A flexible remote controlled target system

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Introduction

The cyclotron used for the production of short-lived positron emitting radionuclides is inside the nuclear physics research facility, the Kernfysich Versneller Instituut (KVI), of the University of Groningen. The distance between the University Hospital and the KVI amounts to 5 km. The maximum energy available on this cyclotron is given by $E_{max} = 160\ q^2/A$, with q the charge state and A the mass number of the accelerated ions. For protons, however, the maximum energy is limited to 65 MeV. At the KVI the Department of Nuclear Medicine operates the irradiation cell, the radiochemical laboratories, both high and low level and the Positron Emission Tomography facilities. Since all kinds of experimental facilities are available in the extended beam guiding system, only one irradiation facility is available. In order to have an optimum use of the available beam time, normally 8 hours/week in one shift, a flexible remote controlled target system is prerequisite. To meet these demands a target system was designed with which it is possible to change targets within two minutes, independent of radiation levels. The radioactive products from gastargets can be directed to the individual fume hoods in both, the high and the low level, laboratories. Irradiated fluids or solid state targets can be transported to the high level laboratory by an electric transport system.

Beam transport

The beam lay out of the KVI is shown in figure 1. To reach the irradiation cell, the G cell, the extracted beam is transported via the X-line , switching magnet SM and S-line into G-line. The different slits in the S-line, a beam line normally used to increase the energy resolution of the beam by the analyzing magnet (AM), are set at their maximum opening. With a vertically parallel beam it is possible to enter the G-line without beam losses. The remanent magnetism of the analyzing magnet is compensated for by a small reverse current through the magnet coils. With the quadrupole doublet the beam spot at the end of the G-line can be controlled. The minimum spot size is 2 x 4 mm^2. Due to the limitation in vertical size inside the analyzing magnet the beam is diverging in the horizontal plane. For this reason the diameter of the beam pipe after the analyzing magnet has been increased from its standard value of 50 mm to 70 mm.

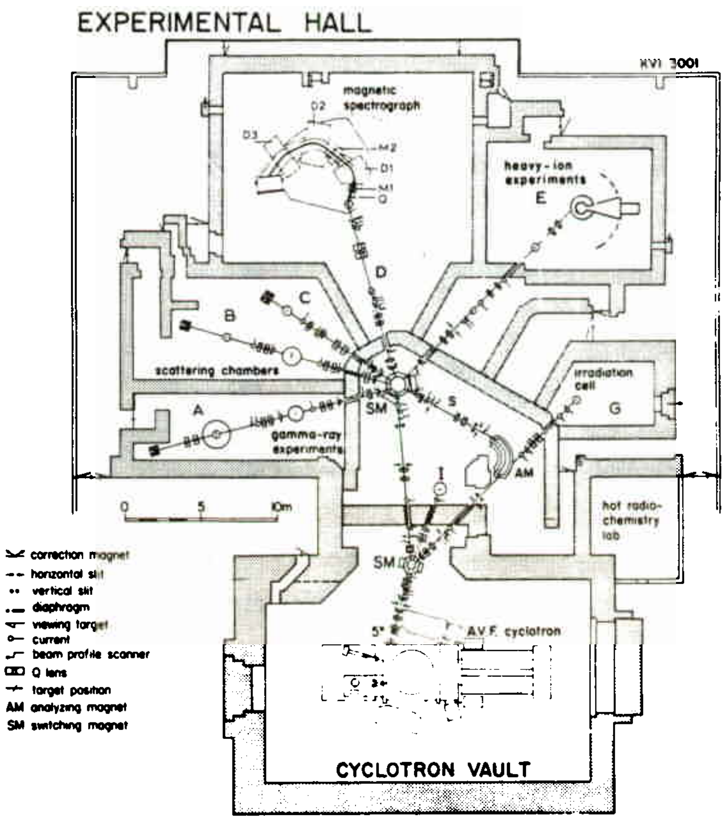

Figure 1
Lay out of the beam guiding system

Gas target system

For the irradiation of gases three gas targets are available. From the high level laboratory each of the gas targets can be positioned at the end of the beam pipe under control of a pushbutton operated system. Optical inspection is possible via a closed TV circuit. The gas targets are moved perpendicular on the beam pipe, see figure 2. The stop at the end of the beam pipe is set by a microswitch contact. After this stop the target of choise is clamped onto the end of the beam pipe by pressurized air. The fitting is not that critical since a conical shaped end flange on the beam pipe and a conical shaped nozzle on the targets is used. In order to avoid activation of the air between the end foil of the beam pipe (25 μm SS) and the entrance window of the gas targets a Helium flow is present.

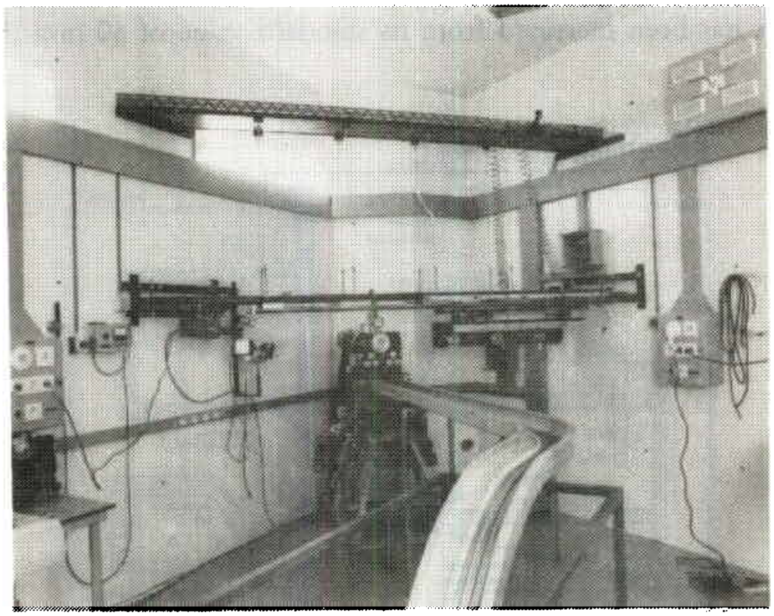

Figure 2
Irradiation cell with gas target and target transport system

The gas in– and outlets are made of stainless steel tubing, 1/8 inch outer diameter, 2.2 mm inner diameter. The outlets of the gas targets are connected to both radiochemical laboratories. By a pushbutton panel the gastarget and its connection to one of the fume hoods in one of both laboratories is selected. Each outlet has its own flow controller. The pressure inside of the target is determined by the pressure reducer on the gastank. By this pushbutton system a flexible delivery of the radioactive products of the gas targets is established.

The specifications of the gas targets in use at the moment are the following:

GT–1: $^{15}O_2$ target, 15 cm long, 2.5 cm inner diameter. Operated at 1.3 bar. Nuclear reaction: $^{14}N(d,n)^{15}O$. Beam energy on the target gas is 6.5 MeV. Aluminium entrance foil. Target gas is N_2 (96 %) and O_2 (4 %) or N_2 (97.5 %) and CO_2 (2.5 %) for the production of $C^{15}O_2$.

GT–2: $^{11}CO_2$ target, 31 cm long, 2.5 cm inner diameter. Operated at 13 bar. Nuclear reaction: $^{14}N(p,\alpha)^{11}C$. Beam energy on the target gas is 18 MeV. Aluminium entrance foil. Target gas in N_2 (99.9999 %).

GT–3: $^{11}CH_4$ target. Same specifications as GT–2. Target gas is N_2 (95%) and H_2 (5 %).

All three targets are always pressurized and are only used for the production of the precursor they were designed for. This procedure is especially important for target delivering precursors for the synthesis of radiopharmaceuticals with high specific activities. With the $^{11}CO_2$ target it is possible to produce 1–^{11}C–DOPA <1> with a specific activity of 10^6 Ci/mol. Carbon-11 labeled methyl-spiperone has been synthesized with specific activities up to 0.5 Ci/mol. The value of this procedure becomes evident when a synthesis is done just after the target has been opened for one or the other reason and only much lower specific activities can be obtained. The specific acitivity of the end product will increase again in time and by both, flushing target gas and by irradiating it. This procedure is of course of much less importance for the $^{15}O_2$ target.

Target transportation system

For the irradiation of fluids and solid state targets a target transportation system was developed. The transportation system is based on a commercial transportation system known as a 'Telelift' system, see figure 2. This rail system connects the irradiation cell to the high level laboratory via a transportation car storage ring in the basement of the experimental hall. The cars are stripped versions of the commercial version. On these flat cars each target can built and a standard construction for the connection with the beam pipe was designed. This coupling mechanism was constructed in such a way that next to a solid connection of the car to the end of the beam pipe also cooling water, pressurized air and electrical connections can plugged through from the end of the beam pipe onto the car. This has been enabled by adopting the following procedure and construction. At a distance of approximately 10 cm from the end of the beam pipe the target car stops. At this position fitting pens correct the car position if necessary. Also a grip, fixed to the end of the beam pipe, is now automatically connected to the car by a spring mechanism. By pushbutton the pressurized air is activated and the car, together with the last part of the rail system, is clamped onto the end flange of the beam pipe. Since the same conical shapes of end flange and nozzle of target are used as in the case of the gas targets the exact position of the target is not that critical. Optical inspection is possible via a closed TV circuit. After irradiation the reversed procedure is followed and the target car can either be sent to the high level laboratory or to the storage ring in the basement. In this storage ring maximum 10 cars can be placed with each a different target. In this way a permanent set up is available and each target can be used by means of a simple pushbutton system. At the other end of the transportation system, in the high level laboratory, a system identical to the one at the end of the beam pipe is installed. Here the target material van be loaded or unloaded.
Production targets in use at the moment with the transportation system are:

^{13}N target:
Nitrogen-13 is produced from water contained in a titanium cup (10 cm^3). The water is irradiated by 20 MeV protons. The nuclear reaction used is $^{16}O(p,\alpha)^{13}N$ and the nitrogen-13 is present in the water as $^{13}NO_2^-$ or $^{13}NO_3^-$. The water is put into the target by syringe via a magnetic valve and removed by a pump into a hot cell. In this cell a remote controlled set-up is present to produce $^{13}NH_3$ or $^{13}N_2$ from the irradiated water. The last product can be produced for inhalation or for i.v. injection <2>. The connection to the pump is made automatically at the end of the transportation system in the laboratory.

^{75}Br target:
Using enriched ^{76}Se it is possible to produce ^{75}Br with only 1.4 % ^{76}Br as contaminant in useful quantities <3,4>. Since the radiation dose of ^{76}Br is over 10 times the of ^{75}Br a quick separation of the bromine from the target material is required. After irradiation the target material is put into an oven inside a hot cell with help of a manipulator. After this dry distillation the target material, Cu_2Se, is used again. The bromine-75 is used for the labelling of estrogens.

References

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