DESIGN OF A CHANNEL FOR IRRADIATION OF SOLID TARGETS

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The channel for production of radioisotopes of the TESLA Accelerator Installation will have three subchannels - for the irradiation of solid, liquid and gaseous targets. The subchannel for the irradiation of solid targets is fully automatic, and its main parts are: (1) the ion beam line, (2) the ion beam diagnostic unit, (3) the target station, (4) the target transporting system, (5) the target receiving system, and (6) the safety and control system. The solid target station can accept two types of targets: (a) the high ion beam current targets - for the routine production of radionuclides, and (b) the low current targets - for the experimental production of radionuclides. The receiving system is placed outside the shielding vault and it enables the packing of the irradiated target into a lead container, the insertion of the target into a hot cell, or the manual operations with the target, if its radioactivation is low. The subchannel will be being used for the routine production of γ-emitters ^{201}Tl, ^{111}In and ^{67}Ga, and for the experimental production of long lived positron emitters.

1 Introduction

The VINCY Cyclotron is designed to be a multipurpose accelerator and it will be an irreplaceable tool for gaining research work in the fields of nuclear and atomic physics, radiation chemistry, biology and physics, and medical applications [1-3]. Nearly 50% of its beam time will be used for medical applications: partly for proton therapy, and mainly for the production of radionuclides for medical purposes [4].

The concept of the channel for production of radionuclides (channel H4) was made taking into account the needs of the medical community in the southeastern region of Europe, the existing infrastructure and know-how of the Vinča Institute of Nuclear Sciences (where the installation is situated), and the technical characteristics of the VINCY Cyclotron. It has been decided that the channel for production of radioisotopes has to provide the routine production of ^{201}Tl, ^{111}In, ^{67}Ga, ^{123}I and ^{18}F, and a number of other radionuclides for experimental purposes. The production of radionuclides will be achieved in fully automatic target stations for irradiation of solid, gaseous and liquid targets. The gaseous and liquid target stations will be dedicated for routine production of ^{123}I and ^{18}F only, while the solid target station will be used for activation measurements and experimental production of long lived positron emitters as well.

2 Engineering design of the channel

2.1 Design principles

The design of this channel was directed by the following principles: a) the routine production of radionuclides has to comply with the GMP regulations for the production of radiopharmaceuticals, b) its operation has to comply with the ALARA principle concerning radiation safety (there must be no need to enter the shielding vault for preparing the targets before and after irradiation), c) the scheduled maintenance work should be minimized, and d) the design of the solid target station has to enable the routine production of radionuclides, as well as the irradiation of different targets for experimental purposes without making any changes to the station.

The main parts of the channel are: (1) the ion beam lines, (2) the ion beam diagnostic units, (3) the target stations, (4) the target transporting systems, (5) the target receiving systems, and (6) the safety and control system. The engineering design of the target station for irradiation of solid targets has been accomplished and its fabrication will start in the first half of 1998. Its main parts will be elaborated in more detail to highlight the design philosophy of the whole channel.

2.2 The ion beam lines

The first element of the beam line in the shielding vault for production of radioisotopes will be a neutron blocker, to ensure safe maintenance work in the vault while the cyclotron delivers the beam to other channels [5].

The ion beam lines of the channel for production of radioisotopes will consist of three sections: one straight section delivering the beam directly from the Cyclotron to the solid target station (≈20 m), and two bended sections created by a ±27° switching magnet, delivering the beam to the gaseous and liquid target stations. The straight section will be able to deliver any beam extracted from the Cyclotron to the solid target (light and heavy ions) in order to provide a versatile tool for activation measurements in addition to the routine production of radionuclides for medical purposes.

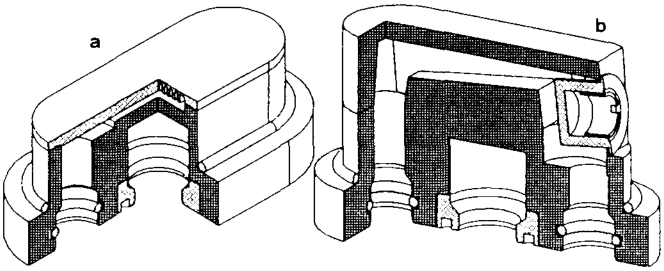

Figure 1: Sections through high power electroplated target (a) and low power target for irradiation of solids and stacks of foils (b).

Four diagnostic boxes will be installed along the beam lines: one in front of the switching magnet and one in front of each target station. These diagnostic units will consist of a beam viewer (scintillator), collimator and Faraday cup, and they will serve as pumping stations as well.

2.3 Targetry

The solid target station will be able to accept targets designed both for 7 and 90° irradiation geometry. The targets used for routine production will be prepared by electroplating on a silver substrate (Fig. 1a). They can be irradiated with a 1.5 kW beam using the 7° geometry. The cooling of these targets is enhanced by fins on the back side of the silver substrate designed so that the highest temperature on the surface of the target will not exceed 110 °C. The targets designed for irradiation under a 90° geometry (Fig. 1b) will be used for experimental purposes only. They can be used for irradiation of stacks of foils or pressed tablets with 50 W beams.

The targets will be equipped with NBR gaskets (for sealing between cooling water and air, and vacuum in the irradiation chamber and air) that will be replaced before each irradiation. The outer surface of the targets will be covered by a layer of Al_2O_3 in order to electrically insulate them from the vacuum chamber, for on-target beam current measurements.

2.4 Target station

The solid target station will be placed in a shielding vault (Fig. 2) together with a gaseous and liquid target station. Its main parts are: 1. the transport carriage station; 2. the manipulator; 3. the irradiation chamber; and 4. the target cooling system (Fig. 3).

The trolley based transport carriage can carry two targets at the same time. The carriage station has two positions for allowing the access to both targets by the manipulator. This way, in only one run it can bring the new target for irradiation and take away the irradiated target.

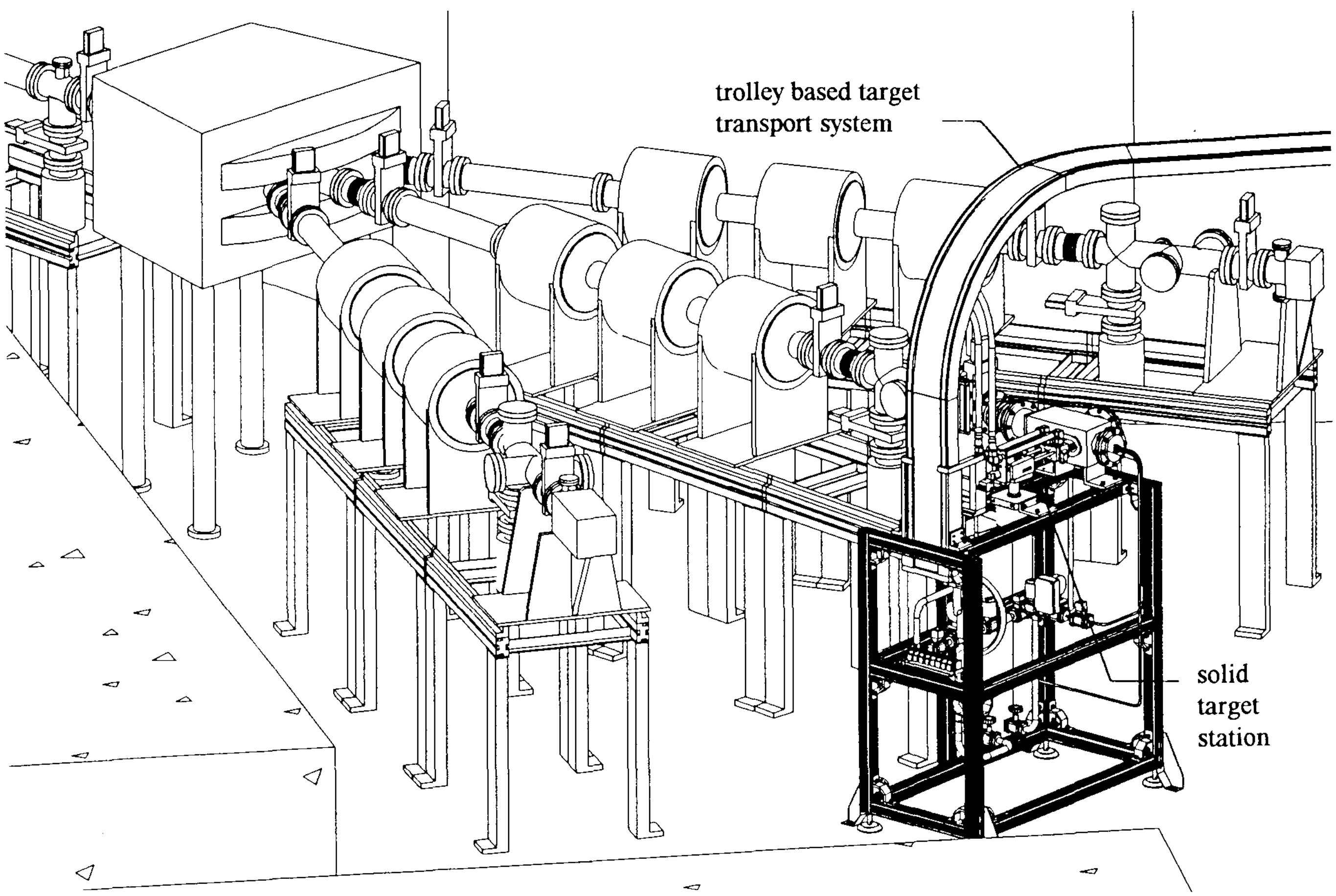

Figure 2: The solid target station positioned in the target area of the channel for production of radioisotopes.

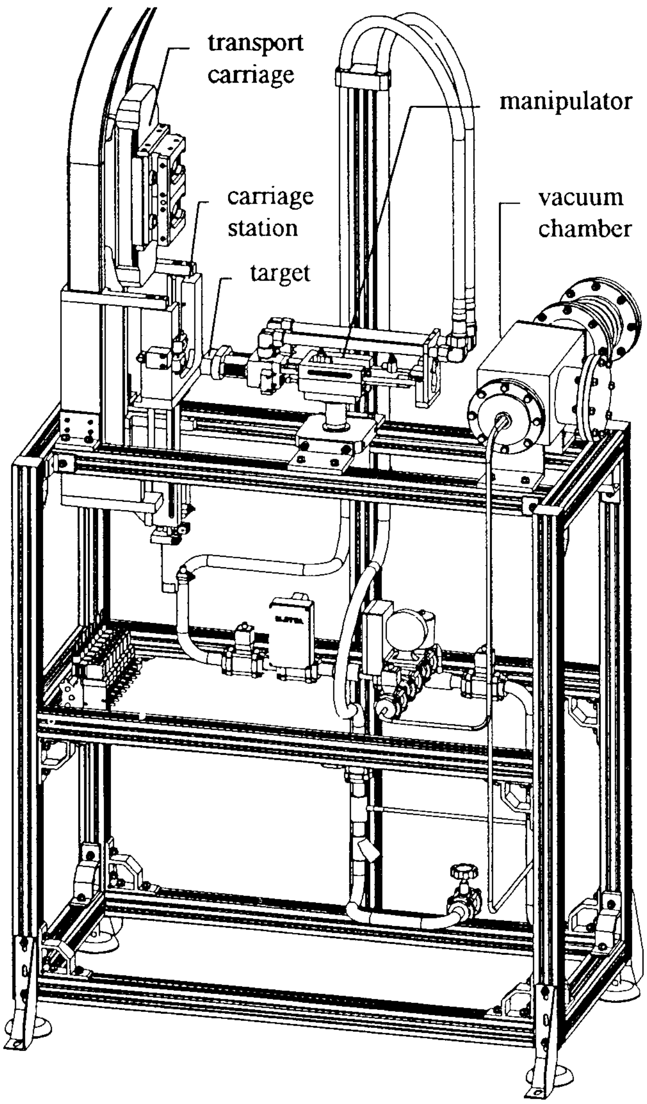

Figure 3: The solid target station

This feature is useful for the production of several consecutive batches of short lived nuclides for experimental purposes. The trolley based transport system was selected due to its flexibility in case of future upgrades: the weight, size and shape of the targets is limited by the duct in the shielding vault only.

The manipulator, driven by pneumo-cylinders, will lock and remove the target from the transport system, place and hold it in the vacuum chamber, and provide cooling during the irradiation. After inserting the target into the vacuum chamber, the gate valve in front of the target will be opened, and it will be evacuated through the beam diagnostic box.

There is a specially designed electron deflector inside the vacuum chamber, placed in front of the target, for precise on-target beam current measurement, simulating a Faraday cup. The vacuum chamber has also a flange in front of the target, for mounting an infra-red target temperature measuring device.

The targets will be cooled by deionized water, 20 $dm^3 \cdot min^{-1}$ at 24 °C. The inlet pressure, flow and temperature of the cooling water will be continuously monitored during the irradiation. After the irradiation, the cooling water will be blown out from the target by compressed air, the manipulator will remove the target from the vacuum chamber and place it in the transport carriage.

2.5 Target transport

The targets will be transported to the target station for irradiation and back, from a service station placed in a small hot laboratory bellow the shielding vault, using a trolley based transport system. In order to decrease the radiation induced activation of the transport carriage, it will be parked outside the shielding vault during the irradiation.

This service station (Fig. 4) can remotely place the irradiated target into a transport container in order to transport the target into the hot laboratory facility (situated 200 m from the VINCY Cyclotron) for further processing. In addition, it can insert it directly into a hot cell situated near the service station via an air-lock, or to allow for manual handling of the target. Using this versatile service station, the targets can be launched for irradiation from three different positions: from the hot cell, from the transport container, or from a manual position.

2.6 Safety and control system

The target station, the service station and the transport system will be controlled by a PC based control system. This system will be integrated into the control system of the TESLA Accelerator Installation. However, it will act independently and its functioning cannot be affected by the central control system.

The targets will be coded by holes on their back and the manipulator head will have several microswitches for decoding. This way, the control system can recognize if the target is locked correctly by the manipulator. In addition, the control system can distinguish between different target types, enabling the operator to cross-check the correctness of the irradiation procedure and to automatically generate the irradiation protocol according to GMP requirements.

The safety system will be redundant and the safety interlocks will be hard wired to a Faraday cup to stop the beam before the Cyclotron in case of a malfunction during irradiation.

3 Conclusion

The engineering design of the channel for production of radioisotopes is completed. Its design fulfilles the requirements set up by the concept of this channel. Its

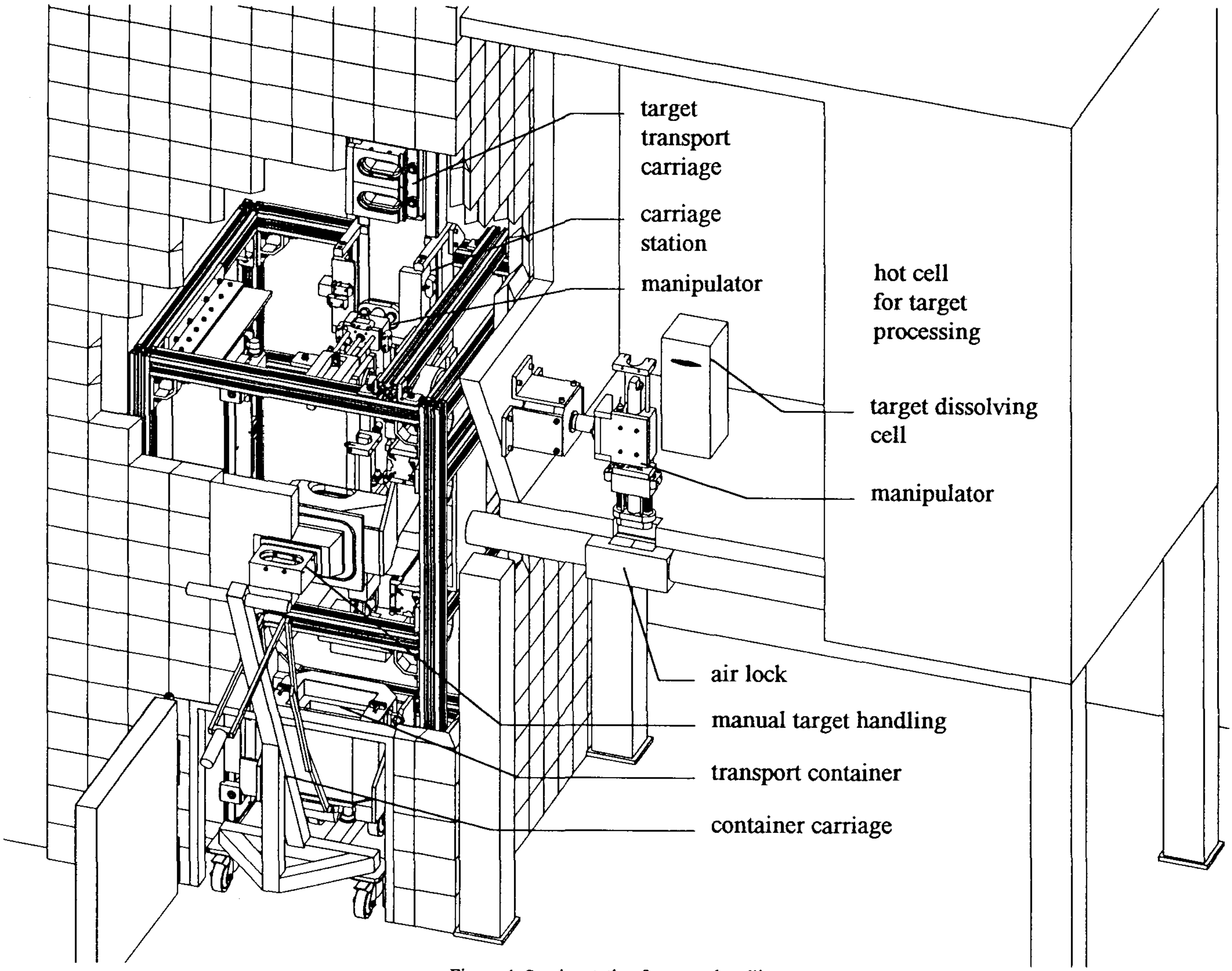

Figure 4: Service station for target handling

construction will provide a versatile tool for both routine production of radioisotopes and research and development work in this field. The routine production of radionuclides (^{201}Tl) with this target station at the TESLA Accelerator Installation using the VINCY Cyclotron is expected to begin in 1999. The experimental production of ^{67}Ga and ^{111}In, as well as a research project related to the production of long lived positron emitters and labeling of new radiopharmaceuticals will commence in the second half of 1999.

4 References

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