PROGRESS ON THE UPGRADE FOR TRT AT NIRS CYCLOTRON FACILITY

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Abstract

The cyclotron facility at National Institute of Radiological Sciences (NIRS) includes two cyclotrons, a NIRS-930 cyclotron (Thomson-CSF, Kb=110 MeV and Kf=90 MeV) and a small cyclotron HM-18 (Sumitomo-Heavy-Industry) [1]. The NIRS-930 cyclotron has been used for radionuclide production, nuclear physics, detector development and so on, since the first beam in 1973. The HM-18 has been used for radionuclide production for PET since 1994.

In recent years, the production of radionuclides for Targeted Radionuclide Therapy (TRT) by using NIRS-930 has been one of the most important activities in NIRS. Since demand of radionuclide users on beam intensity is growing, we have launched to upgrade the cyclotron facility, such as installation of multi-harmonic beam buncher in NIRS-930 and a reinforcement of nuclear ventilation system in a cave.

Progress on the upgrade for TRT at the cyclotron facility and status of the NIRS cyclotrons are to be presented in this report.

INTRODUCTION

The NIRS-930 cyclotron has been mainly operated to produce radionuclides. The system layout of NIRS-930 facility is shown in Fig. 1. This facility has 10 beam ports, and 4 beam ports of them are exclusively used for radionuclide production. The C-1 and C-2 beam port are used for production of radionuclides for PET. The C-4 beam port is used for production of metal radionuclides such as ^{62}Zn/^{62}Cu for SPECT. The C-9 beam port is used for production of radionuclides with a low-melting-point solid target such as ^{124}I and ^{76}Br [2]. In addition to these 4 beam ports, renewal of the C-3 beam port is in progress for radionuclides production. This beam line has wobbler magnets for avoiding heat concentration on a target [3]. Radionuclide production using this beam port will be started in January, 2015.

The ratio of operation times of NIRS-930 in fiscal year 2014 is shown in Fig. 2. The radionuclide production account for 49% of the operation times, and its related operation, namely beam tuning and machine studies to make a suitable beam, was 21%. Thus, almost 70% of whole operation time was shared for the purpose of radionuclides production.

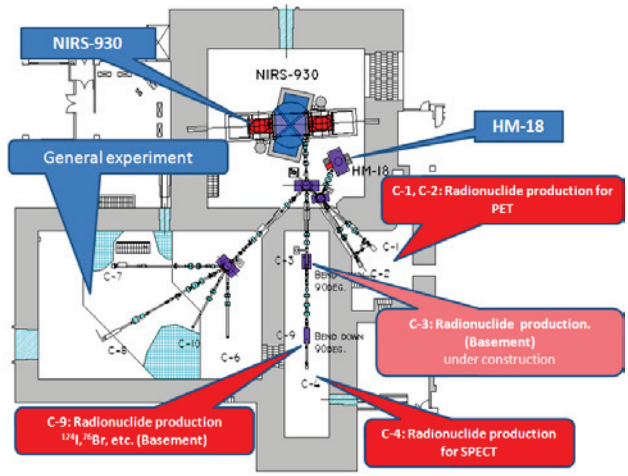

Figure 1: The system layout of the NIRS-930 facility.

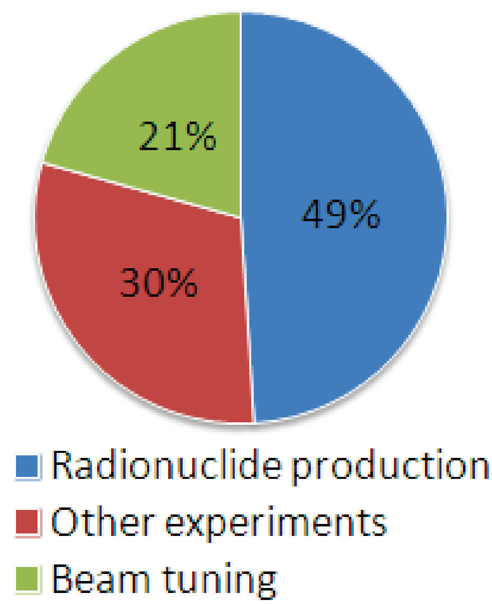

Figure 2: The ratio of operation times of NIRS-930 in fiscal year 2014.

CURRENT STATE OF RADIONUCLIDE PRODUCTION USING NIRS-930

In the past, radionuclide produced using NIRS-930 was mainly used for molecular imaging such as PET and SPECT. In recent years, production techniques of radionuclides such as ^{211}At, ^{186}Re, ^{64}Cu, and ^{67}Cu have been developed and applied for studies of TRT at NIRS.

A list of radionuclide produced NIRS-930 is shown in Table 1 with reactions and beams. The highest beam power is 600 W at 30 MeV proton 20 eμA.

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The proton beams of 12-60 MeV are mainly used for the production of radionuclides such as ^{64}Cu, ^{67}Cu, ^{89}Zr, ^{62}Zn/^{62}Cu, and ^{124}I. The Helium beams of 30-75 MeV are used for production of ^{155}Tb, ^{211}At, and ^{28}Mg. The deuteron beams of 20 MeV are used for production of ^{177}Lu and ^{186}Re.

In radionuclide production with low energy protons such as ^{64}Cu and ^{124}I, the beam intensity is insufficient to produce required yield. It is difficult to increase the beam intensity because of the space charge effect at beam injection. Therefore, H_2^+ beam has been used instead of proton beam.

Table 1: List of Radionuclide Production Using NIRS930

Radionuclide	Reaction	Beam
^{89}Zr	^{89}Y(p, n) ^{89}Zr	15 MeV proton 10 eμA
^{11}C	^{14}N(p, α) ^{11}C	18 MeV proton 20 eμA
^{62}Zn/^{62}Cu	^{nat}Cu(p, 2n) ^{62}Zn	30 MeV proton 20 eμA
^{68}Ge	^{nat}Ga(p, x) ^{68}Ge	30 MeV proton 20 eμA
^{67}Cu	^{68}Zn(p, 2p) ^{67}Cu	60 MeV proton 5 eμA
	^{64}Ni(α, p) ^{67}Cu	40 MeV He 15 eμA
^{64}Cu	^{64}Ni(p, n) ^{64}Cu	12 MeV proton (H_2^+ 24 MeV) 10 eμA
^{124}I	^{124}Te(p, n) ^{124}I	13.5 MeV proton (H_2^+ 27 MeV) 10 eμA
^{177}Lu	$^{nat(176)}$Yb(d, n) ^{177}Lu	20 MeV deuteron 10 eμA
^{43}Sc	$^{nat(40)}$Ca(α, x) ^{43}Sc	34 MeV He 10 eμA
^{47}Sc	^{44}Ca(α, p) ^{47}Sc	34 MeV He 10 eμA

INCREASED OF BEAM INTENSITY 34 MEV HELIUM

A demand on higher beam intensity for 34 MeV He^{2+} is growing in radionuclide production for TRT. Therefore beam intensity was increased by adjusting operation parameter. Progress of extracted beam intensity and extraction efficiency is shown on Fig. 3. In beam tuning, operation parameters such as deflector voltage, current of magnetic channel, harmonic coil and so on were adjusted. In Fig. 3 marks “A” and “C” shows adjustment of trim coil field with beam phase [4]. The beam phase is shown on Fig. 4. The ordinate axis is beam phase (the ideal acceleration phase =0) and the abscissa axis is phase probe number. The beam phase excursion was reduced to ±5 degree. In Fig. 3 mark “B” shows adjustment of injection energy and magnetic field at central region.

Tables 2 and 3 show the results of beam tuning in beam intensity and efficiency. The beam current at inflector is stopped beam by change a connection inflector electrode to current meter from inflector voltage power supply. The R=920 mm is extraction radius and entrance of electric deflector. The extracted beam intensity was measured at the first faraday cup at NIRS-930 beam line. The extraction efficiency is defined by the ratio of the extracted beam intensity to the beam intensity at R=920 mm, and it was 92%. The extracted beam current was 24.5 eμA. Then, the beam intensity at the target for radionuclide production was 20 eμA.

Figure 5 shows the dependence of the extracted beam intensity on the extraction efficiency. The beam intensity increases with the extraction efficiency.

Further improvement in the beam intensity is demanded. The desired beam intensity at the target is 30 eμA. Thus, we are planning to increase the beam intensity by improvement of beam buncher to multi harmonic type and optimization of the injection beam line including ion source.

Table 2: The Beam Intensity of 34 MeV He^{2+}

Inflector [eμA]	R=920 mm [eμA]	Extracted [eμA]
53.2	26.6	24.5

Table 3: The Beam Efficiency of 34 MeV He^{2+}

R=920 mm /Inflector	Extracted /R=920 mm	Extracted /Inflector
50%	92%	46%

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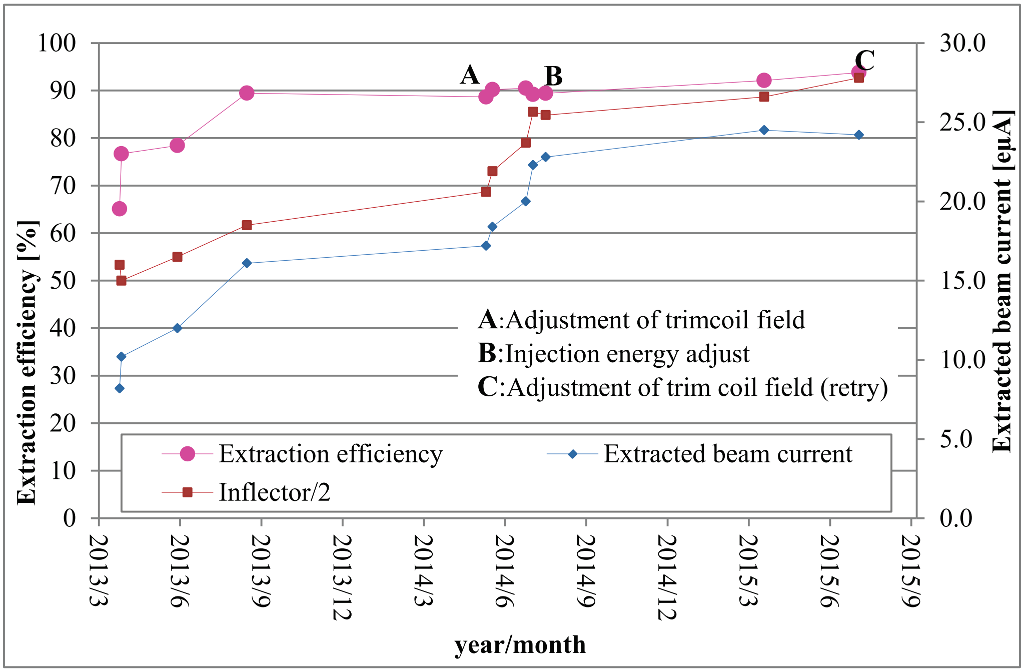

Figure 3: Progress of extraction efficiency and extracted beam intensity by the operation for beam tuning.

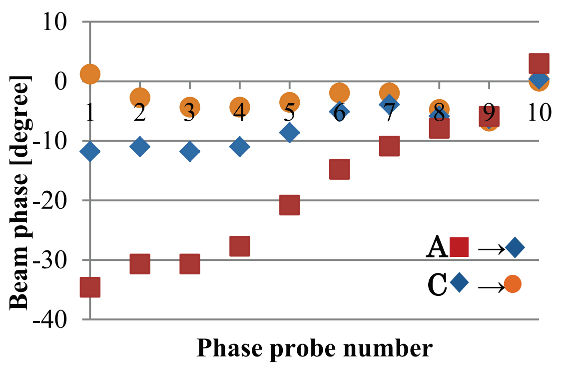

Figure 4: The excursion of beam phase when the operation for beam tuning.

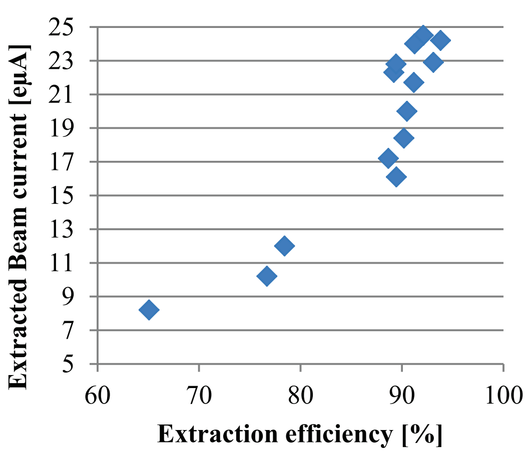

Figure 5: Extraction efficiency and extracted beam intensity.

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