 minutes. After the extraction from the ion source the ions have a typical energy of 35 keV. The SO-110 ion source is capable of producing $^{12}C^-$ beam with intensities of up to 250 μA, which then is injected into the accelerator. The source embodiment is on ground potential which allows easy access and assures the protection against the high voltage. The system can be equipped with two ion sources for low and high activity samples. For this, a rotatable electrostatic deflector is inserted as beam switch between the ion sources and the injector magnet.

The injector. The ions extracted from the ion source are injected in the low-energy 90° magnet with the radius of 400 mm and the mass energy product of 8.4 amu·MeV. The magnet supports the injection of ions with the charge 1 – at energy of 35 keV with masses of up 240 amu.

For example, for ions of $^{27}Al^-$ into the magnet, considering that the charge state is $Z = -1$, the mass energy product is $M \times E/Z^2 = 0.945$ amu·MeV. This means that the mass energy product of the magnet of 8.4 amu·MeV is sufficient for experiments with Al.

The low and also the high-energy magnets have been designed to support the analysis of heavy elements till ^{129}I and Pu.

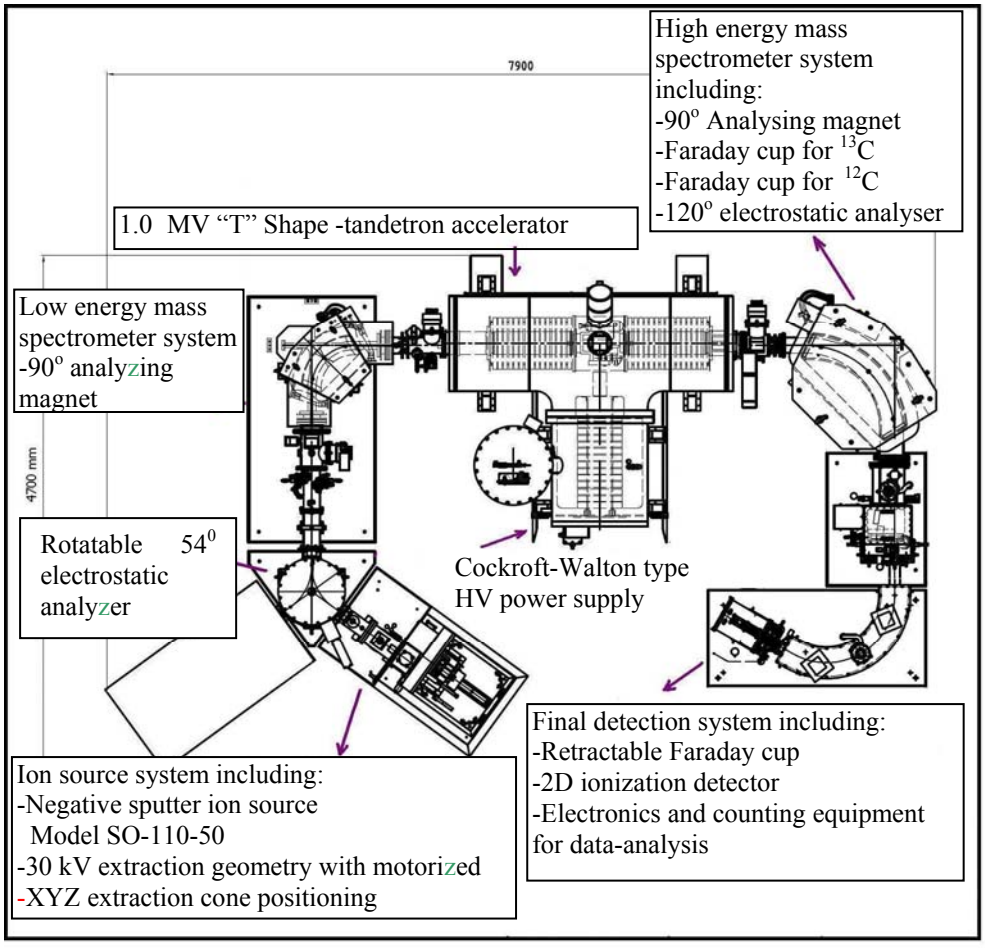

Fig. 1 – Schematic drawing of 1MV tandetron AMS System model 4110Bo-AMS.

The core of the system is the 1 MV *tandetron accelerator* with the Cockroft-Walton type HV power supply. The terminal voltage is in the range of 0.1–1 MV. The accelerator tubes consist of glass insulators and dished electrodes. The accelerator terminal is designed for high stripper gas thickness to destroy the interfering molecules that is needed for AMS at charge state 1+. For example in the case of carbon experiments, molecules like ^{13}CH and $^{12}CH_2$ in charge state 1+ are broken-up by the stripper gas to avoid the interference with ^{14}C ions.

High energy mass spectrometer system. At the high-energy extension the ions are mass analyzed in the 90° magnet with the radius of 850 mm and the mass energy product of 72 amu·MeV.

In the case of Al experiments, the magnet allows the transport of the ions of $^{27}Al^{3+}$, at the energy of 4 MeV (the mass energy product is 12 amu·MeV).

Due to the mass energy product of 72 amu·MeV, the high-energy magnet supports measurements till $^{244}Pu^{3+}$.

In this part of the system one fixed position Faraday-cup is used only for the measurement of ^{12}C. A second Faraday-cup, which is adjustable, can be used for the measurement of all other isotopes, ^{13}C, ^{9}Be, ^{27}Al and ^{127}I.

The rare isotopes are measured in the *final detection system* which contains mainly a 2D ionization chamber.

A computer control system controls the entire accelerator and also is used for processing the data off-line, including determination of radiocarbon ages in the case of carbon measurements.

The expected characteristics of the 1 MV tandetron AMS system, model 4110Bo-AMS, given for carbon, beryllium and aluminum are shown in Table 1 [6].

Table 1

Characteristics of the 1 MV tandetron AMS system, model 4110Bo-AMS for carbon, beryllium and aluminum experiments

Element	Ion Source output	Terminal Voltage [MV]	Background	Precision
carbon (solid)	40 μA $^{12}C^-$	0.7	3×10^{-15} (a)	0.5% for $^{14}C/^{12}C$ at ~10^{-12} 0.3% for $^{13}C/^{12}C$
beryllium	2–4 μA $^{9}BeO^-$	1	2×10^{-14} (b)	1% for $^{10}Be/^{9}Be$ at ~10^{-12}
aluminum	0.5-2 μA $^{27}Al^-$	0.7	5×10^{-14} (c)	1% for $^{26}Al/^{27}Al$ at ~10^{-11}

(a) for ratio of isotopes $^{14}C/^{12}C$ and $^{13}C/^{12}C$
(b) for ratio of isotopes $^{10}Be/^{9}Be$
(c) for ratio of isotopes $^{26}Al/^{27}Al$

2.3. Chemistry laboratory

The Center of radiocarbon will have also a laboratory of chemistry with a state-of-the-art installation for the preparation of samples for the AMS technique.

3. APPLICATIONS

As the number of AMS facilities has grown in the last years, the number of applications has increased too [7]. In the following we discuss the AMS applications which can be done also at the *Tandimed* Center of IFIN-HH.

^{14}C is still the most important AMS isotope with the well known and the traditional application of dating. Archaeology but also art objects benefit from the estimation of the age by the ^{14}C method [8-10]. Due to the prominent role of the carbon in environmental and biological sciences, the determinations of ^{14}C have another large number of important applications among which we mention:

– the study of radiocarbon as a tracer of the bio-geochemical cycle of carbon, a key cycle of the climatic system, which appears in the problem of the greenhouse effect;

– the monitoring of the ^{14}C releases in environment by nuclear reactors [11];

– studies of the transfer and metabolism of radiocarbon in animals and humans;

– the use of ^{14}C tracers in medicine and agriculture;

– the reconstruction of the marine circulation and the study of the ventilation of deep marine waters in relation to the overall climatic changes;

– studies of the carcinogenic potential in food.

Other isotopes like ^{10}Be and ^{26}Al are used to obtain hydro-geological information. The surface of the rocks is bombarded with cosmic rays which cause the production of ^{10}Be, with the half–life of 1.6 My and the accumulated amounts of this isotope can be measured by AMS and used to date the rock, (exposure dating). ^{10}Be is also found in marine sediments and ice and its concentration is related to the solar magnetic activity in the past [12]. The concentration of ^{10}Be is very low and even using AMS technique is difficult to be determined.

^{26}Al with its half-life of 717000 years is used for dating in geology and is used also in biomedicine as a tracer [13–14].

The presence of ^{129}I in nature is mainly due to the fission of ^{235}U. Having a half-life of approximately 16 My it is used to trace the migration of nuclear waste from nuclear storage and reprocessing plants and nuclear power plants, and also as marine tracer. The spreading of ^{129}I in sea waters and oceans is due probably to the nuclear weapons tests from the years 1950s and then it was transported in the atmosphere and oceans [15]. Using a 1 MV AMS system, the isotopes of Pu have been tested in pioneering work in soil samples from Palomares, Spain [16].

4. CONCLUSIONS

The center of radiocarbon for environment and bioscineces, *Tandimed* will bring a new direction of research at IFIN-HH, Magurele. The new state-of-the-art 1 MV tandetron AMS system will allow a number of AMS applications based on measurements of carbon, aluminum and beryllium. For studies based on other

elements suppresion of isobars must be researched. By its infrastructure and research thematic the *Tandimed* Center will be a unique center in Romania and in South-Eastern Europe.

REFERENCES

1. M. Suter, S. Jacob, H. A. Synal, *AMS of ^{14}C at low energies*, Nucl. Instrum. Methods, **B 123**, 148–152 (1997).
2. H. A. Synal, S. Jacob, M. Suter, *The PSI/ETH small radiocarbon dating system*., Nucl. Instrum. Methods, **B 172**, 1–7 (2000).
3. J. B. Schroeder, T. M. Hauser, G. M. Klody, G. A. Norton, *Initial results with low energy single stage AMS*, Radiocarbon **46**, *1*, 1–4 (2004).
4. H. A. Synal, M. Stocker, M. Suter, *MICADAS: A new compact radiocarbon AMS system*, Proceedings of the 10th International Conference on Accelerator Mass Spectrometry, Berkeley; CA. Nucl. Instrum. Methods, **B 259**, 7–13 (2007).
5. M.G. Klein, D.J.W. Mous, A. Gottdang, *A compact 1 MV multi-element AMS System*, Nucl. Instrum. Methods, **B 249**, 764–767 (2006).
6. M. G. Klein, H. J. van Staveren, D. J. W. Mous, A. Gottdang, *Performance of the compact HVE 1 MV multi-element AMS system*, Nucl. Instrum. Methods, **B 259**, 184–187 (2007).
7. R. Hellborg and G. Skog, *Accelerator mass spectrometry*, Mass Spectrometry Reviews, **27**, *5*, 398–427 (2008).
8. A. Olariu, R. Hellborg, K. Stenstrom, G. Skog, M. Faarinen, P. Persson, B. Erlandsson, E. Alexandrescu, *Dating of some Romanian fossil bones by combined nuclear methods*, Journal of Radioanalytical And Nuclear Chemistry, **253**, *2*, 307-311 (2002).
9. A. Olariu, R. Hellborg, K. Stenstrom, G. Skog, M. Faarinen, P. Persson, B. Erlandsson, E. Alexandrescu, *International Conference on Applications of High Precision Atomic & Nuclear Methods*, Neptun, Romania, 2–6 September, 2002; *Proceedings of the International Conference on Applications of High Precision Atomic & Nuclear Methods*, Neptun, Romania, 2–6 September 2002, Editura Academiei Române, Bucuresti, 2005.
10. E. Alexandrescu, A. Olariu, G. Skog, K. Stenström, R. Hellborg, *Os fossiles humains des grottes Muierii et Cioclovina*, Roumanie, Anthropologie, **114**, *3*, 341–353 (2010).
11. Å. Magnusson, K. Stenström, G. Skog, D. Adliene, G. Adlys, R. Hellborg , A. Olariu, M. Zakaria, C. Rääf, S. Mattsson, *Levels of 14C in the Terrestrial Environment in the Vicinity of two European Nuclear Power Plants*, Radiocarbon, **46**, *2*, 863–868 (2004).
12. G. M. Raisbeck, F. Yiou, O. Cattani, J. Jouzel, *^{10}Be evidence for the Matuyama-Brunhes geomagnetic reversal in the EPICA dome C ice Core*, Nature, **444 (7115),** 82–84 (2006).
13. M. Faarinen, C.-E. Magnusson, R. Hellborg, S. Mattsson, M. Kiisk, P. Persson, A. Schütz, G. Skog**,** K. Stenström**,** *^{26}Al investigations at the AMS-laboratory in Lund*, Journal of Inorganic Biochemistry, **87**, *1–2*, 57–61 (2001).
14. M. Faarinen, C.-E. Magnusson, R. Hellborg, S. Mattsson, M. Kiisk, P. Persson, A. Schütz, *^{26}Al investigations at the AMS-laboratory in Lund*; http://www.fysik.lu.se/ams/Lankar/Abstract/24full.pdf.
15. F. Yioua, G. M. Raisbecka, G. C. Christensenb, E. Holm, *$^{129}I/^{127}I$, $^{129}I/^{137}Cs$ and $^{129}I/^{99}Tc$ in the Norwegian coastal current from 1980 to 1998*, Journal of Environmental Radioactivity, **60,** 61–71 (2002).
16. E. Chamizo, S. M. Enamorado, M. Garcia-Leon M, *Plutonium measurements on the 1 MV AMS system at the Centro Nacional de Aceleradores (CNA)*, Nucl. Instrum. Methods, **B 266,** 4948–4954 (2008).