USERS SATISFACTION IN RADIONUCLIDES PRODUCTION -PRESENT AND FUTURE

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Abstract

A NIRS-930 cyclotron [1] has been used for various purposes since the first beam in 1973. Among others, Radionuclide production has been one of the most important purposes at the NIRS-930.

Since the users on the radionuclides production are now demanding to increase beam intensity for effective production, we have launched upgrade of the NIRS-930 as a new plan oriented for higher intensity beams and stable operation is now under development based on our operation experiences, and it will hopefully be one of the world front-running facilities.

INTRODUCTION

The NIRS-930 cyclotron has been mainly operated to produce radionuclides. The ratio of operation times of NIRS-930 in 2013 fiscal year is shown in Fig 1. The fraction of the radionuclides production reached to 44%, and its related ~~relational~~ operation, namely beam tuning and machine studies to make a suitable beam was 26%. Thus, about 3/4 of whole operation time was shared for the purpose of radionuclides production.

Typical conditions for radionuclide production operated recently is shown in Table 1. The proton beams of 12–30 MeV are used for medium half-life radionuclides production, e.g. ^{64}Cu, ^{89}Zr, ^{62}Zn/^{62}Cu, or ^{124}I. And helium beam of 75 MeV is used for ^{28}Mg production. In most cases, relatively long time of irradiation is required to produce a certain amount of activities.

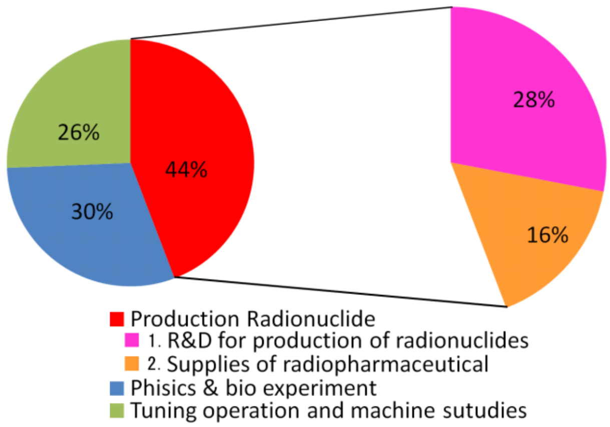

Figure 1: The ratio of operation time for purposes of NIRS-930 in 2013 fiscal year.

Table 1: Examples of irradiation for radionuclide production

Production	Beam[MeV]		Beam intensity [μA]	Irradiation time [h]
^{64}Cu	proton	12	10	2.7
^{89}Zr	proton	15	15	2.5
^{62}Zn/^{62}Cu	proton	30	20	9
^{124}I	H_2^+*	27	10	4
^{28}Mg	He^{2+}	75	15	4

*Practically, 13.5 MeV protons on target

PRESENT DEMAND

The NIRS-930 has two applications in the case of radionuclide production. One is conventional productions of radiopharmaceutical for medical imaging such as PET. The other is experimental, research and development purpose, particularly to establish new methods for effective production of radionuclide. Here we discuss the priority of operational items based on the present demand from the above users in each case of production.

1. R&D for production of radionuclide

The beam intensity is the first priority in the R&D irradiation. The uniformity of beam profile is also important to evaluate the developing irradiation system because these two parameters strongly affect the target integrity and cooling efficiency.

1st = Intensity
2nd = Uniformity
3rd = Stability
4th = Accuracy of beam energy
5th = Beam size

2. Supplies of radiopharmaceutical

Since the time limit of conventional production including purification, labelling and preparation is strict, the beam stability is the first priority. The beam intensity as high as possible is the second one that affects the production yield directly.

1st = Stability
2nd = Intensity
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4th = Accuracy of beam energy
5th = Beam size

Beam condition for production of radionuclides

In the following sections, each item of beam condition is considered in connection with the usage purpose.

Beam intensity (R&D 1st. , Supplies 2nd)

If beam intensity is increased, the beam irradiation time can be shortened by the increase of production rate..

The increase of beam intensity at low energy proton beam such as 13.5 MeV protons was difficult because of space charge effect at high current injection beam. Therefore 27 MeV H_2^+ beam has been used instead of proton beam. But, this beam has problem that activates the internal electrode. The H_2^+ beam is separated to H^+ beam in acceleration region at the cyclotron.

Beam stability (R&D 3rd. , Supplies 1st)

The beam stability is very important for the quality of radiopharmaceutical. The recent long irradiation time is 10 hours. The beam was stopped several times during in this irradiation time by the radio frequency (RF) voltage regulation system down from discharges at dee-electrode and deflector down from discharges. The beam stop time by deflector down is 5 min. or less. The beams stop time by RF system is 3 min. or less. The NIRS-930 cyclotron is too old for long time stable operation.

Beam uniformity (R&D 2nd, Supplies 3rd)

The ideal beam density is uniform beam to avoid the damages by concentration of heat in target system for production of radionuclide. Therefore beam uniformity for R&D is more important than case of supplies of radiopharmaceutical. The present beam spot size is usually used at φ8-20 mm for both purposes. The several target system for R&D have problem by concentration of heat. In this case, the monitoring of beam density is very important at high intensity beam. The alumina beam viewer is usually used for the monitoring of beam density. But, when the intensity isn't low, the beam density can't be monitored by alumina beam viewer. A new alumina beam viewer has been developed in order to monitor the density of high intensity beam [2]. And, the beam scanning system was examined in order to respond to the recent demand of beam spot size of φ30 mm for the new target of vertical beam irradiation system [3].

Accuracy of beam energy (R&D 4th, Supplies 4th)

The accuracy of beam energy is satisfied for both purposes. The beam energy was measured by TOF with the beam bunch monitor when the accuracy of beam energy is necessary [4]. Therefore the beam energy was adjusted with less then ±1 MeV accuracy by tuning of acceleration frequency in first beam parameter operation if necessary.

Beam size (R&D 5th, Supplies 5th)

The demand for beam size control is not often. The present beam spot size is usually used at φ8-20 mm for production of radionuclide. The beam spot size was monitored only at low intensity beam. A beam collimator was used at places upstream of the target in order to cut off unnecessary beam. But, the attentions are required for the beam losses that generate the unnecessary radioactivity.

FUTURE DEMAND

A high intensity beam attracts the highest interest in the future demand and operation to produce beta/alpha emitters for the application of internal radionuclide therapy. The production yields of therapeutic candidates, e.g. ^{67}Cu, ^{47}Sc, or ^{211}At, are typically lower at 1–2 order of magnitude than those of imaging nuclides, the beam intensity as high as possible, likely 50 μA or higher, is thus favorable and essential.

The present maximum beam currents of the NIRS-930 cyclotron are unfortunately 10 μA at *E*p = 60 MeV or 20 μA at *E*α = 35 MeV Helium, respectively.

Future facility plan

Due to the regulation concerning with radiation protection, our cyclotron facility is hardly to carry out high power operations at above demands. Therefore, we are proposing a new facility plan as a flagship institute for the next generation (Fig. 2).

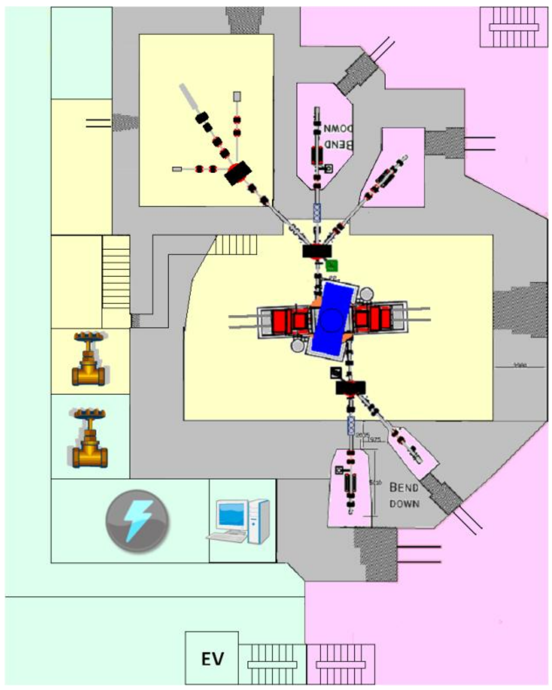

Figure 2: The drawing of future layout plans.

The target processing areas (hot cells, etc) is located on the second floor or a basement.

☐ Primary radiation control area
(Sealed and un-sealed radio isotopes)
☐ Secondary radiation control area
(Sealed radio isotopes)
☐ Ordinary area

The cyclotron parameter, *K* number is 110 in this plan, which is the same as the present NIRS-930, where the *E*p(max) = 70 MeV. However, the maximum current of 50–100 µA can be realized only by the acceleration of negative hydrogen. The positive helium beam is planned to be 50 µA at 40 MeV. And the cyclotron of future plan can be variable beam energy by changing the radio frequency.

This cyclotron has two side output ports of negative ion beam, it can be simultaneous irradiation by foil stripping extraction. The positive ion beam has only one side output port. Ion source is composed of multi-cusp ion source and ECR ion source in this future plan. This future facility has several horizontal irradiation lines and vertical irradiation lines for production of radionuclide and other experiment room with three horizontal irradiation lines.

Relative issues and countermeasures

Irradiations with higher energy and higher intensity beam sometimes induce problematic results. For example as our experience, an industrial robotic system for remote handling of targets or an electric control system of accelerator had unpredicted frequent malfunctions after the hard condition of bombardment. These equipment available nowadays are embedded with highly integrated semiconductors, which are very sensitive to neutrons, thus we assume that malfunctions we met were caused by the high flux of radiation and neutrons. Indeed, devices nearer to the target, with the highest field of radiation, showed higher rate of failure than those placed far from the target in the irradiation vault. Hence, we will install another device which is driven by pneumatic cylinder and hard-wired-relays. Consequently, our operation is expected to be stable without troubles.

REFERENCES

[1] S. Hojo, et. Al, “Present status of cyclotrons (NIRS-930, HM-18) at NIRS” Proceedings of cyclotrons2013, Vancouver, BC, Canada, MOPPT008, 46-48 ISBN 978-3-95450-128-1(2013)

[2] Y. Takahashi, et. Al, “Operation of NIRS Cyclotrons” Proceedings of WAO2014, Germany,

[3] K. Katagiri, et. Al, “Design of Beam transport lines for radioisotope production systems in NIRS cyclotron Facility” Proceedings of IPAC2014, Germany, WEPRO088, 2162-2164 (2014)

[4] S. Hojo, et. Al, “A beam energy measurement system at NIRS-930 cyclotron” Proceedings of cyclotron and their applications 2004 18P02, 407-409, (2004)