



Development and test of a cryogenic trap system dedicated to confinement of radioactive volatile isotopes in SPIRAL2 post-accelerator

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ABSTRACT

A cryogenic trap system called Cryotrap has been studied and developed in the framework of nuclear safety studies for SPIRAL2 accelerator. The main objective of Cryotrap is to confine and reduce strongly the migration of radioactive volatile isotopes in beam lines. These radioactive gases are produced after interaction between a deuteron beam and a fissile target. Mainly, Cryotrap is composed by a vacuum vessel and two copper thermal screens maintained separately at two temperatures $T_1=80$ K and $T_2=20$ K. A Cryocooler with two stages at previous temperatures is used to remove static heat losses of the cryostat and ensure an efficient cooling of the system. Due to strong radiological constraints that surround Cryotrap, the coupling system between Cryocooler and thermal screens is based on aluminum thermo-mechanical contraction. The main objective of this original design is to limit direct human maintenance interventions and provide maximum automated operations. A preliminary prototype of Cryotrap has been developed and tested at GANIL laboratory to validate its design, and determine its thermal performance and trapping efficiency. In this paper, we will first introduce briefly SPIRAL2 project and discuss the main role of Cryotrap in nuclear safety of the accelerator. Then, we will describe the proposed conceptual design of Cryotrap and its main characteristics. After that, we will focus on test experiment and analyze experimental data. Finally, we will present preliminary results of gas trapping efficiency tests.

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1. Introduction

SPIRAL2 is a rare isotope accelerator that will be installed at GANIL Caen laboratory next few years [1]. This machine is dedicated for the production of high intensity radioactive ion beams using ISOL technique (Isotope Separation On Line). SPIRAL2 facility is based on a high power superconducting driver LINAC delivering mainly a deuteron beam with 5 mA intensity and 40 MeV energy. Other varieties of heavy-ion beams are also accelerated at energies up to 14.5 MeV/u with high intensities. Radioactive beams are produced by irradiating a target system composed of a carbon converter maintained at 2000 °C and a high density Uranium source (UCx). This reaction produces neutrons with a high fission rate that can reach 10^{14} per second. Fission products of different reactions are then scattered out of the target, ionized, separated on line and post-accelerated into the existing CIME cyclotron at GANIL (Fig. 1). Obtained secondary radioactive beams will be used in different experimental areas to perform many experiments in a wide range of neutron and proton rich

nuclei far from the line of stability besides various applied and multidisciplinary physics [2].

Produced fission species from target irradiation reactions create strong radiological and environmental constraints that lead to many challenges in accelerator nuclear safety studies [3]. These studies are very important because activity in the target after 90 days irradiation will be about $4 \cdot 10^{14}$ Bq with more than 65% in a volatile state at 2000 °C [4]. Therefore, large quantities of toxic and undesirable radioactive volatile species can contaminate beam lines, vacuum system and experimental areas. That is why a dedicated cryogenic trap system named Cryotrap has been developed to confine these species and protect accelerator from a general and uncontrollable contamination. Study, design and fabrication of Cryotrap have been made within collaboration between GANIL and IPN ORSAY laboratories. It will be installed in an enclosed zone called SPIRAL2 production building near target ion source system.

2. Main characteristics of Cryotrap system

The main goal of Cryotrap is to reduce considerably and confine radioactive volatile isotopes near SPIRAL2 target ion source system.

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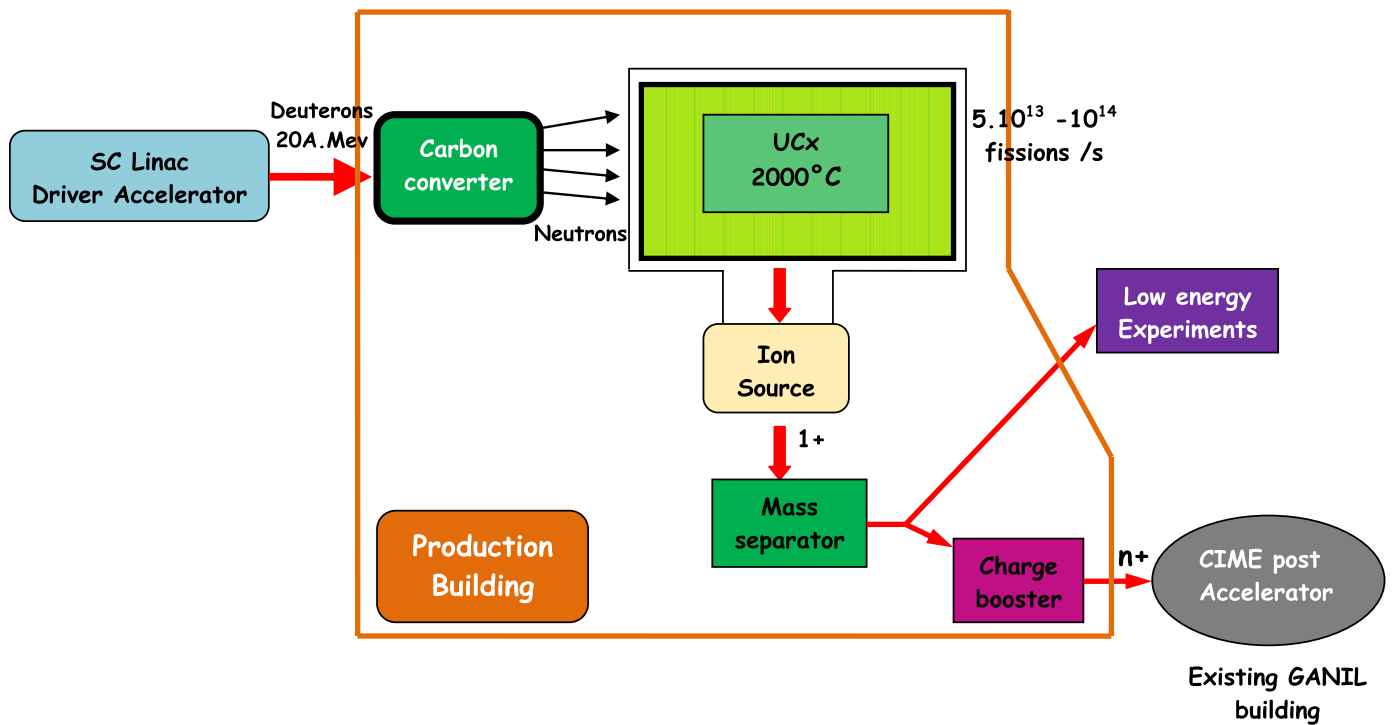


Fig. 1. Schematic view of radioactive beams production process.

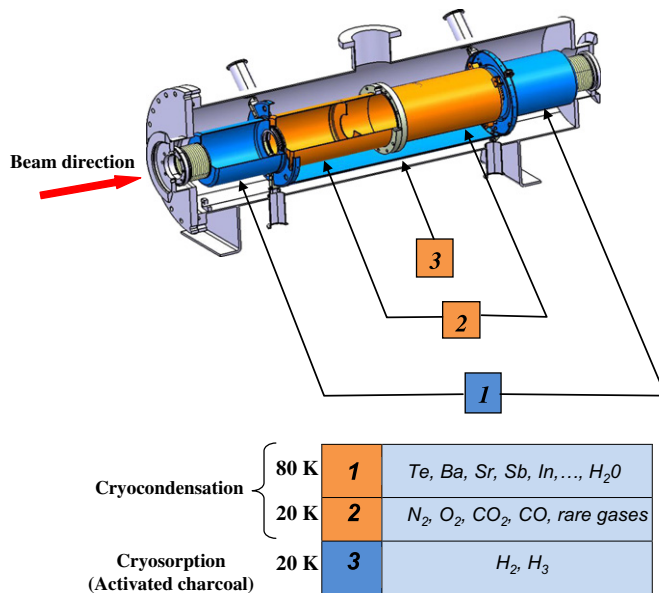


Fig. 2. Cryotrap system and trapped gases for each temperature.

It uses mechanism of cryo-condensation and cryo-sorption to capture efficiently undesirable molecules on surfaces maintained at cryogenic temperatures [4]. Preliminary nuclear safety studies of SPIRAL2 accelerator [6] specify that Cryotrap should reach a trapping efficiency of 99.9% for high level radioactivity gases.

Cryotrap will be composed of three separated trapping areas (Fig. 2) corresponding to different temperatures of condensation for most volatile isotopes [5]. First and second trapping areas should be cooled at temperatures lower than 80 K and 20 K. The central trapping surface will be covered by active charcoal and maintained at 20 K to capture Tritium by cryosorption. A cylindrical shape of trapping surfaces has been chosen to ensure maximum probability of retention for most volatile species.

3. Cryotrap conceptual design

Many references show that cold trapping systems has been developed and used in accelerators for nuclear safety and radio-protection purposes. MAFF project [7] has used aluminum Cryo-panel to confine radioactive gases near their fission source using helium gas at temperature around 10–15 K provided by a dedicated liquefier. KATRIN experiment [8] has used a special liquid helium cryostat to cool down trapping surfaces at 4.2 K to trap Tritium.

Many technical solutions have been proposed to cool down Cryotrap for SPIRAL2 accelerator. The most interesting solution was to use cryogenic fluids (helium gas at 20 K, liquid nitrogen at 80 K) and heat exchangers to cool down trapping surfaces. But, this solution has the following disadvantages:

- Nuclear safety directives do not accept that a cryogenic fluid circulates between a normal area and highly radioactive area. The reason is the transformation of helium gas into Tritium, which is very dangerous when it is inhaled accidentally.
- Access and manipulation of cryogenic system during maintenance or failures is a very difficult task especially in an enclosed zone like production building.
- All apparatus in the production building must be tele-operated by special robots and complex operations like manipulation of cryogenic connectors are extremely difficult to be done.
- A dedicated helium liquefier is necessary to have continuous cold helium gas production, which increases considerably the cost.

These reasons lead to adopt an original solution that consists of using a thermal coupler that contracts naturally at low temperatures to ensure connection between a Cryocooler and trapping surfaces. In fact, this solution offers two cold sources at 80 K and 20 K delivered by one Cryocooler, which is certainly less expensive than a liquefier. This solution provides also other advantages like tele-operability and autonomy.

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