EXTENSION OF THE IRRADIATION SYSTEM AT TIARA FOR PRODUCTION OF RADIOISOTOPES TO BE USED IN PLANT PHYSIOLOGY

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Abstract

A target irradiation system for radioisotope production at the TIARA AVF cyclotron facility has been improved for extending physiological studies of plants. Experiments using a positron imaging technique require a variety of positron-emitting radioisotopes and their labelled compounds. Therefore, a compact revolver equipped with six target chambers for gas and liquid targets were newly constructed, in addition to the original target irradiation system consisting of two solid target chambers and one gas target chamber, placed on the movable table. The control system was also reconstructed with a local area network for communication between the control station beside the irradiation port and the hot laboratory. Use of this system enables us to produce routinely positron-emitting tracers for plant physiology.

INTRODUCTION

At the Takasaki-site of JAERI, production methods have been developed for potentially useful radioisotopes mainly in medicine and life science research using the TIARA AVF cyclotron. For this purpose, solid, gas and liquids targets must be irradiated and chemically processed to produce the isotopes of light and heavy elements and their labelled compounds.

Recently, the TIARA radioisotope-production research facility has provided new possibilities of studying dynamically the physiological function of plants *in vivo* with positron emitters: a positron emitting tracer imaging system (PETIS)[1] (see Fig.1) has been developed together with production methods of positron emitters. Using the PETIS technique, the physiological functions of plants have been made clear recently. As this technique became one of important means in this field, experiments using the PETIS require a variety of positron-emitting radioisotopes and their labelled compounds during a limited machine time. Table 1 lists the positron emitters which we have produced so far.[2,3]

In the present paper we describe the new target irradiation system adding to the original irradiation target system for routine production to produce the positron emitting tracers for extending physiological studies in plants.

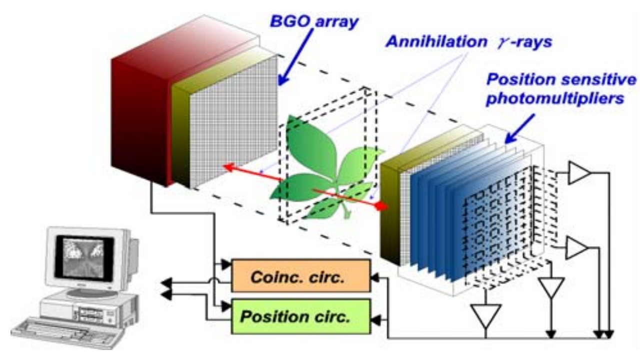

Fig.1 Positron emitting tracer imaging system

Table1: Production and application of positron emitters in TIARA

Nuclide	Half-life	Reaction	Target material	Tracer for experiments on plants
^{11}C	20 min	$^{14}N(p,\alpha)^{11}C$	N_2 gas	CO_2 (products of photosyntesize), Methionine
^{13}N	10 min	$^{16}O(p,\alpha)^{13}N$	[^{16}O] H_2O, $H_2{}^{16}O$ (^{18}O-depleted)	NO_3^-, NH_4^+, N_2
^{18}F	110 min	$^{16}O(\alpha, pn)^{18}F$, $^{18}O(p,n)^{18}F$	[^{16}O] H_2O, [^{18}O] H_2O	Aqueous F^-,FDG, F-Proline
^{48}V	16 day	$^{45}Sc(\alpha, p)^{48}V$	Sc foil	$H_2VO_4^-$
^{52}Mn	20 min	$^{nat}Cr(p, xn)^{52}Mn$	Cr foil	Mn^{2+}
^{52}Fe	10 min	$^{nat}Cr(\alpha, xn)^{52}Fe$	Cr foil	Fe^{3+}
^{62}Zn	110 min	$^{nat}Cu(p,n)^{62}Zn$	Cu foil	Zn^{2+}
^{76}Br	16 h	$^{75}As(\alpha,3n)^{76}Br$, $^{76}Se(p,n)^{76}Br$, $^{nat}Br(p,xn)^{76}Kr$-^{76}Br	As, Se and NaBr pellets	Br^-
^{105}Cd	56 min	$^{nat}Br(p,xn)^{105}Cd$	Ag foil	Cd^{2+}
^{107}Cd	6.5 h	$^{nat}Br(p,xn)^{107}Cd$	Ag foil	Cd^{2+}

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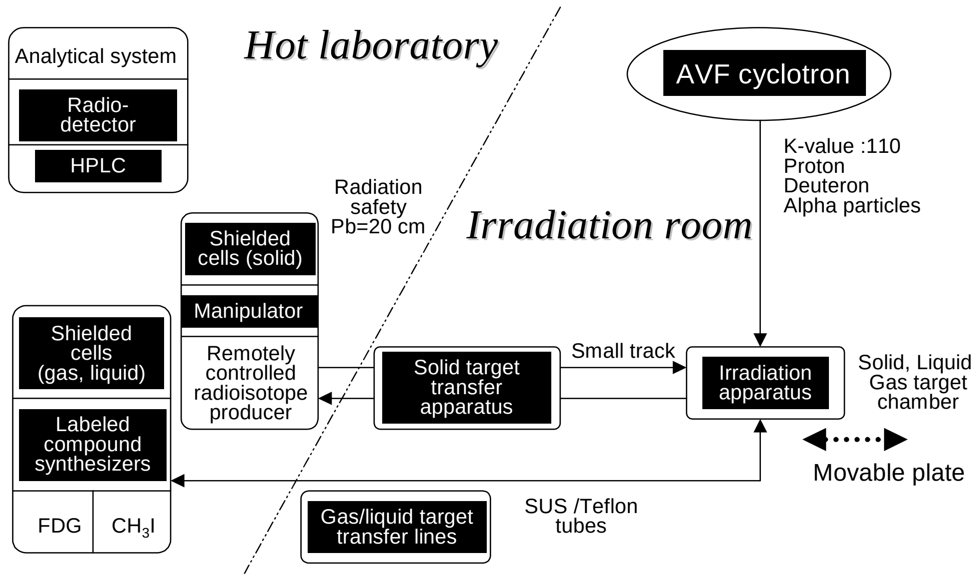


Fig 2 Layout of the TIARA radioisotope-production research facility

RADIOISOTOPE-PRODUCTION RESEARCH FACILITY

In 1993, the radioisotope-production research facility was constructed in TIARA. Since the AVF cyclotron with a K-number of 110 delivers energetic light-ion beams such as protons and α-particles with energies up to 90 MeV and 100 MeV, respectively, a variety of nuclear reactions can be available. Figure 2 shows the layout of the TIARA radioisotope-production research facility. The facility consists of an irradiation apparatus, a target transfer system and shielded cells. Each instrument has been designed for differential targets such as solid, liquid and gas, and for applications of a variety of nuclear reactions.

Irradiation apparatus

One beam line is available for the radioisotope production and the original irradiation ports consisting of two solid target chambers, one gas target chamber and a beam preparation chamber are integrated on a movable plate.

Target transfer system

As targets are transported semi-automatically between the irradiation port and the hot laboratory, different targets can be irradiated sequentially at short intervals; a gas target is transported through tubing, and a solid target are carried by a truck running on a mono-rail line. The solid target chamber is set on the beam line by the handling apparatus.

Shielded cells

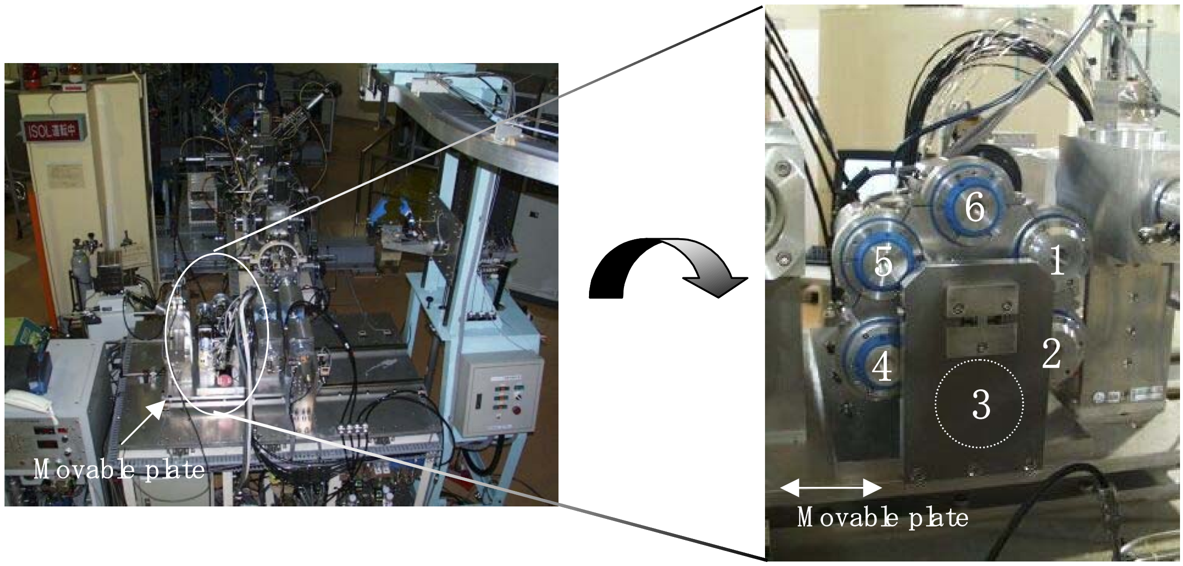
Three shielded cells are installed in the hot laboratory to treat high level radioactivity produced in a solid target. These shielded cells are interconnected to carry a target and a product by a train moving under the floor of the cells. Each of the cells is furnished with a pair of manipulators.

Units of labelled compound synthesis, called CBB(“Chemical Black Box”), are installed in the shielded cells named CBB cells. In the CBBs, compounds will be automatically labelled with short-lived positron emitters like ^{11}C, ^{13}N, ^{15}O and ^{18}F, produced from gas and liquid targets. The CBB cells are furnished with tubing of irradiated targets, compressed air and nitrogen, and cables to control the CBBs.

NEW IRRADIATION SYSTEM FOR GAS/LIQUIDS TARGETS

In view of the intended usage for routine production of a variety of positron emitters during a limited machine time we summarize here the design features especially optimized for some conditions:

- To production of positron emitters at high purity: exclusive target chambers
- To effectively use of of a limited machine-time: a variety of target chambers, irradiation at a short intervals
- To the future extension
- To easy operation



Target changer system

Instead of the original irradiation port for a gas target, the new irradiation port with the target changer was constructed. The target changer is a compact revolver which is equipped with six target chambers. The changer is 45 kg in weight and has dimensions of 320 mm high, 280 mm wide and 470 mm deep. The target chambers can be changeable depending on the irradiation. It will take about only 1 min to change targets.

Target chambers have been designed to optimize the production of $^{11}CO_2$, $^{13}N_2$, $^{13}NO_3^-$, $^{13}NH_4^+$, $^{18}F^-$, $^{18}F_2$. Particularly, thickness and materials of a target window are optimized to produce these positron emitters with high purity. In addition, measurement of irradiation current is possible on target.

Using this system, we can available positron emitting tracers, such as $^{13}NO_3^-$, $^{13}NH_4^+$ and $^{18}F^-$, which are produced from a liquid target irradiation. Furthermore, utilization of excusive target chambers was realized a stable production of labelled compounds.

Control system

The control system was also reconstructed with a local area network for communication between the control station beside the irradiation port and the hot laboratory. All equippments of the TIARA radioisotope facility can be remotly controlled on the system which is performed by a sequential program or manually. The easy oparation is achieved by the sequential program.

CONCLUSION

This system enables us to produce routinely and safely positron-emitting tracers for plant physiology. Such quality also provides wide possibilities for research and development of further target preparation technologies.

REFERENCES

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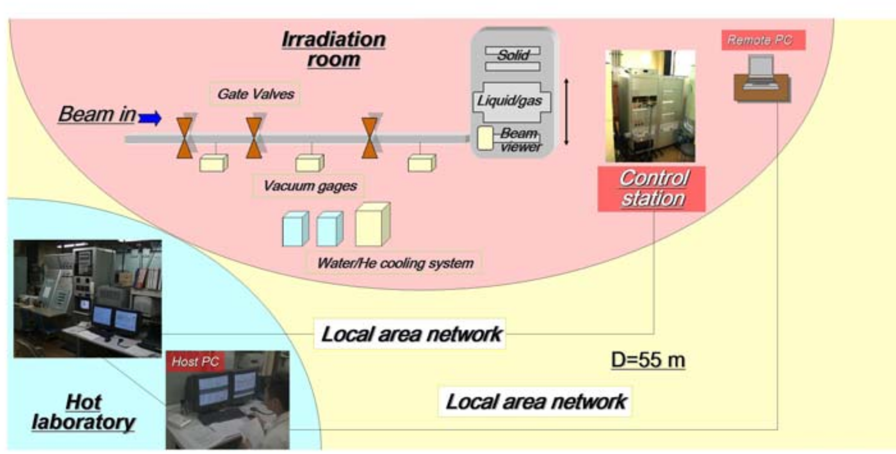

Fig. 4 Layout of the control system.