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Recent developments of the 1 MV AMS facility at the Centro Nacional de Aceleradores

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ABSTRACT

The Centro Nacional de Aceleradores (CNA) hosts a 1 MV accelerator mass spectrometry (AMS) apparatus since September 2005. In order to improve its overall performance, several updates have been made on the existing facility during the last 10 years of operation. In this paper, two modifications conducted in 2015 will be described.

To increase the transmission of the ions through the accelerator, the stripping gas on the 1 MV CNA machine was changed from Ar to He. The measured maximum transmission for almost every isotope results to be higher, especially for heavy masses: for instance, in the case of uranium in the 3+ charge state, the transmission increased from 11% with Ar gas to about 38% with He gas.

The second advance consisted of the substitution of the existing gas ionization chamber with a new one provided by ETH Zurich. The ETH detector features with its miniaturized design and is optimized for low energy AMS (i.e. very low electronic noise and efficient charge collection). As the electronic noise is the most important contribution to the resolution for light ions, the total energy resolution has been reduced by 15% in the case of ^{10}Be, allowing a better discrimination against its isobar, ^{10}B. For the heaviest radionuclides where the quality of the spectra is determined by the charge carrier production in the gas, the resolution for 2.7 MeV uranium ions was improved by 30%, probably due to a more efficient charge collection.

1. Introduction

Accelerator mass spectrometry (AMS) is one of the most sensitive methods for detecting long-lived radionuclides. This technique allows measuring a family of radioisotopes characterized by half-lives ranging from 5000 years up to few 10^7 years and present in the environment with natural concentrations of the order of 10^{-15}–10^{-8}.

In the recent years, the number of low-energy AMS (LE-AMS) facilities operating at terminal voltages below 1 MV was steadily growing worldwide, mainly due to the reduced costs and the maintenance effort of small, compact facilities. In this context, the advancement of these machines concerning stability, efficiency and sensitivity is of great interest to the AMS community.

Since September 2005 the Centro Nacional de Aceleradores (CNA), in Seville, hosts a 1 MV AMS facility named SARA (acronym for Spanish Accelerator for Radionuclides Analysis), which belongs to the first generation of compact multi-elemental AMS facilities designed and manufactured by High Voltage Engineering Europe (HVEE, Amersfoort, Netherlands) [1]. The isotopes studied with SARA at CNA are ^{10}Be, ^{14}C, ^{26}Al, ^{41}Ca, ^{129}I and actinides such as ^{239,240}Pu, ^{236}U and ^{237}Np. Since 2012, radiocarbon measurements have been performed almost exclusively at the Spanish MICADAS, a compact 200 kV ^{14}C-dedicated system designed and manufactured by ETH Zurich (Zurich, Switzerland) [2].

During the decade SARA has been in operation, many efforts have been undertaken to optimize the measurement conditions and to expand the list of radionuclides which can be investigated with this system. Several hardware and software changes have been made to the original facility in order to improve its performance, as described in [3].

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In this paper, the two most significant improvements to SARA's counting efficiency and detection resolution conducted in 2015 are highlighted. To improve the transmission of the beam through the accelerator, the originally installed Ar stripping gas has been replaced by He, whose suitability on low energy facilities has been showed in previous work at different energies than SARA [4–6]. Furthermore, a new gas ionization chamber (GIC) designed at the ETH Zurich for LE-AMS purposes has been installed as rare isotope detector. In the following sections, these two developments are discussed and first experimental results are presented.

2. Description of the AMS technique and modifications aims

Detailed information about the SARA facility and its components are summarized in previous publications [1,7], as well as the upgrades the machine underwent during the first 9 years of operation [3]. Thus, just a brief overview is presented here.

The source generates a negative ion beam (X^-) through a Cs^+ sputtering process. The ions are selected according to their mass by a low energy (LE) 90° bending magnet before entering the 1 MV Tandetron accelerator. Negative ions are accelerated towards the positive voltage applied at the accelerator terminal, where they are stripped to positive ions ($X^- \rightarrow X^{n+}$) in a collision cell (the so-called stripper) and molecules are dissociated. Due to the charge reversal in the stripper, the ion beam is again accelerated towards ground potential. In order to select the mass m, the charge state q and the energy E of the investigated isotope, as well as to filter molecular fragments, a high energy (HE) spectrometer consisting of a 90° deflection magnet (m/q filter) and a 110° electrostatic deflector (E/q filter) is following the accelerator. Finally, the single radionuclide ions are counted and identified in a $\Delta E - E_{res}$ gas ionization chamber, while the stable isotope current is detected in off-axis Faraday cups mounted in the analyser chamber just before the electrostatic analyser. Efficient transport and focusing of the ion beam are achieved due to an optimized design of the ion optics of the system [8]. Dedicated electronics and software is needed to process the signals acquired by the detecting devices.

The complexity of such a system arises from the necessity of obtaining an optimal beam transport from the source to the detector, while achieving a background suppression of up to 15 orders of magnitude. In this context, the stripping process as well as the detection of the rare isotope is of great importance for the optimization of an AMS instrument. In the next two sections, these two items will be discussed more in detail with a special focus on the stripper and detector modifications conducted at the SARA facility.

2.1. The stripping process

The stripping is one of the key processes in AMS: on the one hand it is responsible for the entire dissociation of the molecular interferences and on the other hand it determines the measurement efficiency. In the stripper, placed at the terminal of the tandem accelerator, the negative atomic and molecular ions experience charge exchange processes (ionization and electron capture) resulting in a charge reversal of the ion beam with various positive charge states. The injected molecules are dissociated thereby by reaching charge states higher than 2+ or by multiple collisions in the stripper. The fraction of the total incident particles that populates a given charge state after the stripping process corresponds to the stripping yield. Many particles cannot be transmitted through the stripper channel (i.e. a cylinder with 6 mm diameter and 30 cm length), due to the angular straggling that the beam experiences when passing through the target gas. The fraction of lost particles defines the optical transmission through the accelerator which, multiplied with the stripping yield, gives the accelerator transmission for a given charge state. As multiple positive charge states are produced, a significant fraction of the beam is lost because of the selection of a given charge by the HE magnet.

In this context, it can be reasoned that the stripper thickness is a critical point for the measurement performance of an AMS system. The stripper density needs to be high enough to assure an entire dissociation of the molecular interferences, since for charge states below 3+ molecules might survive the stripping process [9]. For this reason in many cases stripper mass thicknesses have to be set to such high values, that significant transmission losses due to angular straggling are observable. Additionally, a higher presence of residual gas in the acceleration tubes is noticeable, which results in an increase of the background caused by scattering and charge exchange processes in the accelerator tubes.

All these processes depend on the nature of the stripping gas. Recent studies performed on other LE-AMS facilities showed the advantages of using helium gas as a stripper [4,5]. For uranium ions at stripping energies between 80 and 500 keV, the mean charge state in a He gas is higher than in other gaseous or solid strippers, resulting in a strongly populated 3+ charge state (i.e. three times higher compared to Ar). At the same time, scattering losses are significantly reduced due to the lower atomic number of the target nuclei ($Z = 2$); about 20% of the beam is lost against the 30% measured for heavier gases like Ar ($Z = 20$) [5]. In addition to the promising results obtained at terminal voltages below 600 kV, it has been recently reported that actinides measurements benefit also from He stripping between 1 and 2 MV terminal voltages, with charge state yields for 3+ of about 40% [6].

Helium as stripping gas showed also very interesting results for light ions as Be and Al. In the energy range between 300 and 600 keV maximal transmissions of 50–60% for Al in the 2+ charge state have been reported [10]. But the very high presence of the m/q ambiguity $^{13}C^{1+}$ makes the application of external absorbers before the detector necessary.

An unexpected behavior is observable for beryllium injected as BeO^- in the 2+ charge state for stripping energies between 90 keV ($V_T \sim 220$ kV) and 200 keV ($V_T \sim 525$ kV): a local transmission maximum of 37% appears at about 120 keV (corresponding to a terminal voltage $V_T \sim 300$ kV). This is unusual, because the mean charge state ordinarily increases with the beam energy.

In conclusion, the advantages of He stripping have been shown at different facilities. However, there are no experimental data available yet for terminal voltages between 600 kV and 1 MV, which are accessible with the SARA system. Therefore, the obtained information on the CNA facility will be the key for a better understanding of the stripping process with He at low energies, and to explore the limits of this technique on a basic AMS system, where no additional kinematic filters have been added to the HE side of the spectrometer.

2.2. The detection of the rare isotopes

At SARA the rare isotopes are detected and counted in a $\Delta E - E_{res}$ gas ionization chamber (GIC) placed at the end of the line. Even if the GICs used in LE-AMS can have different designs, some characteristics are common. Here only a very brief description on the most important properties of gas detectors will be given. A detailed discussion about the working principle and optimization of GICs for low energy applications can be found in [11,12].

The splitting of the anode in two plates gives the opportunity of obtaining $\Delta E - E_{res}$ information making the discrimination of light isobars (e.g. ^{10}B during the measurement of ^{10}Be) possible in the chamber. A Frisch grid, placed in front of the anodes, removes the position dependency from the induced signal on the electrodes. As entrance windows, extremely thin and homogeneous silicon

nitride membranes (i.e. $Si_3N_{3.1}H_{0.06}$ [13]) are used, taking advantage of the low energy loss (small dead layer) and straggling the ions suffer during the passage of these foils. Silicon nitride window dimensions have to be chosen to withstand the pressure difference between the inside and the outside of the detector while achieving a high beam acceptance: typical thicknesses are ranging between 30 and 100 nm with an area not smaller than 3×3 mm^2. These detector windows are usually mounted on dedicated holders which allow a fast and easy exchange. Isobutane (C_4H_{10}) is one of the most common detector gases, since a comparatively low amount of energy is needed to produce an ion–electron pair ($\sim$23 eV) [12].

The signals from both anodes are independently processed in a traditional electronic chain consisting of a preamplifier, a shaping amplifier, an Analog to Digital Converter (ADC) and a MultiChannel Analyser (MCA), before being displayed in a two-dimensional spectrum using the software MPA-NT (FAST ComTec. GmbH, Oberhaching, Germany).

In general, optimizing the detector performance means maximizing the signal height and minimizing its variation, e.g. the resolution. The signal height can be essentially optimized by minimizing dead layers (entrance window), utilizing a gas providing a high ionization yield per energy loss and configuring the detector geometry for an efficient charge collection (e.g. design of the Frisch grid). In the case of a GIC as described above, the resolution mainly depends on three factors: (i) the energy straggling in the entrance window, (ii) the electronic noise and (iii) the statistics of charge carrier production and collection inside of the detector. These three effects contribute in different ways to the total energy resolution depending on the detected isotope and its energy [12]: the electronic noise is dominant at low energies for light ions as Be, whereas the statistical fluctuations related to charge production and collection determine the achievable resolution for the heaviest ions as ^{129}I or actinides. The energy straggling due to the silicon nitride membrane always represents a minor contribution and it's an effect of the reduced thickness and the uniformity that characterize these foils despite plastic materials [13].

3. System modifications

During the last year, SARA underwent two important developments: (i) the stripping gas was changed from the originally installed Ar to He, (ii) the existing GIC was replaced by a low noise detector designed and manufactured by the ETH Zurich. Both system modifications are presented in the successive subsections.

3.1. Helium stripper gas

Following the encouraging results obtained using He as stripping gas discussed before [4–6,10], the conversion of SARA's stripper from Ar to He gas was realized in January 2015. It was achieved by changing the originally installed Ar gas bottle, placed inside the terminal of the Tandetron accelerator, by a new one filled with He gas. Being gas dependent, the vacuum gauge placed in the middle of the stripper channel (i.e. Thermovac Transmitter TTR216S) was recalibrated to show reliable pressure reading for He gas. The already existing 400 l/s turbo-molecular pump is used to recirculate the stripping gas and to ensure good vacuum conditions along the LE and HE acceleration tubes.

3.2. New $\Delta E - E_{res}$ gas ionization chamber

The GIC originally installed at the end of SARA's beam line was produced by HVEE. Anodes' shapes and positions are designed for low detector capacitance and their lengths are 15 and 31 cm, respectively. Voltage divider rings create a homogeneous electrostatic field perpendicular to the incoming ions. ORTEC preamplifiers mounted outside of the detector chamber are connected to the anodes through a 10 cm cable. Detector specifications and constructive details can be found in [1].

The installation of a miniaturized GIC, which was provided by ETH Zurich and optimized for low energy AMS purposes, considerably improved the detection of ^{10}Be with SARA. Both anodes have a length of 5 cm with a maximized active area and CREMAT's CR-110 preamplifier modules are mounted directly on the anode plates through an AC coupling in order to minimize the capacitance introduced by cables. In this way, the overall capacitance associated to the detector is reduced introducing less preamplifier noise [11]. A schematic of the ETH GIC is shown in Fig. 1 and perspective views are given in Fig. 2 [14].

4. Results

In Table 1 first results of the maximum transmissions and the abundance sensitivities obtained on our facility using He gas as stripper are summarized. The values achieved with Ar are given as well [3]. In the following, the most relevant information for every radionuclide is summarized.

4.1. ^{10}Be

One of the most interesting isotopes measured by low energy AMS is ^{10}Be for its applications in geology and environmental sciences.

Using He as stripper gas, the maximum measured transmission for beryllium does not present important changes at the stripping energy of 370 keV, corresponding to SARA's maximum terminal voltage (i.e. 1 MV). For the 1+ charge state, the maximum transmission has not changed, being 58% with both Ar [15] and He, while in the charge state 2+ it reduced from 25% to 21.4% (Table 1).

The presence of a Be^{2+} transmission maximum at a stripping energy of 120 keV highlighted in [10] encouraged the measurement of the transmission in the whole energy range allowed by the machine, i.e. stripping energies between 170 keV ($V_T \sim 450$ kV) and 370 keV ($V_T \sim 1000$ kV). The lowest terminal voltages are determined by the accelerator design and by the focusing system, in particular by the lowest limit reached by the Q-Snout lens placed at the entrance of the accelerator. A decreasing behavior of the transmission has been revealed until the stripping energy of 280 keV ($V_T \sim 750$ kV), where a transmission of 20.2% has been recorded before the yield for the 2+ charge state slowly increases again (Fig. 3). Therefore, two local maximum values have been recorded: the first one at a stripping energy of 170 keV, corresponding to a transmission of 22.5%, and another one at the stripping energies of 370 keV, where the transmission amounts to 21.4%.

The measurement of Be is affected by the isobaric interference ^{10}B, which has to be suppressed by about 6–10 orders of magnitude (depending on the BeO sample). The resulting boron intensities would lead to a saturation of GIC's electronics and makes the ^{10}Be detection in the conventional way impossible. Therefore a ^{10}B suppression of 4–5 orders of magnitude is needed before entering the detector, which is performed by inserting a thin degrader foil into the beam trajectory between the HE magnet and the ESA [15]. Having different stopping powers, most of the ^{10}B is physically removed if the ESA is set to select ^{10}Be. Anyhow, part of high-energy ^{10}B tail still reaches the detector, where it is discriminated from ^{10}Be in the $\Delta E - E_{res}$ spectrum. Silicon nitride foils with thicknesses of 75, 100 or 150 nm are adopted as degraders

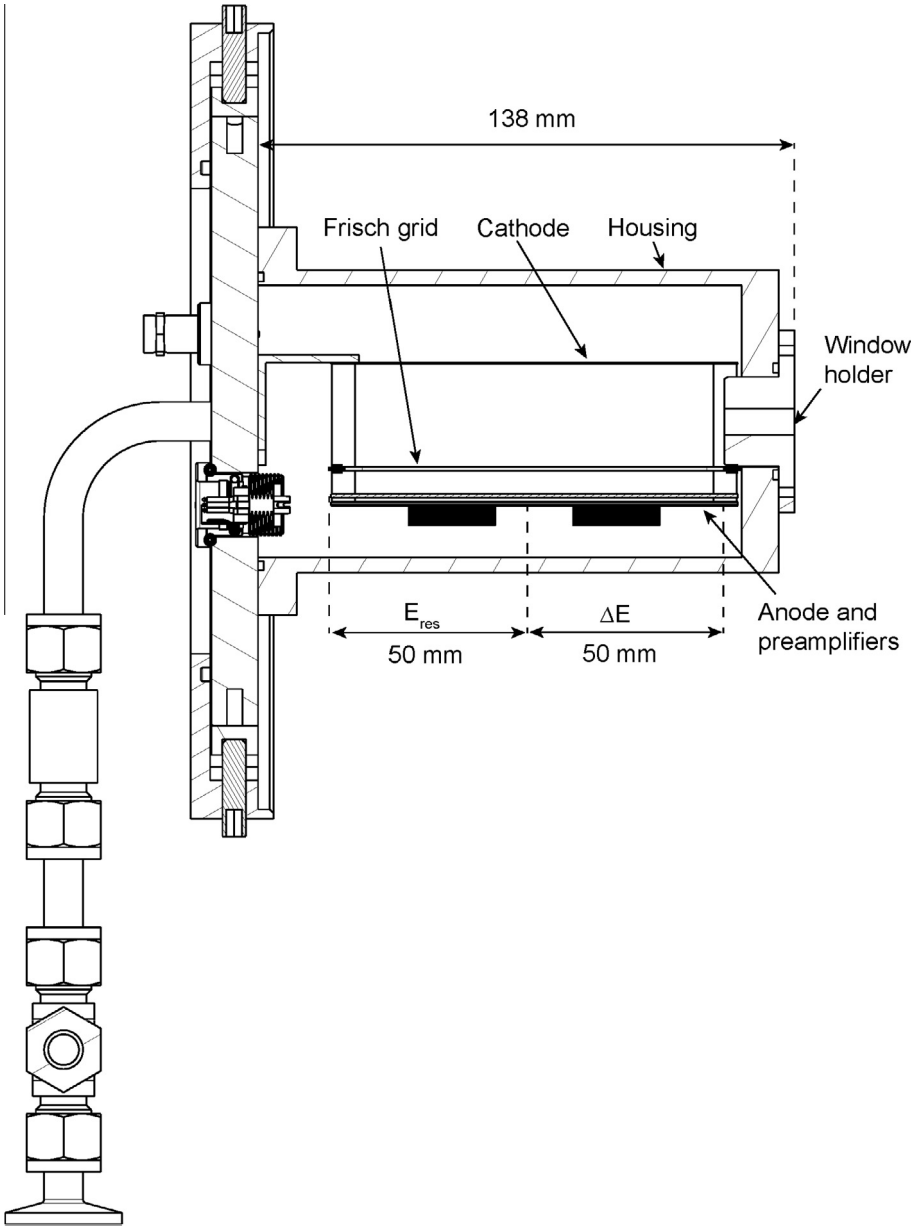

Fig. 1. Schematic representation of the ETH detector.

for the experiments. The degrader foil acts as a second stripper resulting in a charge state distribution of the beam after the passage of the foil.

Thus the overall transmission (i.e. the transmission through the accelerator into the detector) is not only affected by the transmission achieved through the Tandetron, but also by the yield of the selected charge state and the losses due to energy and angular straggling after the degrader foil. In this context, the importance of an optimal transmission through the accelerator into the detector for the measurement performance of ^{10}Be is evident [16].

Experiments have been performed at 1 MV and 470 kV terminal voltages with a 100 nm silicon nitride degrader and a 5×5 mm^2 window at the detector entrance. The results of the transport efficiencies for different charge states are summarized in Table 2.

At 1 MV measurements were made for the 1+ and 2+ charge state after the accelerator and 2+ after the degrader. Although the transmission through the accelerator is almost three times smaller for the 2+, the difference in the overall transmission is less than 20%. The energy for the 2+ charge state is significantly higher resulting in a better transport efficiency of ^{10}Be ions through the degrader into the detector due to higher stripping yields for the 2+ charge state after the degrader and less angular and energy straggling. A more detailed and quantitative analysis of the different processes in the degrader depending on the energy will be discussed in a separate publication.

Beside the efficiency, also the question arises on how the background is affected by the stripper conversion and the new detector. In Table 1 the background levels before and after the facility modifications are summarized. Under routine measurement conditions, i.e. charge state 1+ after the accelerator [15], the background increased by a factor of two to a level of $4{\cdot}10^{-14}$. Possible sources for this additional background could be a lower isobar suppression provided by the new GIC or a higher intensity of ions as ^{9}Be reaching the detector by scattering and charge exchange processes in the acceleration tube [16].

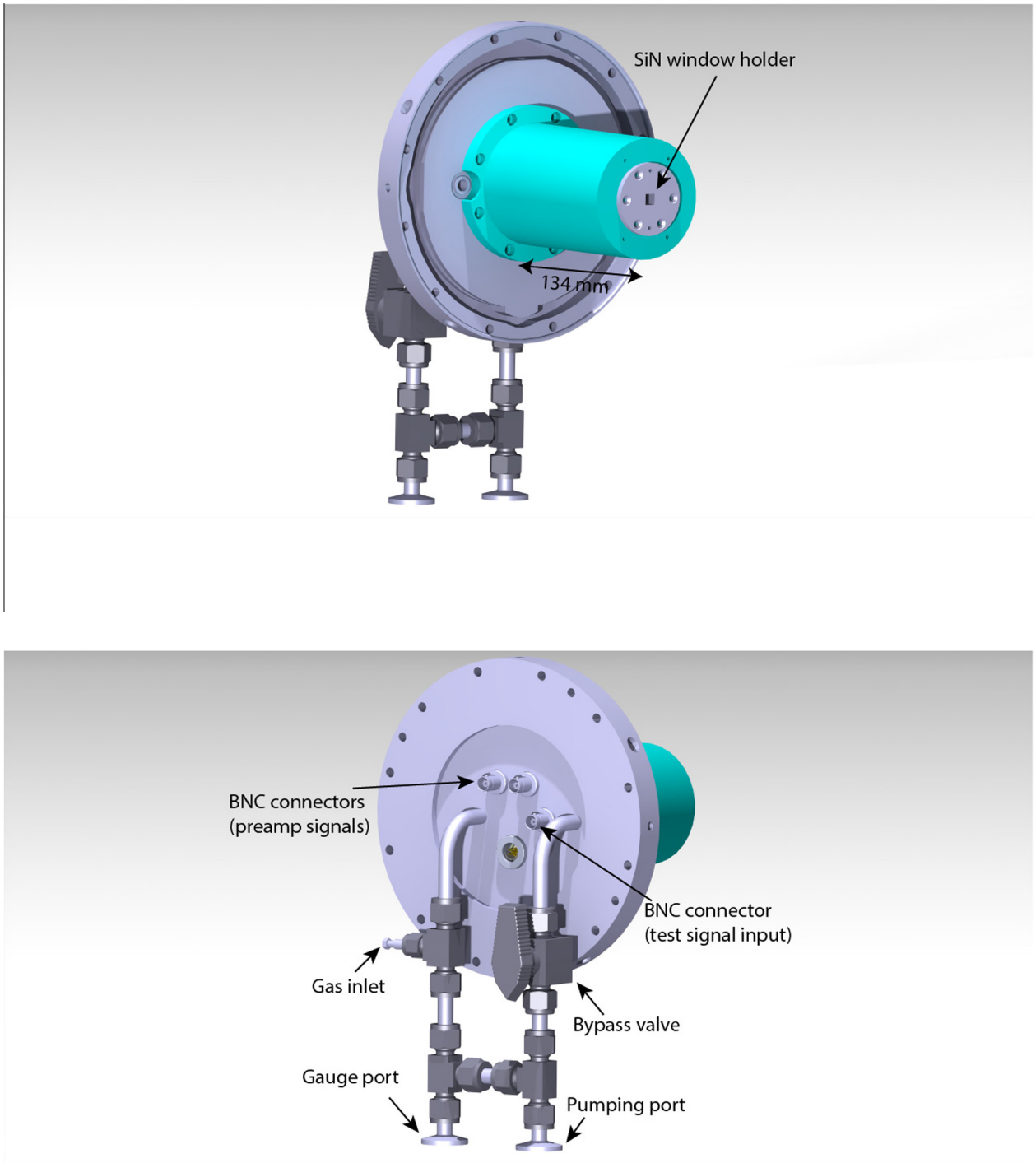

Fig. 2. ETH detector front and back.

In Fig. 4, $\Delta E - E_{res}$ spectra are illustrated of a BeO standard sample obtained for the 1+ and 2+ charge states used after the terminal stripper. Both spectra demonstrate a very good and distinct separation between the two isobars and as it will discussed subsequently the energy resolution for Be could be significantly improved by the application of the new detector. For this reason it is rather unlikely that boron tailing into the beryllium peak is responsible for the increased background.

A degradation of the vacuum conditions in the acceleration tubes after the conversion to He stripping would cause a higher probability of scattering and charge exchange processes resulting in a higher background level. This assumption would be consistent with the observations made for the 2+ charge state. A lower background level of $2{\cdot}10^{-14}$ was measured, which could be explained by a lower probability of producing interfering $^{9}Be^{2+}$ ions by charge exchange in the accelerator tube compared with the 1+ charge

Table 1
Recap of the measured maximum transmissions and abundance sensitivities obtained for different isotopes and charge states with both Ar and He stripper. The terminal voltage is limited by the HE spectrometer acceptance.

Isotope	Charge state	Terminal voltage (kV)	Energy (keV)	Ar gas		He gas	
				Transm. (%)	Background	Transm. (%)	Background
Beryllium (2+ after degrader)	1+	1000	1370	58	$2{\cdot}10^{-14}$	58	$4{\cdot}10^{-14}$
	2+	1000	2370	25	$1{\cdot}10^{-14}$	22	$2{\cdot}10^{-14}$
Aluminum	1+	700	1440	23	$3{\cdot}10^{-14}$	38	–
	2+	1000	2650	54	–	52	–
	3+	1000	3650	12	$2{\cdot}10^{-14}$	18	$9{\cdot}10^{-14}$
Uranium	3+	650	2590	11	$5{\cdot}10^{-11}$	38	$9{\cdot}10^{-11}$

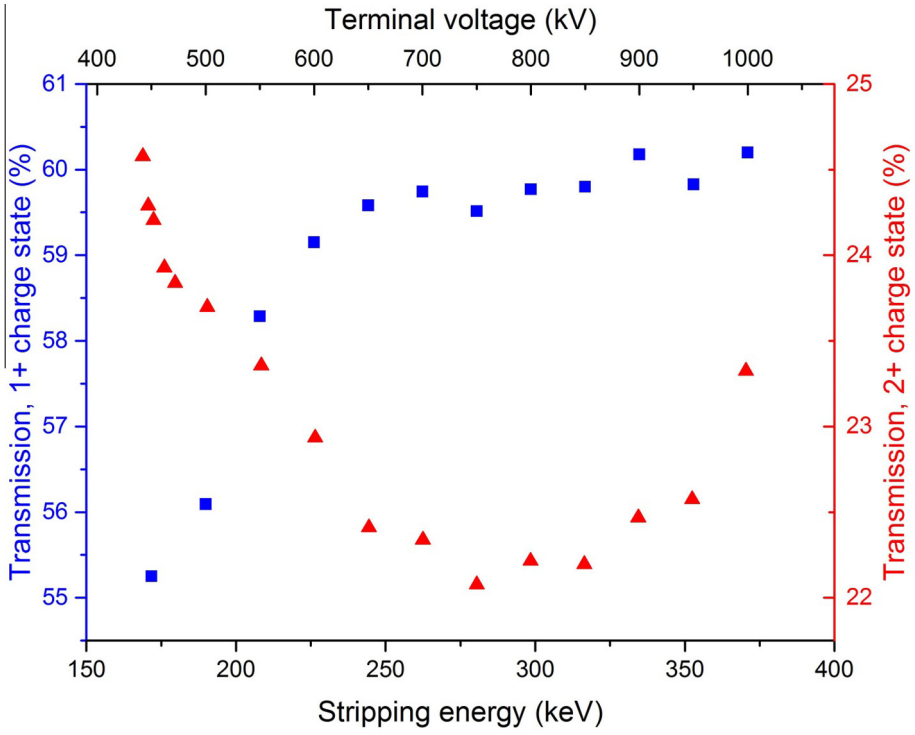

Fig. 3. ^{9}Be transmission as a function of the stripping energy in both 1+ (blue) and 2+ (red) charge states. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 2
Transmission achieved at terminal voltages of 1 MV and 470 kV. The achieved overall transmission at 470 kV terminal voltage for the 2+ charge state after the accelerator are significantly lower than the results achieved at 1 MV.

Terminal voltage (MV)	Charge state stripper	Energy (keV)	Transm. accelerator (%)	Charge state degrader	Trans. degrader (%)	Overall transm. (%)
1	1+	1370	58	2+	10	6
1	2+	2370	21.4	2+	23.4	5
0.47	2+	1120	21.8	2+	8	2
0.47	2+	1120	21.8	1+	<5	<1

state. But further investigations have to be performed to proof this hypothesis, considering also the memory effect in the ion source.

In order to evaluate the performance of the new detector for beryllium measurements, ^{9}Be resolution has been measured with HVEE and ETH GICs. The beam energy was 1300 keV in both cases and the detector pressure was adjusted in order to fully stop ions in the first anode. The entrance silicon nitride windows mounted on the old and the new detectors had thicknesses of 40 and 50 nm, respectively. The total resolution measured with the ETH detector is 34 keV, against the 40 keV acquired with the previous setup. To better understand this improvement, the electronic noise has been measured through a pulser device and the energy straggling in the entrance windows has been calculated using the formula presented in [17]. The contribution due to statistical fluctuations in the production and collection of charge has been calculated subtracting the squares of the electronic noise and silicon nitride contribution from the square of the total resolution:

$$r_{gas}^2 = r_{tot}^2 - r_{noise}^2 - r_{foil}^2 \quad (1)$$

Results are shown in Table 3. A drastic difference in the electronic noise values has been recorded for the chambers under comparison: the optimized, compact ETH detector has an associated noise of 22 keV, opposed to the 29 keV measured with the HVEE design. The straggling in the silicon nitride window depends on the thickness and could still be improved mounting a thinner foil:

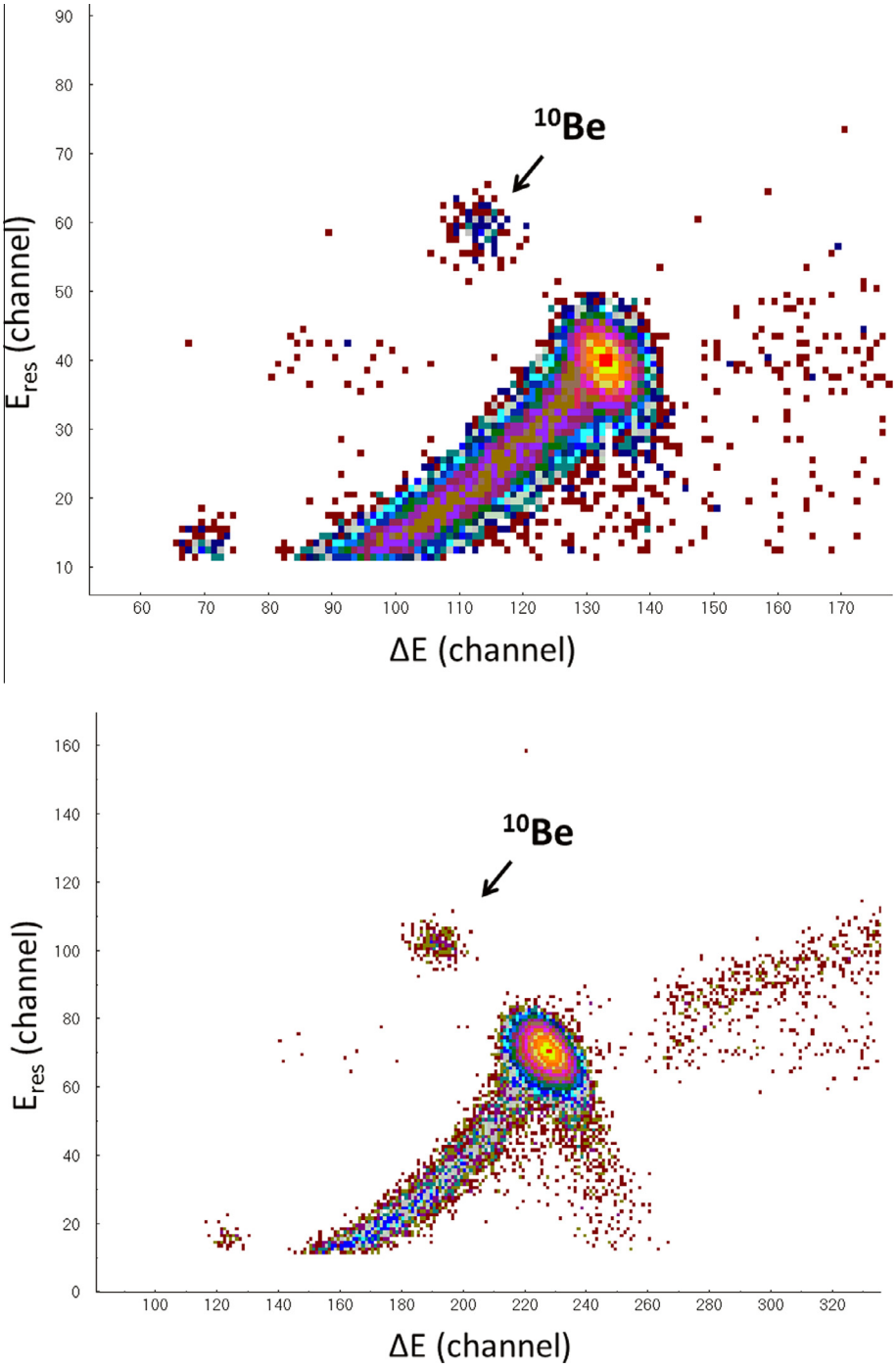

Fig. 4. ^{10}Be spectra recorded with the He stripper and the ETH detector. *Above:* 1+ charge state after the accelerator, 2+ charge state after the degrader foil. *Below:* 2+ charge state after the accelerator, 2+ charge state after the degrader foil.

Table 3
Different contributions to the total resolution of a ^{9}Be beam at 1300 keV.

	FWHM (keV)	Electronic noise (keV)	$Si_3N_{3.1}$ thickness (nm)	$Si_3N_{3.1}$ straggling (keV)	Gas (keV)
Old GIC	40	29	40	8	26
ETH GIC	34	22	50	9	25

for example, a 30 nm window, so far the thinnest available on the market. Yet, the improvement of the total resolution due to a thinner foil would be small. The contribution due to the charge production and collection is almost the same for the two detectors.

4.2. ^{26}Al

^{27}Al transmissions have been measured in the charge states 1+ at 0.7 MV because of the HE spectrometer acceptance, whereas

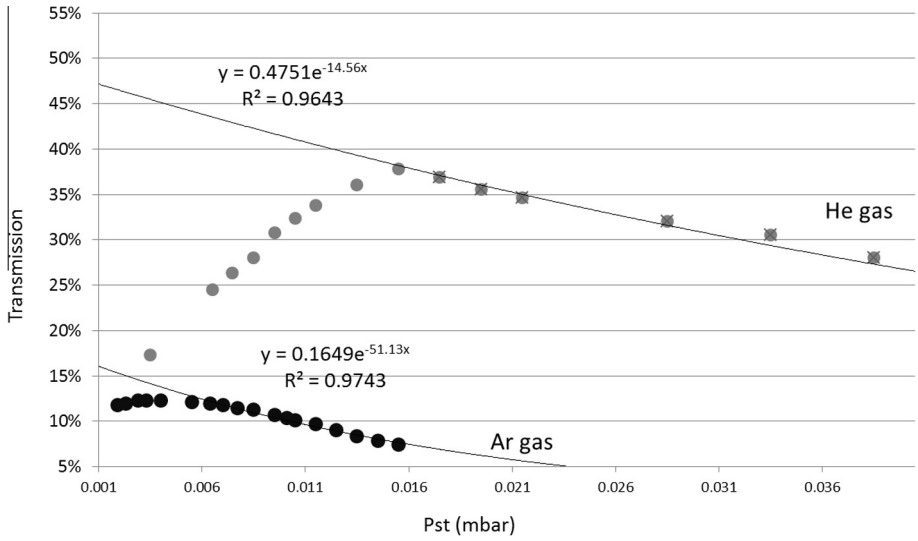

Fig. 5. Transmission curves for U^{3+} for He gas and Ar gas as strippers at 670 kV terminal voltage. The He results were obtained in March, 2015. The Ar gas data were reported in [21]. The exponential fits show the optical losses due to the angular scattering in the corresponding gas and to charge exchange processes in the acceleration tubes.

they have been measured in the charge states 2+ and 3+ at the maximum terminal voltage.

The highest transmissions have been obtained in the charge state 2+, with a maximum value of 52% with He stripper and 54% with Ar [18] measured at 1 MV. At lower energies, the difference between the effects of the two gases on this charge state is more evident: indeed, at a terminal voltage of 500 kV (~1300 keV), the maximum transmission recorded is 25% with Ar [19] and 60% with He [10]. However, the intense m/q ambiguity of $^{13}C^{+}$ makes the direct measurement in a GIC impossible [10]. Even if these two ions have different energy, they cannot be discriminated in the $\Delta E - E_{res}$ detector because $^{13}C^{+}$ is so abundant to saturate the electronics. The implementation of a passive absorber cell at the entrance of the detector can give a chance of discriminating $^{26}Al^{2+}$ from its interference [10,20], which will be tested in the future.

The charge state 1+ at 0.7 MV has increased its maximum transmission from 23% with Ar to 38% with He. Anyhow, this charge state is characterized by a high molecular background level [10,18] and requires further investigations. The maximum transmission detected in the charge state 3+ has increased, passing from 13% with Ar [18] to 18% with He. Even if the background significantly increased to $9{\cdot}10^{-14}$, so far the 3+ charge state represents the best choice for high level measurements.

4.3. ^{236}U

One of the most challenging AMS radionuclides is ^{236}U. The $^{236}U/^{238}U$ atom ratios that can be found in modern environmental samples range from about 10^{-11} to above 10^{-9}. Therefore, very demanding abundance sensitivities are necessary to investigate the applications of this radionuclide. Using Ar gas as stripper, it was demonstrated that a background of about $5{\cdot}10^{-11}$ could be achieved on the 1 MV CNA AMS system, with an overall transmission through the accelerator of about 11% for 670 kV terminal voltage [21]. In order to determine the new experimental settings using He gas as stripper, the transmission through the accelerator was studied for the 3+ charge state for increasing stripper gas pressures using the same terminal voltage. In Fig. 5, the measured transmission as a function of the stripper thickness is shown together with results reported in [21] using Ar gas as comparison. With the new setup, the maximum achievable transmission through the accelerator is 38%, which corresponds to a charge state yield of 47% (i.e. 20% transmission loss in the stripper channel). This is in agreement with the results reported for lower and higher terminal voltages by the ETH and the VERA groups in [5,6]. It is remarkable that an improvement of the measured transmission has been noticed over time, probably due to a gradual purification of the gas. This effect will be studied in more detail during the next years for all the investigated radionuclides. On the other hand, a worsening of the $^{236}U/^{238}U$ background ratio has been observed, from $5{\cdot}10^{-11}$ for Ar gas to $9{\cdot}10^{-11}$ for He gas for stripper gas pressures corresponding to the maximum transmissions (Table 1). This was expected in advance, as more residual gas might be present along the acceleration tubes due to the higher stripper gas pressures now needed to reach equilibrium conditions (i.e. a factor of 3 higher in our case, as it can be deduced from Fig. 5). Indeed, more scattered ^{235}U and ^{238}U molecular fragments might be produced along the second acceleration stage and might reach the detector. Uranium-hydrides severely contribute to the background when the machine sensitivity level can reach down to 10^{-12} [9], but should contribute less with the current sensitivity achievable at the SARA facility (almost 10^{-10}). Anyhow, further investigation will be realized in order to understand the different background contributions.

Regarding the performance of the detector, a total energy resolution (i.e. FWHM) for 2.7 MeV uranium ions of 7% was achieved with the ETH GIC, against the 10% obtained with the HVEE design. Those results have been obtained with the same procedure previously described for beryllium: uranium ions were stopped along the first anode of the corresponding detector by adjusting the detector gas pressures accordingly (i.e. 15 mbar for the ETH detector and 7 for the HVEE one). The most likely explanation for this improvement is a more efficient charge collection in the first case as the resolution for heavy ions is determined by the charge production in the active area of the detector, as stated before.

5. Conclusions

Two important developments of the AMS facility hosted at the CNA have been presented.

The replacement of the original Ar stripping gas with He showed an increase of the transmission through the accelerator for many ions. Very promising results have been found especially for heavy isotopes, even if, according to preliminary results, the

recorded background is higher with the new stripper. This was expected, because the need of applying higher stripper thicknesses leads to a worsening of the vacuum conditions in the acceleration tubes and to an increase of scattering processes. To take the maximum advantage from the new stripper, detailed studies of the background and research on the best measurements conditions will be carried out in the future for all the investigated radionuclides.

The installation of a new GIC, optimized for LE-AMS purposes, improved the ions resolution by minimizing of the electronic noise associated with detector and acquisition chain. As the electronic noise represents a relevant contribution to the resolution of light ions such as beryllium, a reduction of the FWHM from 40 to 34 keV has been recorded for a 1400 keV ^{9}Be beam. A better resolution has been observed also for heavy ions, demonstrating the more efficient charge collection of the ETH detector.

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