RADIO-ACTIVATION EFFECT OF TARGET ROOMS FOR PEFP'S 20~100 MeV LINEAR ACCELERATOR*

Se-Jin Ra#, Kye-Ryung Kim, Myung Hwan Jung, PEFP, KAERI, Daejeon, Koera

Abstract

PEFP (Proton Engineering Frontier Project) has developed a 20~100 MeV/20 mA proton linear accelerator, proton beam utilization technology and accelerator applications, in order to acquire core technologies which are essential to develop future science and secure the industrial competitiveness. In the experimental hall, 10 target rooms will be constructed for the research of radioisotopes, material, medical, neutron source, etc.

In the irradiation experiments using proton beam of more than a few MeV energy, radio-activation of targets and equipments, such as beam window, SOBP, degrader, beam dump, etc, can essentially be caused by the proton induced nuclear reactions. Highly radioactive beam line equipments occasionally make some problems or inconveniences concerning with sample handling and post-treatment because we have to wait for the samples to be cooled down under the safe value for radiation protection. So we roughly estimated radiation dose rate from equipments with proton beam irradiation condition of each target room. In this study, we used the Monte Carlo N-particle Transport Code for calculating radio-activation.

INTRODUCTION

In the PEFP facility, 5 target rooms for 20 MeV and another 5 target rooms for 100 MeV (Table 1) will be constructed. Each target room has different operation conditions, such as proton beam current, beam line equipments, target material, beam irradiation time, and beam operation scenario. Min et al. [1] calculated radiation dose rate for secondary neutron and gamma ray from mainly targets and concrete wall during proton beam irradiation. From this result, they performed shielding design for each target room of PEFP facility. But we did not have any data for radio-activation of beam line equipments that could be main sources of unnecessary radiation exposure for user and operator. For the target rooms of TR21 ~ TR25, the radio-activation of equipments is not severer than the target rooms of TR101 ~ TR105. The TR101 and TR105 are for radio-isotopes production and neutron source respectively, so there are almost no accesses of person in the target rooms except for maintenance. Therefore, we studied for TR102 ~ TR103 in this paper. In this study, we calculated gamma dose rate from beam line equipments after proton beam irradiation by using Monte Carlo N-Particle eXtended code, Particle and Heavy Ion Transport code, and DCHAIN/SP code, so we will use these results for radiation safety of PEFP's proton beam irradiation experiments.

*Work supported by the Proton Engineering Frontier Project in the MEST (Ministry of Education, Science and Technology) of the Korean government
#nsj0930@kaeri.re.kr

Table 1: Operation conditions.

Target Room	Application Field	Repetition Rate [Hz]	Average Beam Current [mA]
TR21	Semiconductor	60	0.6
TR22	Life & medical science	15	0.06
TR23	Material, energy, and environment	30	0.6
TR24	Physics, chemistry	15	0.06
TR25	RI production	60	1.2
TR101	RI production	60	0.6
TR102	Medical (Proton therapy research)	7.5	0.01
TR103	Material, energy, and environment	15	0.3
TR104	Physics, chemistry	7.5	0.01
TR105	Neutron source	60	1.6

EXPERIMENT

Code Simulation

First, we calculated secondary neutron produced by proton beam with MCNPX code and production rate of radioisotopes in beam line equipments with PHITS code. With these results of MCNPX and PHITS, we calculated radio-activity and gamma-ray energy intensity of equipments with various proton beam operation condition by using DCHAIN-SP code [2]. Finally we evaluated gamma dose rate from the previously calculated gamma-ray energy intensity with MCNPX code. For various irradiation time conditions, we set 6 different irradiation times: 10 sec, 30 sec, 60 sec, 120 sec, 300 sec, and 600 sec, then we evaluated gamma dose rate for an hour.

Schematic Diagram and Characteristics of Equipment

The schematic diagram of the model applied to the code simulation is shown in Figure 1. Measured point of gamma dose rate in the Figure 1 is about 33 cm distance from the center of beam dump and expected as common workspace of users when users set and exchange samples. The characteristics of equipments, such as material, density, and thickness of beam line equipments, are described in Table 2.

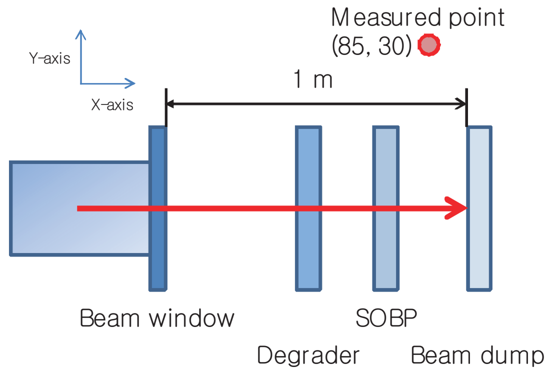

Figure 1: The schematic diagram for code simulation.

Table 2: Characteristics of equipment.

Equipment	Material	Density [g/cm^3]	Thickness [mm]	Δ E [MeV]
Beam Window	AlBeMet	2.071	5	6.4
Degrader	Aluminium	2.700	26	55.2
SOBP	PMMA ($C_5H_8O_2$)	1.200	50	10.2
Beam dump	Carbon	2.267	40	27.0

RESULTS

Beam Window

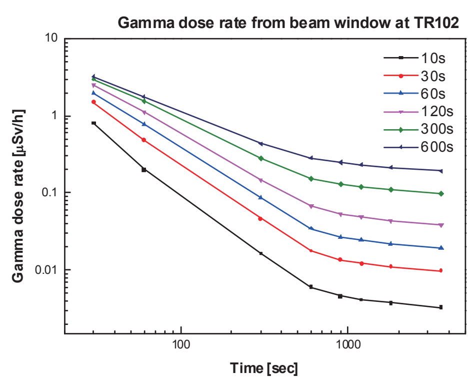

Figure 2: Gamma dose rate of beam window at TR102.

The gamma dose rate of beam window (figure 2) at measured point is relatively lower than the other equipments, because of energy deposit of beam window (6 MeV) and distance between beam window and measured point (about 90 cm). Table 3 shows the radio-activity of produced radio-isotopes. The radio-activity of beam window for TR103 is about 30 times higher than that of TR102 because of the difference of the average beam current. The gamma dose rate of TR103 is also about 30 times higher than TR102.

Table 3: Radio-activity of produced major radio-isotopes in beam window (after 10 sec proton beam irradiation).

Radio isotope		Activity [Bq]	Rate [%]	Half-Life [sec]
^{6}He	TR102	1.28E+09	10.56	0.808
	TR103	3.85E+10	10.56	
^{8}Li	TR102	3.06E+09	25.17	0.838
	TR103	9.18E+10	25.17	
^{8}Be	TR102	3.44E+09	28.26	6.7E-17
	TR103	1.03E+11	28.26	
^{27}Si	TR102	1.91E+09	15.72	4.17
	TR103	5.74E+10	15.72	

Degrader

Figure 3 shows the gamma dose rate of degrader at TR102. The gamma dose rate dropped rapidly in the first few minute due to the production of radio-isotopes having a few second half lives (Table 4).

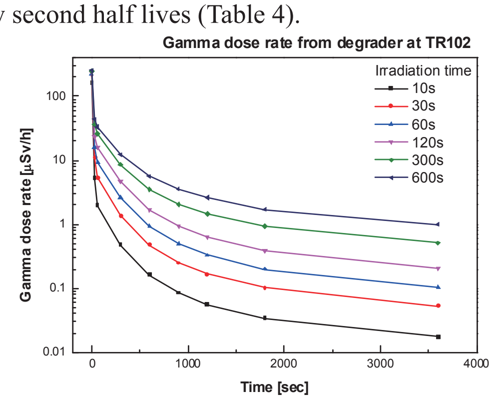

Figure 3: Gamma dose rate of degrader at TR102.

Table 4: Radio-activity of produced major radio-isotopes in degrader (after 10 sec proton beam irradiation).

Radio isotope	Activity [Bq]	Rate [%]	Half-Life [sec]
^{23}Mg	9.47E+09	2.98	11.3
^{25}Al	5.84E+10	18.37	7.18
^{26m}Al	2.00E+10	6.29	6.35
^{26}Si	3.24E+10	10.21	2.23
^{27}Si	1.63E+11	51.25	4.17

SOBP

The gamma dose rate of SOBP also dropped rapidly in the first few minute because of radio-isotopes having a short half-life, such as ^{12}B, ^{12}N, ^{16}N, and ^{11}B (Table 5). After 10 minutes, most of radio-isotopes having a short half-life decayed, and only ^{11}C remained. Hence reduction rate was constant.

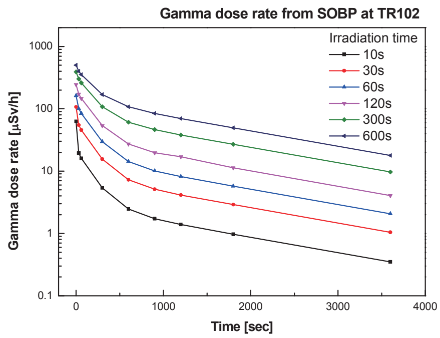

Figure 4: Gamma dose rate of SOBP at TR102.

Table 5: Radio-activity of produced major radio-isotopes in SOBP (after 10 sec proton beam irradiation).

Radio isotope	Activity [Bq]	Rate [%]	Half-Life [sec]
^{8}Be	4.45E+08	5.77	6.7e-17
^{8}B	3.12E+08	4.05	0.77
^{11}B	1.07E+09	13.92	0.0202
^{11}C	2.82E+08	3.67	1223
^{12}N	3.31E+09	42.94	0.011
^{15}O	1.66E+09	21.49	122

Beam Dump

Table 6 shows produced radio-isotopes in beam dump. Most of the radio-isotopes, except ^{11}C and ^{26m}Al, have a short half life, so reduction rate was same as SOBP from 1 minute after beam irradiation.

Table 6: Radio-activity of produced major radio-isotopes in beam dump (after 10 sec proton beam irradiation).

Radio isotope	Activity [Bq]	Rate [%]	Half-Life [sec]
^{8}Be	1.45E+09	4.78	6.7e-17
^{12}B	1.56E+09	5.16	0.0202
^{11}C	7.12E+08	2.35	1223
^{12}N	2.28E+10	75.37	0.011
^{24m}Na	1.93E+09	6.37	0.0202
^{26m}Al	7.16E+08	2.37	6.35

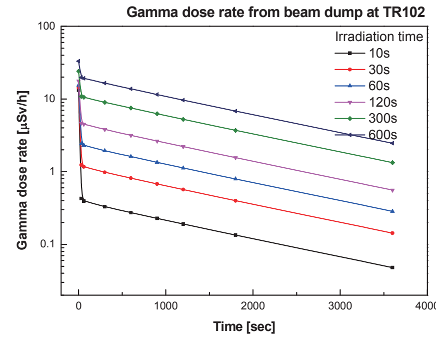

Figure 5: Gamma dose rate of beam dump at TR102.

Total gamma dose rates of all equipments are shown in the figure 6. The gamma dose rate dropped under 12.5 µSv/h within an hour, except 600 second irradiation. Time for changing sample is less than 5 minutes in most experiments, so radiation exposure is not severe at TR102. Because the gamma dose rate of TR103 is 30 times higher than TR102, we need to be careful at TR103.

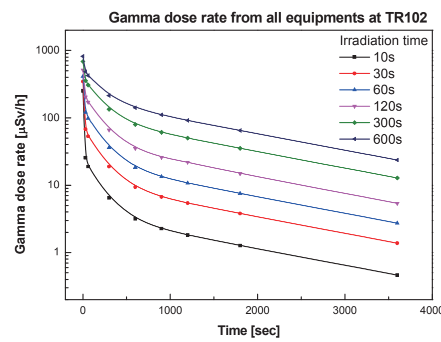

Figure 6: Gamma dose rate of all equipments at TR102.

DISCUSSION AND CONCULSION

In this paper, we evaluated gamma dose rate of beam line equipments with restrictive condition because we did not have actual designs of equipments yet. Furthermore, we calculated to apply only average beam current so the results can be further differences with real experiments. When construction of PEFP's facility is completed and 100 MeV proton beam is started to provide, we can use these data to evaluate real dose rate of equipments and samples with actual conditions.

REFERENCES

[1] Y.S. Min, C.W. Lee, K. J. Mun, J. Nam, and Jun Yeon Kim, J. Kor. Phys. Soc. 56 (2010) 1971.

[2] Kye-Ryung Kim, Myung-Hwan Jung, Hyun-Ook Kim, Cheol-Woo Lee, Ji-Ho Jang, Myoung-Ki Min, Geun-Seok Chai, and Hong-Joo Kim, "Preliminary Results of Sample Activation Measurement Using A HPGe Detector for the Nano Particle Fabrication by Proton Beam", PAC'09, Vancouver, May 2009, TU6PFP011, p. 1315 (2009), http://www.JACoW.org.