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^{10}Be low-energy AMS with the passive absorber technique

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ABSTRACT

The passive absorber technique is one of the most common ways to suppress the ^{10}B interference during ^{10}Be measurements at facilities working with beam energies above 7 MeV. At lower energies, the range straggling complicates the application of absorbers, so that other suppression techniques are normally preferred. Several experiments were conducted at the SARA (hosted at Centro Nacional de Aceleradores, Seville, Spain) and VERA (Faculty of Physics, University of Vienna, Austria) AMS facilities to demonstrate the potential of the passive absorber technique also at and below 2.4 MeV. Two different absorber setups were installed and tested. For the detection of the rare isotopes both facilities used a gas ionization chamber optimized for light ions detection based on the same design. The absorber installed at the SARA facility was a combination of SiN foils and an isobutane gas volume, whereas VERA was equipped with an absorber constituted of a stack of SiN foils. In both cases, ^{10}Be could be clearly separated from ^{10}B and the use of a passive absorber at the entrance of the detector gave higher transmission compared to the degrader method.

Depending on the absorber design, different background contributions could be identified: Rutherford scattering of ^{10}B on the protons contained in the SiN foils and isobutane gas was responsible of a severe background at SARA, and fragments from ^{9}Be^{1}H molecules surviving the stripping process resulted in events partially overlapping the ^{10}Be gate at VERA. The measured transmissions and background levels will be presented for the tested setups, as well as the advantages and disadvantages of each absorber design.

1. Introduction

^{10}Be is one of the most measured radionuclides by means of the accelerator mass spectrometry (AMS) technique, having a wide range of applications in environmental sciences and geology. However, ^{10}Be AMS measurements necessarily involve the suppression of the isobar ^{10}B (stable, 19.9% isotopic abundance), as the mass difference $\Delta M/M = 5.96{\cdot}10^{-5}$ relative to ^{10}Be cannot be completely resolved by the mass spectrometers used in AMS and ^{10}Be detection in a gas ionization chamber (GIC) is complicated due to the ^{10}B count rate, which is high enough to drive the detector electronics into saturation even from chemically cleaned samples.

^{10}B can be suppressed by preparing ^{10}Be samples in form of fluoride compounds such as BeF_2 or $BaBeF_4$, from which the BeF^- anion is analyzed in the low-energy side of the AMS facility. Most of ^{10}B is suppressed in the sputtering ion source, since $^{10}B^{19}F^-$ molecules are metastable and dissociate on the injection side of the spectrometer [1], and residual ^{10}B coming from other 29 mass molecules (e.g. $^{9}Be^{10}B_2^-$ or $^{10}B^{17}O^1H_2^-$) can be separated from ^{10}Be in a $\Delta E\text{-}E_{final}$ GIC [2]. However, the extracted $^{9}BeF^-$ currents are too low (50–100 nA at the entrance of the accelerator) and unstable to assess efficient measurements [3].

Samples are therefore prepared as BeO, whose procedure is well known and practical for routine analysis. The extracted $^{9}BeO^-$ currents are higher and more stable compared to the ones of fluoride compounds, reaching values of few μA. The drawback is that both BeO^- and BO^- molecules are produced in the ion source. The ^{10}B/^{9}Be ratio in the samples is typically of the order of 10^{-5}. In principle, ^{10}B suppression could take place in a multi-anode detection system, but ^{10}B provides count rates of 10^7 ions/s in the detector overwhelming the acquisition electronics. Therefore, ^{10}B intensity has to be reduced to few 10^3 ions/s before entering the detection system in order to measure ^{10}Be/^{9}Be isotopic ratios of $10^{-15}-10^{-12}$, which are required by common ^{10}Be applications.

The ^{10}B suppression techniques that have been developed during the years within the AMS community take advantage of the different

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stopping powers of materials to the isobars. Two approaches have been used so far: the so-called degrader and absorber techniques.

In the degrader technique, the beam passes through a thin foil placed in front of an electrostatic or magnetic deflector [4]. Since ^{10}Be and ^{10}B ions emerge from the degrader foil with different average energies, ^{10}B can be physically separated by the following filter and a suppression of 4–5 orders of magnitude is achieved [4,5]. The residual ^{10}B, coming from the high energy tail of the resulting energy distribution and from eventual scattering processes in the deflector, is separated from ^{10}Be in a ΔE-E_{final} GIC. The disadvantages of this technique are the considerable losses produced by the distribution of charge states, since only one of them can be selected by the subsequent kinematic filter, as well as energy and angular stragglings that affect the beam after the passage through the degrader. At energies below 2.5 MeV, 70–80% of the beam can be lost in the high-energy (HE) spectrometer because of the degrader [5–7].

The passive absorber technique uses an absorber material installed in front of the detector. Its principle of operation is based on that interfering species have shorter ranges than the ions of interest. The 10 beam originating from the stripping process in the accelerator travels through the HE spectrometer at a selected charge state to the detector, so that ^{10}Be and ^{10}B reach the absorber with the same energy. Having a higher nuclear charge, ^{10}B (Z = 5) experiences a stronger deceleration than ^{10}Be (Z = 4) and is stopped at a shorter distance. The absorber thickness can thus be set to fully stop the interference and allow exclusively ^{10}Be to enter the detector.

The passive absorber technique was originally applied for ^{10}Be measurements at AMS systems operating at 6 MV [8] and is an affirmed and efficient method to measure ^{10}Be at facilities operating at terminal voltages of 3 MV and above [9–13]. In these cases, beam losses in the absorber are considerably lower than the ones caused by a degrader (e.g. just 20% of the ^{10}Be ions are lost at 3 MV with a proper absorber/GIC setup [13]).

At terminal voltages of 1 MV and below (i.e. at ^{10}Be beam energies below 2.5 MeV), the energy and range stragglings worsen the separation between the isobars and the detector resolution compromises the effectiveness of the technique. Degraders applied in these cases provide excellent ^{10}B suppression, but with overall efficiencies below 10% [5–7].

The recently developed high-resolution GICs for AMS purposes gave a chance to use passive absorbers also at low energy [14–17]. In [18,19], the feasibility of this technique was demonstrated at a terminal voltage of 600 kV. Following the promising results presented in those works, two different absorber devices have been tested at the Spanish accelerator for Radionuclides Analysis (SARA) and at the Vienna Environmental Research Accelerator (VERA) in order to investigate the passive absorber method at ^{10}Be beam energies below 2.5 MeV.

2. Experimental setups

The most important property of a passive absorber is its homogeneity, which is particularly critical at low beam energies. Silicon nitride (SiN, $Si_3N_{3.1}H_{0.06}$ [20]) foils have been demonstrated to be very useful as components of passive absorber devices at both high [13,21] and low energies [18,19], as their homogeneity and availability of thicknesses from 30 to several 100 nm make these membranes more suitable than other materials. Secondly, a high level of homogeneity can be obtained with passive absorbers based on gas cells enclosed between SiN membranes.

To verify the pros and cons of two different absorber setups, a gas cell enclosed between two SiN foils and a SiN foil-stack absorber have been tested at SARA and VERA, respectively, with ^{10}Be beam energies of about 2.4 MeV. Both AMS facilities are equipped with a high-resolution GIC based on the design developed at ETH [7,14]. This makes the results directly and easily comparable. Details concerning the absorber designs and the detecting system are given in the following sections.

2.1. SARA'S absorber

SARA is a compact, multi-elemental AMS facility, whose maximum terminal voltage is 1 MV. Detailed specifications of the system are summarized in [22–25]. All the experiments described in this article have been carried out after the upgrade of the facility in 2014 [7], which consisted on the replacement of the stripper gas supply from Ar to He and the installation of a high-resolution GIC optimized for low-energy AMS. ^{10}Be measurements were thoroughly investigated and optimized since the installation of the facility in 2006 [3,7]. It was demonstrated that the most populated charge states after the stripping process at 1 MV terminal voltage are 1 + (55–60% transmission) and 2 + (20–25% transmission), with both Ar and He gas strippers.

^{10}Be is normally measured at the SARA system using the degrader method. This results in relatively low overall efficiencies (5–6%), if the beam losses in the stripper and in the high-energy spectrometer are considered. The blank ratio for normal ^{10}Be operation is of few 10^{-14} [3,7].

The passive absorber used for the experiments at SARA is a combination of SiN foils and a gas volume, and is similar to the one tested at ETH at terminal voltage below 600 kV [18]. It consists on a modified entrance window holder for the GIC (Fig. 1). With this absorber design, the incoming beam passes through a first SiN window, a gas volume and a second SiN foil before reaching the active area of the detector (Fig. 2).

The first SiN foil separates the absorber/GIC gas from the rest of the beam line, which is at high vacuum (10^{-7} mbar). A 500 nm thickness and a 5 5 mm^2 area make the membrane able to withstand a pressure of 500 mbar; being so thick, on the one hand it is responsible for an initial beam energy reduction and on the other hand allows to work with a wide range of absorber gas pressures. The absorber volume between the two SiN foils has a length of 16 mm and is connected to the detector via a hole with a 1 mm diameter, thus the absorber cell and the GIC are filled with isobutane (C_4H_{10}) gas at equal pressure. This setup has as the main advantage of allowing an easy and fast change of the absorber mass thickness. The second SiN foil has a thickness of 75 nm, an area of 5 5 mm^2 and avoids that charges created in the absorber gas reach the active volume of the detector.

At 1 MV terminal voltage, ^{10}Be ions in the 2+ charge state have 2400 keV energy, whereas the ones in the 1+ carry just 1400 keV, for which a better separation from the ^{10}B peak is expected in the first case. Nevertheless, $^{10}Be^{1+}$ ions are still worth of interest because of the higher transmission through the accelerator (above 50%).

2.2. VERA'S absorber

The VERA AMS facility can operate at terminal voltages between 1.6 and 3 MV [26]. ^{10}Be measurements are routinely done at 3 MV in the 2+ charge state, i.e. at a beam energy of about 7 MeV, with a passive absorber based on a stack of SiN foils [13]. In such a setup, the GIC

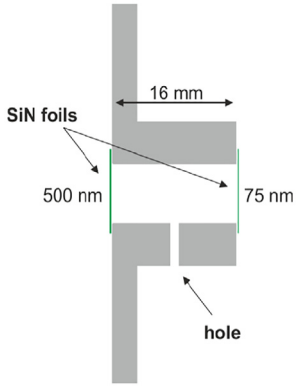


Fig. 1. The modified GIC window holder used as a passive absorber.

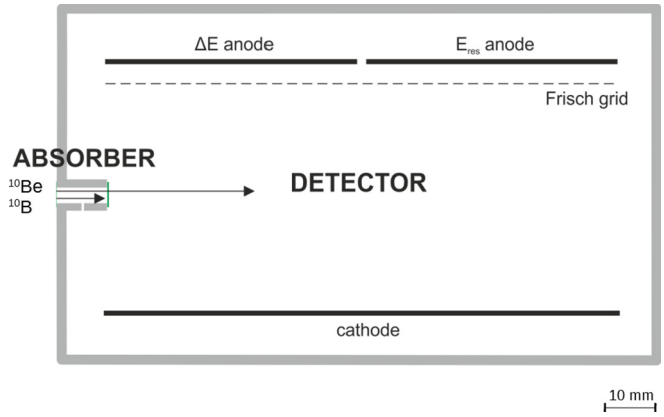


Fig. 2. Sketch of the absorber setup at SARA.

window holder carries several SiN foils positioned on a metallic grid foil tray.

In order to reproduce a 2400 keV beam energy (i.e. the energy of $^{10}Be^{2+}$ at SARA at 1 MV), the 1+ charge state was selected with the accelerator's terminal voltage set at 1.7 MV. Both He and Ar stripper gas were tested during the experiments. SRIM simulations of the 2400 keV beam predict a complete ^{10}B suppression without affecting the ^{10}Be transmission in a relevant way for SiN mass thicknesses ranging between 810 and 890 μg/cm^2. During the experiments, two 1 μm thickness foils were placed in the holder and a 0.5 μm thick membrane was mounted as the detector entrance window, obtaining a total SiN thickness of 2.5 μm (860 μg/cm^2 mass thickness). Foil thicknesses were previously determined by energy loss measurements of α particles from a ^{241}Am source. All the membranes have an area of 10 10 mm^2, in order to maximize the beam angular acceptance. A schematic representation of the experimental setup used at VERA to test the passive absorber at low energies is given in Fig. 3.

2.3. The high-resolution GIC

The detector installed at the SARA system is a miniaturized GIC manufactured at ETH [7,14]. Such a detector has been conceived for AMS purposes and is characterized by a low-noise design, which makes it particularly adapt to the detection of light ions as ^{10}Be at low beam energies [15,16]. The anode is split in two 5 cm long plates to obtain both ΔE and E$_{final}$ signals and a Frisch grid is placed in front of them. Low-noise CREMAT CR-110 preamplifier modules [27] are mounted directly on the anodic plates through AC coupling in order to minimize the capacitance introduced by cables.

VERA has a GIC based on the same design [28]. This makes the results directly and easily comparable. The only difference is that the GIC anodes at VERA have a length of 3 cm.

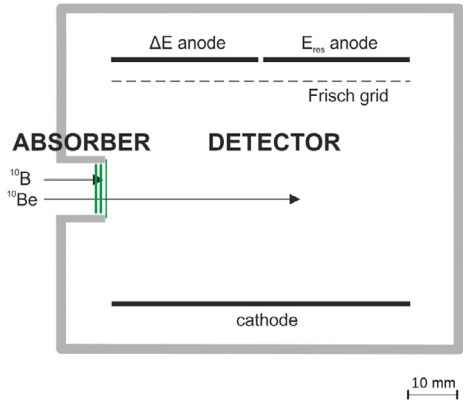


Fig. 3. Schematic representation of the absorber/GIC setup used during the experiments at VERA.

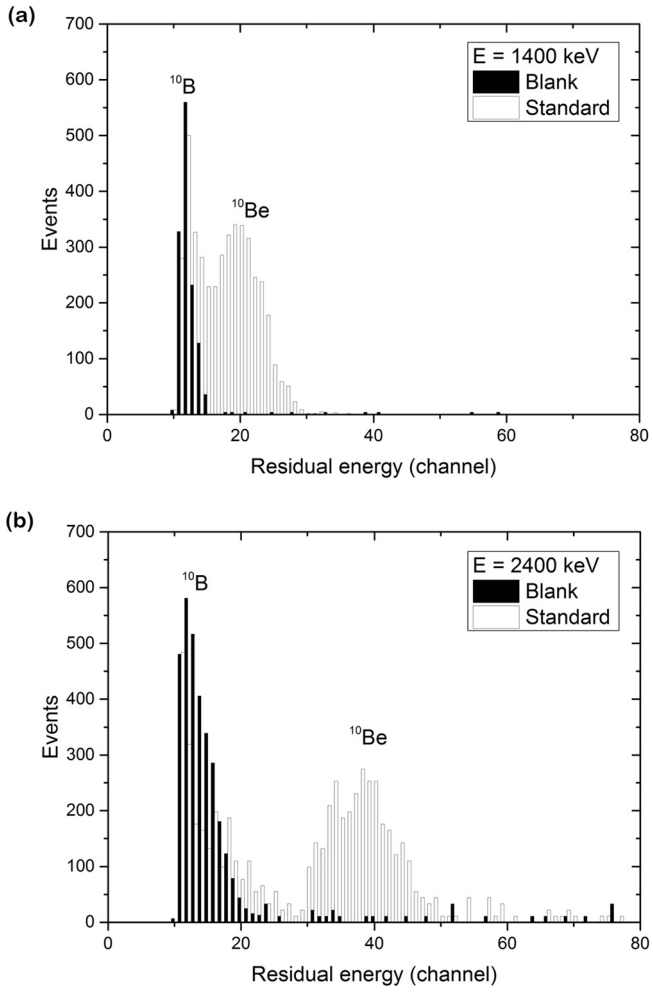


Fig. 4. ^{10}Be and ^{10}B spectra with the gas cell absorber tested at the SARA facility of blank and reference (nominal ^{10}Be/^{9}Be ratio of 2.4·10^{-10}) samples. The ADC threshold was set at channel 10. (a) $^{10}Be^{1+}$, 1400 keV energy. Isobutane pressure of 45 mbar. (b) $^{10}Be^{2+}$, 2400 keV energy. Isobutane pressure of 73 mbar.

3. Results

3.1. Gas cell absorber at SARA

The isobars ^{10}Be and ^{10}B could be clearly identified both at 1400 and 2400 keV in the residual energy spectra (Fig. 4). The absorber/GIC pressures applied during the experiments were high enough to stop both ^{10}B and ^{10}Be ions in the first anode as confirmed by SRIM simulations.

$^{10}Be^{1+}$ arrives into the detector with an energy of 1400 keV. However, the ^{10}B high-energy tail overlaps the ^{10}Be peak, forcing to apply strict cuts to the energy signal or to increase the absorber/GIC gas. By filling the detector with 47 mbar isobutane pressure, it was possible to achieve a complete ^{10}B suppression, but the low-energy fraction of the ^{10}Be peak is lost.

At 2400 keV beam energy, the separation between ^{10}Be and ^{10}B is much better because of the higher energy of the ions (Fig. 4b). ^{10}B could be completely stopped in the absorber by applying an isobutane pressure of 75 mbar without cutting the ^{10}Be peak. However, measurements were complicated by the presence of a severe, continuous background. A ^{10}Be transmission of about 60% through the absorber material was

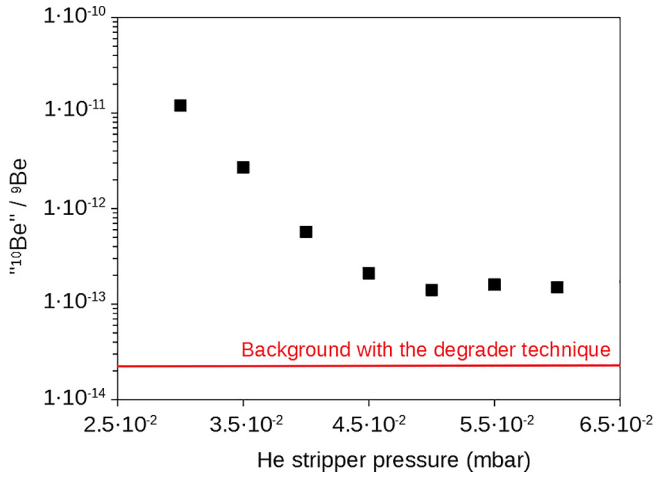


Fig. 5. $^{10}Be^{1+}$ background ratios recorded at SARA with a blank sample as a function of the stripper gas pressure. The background measured with the degrader technique is reported [7]. Blank samples can be measured below the 10^{-16} level at systems operating at higher terminal voltages or equipped with an additional magnet in the high-energy spectrometer [6,13].

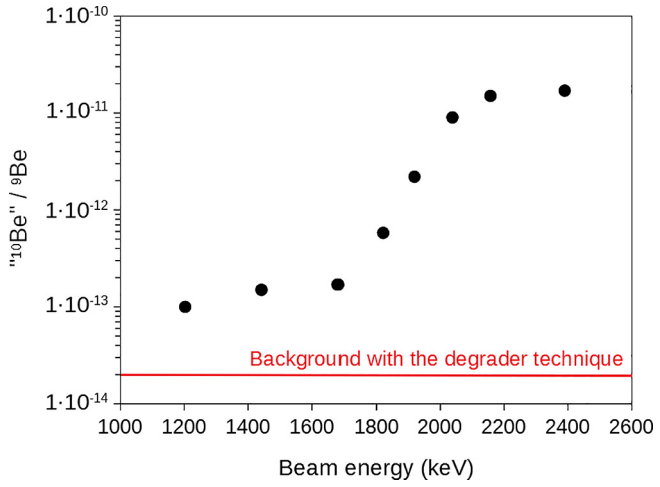


Fig. 6. $^{10}Be/^{9}Be$ background ratios of a blank sample as a function of the beam energy at SARA. The background measured with the degrader technique is reported [7]. Blank samples can be measured below the 10^{-16} level at systems operating at higher terminal voltages or equipped with an additional magnet in the high-energy spectrometer [6,13].

estimated with the high-level standard (nominal $^{10}Be/^{9}Be$ isotopic ratio of $2.4{\cdot}10^{-10}$) kindly provided by the Ion Beam Physics group at ETH.

The different background contributions were investigated and, when possible, minimized. A background source is represented by 10 molecules that survive the stripping process and travel through the HE spectrometer to the absorber/GIC, breaking down in the first SiN window. In the case of $^{9}Be^{1}H$, which is the most abundant molecule, ^{9}Be created in the break-up enters the absorber with about 9/10 of the ^{10}Be energy and reaches the active volume of the detector. Signals generated by ^{9}Be appear in the spectra as background events between the ^{10}B high-energy tail and the ^{10}Be peak. This molecular background is present at both 1400 and 2400 keV; however, it is easily reduced by increasing the stripper pressure to destroy $^{9}Be^{1}H$ molecules in the accelerator and remove ^{9}Be in the HE spectrometer. At 1400 keV the exponential decrease of the background with the applied He stripper gas pressure (Fig. 5) results in full molecular suppression at $5{\cdot}10^{-2}$ mbar. This stripper density corresponds to a 52% transmission of the $^{10}Be^{1+}$ beam through the accelerator.

In this configuration, a 32% transmission through the absorber was obtained and the blank was measured at $^{10}Be/^{9}Be = 3{\cdot}10^{-13}$. Therefore, an overall efficiency of 17% was achieved, which is almost three times higher than the maximum one of 6% obtained at SARA with the degrader technique. The background estimated with the absorber is one order of magnitude higher than with degrader foils [7].

Once the molecular interference was removed, the presence of a continuous background became evident and was extremely intense at 2400 keV (Fig. 4b). $^{10}Be/^{9}Be$ background ratios were estimated at different beam energies, obtained by selecting the 2+ charge state at the accelerator exit with terminal voltage between 0.5 and 1 MV (Fig. 6). A jump of two orders of magnitude was found between 1700 and 2100 keV.

Two different processes might be responsible for this background: (i) the $^{10}B(p,\alpha)^{7}Be$ reaction and (ii) Rutherford scattering of ^{10}B on protons. These two reactions involve the ^{10}B present in the incoming beam and the protons contained in the absorber, which are abundant both in the SiN foils ($Si_3N_{3.1}H_{0.06}$ [20]) and in the isobutane gas (C_4H_{10}).

The $^{10}B(p,\alpha)^{7}Be$ nuclear reaction occurs between ^{10}B and protons and results in α and ^{7}Be particles. Its cross section increases with the projectiles energy in the range studied at the SARA facility [29–31], meaning that the probability for the $^{10}B(p,\alpha)^{7}Be$ reaction to occur is maximal at the first SiN foil of the absorber, since the ^{10}B ions have maximal energies when they hit it. For a 2.4 MeV ^{10}B beam, the resulting α and ^{7}Be have maximal energies of about 3.5 MeV as the reaction Q-value is 1.15 MeV [32]. According to SRIM simulations, if the absorber pressure is 75 mbar, ^{10}B is completely stopped in the absorber volume (in the gas or in the second SiN foil). ^{10}Be passes through the absorber and accesses the detector active area with a residual average energy of 220 keV. The 3.5 MeV α particles produced in the first SiN foil enter the detector with 2.9 MeV energy and are not stopped in the first anode, losing about 2.1 MeV there. The 3.5 MeV ^{7}Be would pass the absorber and enter the chamber with an energy of about 640 keV, which would be completely released into the first anode creating a signal at much higher channels than ^{10}Be. Taking into account that the energy of both products can be lower, both α and ^{7}Be particles could be responsible for background events.

The second contribution to the background is represented by Rutherford scattering of ^{10}B on protons, which are knocked out from the first absorber window with a maximal energy:

$$E_{max} = \frac{4m_H m_B}{(m_H + m_B)^2} \cdot E_B \approx \frac{1}{3} E_B$$

where m_H and m_B are the colliding particles masses and E_B the incoming beam energy. For E_B of 2400 keV, scattered protons in the 500 nm SiN foil have maximal energies E_{max} of about 800 keV. According to SRIM simulations, if the absorber pressure is set at 75 mbar, ^{10}B is completely stopped into the absorber volume whereas ^{10}Be accesses the detector active area with a residual energy of 220 keV. In these conditions, the 800 keV protons produced in the first foil enter the GIC with a residual energy of 630 keV. An evidence of the occurrence of scattering is represented by the peak generated by H entering the detector with the maximal energy, which is normally well visible in the residual energy spectra of 2400 keV beams (Fig. 7). The continuous background at lower channels stems from (i) non-central collisions that generate slow protons and (ii) the interactions at different foil thicknesses where ^{10}B already lost part of its initial energy.

In the energy range between 1400 and 2400 keV and for the examined absorber design, the Rutherford cross section is 3–4 orders of magnitude higher than the one of the $^{10}B(p,\alpha)^{7}Be$ reaction [18], so the Rutherford process is the main source of the observed background.

The Rutherford scattering occurs primarily in the first 500 nm SiN foil. If the beam initial energy is 2400 keV, ^{10}B ions reach the absorber gas volume with a residual energy of 1600 keV, which is high enough to accelerate isobutane protons into the active volume of the detector. An

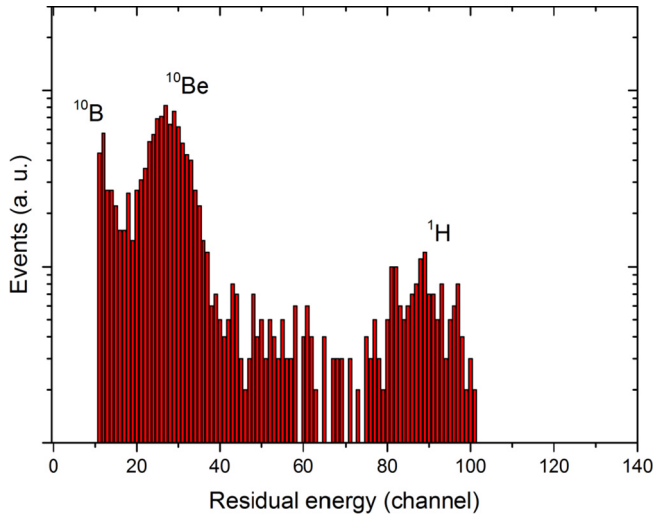


Fig. 7. Residual energy spectrum of a standard sample (nominal ^{10}Be/^{9}Be ratio of $2.4{\cdot}10^{-10}$) acquired at SARA with the gas absorber. The incoming 10 beam carries 2400 keV energy.

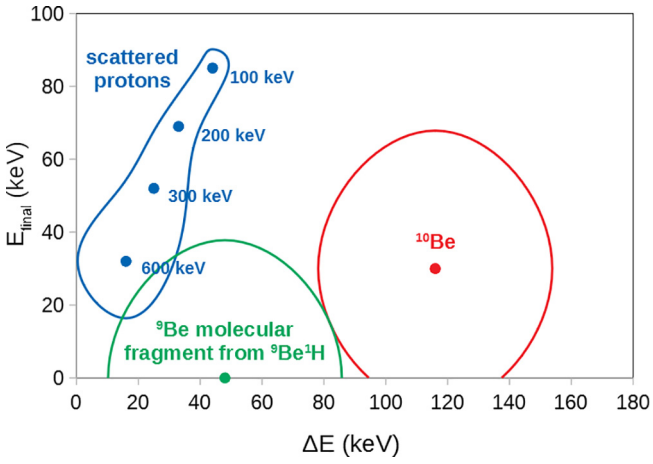


Fig. 9. SRIM simulations of energy losses in the two GIC's sections of ^{10}Be, scattered protons and ^{9}Be molecular fragment from ^{9}Be^{1}H. The isobutane pressure assumed for the simulation was 7 mbar. The FWHMs characterizing the different ions were calculated as the root sum square of the electronic noise, and the energy stragglings in the gas and in the absorber foils.

explanation for the drastically reduced background at beam energies below 1700 keV is that in this case the absorber gas is not such an important contribution because of the too low ^{10}B residual energy. The second SiN window does not contribute to the continuous background because ^{10}B ions have already lost the most of their energy when they hit it.

3.2. Foil stack absorber at VERA

Also in the case of using a stack of foils as passive absorber material, a very good ^{10}B suppression could be achieved. No adjustments to the beam energy were needed, meaning that SRIM simulations provided reliable values for the SiN foil thickness (Section 2.2). By setting a GIC isobutane pressure to about 10 mbar, 2D spectra were acquired at VERA (Fig. 8), where ^{10}Be can be clearly separated from interferences. The total count rate recorded in the first anode was sufficiently low to suggest that ^{10}B ions were completely stopped in the absorber foils. Scattered protons are produced also with the VERA absorber setup and reach the active volume of the GIC with a maximal energy of about 600 keV. However, because of the low isobutane pressure, they are not stopped into the detector and release very little energy in the two GIC

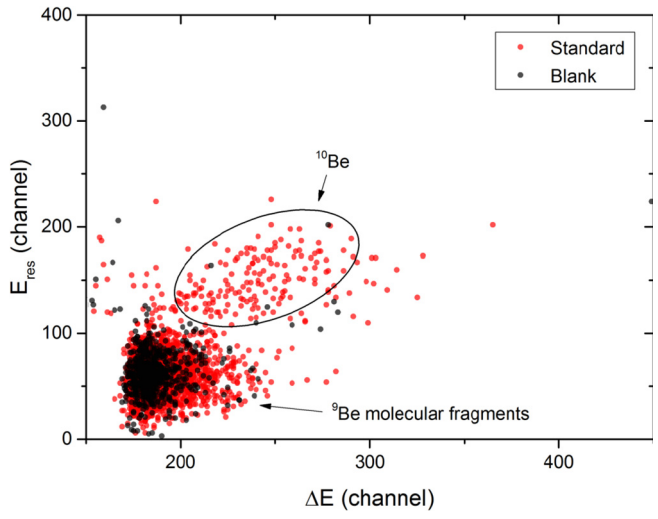


Fig. 8. 2D ^{10}Be spectra acquired at the VERA facility with an absorber constituted of SiN foils at a beam energy of 2400 keV.

sections (about 75 keV in both the 3 cm length anodes), generating signals at low channels that don't interfere with the ^{10}Be detection.

The intensity of the peak that appears in the spectrum at lower channels than ^{10}Be presents a strong dependency on the stripper pressure, and therefore it is identified as ^{9}Be originating from the break-up of ^{9}Be^{1}H molecules in the first absorber foil. To confirm this hypothesis, the energy losses in the two GIC's sections of ^{10}Be, scattered protons at different energies and ^{9}Be molecular fragments were simulated with SRIM (Fig. 9). At an isobutane pressure of 10 mbar, ^{10}Be ions were detected in 2D spectra (Fig. 8), whereas according to SRIM they should be stopped in the first anode. The software, indeed, overestimates energy losses in isobutane at low beam energies [19]. For this reason, the isobutane pressure used for the simulations was 7 mbar.

The energy spread of the ions in the GIC depends on three factors: (i) the preamplifiers electronic noise, (ii) the energy straggling in the absorber foils and (iii) statistics of charge production and collection in the gas. Contributions (i) and (iii) were measured in the ETH GIC for different ions and published in [16,14]. Contribution (ii) can be calculated by applying the semi-empirical Sun's formula [33] and is the most relevant contribution because of the large SiN foil total thickness (2.5 μm). As scattered ions can be produced at different thicknesses, the resulting contribution is lower with decreasing energy. The region where the different ions appear was then identified by calculating the root sum square of the previously listed contributions (i), (ii) and (iii).

The SRIM simulations drive to the conclusion that the signals appearing in the energy spectrum at low channel are ^{9}Be molecular fragments. They represent the main background source since some of those events enter the ^{10}Be gate. A full molecular suppression required the application of too elevate stripper pressures and resulted in a severe efficiency reduction: at a He or Ar stripper pressure high enough to remove the most of the molecules but corresponding to a reasonable beam transmission through the accelerator, the background from the ^{9}Be molecular fragments forced to apply strict selections to the accepted signals. In this configuration, a transmission of about 20% through the absorber with a background ^{10}Be/^{9}Be ratio of few 10^{-14} was measured.

Thus, the experiments conducted at VERA demonstrate that ^{10}Be measurements with a stack of foils absorber are actually possible also at SARA's beam energies. The potential of this technique lies in the fact that the detector efficiency without applying strict cuts is about 75%. Since ^{9}Be molecular fragments are the main cause of background, the use of SiN foils with a smaller area (i.e. less angular acceptance) is expected to be of benefit. Indeed, molecular fragments result from a break-up with some angle relative to the beam direction and necessarily

have a wider angular straggling than ^{10}Be ions. However, further tests and experiments are required to have more quantitative information.

4. Conclusions

The experiments carried out at the SARA and VERA AMS facilities clearly demonstrate the potential of the passive absorber technique for ^{10}Be measurements at 2400 keV beam energy.

Excellent ^{10}B suppression and a good separation from the background was obtained with the stack of foils setup. Nevertheless, the absorber tested during the experiments represents a proof of concept, which provides useful information to enhance the absorber design and make it routinely usable. Further studies are indeed necessary in order to define the absorber foils dimensions and minimize background originated from 10 molecules as ^{9}Be^{1}H.

The detecting system can be further improved to increase the separation between ^{10}Be and ^{10}B. At the extremely low energies of the ^{10}Be ions, CoolFET® preamplifiers from Amptek [34] provide higher resolution than CREMATs, whose characteristics are suitable for the routine operation involving 1–10 MeV ions [14,35,15,16]. Since ^{10}Be accesses the active volume of the detector after passing through the absorber with extremely low energies (100–200 keV), a better resolution is expected by the replacement of the preamplifiers.

This work shows the possibilities of carrying out very efficient ^{10}Be measurements at terminal voltages of 1 MV. The stack of foils setup will be implemented, tested and optimized at the SARA facility, where ^{10}Be^{2+} will be used instead of ^{10}Be^{1+} tested at VERA. As the probability for molecules to pass the stripping process is lower in the 2+ than the 1+ charge state, an improvement in the background is expected.

Still, the pros/cons between the degrader and absorber method is not sufficiently clear. It is at present a matter of trade off between background and efficiency. Further studies are needed to reach definitive conclusions.

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