In: World Scientific, Singapore (1999) 181 - 188

HARD-VERA AND SOFT-VERA

A. PRILLER, P. STEIER, R. GOLSER, W. KUTSCHERA, W. ROM, A. WALLNER, E. WILD

Vienna Environmental Research Accelerator
Institut für Radiumforschung und Kernphysik
der Universität Wien
Währinger Str. 17, A-1090 Vienna, Austria
E-Mail: priller@pap.univie.ac.at
http://www.univie.ac.at/Kernphysik/irk-engl.htm
Tel. ++43 - 1 - 40 480 703
FAX ++43 - 1 - 40 76 200

1 Introduction

VERA, the Vienna Environmental Research Accelerator[1], is a new facility dedicated to Accelerator Mass Spectrometry (AMS). The installation at the Institut für Radiumforschung und Kernphysik started in the fall of 1995, and acceptance was reached[2] in March 1996. Since that time, the overall good performance of the facility allowed us to carry out an extended AMS program for ^{14}C and ^{26}Al measurements. The current research projects include nuclear physics[3], archaeology[4], atmospheric science[5], paleoclimatology and the measuring of forensic samples[4,6]. VERA was designed and built by National Electrostatic Corporation (NEC, Middleton, Wisconsin, USA), and is based on a 3-MV Pelletron tandem accelerator. Although fully automated AMS measurements have already been performed with VERA demonstrating the overall reliability of the facility, in this paper we would like to point out some lessons we learned on hardware and software with this new machine. In the following we describe a few critical parameters of the system. Figure 1 shows the essential lay-out and the properties of the individual components. Additional information on some of these components is given in this paper.

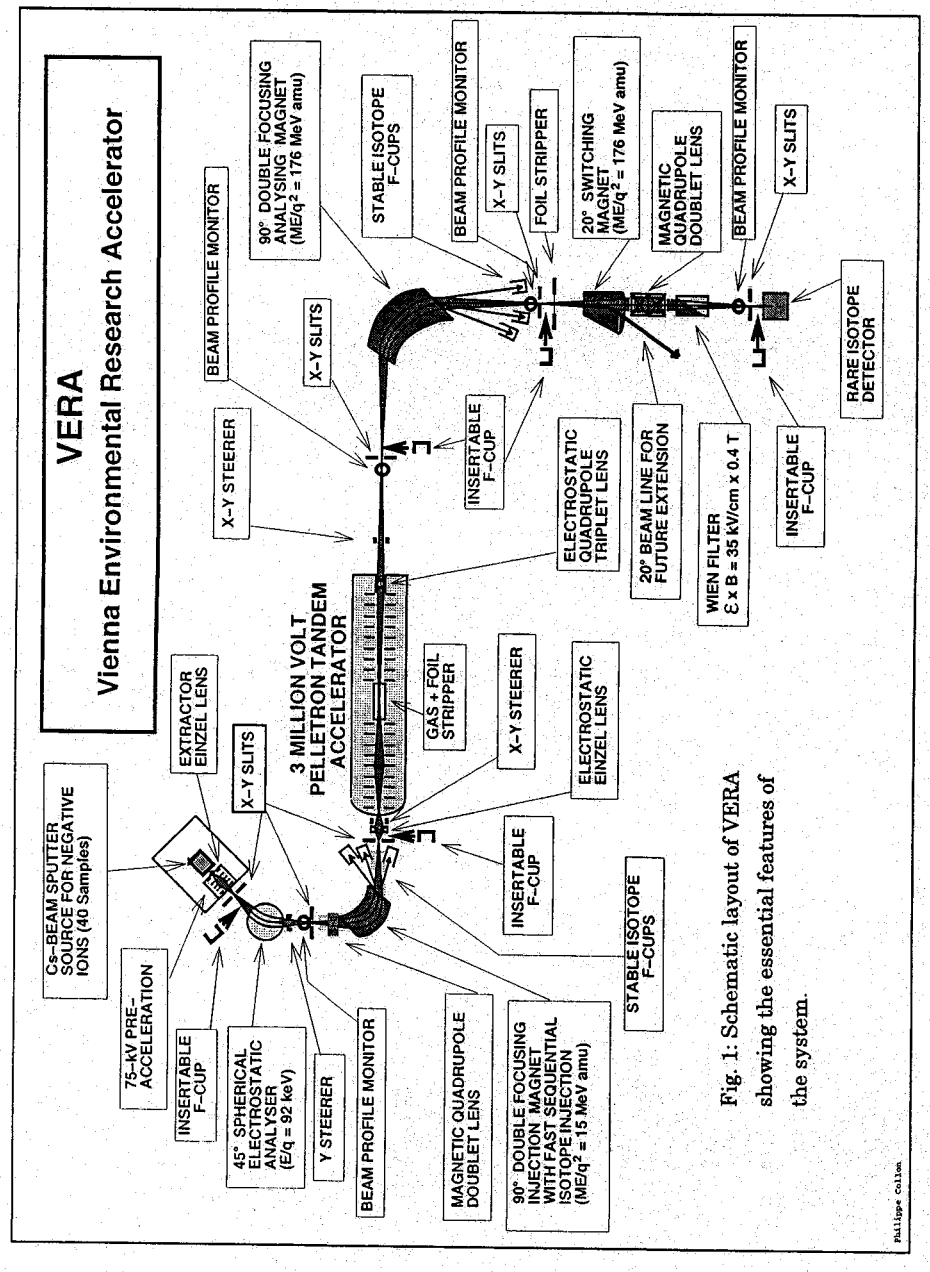

Fig. 1: Schematic layout of VERA showing the essential features of the system.

2 Hardware

2.1 *Ion Source*

In the MC SNICS negative ion source we are still using the old-style Cs-focus and the old-style cathode wheel (see manual MC SNICS ION SOURCE Model 2JA032110, dating 6/94) instead of the new design introduced by the Arizona AMS group in Tucson (see manual MC SNICS ION SOURCE Model 2JA032110, updated 3/96). Up to now, we do not see any reason to switch to the new design.

2.2 *Sequential Isotope Injection*

VERA is designed for fast sequential injection of isotopes. This is achieved by applying different voltages to the insulated vacuum chamber of the injection magnet, which leads to the same magnetic rigidity for different isotopes. During an AMS measurement for ^{14}C, the voltage applied to the chamber is about 12 kV for ^{12}C, 6 kV for ^{13}C and 1 kV for ^{14}C. Although it takes only 20 µs to switch the voltage, stable beam current conditions are reached after about 200 µs. For a complete isotope cycle the voltage is set to 12 kV for 0.5 ms, to 6 kV for 3 ms, and to 1 kV for 100 ms. We use high-voltage TREK P0705 and TREK 50/750 power supplies for this purpose.

2.3 *Injection Magnet*

After installation and first tests [2], we found that the current shim angles of the injection magnet do not provide proper focusing of the beam at the image slits. The effective angles of the field we calculated are both 23 degree, instead of the required 26.5 degree. NEC added a magnetic quadrupole doublet just in front of the injection magnet to correct for this deficiency. Since the installation the measured horizontal width of the beam at the image slits is 5.5 mm, giving a mass resolution of about 80. Therefore, the corrections are sufficient for light ions only. A better focusing in the horizontal direction (required for higher mass resolution) widens the beam vertically resulting in a considerably

reduced transmission through the accelerator (the limiting aperture in the gas stripper channel has a diameter of 8 mm).

2.4 *Tandem Accelerator*

The 3-MV tandem accelerator is of the Pelletron type (model 9SDH-2). The maintenance of the accelerator structure can be conveniently performed by rotating the tank clockwise around a pivot point near the low energy entrance, and pulling the whole accelerator structure out of the tank. Before opening, the SF_6 (about 6 bar) is transferred to a liquid storage system (DILO, Germany). A special feature is a supply line from ground to the stripper gas bottle in the terminal. It allows to refill the stripper gas bottle without opening the tank. Up to now we strip with argon from the bottle in the terminal, while the supply line is filled with 10 bar of N_2.

After one year of operation, the tank was opened for maintenance. We were surprised to find that chain #1 (at the right side of the accelerator structure) was severely damaged, though still operable. Small metal pieces where missing from the edges of many pellets, lying in the accelerator tank hampering the stability of the terminal voltage. The damage of the pellets was due to an idler pulley in the terminal which had lost its conducting rubber lining for as yet unknown reasons. The only hint was the fact that the damaged chain never ran as smoothly as chain #2. Off course, we replaced chain #1.

Unfortunately, the new chain #1 also does not run very smoothly. It is bouncing horizontally as well as vertically. The frequency of these oscillations apparently is the same as the revolution time of the chain. We checked the alignment but could not find any misalignment. However, we did not pay particular attention to the idler pulley-chain contact, which we were told later to be important for smooth running. We have to do this when opening the accelerator for maintenance next time. In the mean time we use only the good, smoothly running chain #2. David Weisser from ANU provided the hint how to discharge the switched-off chain. After having discharged the pellets, the electrostatic field is not able to move the chain.

2.5 *Analyzing Magnet*

The analyzing magnet (Danfysik) has a high mass-energy product, and a nominal mass resolution of about 600 with a slit opening of 4 mm at the object and image slits. It provides bending power up to the heaviest radioisotopes, e.g. $^{244}Pu^{5+}$ ions at 3-MV terminal voltage.

2.6 *Beamline System*

The base pressure in the original beam line system (see figure 1) is kept in the 10^{-9} Torr range by an all cryopump system (seven pumps) when using the zero degree beam line behind the switcher magnet. Recently, we installed a time-of-flight beamline at the 20 degree port of the switcher magnet for beam developments of havier radioisotopes (e.g. ^{129}I). This beam line is pumped by two turbo molecular pumps.

2.7 *Power Requirement*

A maximum electric power of 100 kW is available for the operation of VERA. The water and air cooling system is designed to provide a maximum cooling power of 70 kW. The high power end is needed for AMS experiments with very heavy radioisotopes.

3 Software

The control system of VERA runs on two UNIX computers. The basic control software named AccelNET contains the hardware interface, a central parameter database, and a graphical user interface. It was supplied by NEC. Almost all machine parameters can be displayed and changed under computer control. So we could focus on automation of the various routine tasks by using computer programs we call 'scripts'. These program communicate with VERA by reading and setting parameters of the AccelNET data base.

3.1 *The Script Concept*

There are three kinds of tasks where the still growing set of scripts has proven to be valuable: First they allow us to use VERA without understanding every underlying technical detail. They handle tasks like switching on and off all the electronics, they set the bending magnets in a reproducible way, and they set the Pelletron to the terminal voltage wanted. Furthermore, scripts can perform time consuming tasks without an operator (unattended operation). They warm up the source or let it cool down, and they condition the accelerator over night. The third group serves as tools for tuning ion beams.

The scripts are implemented as UNIX shell scripts or as C programs. They do not feature a graphical user interface but they provide traditional command lines. The absence of an intuitive user surface is the main disadvantage of the current implementation, as well as the low speed of the UNIX shell scripts. We think that these disadvantages are compensated by the short implementation time and by the fact that almost every physics student can write programs using the command line interface, whereas graphical interfaces require specially trained programmers. However, once the functionality has been established a graphical 'shell' around the existing programs is an option.

3.2 *^{14}C Measurements*

The most important script 'dorun' performs unattended ^{14}C measurement series. The unknown samples, standards, and chemistry blanks as well as machine blanks (graphite not containing any measurable ^{14}C) are measured several times and a simple automatic data evaluation is done, in order to give information on the momentary status of the measurements. Work on a complete automatic data evaluation is in progress.

3.3 *^{26}Al Measurements*

A similar but more sophisticated script exists for ^{26}Al measurements. Here the fast sequencing implemented in the hardware cannot be used since there is a very high background of scattered ions when ^{27}Al is injected and measured in the offset F-cup after the analyzing magnet. In order to prevent damage of the rare isotope detector (a surface barrier detector) the script performs slow sequencing. It closes the Faraday cup in front of the detector before ^{27}Al is injected into the accelerator.

3.4 *Automated Operation*

In the near future we will tackle the automated tuning of the ion beam for ^{14}C. The algorithm is already established, but not all used parameters can yet be controlled by the computer.

4 Conclusions

After one and a half year of VERA operation, we feel that on the one hand the facility is already capable to deliver excellent AMS results for light radioisotopes, but on the other hand there is still considerable room for improvements, in particular towards the extension to heavier radioisotopes.

5 Acknowledgment

We acknowledge the prompt response of NEC personnel, whenever technical questions with VERA showed up.

6 References

1. W. Kutschera, P. Collon, H. Friedmann, R. Golser, P. Hille, A. Priller, W. Rom, P. Steier, S. Tagesen, A. Wallner, E. Wild, G. Winkler 1997 VERA: A NEW AMS FACILITY IN VIENNA *Nucl. Instr. and Meth. B* **123**, 47.

2. A. Priller, R. Golser, P. Hille, W. Kutschera, W. Rom, P. Steier, A. Wallner, E. Wild 1997, FIRST PERFORMANCE TESTS OF VERA, *Nucl. Instr. and Meth. B* **123**, 193.

3. A. Wallner, R. Golser, W. Kutschera, A. Priller, P. Steier, H. Vonach, and E. Wild 1998, ^{26}AL MEASUREMENTS WITH VERA, *Paper presented at the 5th International Conference on Accelerators in Applied Research and Technology (ECAART-5), 26-30 August 1997, Eindhoven, The Netherlands, to be published in Nucl. Instr. and Meth. B.*

4. E. Wild, R. Golser, P. Hille, W. Kutschera, A. Priller, S. Puchegger, W Rom, P. Steier, FIRST ^{14}C RESULTS FROM ARCHAEOLOGICAL AND FORENSIC STUDIES AT THE VIENNA ENVIRONMENTAL RESEARCH ACCELERATOR, *Paper presented at the 16th International Radiocarbon Conference, 16-20 June 1997, Groningen, The Netherlands, to be published in Radiocarbon.*

5. R. Weissenbök, S.R. Biegalski, L.A. Currie, D.A. Klinedinst, R. Golser, G.A. Klouda, W. Kutschera, A. Priller, W. Rom, P. Steier, E. Wild, DEVELOPMENT OF ^{14}C MEASUREMENTS TO STUDY SUB-MILLIGRAM CARBON SAMPLES FROM AEROSOLS, *Paper presented at the 16th International Radiocarbon Conference, 16-20 June 1997, Groningen, The Netherlands, to be published in Radiocarbon.*

6. W. Rom, R. Golser, W. Kutschera, A. Priller, S. Puchegger, P. Steier, W. Vycudilik, E. Wild, SYSTEMATIC INVESTIGATIONS OF ^{14}C AMS MEASUREMENTS AND FIRST RESULTS OF A FORENSIC STUDY IN HUMANS, *Paper presented at the 6th International Symposium on the Synthesis and Applications of Isotopes and Isotopically Labeled Compounds, 14-18 September 1997, USA, Proceedings to be published by John Wiley & Sons.*

MASS SPECTROMETRY WITH AN ACCELERATOR: A SUMMARY

Marie-Josée Nadeau
Leibniz-Labor für Altersbestimmung und Isotopenforschung, Christian-Albrechts Universität, Kiel, Germany.

Accelerator mass spectrometry (AMS) is a technique which has spread greatly in the last few years and the equipment used is very diverse. A brief summary of the requirements and/or principles of accelerator mass spectrometry is presented. These principles are seen in use in the description and comparison of two AMS dedicated systems, the IsoTrace Laboratory at the University of Toronto and the Leibniz-Labor at the Christian-Albrechts Universität zu Kiel.

1. Introduction

Accelerator mass spectrometry (AMS), is now twenty years old. It has developed from a somewhat curious way of using an accelerator system to a widely used technique applied to very diverse fields of study from geology to pharmaceutical research. It is a mixture of techniques, borrowed mainly from nuclear physics, which evolved with the goal of measuring the abundance of rare isotopes (typically 10^{-7} to 10^{-16} of the abundant isotopes). This extension of high sensitivity mass spectrometry differs from its more classical counterpart by the use of a second stage of acceleration bringing the ion beams from a few tens of kiloelectronvolts to megaelectronvolts energies. The second stage of acceleration ensures the efficient removal of molecular interferences and provides the extra energy needed for other isobar separation techniques to be used such as rate of energy loss or complete stripping.

Although it is costlier and more complicated than decay counting or conventional mass spectrometry, it is advantageous where decay counting becomes impractical (due to long life-times, low energy radiation or low sample activity) or is just impossible (for stable isotopes). The most widely spread application of AMS is radiocarbon dating where the ratio $^{14}C/^{12}C$ is determined in order to calculate, from the decay of the radioactive ^{14}C, the time elapsed since the sample studied was in interaction with the atmosphere. The technique is also used to determine the ^{10}Be content of different materials such as ice cores for paleoclimate research or ^{129}I in ocean samples. AMS has also proven to be an efficient