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Constraints due to the production of radioactive ion beams in the SPIRAL project.

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Abstract

The radioactive ion beams that will be delivered by the SPIRAL facility will be produced by the interaction of a stable high energy (95 MeV/A) and high intensity ($2\ 10^{13}$ particle/s) primary ion beam delivered by the GANIL cyclotrons with a carbon target heated to 2000°C. During this interaction, some radioactive atoms will be created and will diffuse out of the target before entering into an electron cyclotron resonance ion source where they will be ionized and extracted.

The production of radioactive ion beams with this method implies high radiation fields that activate and can damage materials located in the neighborhood of the target. Therefore, the production system which is composed of the permanent magnet ECR ion source coupled to a graphite target will be changed after two weeks of irradiation. As this ensemble will be very radioactive, this operation has to be supervised by remote control. The radiation levels around the target-ion source system and a detailed description of the different precautions that have been taken for safety and for prevention of contamination and irradiation are presented.

Introduction

The SPIRAL project consists of the production of short time radioactive ion beams by bombarding a thick carbon target with a very energetic stable ion beam (called the primary beam) provided by the GANIL cyclotrons. During this interaction, some radioactive atoms are created and stopped inside the target. Depending on their chemical properties, some of them will diffuse out of the target before entering in an ECR ion source where they will be ionized and extracted. This beam (called the secondary beam) is then accelerated by a dedicated cyclotron and delivered to the experimental areas.

1-Description of the production system

In the first phase of SPIRAL, it is planned to produce the following noble gases radioactive ion beams: $^{6,8}He$, $^{17,18,19,23,24,25,26}Ne$, $^{32,33,34,35,41,42,43,44,45,46}Ar$ and $^{72,73,74,75,76,77}Kr$. These beams will be obtained by impiging a carbon target with one of the following beams: ^{78}Kr (70MeV/A, 2 10^{11}pps), ^{48}Ca (66MeV/A, 2 10^{12}pps), ^{36}Ar (95MeV/A, 1 10^{13}pps), ^{36}S (77MeV/A, 1 10^{13}pps), ^{20}Ne (95MeV/A, 2 10^{13}pps), ^{13}C (82MeV/A, 2 10^{13}pps).

The target has to resist the high power (6kW) deposited by the primary beam. A specially shaped conical sliced target has been calculated and successfully tested at Louvain La Neuve with 6 kW of a 30 MeV proton beam(1). This shape allows keeping the target at a high temperature (2000°C) that favors the exit of the radioactive atoms. In case of a decrease of primary beam intensity, ohmic heating can be added to maintain a constant target temperature.

The target is coupled via a transfer tube with a totally permanent magnet ECR ion source, called Nanogan 2 (see figure 1). This compact source has been designed with two goals in mind. The first one is to produce the same ionization efficiencies as the other classical ECR ion sources. The second one is to minimize the size of the target ion source system in order to decrease the volume of the lead containers in which the system will be stored after irradiation. This source has already been described in detail in ref. 2. The ensemble is composed of the source and the target and is called a target- ion source system (TISS).

The TISS is connected to two front ends: the high energy front end (HEFE) in which the primary beam passes and the low energy front end (LEFE) which allows extraction and optical adaptation of the secondary beam. (see fig. 2).

2 Radiation levels around the target ion source system.

During interaction of the primary beam with the target, a lot of high energy particles and specially neutrons are produced. These high velocity neutrons present a long range in matter and activate the materials along their path[3]. The energy and the density of neutrons depend on the angle with the primary beam axis (see fig. 3). The highest energy and density of neutrons are predicted to be emitted in the direction of the primary beam. For this reason the target has been placed in such a way as to minimize the materials under neutron flow and the first magnet of the source is located at an angle greater than 90°.

After irradiation, it subsists in the cave a gamma radiation delivered by the materials activated by neutrons and by the irradiated target. The figure 4 shows an example of the calculated gamma dose rate 44 cm in front of the target. High levels, such as $6\ 10^4\ \mu Sv\ h^{-1}$ are obtained just after irradiation and forbid any manual operation of the ensemble. For this reason a remotely controlled removal system was studied and built.

3 Choice of materials

Irradiation of some materials, especially polymers, can lead to modifications of mechanical and chemical properties and these reduce the reliability of the equipment which they constitute. Whenever it has been possible, the polymers have been replaced by metallic materials. Ceramic materials and polyurethane that provide strong resistance to radiation (see ref. 4) have been chosen when the use of metallic material was impossible (insulation problems for example).

For the mechanical part of the design, aluminium is preferred to stainless steel and copper materials because its irradiation by neutrons creates less long life time elements[3]. This necessitates the use of ethylene-propylene orings on the different vacuum chambers.

4 Reliability

It is obvious that a system placed in high radiation fields must be reliable. To increase the reliability of our system, we have taken into account the resistance of materials under radiation, their position and their screening, the quick dismounting possibility and the coast.

The first idea was to locate out of the casemate all the elements that were not indispensable near the TISS. So the primary mechanical pumps, the valves located on the primary pumping circuit, the gauges, the air distributors of the valves located inside the casemate, the motors for the connection- disconnection of the TISS, and all the electronics and power supplies have been placed outside the casemate. Only the turbomolecular pumps, the cables and the air or water connections subsist inside the cave.

The switches of the movements are tripled. The first one is located inside the cave while the second one is outside the cave. These two switches are connected to a programmable logical computer. A third switch can stop directly the power supply to the motor.

Two turbomolecular pumps have been installed with valves on each front end that allow , in case of a breakdown of one of these pumps shuting down the valve and keeping the pump under primary vacuum without stopping radioactive ion beam production.

Inside the cave, when it was possible, the elements were placed as far as possible from the target and in the back most neutron emission hemisphere.

5 Contamination and irradiation risks

During production, some radioactive gases are produced and pumped by the vacuum system. In order to limit the amount of radioactivity thrown out in the air, the gas rejected by the primary pumps is stocked in bottles. A system devoted to this problem is continually under studies.

In such systems where a target is activated by primary beams, the risk of dispersion during the disconnection of radioactive elements in the air is present. To limit this risk, the TISS and the front end are closed by valves before any disconnection is begun. The volumes between the valves of the front end and the valves of the TISS, called sas in fig. 2, are aired and controlled by a dedicated detection system before being disconnected.

After the disconnection and removal of the TISS, the two front ends can be removed for maintenance. In order to minimize the dissemination of contamination , a double valve was installed at the entrance of the HEFE and at the exit of the LEFE that permits closure of the chambers before removal and transfer to an area specially adapted to handle contaminated objects.

The removal operation of the front end needs human intervention. To limit the exposure time of workers in the cave to this operation, all electrical, air and water connections of each front end have been joined together on a quick connector. Vacuum disconnections are realized by quick flange clamps.

In the event of a catastrophic contamination dispersion inside the cave precautionary measures such as covering the walls, the ground and the benches with special radio resistant and noncontaminable epoxy coatings used in nuclear plants and installing a nuclear ventilation system have been taken.

References

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(2) - P. Sortais et al, Proc. of the 6th Int. Conf. on Ion Sources, RSI 67 (1996) 867-872

(3) - F. Clapier et al, Proc. of 2nd specialist meeting on shielding aspects of accelerators, targets and irradiation facilities, OECD/NEA/NSC, 12-13 October 1995, CERN Switzerland

(4) - CERN report, Compilation of radiation damage test data, H Schönbacher and M. Tavlet, Geneva 1989.

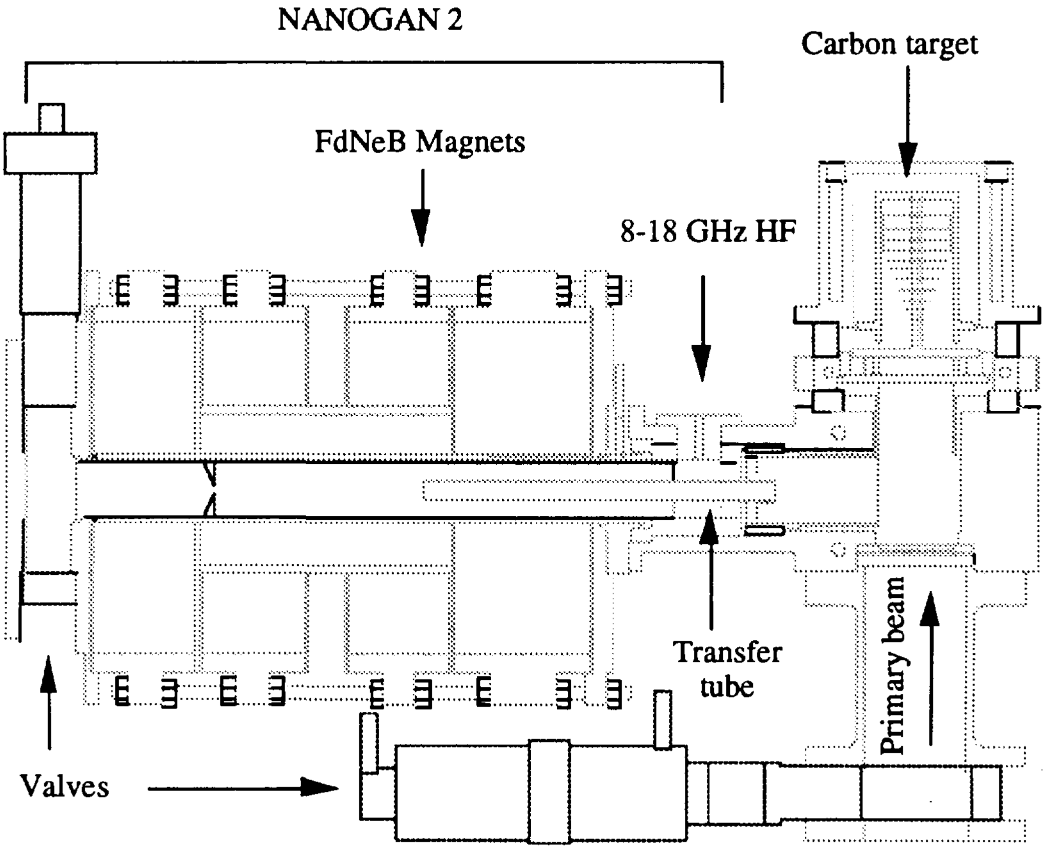

Figure 1: the target ion source system (TISS)

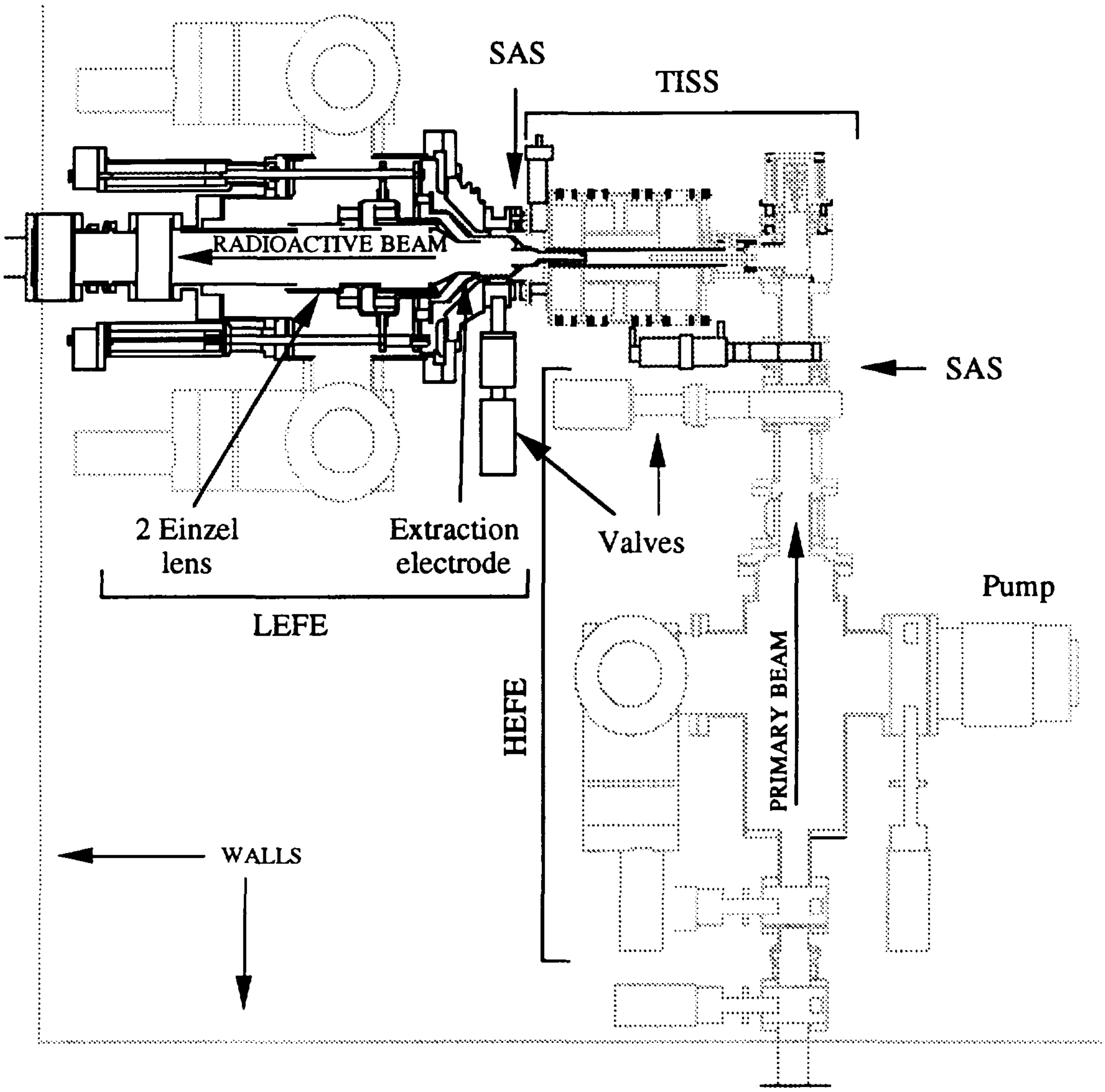

Figure 2: The elements located inside the production cave.

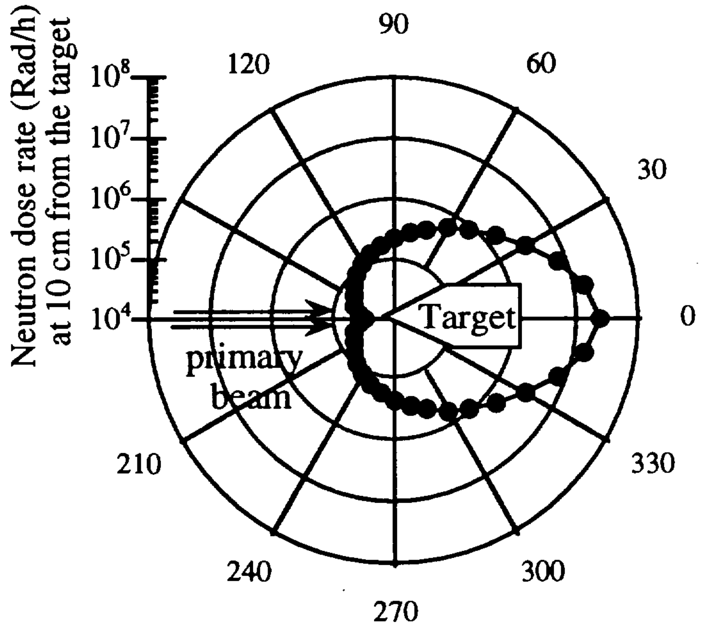

Figure 3: Angular neutron dose rate distribution 10 cm from the target.

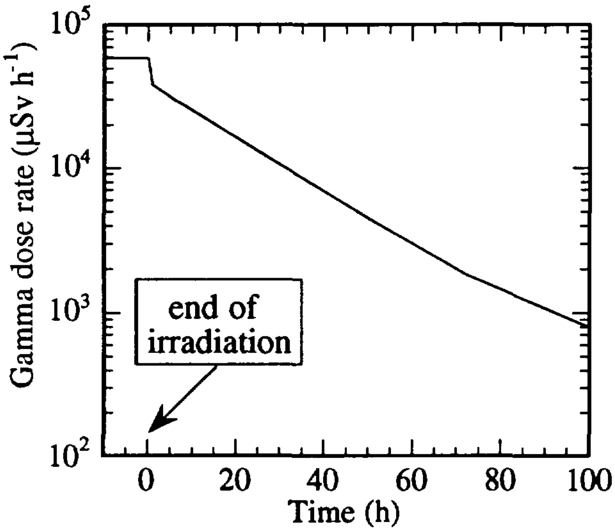

Figure 4: Gamma dose rate after 15 days of irradiation at 47 cm from the target for ^{36}S (77MeV/A, 1 10^{13}pps)-> ^{12}C