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Vacuum Window for IBA C18 Twin Cyclotron's Beamline

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Abstract—This article provides data on the development and creation of a vacuum window module, which will bring out the proton beam of the C18 cyclotron (IBA, Belgium) with energy of 18 MeV from a vacuum environment into the atmosphere. The module is made of aluminum and consists of a flange with a collimator and a helium (He) chamber of foil plates cooling. The module was installed at the end of the cyclotron's beam line. Profile measurements were made for various current values of proton beam from 1 to 30 μA. The vacuum window showed its functionality.

Keywords: cyclotron, beamline, beam extraction, vacuum window

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1. INTRODUCTION

Cyclotron C18 (IBA, Belgium) [1] is intended for the production of medical isotopes. The cyclotron is installed at the "RADIOISOTOPE PRODUCTION CENTER" CJSC [2]. For the needs of experimenters of A. Alikhanyan National Laboratory, AANL (Yerevan Physics Institute) a beam output to the experimental hall was organized. For this purpose, a beam line was equipped, ending with a solid-state target module. Many AANL departments and laboratories carry out their research projects there, from isotope production and nuclear physics to materials science [3–6].

But there are some experiments which require an "open" beam (in the atmosphere), including experiments related to research of radioisotopes obtaining. Similar experiments for the production of medical radioisotopes with an extracted beam on a homemade target module were carried out on the linear electron accelerator LUE-50/75 AANL [7–17]. Such a technique has been used in the world for a long time already. Taking into account all these considerations, a vacuum window module was developed and created in the "Department of Research and Production of Isotopes" of the AANL, which allows to release the proton beam into the atmosphere.

2. VACUUM WINDOW

The entire cyclotron and Beam Line is under vacuum; it is done for the proton beam, during acceleration and irradiation of targets, comes across on its way as few particles as possible. A vacuum window that will allow to take out the beam from a vacuum environment into the atmosphere must meet several conditions: the foil of the window must be as thin as possible for the proton beam loses minimal energy in it; the material of the entire module should be, as far as possible, slightly activated during irradiation for ease of subsequent maintenance; the module must be equipped with a collimator for beam formation; the window and collimator must be cooled because the beam falling on them releases heat that must be removed.

Taking as a basis the above criteria and experience in the operation and maintenance of the solid target module of Nirta Solid Compact Model TS06 of the ELEX Comerce company [18], a vacuum window (window module) was developed. The module consists of the following parts (Fig. 1): a flange with a collimator, which allows it to be connected to the output of the beam line, is cooled with water, and is hermetically sealed with a lid. The flange with the collimator and the vacuum window are separated by a Teflon insulator, which allows to read current values from the collimator. It is necessary to regulate the beam to have the best output. The window itself consists of two sheets of stainless steel foil, each as thick as 50 μm, with a helium cooling chamber between them. Pure helium was chosen as a coolant, taking into account its heat transfer characteristics. The collimator hole, which passes through the entire vacuum window, has a diameter of 12 mm.

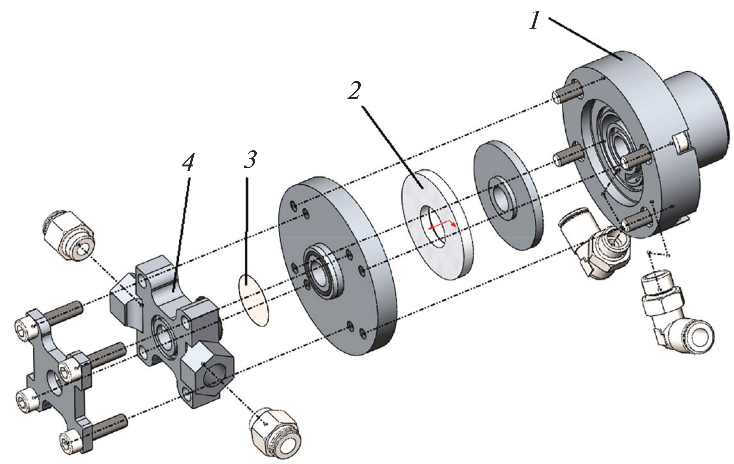

Fig. 1. Vacuum window design: (*1*) collimator-flange, (*2*) insulator, (*3*) window (foil) made of stainless steel, (*4*) helium cooling chamber.

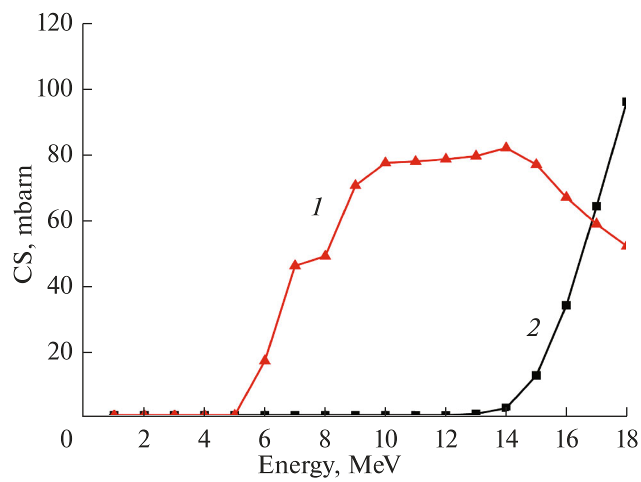

Fig. 2. Cross sections of all possible radioisotopes that are produced in aluminum using the ^{27}Al(p, x) reaction at energies up to 18 MeV: (*1*) ^{27}Si($T_{1/2}$ = 4.7 s), (*2*) ^{26}Al ($T_{1/2}$ = 7 × 10^5 years).

The vacuum window was developed and produced at AANL and installed on the beam line for further testing.

3. MATERIAL SELECTION AND TESTING

The module body is made of aluminum because aluminum is activated very little under a proton beam of a given energy. Only two radioactive isotopes are produced in it: ^{26}Al with a half-life of 7.17 × 10^5 years and ^{27}Si half-life of 4.15 s (Fig. 2). The computations were based on web resource data "TALYS-based evaluated nuclear data library TENDL-2019" [19].

All connections and fittings are made of stainless steel, and gaskets are made of nitrile butadiene rubber (NBR), which does not produce gases in a vacuum. The choice of foil fell on available stainless steel with a thickness of 50 microns. According to computations and simulations using the TRIM/SRIM program [20], a proton beam passing through two sheets of foil and a helium layer loses about 1.5 MeV of energy.

After installation, the module was tested under a 1 μA beam and withstood the load. No deformation or damage to the foil was noticed, heat transfer was normal, there was no water leakage from the collimator, and only a small helium leak was noticed, which was subsequently corrected. After all tests, the beam

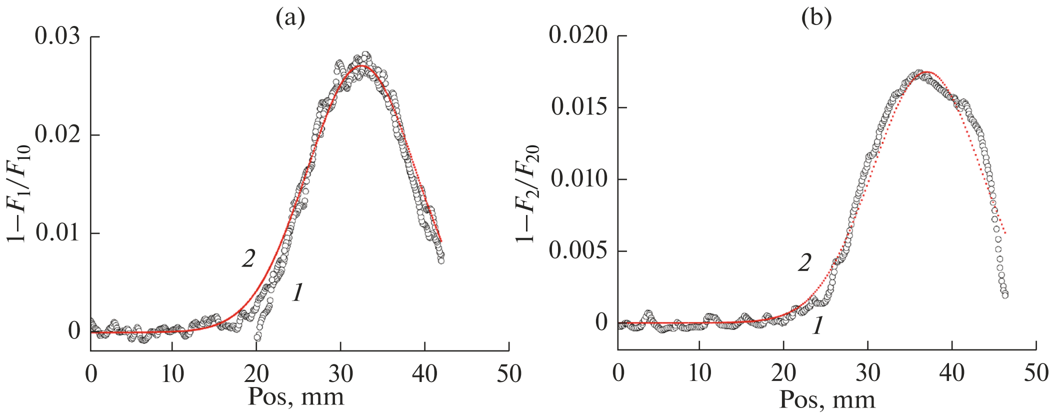

Fig. 3. Beam profile (a) in horizontal and (b) in vertical planes: (*1*) experimental data, (*2*) Gaussian fitting.

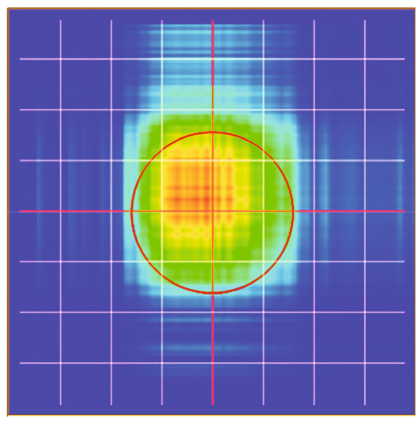

Fig. 4. Reconstruction of the beam profile at a current $I_p = 5\ \mu A$.

profile after the exit out the window module was measured using a vibrating string station [21]. The measurements were carried out at a distance of 62 mm from the end of the module, the results are shown in Fig. 3.

After the module proved its functionality, it was decided to upgrade it so that it would also be possible to measure the intensity of the beam that would pass through the module. The module was equipped with a second current collector which reads the current from the output window for experimenters have all the information about the beam. With this configuration, a three hours test irradiation was carried out; the beam current varied from 1 to 30 μA with steps every 5–6 minutes of 1 μA. The module withstood all the loads, the foil sheets were not damaged. During irradiation, the beam profile was also measured at different intensities. It was noticed that without any operator intervention in correcting the beam's position at cyclotron switching on its center was shifted when one looks at the beam to the left and up (Fig. 4).

4. CONCLUSION

A vacuum window module has been developed and tested to extract a proton beam with the energy of 18 MeV from the beamline of the C18 cyclotron (IBA, Belgium) into the atmosphere. Materials such as aluminum for the module body, and all gaskets and fittings were chosen correctly, but in the future, there are plans to try other materials for the foil instead of stainless steel. The irradiations showed that the module can withstand a beam intensity of up to 30 μA. This module is the first step in the development of special equipment for the cyclotron and the beamline by the Isotope Research and Production Department. The experience gained while working on this device helped to identify possible problems that may arise during the design of subsequent devices, such as modules with autoloading target materials and other special target modules.

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CONFLICT OF INTEREST

As author of this work, I declare that I have no conflicts of interest.

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