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EVALUATION OF ACTIVATED NUCLIDES DUE TO SECONDARY PARTICLES PRODUCED IN STRIPPER FOIL IN J-PARC RCS *

M. Yoshimoto, P.K.Saha, S. Kato, K. Okabe, K. Yamamoto, M. Kinsho,
JAEA/J-PARC, Tokai-Mura, Naka-Gun, Ibaraki-Ken, Japan

Abstract

Multi-turn charge-exchange beam injection is key technique to achieve the high intensity proton beam accelerators. In the J-PARC RCS, 400MeV H- beams from the LINAC are injected to the stripper foils so that the most of beams are converted to protons. The stripper foil is irradiated not only by the injected H- beams but also by the circulating protons. The high energy and intense beam irradiation into the foil generates secondary neutrons and protons via nuclear reactions. These secondary particles cause high residual activation around the stripper foil.

Therefore, an activation analysis method using sample pieces is considered to identify the species of the secondary particles, their energies and emission angles. In the presentation, we report the result of the evaluation of this activation analysis with PHITS codes.

INTRODUCTION

The 3-GeV Rapid Cycling Synchrotron (RCS) of the Japan Proton Accelerator Research Complex (J-PARC) accelerates protons from 400MeV to 3GeV kinetic energy at 25 Hz repetition rate. The RCS has two functions as a proton driver for neutron/muon production at the Material and Life science experimental Facility (MLF) and as a booster of the Main Ring synchrotron (MR) for the Hadron experimental facility (HD) and Neutrino experimental facility (NU) [1].

The most important issue in achieving such a MW-class high power routine beam operation is to keep machine activations within a permissible level, that is, to preserve a better hands-on maintenance environment. Therefore we adopt the ring collimator system to remove the beam halo and to localize the beam loss at the collimator area. And, a large fraction of our effort has been concentrated on reducing and managing beam losses, in the J-PARC RCS [2]. To confirm the effect of the beam loss localization, residual doses along the ring were periodically measured. The measurement results showed that the unexpected high radio-activation was found around the stripper foil [3].

In order to investigate the cause of the high radio-activation around the stripper foil, various foil studies were carried out [4-5]. From the previous some foil studies; it is assumed that the secondary proton and neutron particles generated by the nuclear reaction due to the interaction between the injecting and circulating beam and the stripper foil cause the high radio-activation around the foil. Especially, the secondary proton and neutron in the low energy region, which isotropically emit from the foil, may be key factors. In general, a principal cause of the radio-activation is the beam loss in the accelerator. Thus the effort of the beam loss reduction is most important issue for the high intensity beam tuning. On the other hand, this secondary particle emission from the foil cannot be eliminated, because the interaction between the high energy beam and the foil is not possibly to be avoided in the charge-exchange multi-turn beam injection. Then, we need some kind of countermeasure against the secondary particles emission to achieve a stable beam operation with high power of 1MW. For this purpose, we also should investigate more details about the secondary particles experimentally.

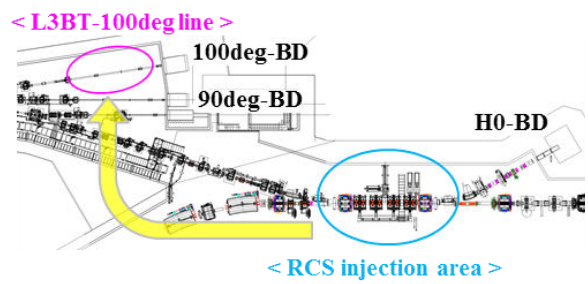

Figure 1: Layout of the new experimental site for secondary particle measurement from the stripper foil.

Figure 2: Picture of a new secondary particle measurement system.

EXPERIMENTAL SYSTEM TO DETECT

Establishment of New Experimental Site

There are various devices in the injection area. Then, it does not have enough space to set some secondary particles detectors. In addition, various beam losses

* Work supported by JSPS KAKENHI Grant Number JP16K05027
† email address yoshimoto.masahiro@jaea.go.jp

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occurred in this area, and the radiation due to the beam losses disturb the secondary particle detection. Therefore, a new experimental site for various beam irradiation tests is established at the L3BT 100deg-BD line as shown in Figure 1. And a new secondary particle measurement system, which consists of a foil moving actuator and a detector vacuum chamber, is setup at the experimental site. Figure 2 shows the picture of measurement system.

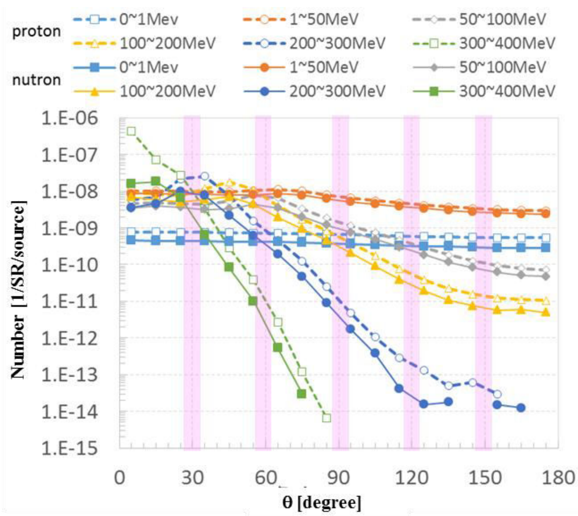

Figure 3: Angle spectrum of secondary proton and neutron particles at the stripper foil

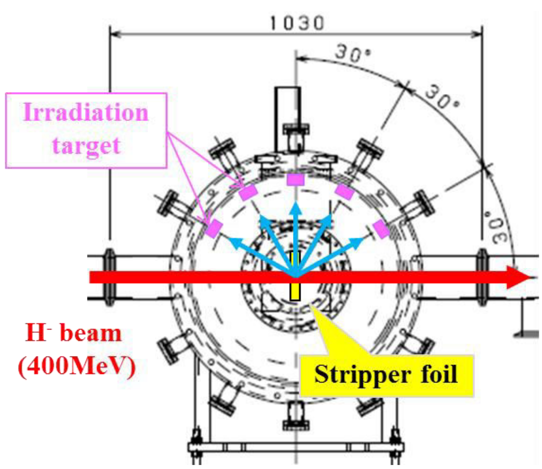

Figure 4: Schematic view of measuring secondary particles from the stripper foil.

Secondary Particle Analysis

Figure 3 shows Angle spectrum of secondary proton and neutron particles at the stripper foil obtained by the PHITS simulation. A goal of this experiment is that the angle spectrums will be obtained experimentally. Figure 4 shows the schematic view of measuring the secondary particles. The detection chamber has ten detection ports without two beam line ports connected at a 30 degree angle relative to the beam traveling direction to detect the secondary particles. As increasing the angle of the detection ports, higher energy elements decrease but lower energy elements is kept almost constant. To evaluate the secondary particles, various methods are examined. In case of a radio-activation analysis method by using some metal irradiation targets, it is important to select the target material and to examine the radionuclides as indicators of secondary proton or neutron with different energy range. Here, we focus the examination of the radio-activation analysis method with PHITS code to search radionuclides as the indicators.

At first, cupper (Cu) piece as the irradiation target was investigated. The scheme of PHITS simulation was as follow; the target size of 10 mm height and 10 mm width and the target thickness of 3 mm were set and the irradiating secondary beam with a diameter of 10mm and a flat surface source is assumed. The irradiating beam energies of 5, 10, 20, 50, 100, 200, and 400 MeV are simulated. From the simulation results, a large amount of nuclides are generated as shown in Figure 5. And radionuclides with emit gamma radiation are picked up from the many produced nuclides, because irradiated targets will be analysed by using Ge semiconductor detector in the experimental stage. A required characteristic of the radionuclides for the indicator is that a number of the radionuclide production generated with proton beam irradiation is greatly different from a number of productions with neutron beam irradiation. In addition, it is preferable that the distribution of radionuclide production with several beam energy range has an only strong peak at an arbitrary energy range. Figure 6 shows the comparison of radionuclide production between proton and neutron irradiations. In these cases, Zn65 is extremely suitable for a proton beam indicator. And Co60 and Co56 are also suited for a neutron and proton indicator respectively. Moreover, the three radionuclides are compared the production of every beam energy and normalized as shown in Figure 7. Zn65 has a high sensitivity within the proton beam energy range of 20 MeV, but Co60 and Co58 don't have a high sensitivity of a certain energy range. From these simulation results, some usable radionuclides for the indicator can be found. But, it is difficult to identify the species and energy by using one radionuclide indicator. In the experimental stage, quantitative evaluation of secondary particles will be analysed by combining the production ratio of the many radionuclides. In that case, the production ratio is used by the simulation results. Thus, to check consistency between the radio-activation analysis method and direct measurement method will be needed.

CONCLUSION

The stripper foil is a key element for high intensity proton beam. In the J-PARC RCS, high residual doses are obtained around the stripper foils. It is caused by not primary particles due to the beam losses but secondary particles due to nuclear reaction at the foil.

In order to evaluate the secondary particles experimentally, a secondary particle measurement system

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is installed at the L3BT 100BD line. Prior examination with PHITS code proves that Cu plate is able to use for irradiation target to makes some radionuclides as the indicator. Thus, the radio-activation analysis method is useful to identify the species and energy of secondary particles.

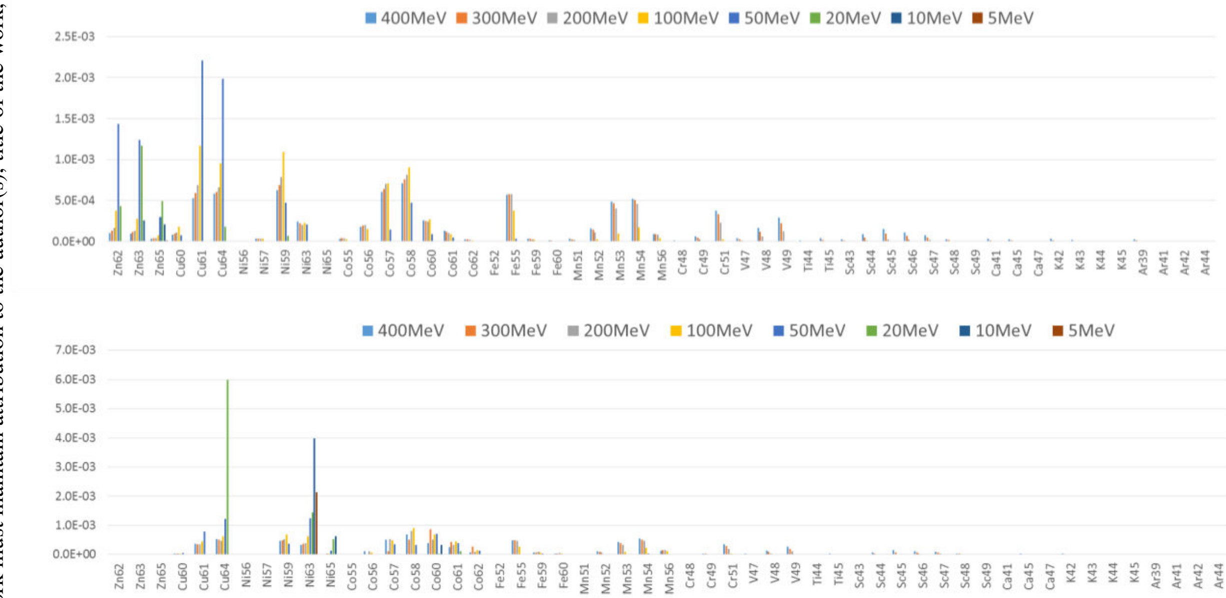

Figure 5: Various nuclides produced from Cu target with proton and neutron beam irradiation.

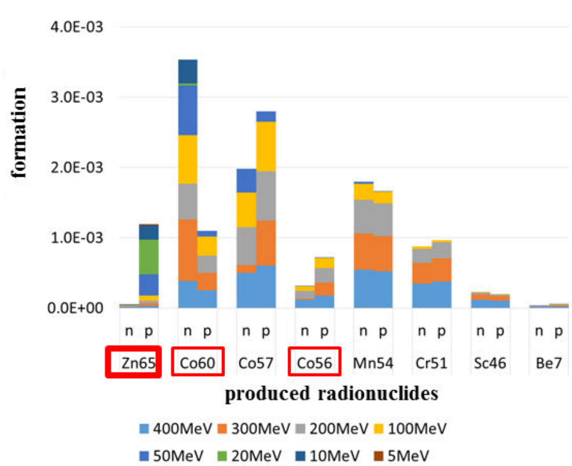

Figure 6: comparison of radionuclide production between proton and neutron irradiations

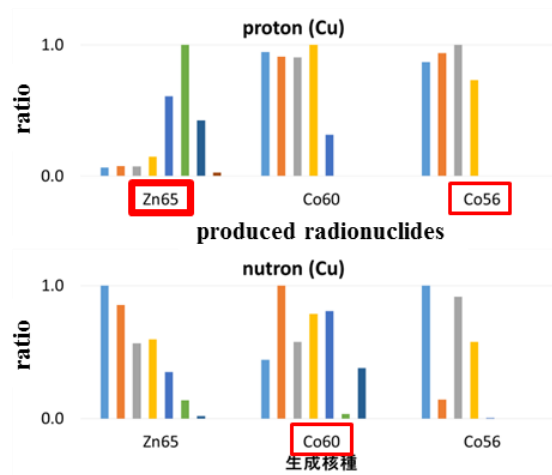

Figure 7: Comparison of normalized production of every beam energy.

ACKNOWLEDGMENT

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