DESIGN OF 100 MEV PROTON BEAM IRRADIATION FACILITY FOR THE PEFP 100 MEV LINAC *

Sang-Pil Yun#, Bum-Sik Park, Kyung-Tae Seol, Young-Gi Song, Han-Sung Kim, Ji-Ho Jang, Hyeok-Jung Kwon and Yong-Sub Cho
PEFP/KAERI, Daejeon, Korea

Abstract

The Proton Engineering Frontier Project (PEFP) will install a 100-MeV proton linear accelerator at Gyeong-ju site. For the beam commissioning of 100 MeV proton linac, the two target rooms (TR 103, TR 23) will be prepared as a starter among 10 target room. To design the irradiation equipment in TR 103, we have investigated general propagation shape and spatial distribution of proton beam, when 100 MeV proton beam extracted from vacuum in the beam lines through beam window by Monte carlo method. On the basis of this result, we have designed beam irradiation components and their configuration. The beam irradiation facility consist of beam window, beam dump, support frame, sample support and beam current monitor. To minimize residual radioactivity induced by incident proton beam, the pure aluminum was selected as the material of beam dump and the aluminum alloy was selected as material of other irradiation equipment. This residual radioactivity of equipment was estimated by Monte carlo method. In this paper, the details of this irradiation equipment design are presented.

INTRODUCTION

The PEFP 100-MeV proton linear accelerator has been developed and will be installed at Gyeong-ju site [1-2]. The 20-MeV or 100-MeV proton beam will be supplied to users who want to utilize proton beams for their own research and development. To meet user's demand, the PEFP will construct a ten target rooms which each of them have own characteristics. But, for the beam commissioning of 100-MeV proton linac, the two target rooms (TR 103, TR 23) will be prepared as a starter among 10 target rooms. The TR 103 target room will be used for 100 MeV proton beam commissioning at the early stage of the accelerator operation. Therefore, the design of irradiation equipment in the target room was focused on the radiation safety, the beam observation and the beam current monitoring.specification

The layout of two target room is shown as figure 1. Two target rooms have 4 × 4 × 3 m space, they are enclosed the concrete shielding wall. The most of the construction work of the target room was completed, but the remaining construction works are still conducting. Figure 2 shows the construction status of the target room.

The proton beams are transported though the beamline to the target room, they are spread out by the octupole magnet up to 300 mm in the target room to provide the large and uniform proton beams to users. Table 1 shows the general specification of the target room.

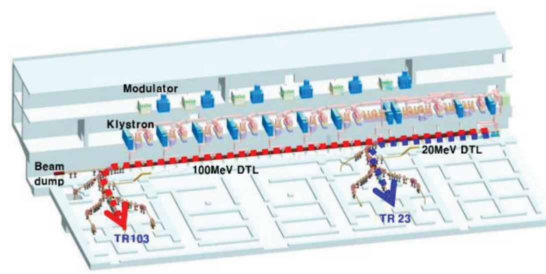


Figure 1: Layout of 100 MeV proton linac.

Table 1: Specification of Target Room

	TR 23	TR 103
Utilization	Material, Energy, Environment	Material, Energy, Environment
Avg. Beam current	0.3 mA	0.6 mA
Beam size	300 mmø (± 10%)	300 mmø (± 10%)
Beam spreading Method	Octupole	Octupole
Space	4 m × 4 m × 3 m	4 m × 4 m × 3 m

(a) Shielding door (b) Inside

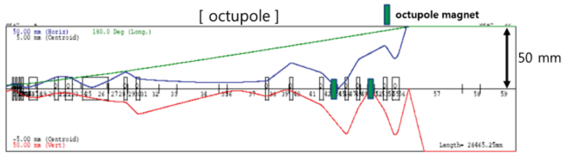
Figure 2: The status of the target room construction.

BEAM OPTICS

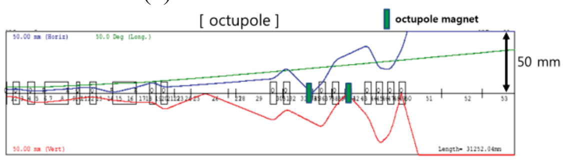
To obtain the large and uniform proton beam of 300 mm, a nonlinear beam spreading method by using octupole magnets was selected [3]. The basic parameters of the beamlines were defined in the simulation with TRACE-3D. These results give us the settings of the quadrupole magnets and octupole magnets (Figure 3).The transverse distribution of the proton beam was studied

*This work is supported by MEST of the Korean government.
spyun@kaeri.re.kr

with TURTLE. These results indicate the beam spreading by the octupole magnet (Figure 5).



(a) 20 MeV beamline



(b) 100 MeV beamline

Figure 3: The transport calculation in the 20 MeV and 100 MeV proton beamlines.

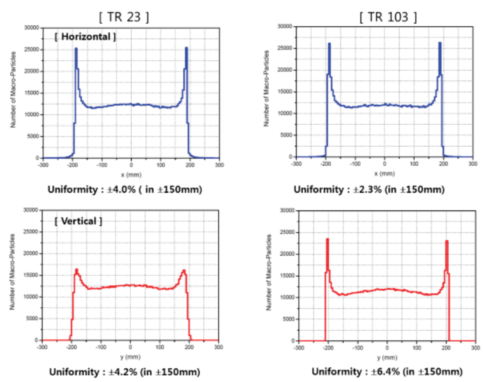


Figure 4: Transverse beam distribution at the beam window in the target room.

100 MEV PROTON IRRADIATION EQUIPMENT

The proton beam irradiation equipment was consisted of the several parts as belows.

- Beam window
- Beam dump
- Support Frame

Beam Window

To utilize the large size of proton beam in condition of the external atmosphere, the large size of beam window will be required. The window material must have a good mechanical property against the stress induced by the pressure difference between vacuum and the external atmosphere. Also, their thickness has to be thin and the atomic number (Z) has to be small to minimize the heat generation induced by the energy transfer of the high current proton beam. To meet the good the mechanical property and the low heat generation, the aluminium-beryllium alloy (AlBeMat) was selected as the beam window material [4]. The beam window was designed to have dia. 300 mm and their thickness was 0.5 mm to transfer the large size proton beam. Figure 5 shows the fabricated the AlBeMat beam window.

Figure 5: The fabricated AlBeMat beam window

Beam Dump

The proton beams are evacuated from the beam window, propagate in the air and then they are stopped in the beam dump. The interaction between the proton beam and the beam dump create the secondary radiation and the residual radioactivity, which are have to be minimized because they can be cause the radiation hazards to the radiation workers or public.

Figure 6 shows the residual radioactivity of the copper, aluminium and graphite after the end of the 1 hour proton beam irradiation, assuming the beam energy is 100 MeV and their intensity is 0.3 mA. This estimation was conducted by FT8 res card (residual nuclei option of the F8 pulse height tally) of MCNPX simulation [5].

The aluminium shows the best performance among the candidate materials as the beam dump materials. The graphite also produces the fast decay isotope. But the Be-7 (T1/2: 53.12 day) can be remained for the long time significantly. Therefore, the aluminium was selected as the beam dump material for 100 MeV proton beam.

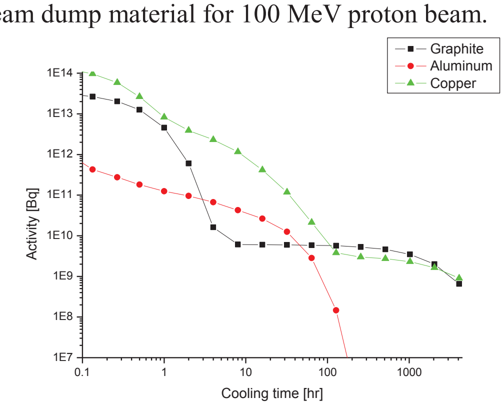


Figure 6: The residual radioactivity of the various materials.

The beam dump was designed to have 40 cm × 40 cm and its thickness was 4 cm to can stop a dia. 30 cm proton beam. The stopping range of 100 MeV proton in the aluminium was estimated as 36.9 mm by the SRIM calculation [6]. For the beam current measurement, the aluminium beam dump body will be isolated by the insulator. The proton beam current can be monitored by the current sensitive pre-amplifier and the oscilloscope.

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For the beam commissioning, the beam power was determined to 1 kW (100 MeV, 10 μA). Thus, the heat load at the beam dump will be 1 kW. To cooling the 1kW heat load at the beam dump. The air cooling by using the two air-blower will be applied. The figure 7 shows the schematics of the designed beam dump.

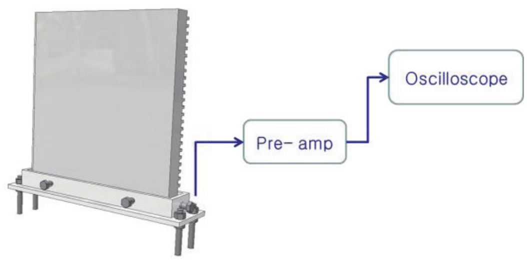

Figure 7: The schematics of the aluminium beam dump.

Support Frame

To minimize the radio-activation which can be caused by the secondary neutron in the target room, the material of all support frame of the target room equipment will be made of pure aluminium. This will be helpful to reduce the radiation dose of the radiation worker and public who access to the target room.

Beam Observation

To measure the beam size and profile of the 100 MeV proton beams which have reached at the beam dump, the Cr doped Al_2O_3 (Chromox) phosphor screen will be attached at the front of the beam dump. The chromox have a good sensitivity and high radiation hardness [7]. The beam spot image at the beam dump can be captured by the CCD camera in the target room and remotely monitored at the control room.

Table 2: The Specification of Chromox.

Name	Composition	Decay time	Rel. Light yield
Chromox	Al_2O_3:Cr	Some msec	1.0

General Arrangement

The reference level of proton beam from the ground was 1200 mm. Therefore all equipment such as the beam window, beam dump and so on in the target room was arranged to match this level. The beam window is positioned at the centre of the target room. The beam dump is positioned at the 1000 mm distance from the beam window. And the two air blowers are positioned at the behind of the beam dump to cooing the 1kW heat load of the beam dump. For the beam observation, two CCD cameras will be positioned at the overhead of beam window and beam dump (Figure 8).

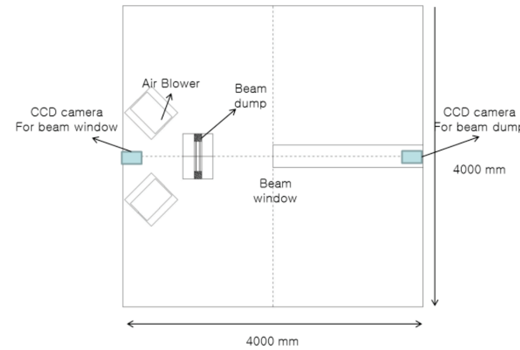

Figure 8: General arrangement of the target room.

CONCLUSION

For the beam commissioning of the 100 MeV proton linac, the proton beam irradiation equipment in the target room were designed, such as the beam window, the beam dump and so on. The AlBeMat beam window is prepared for transferring the large size proton beam to external atmosphere. The all equipment in the target room will be made of the pure aluminium for low radio-activation. This will be contributed to radiation safety of the radiation workers and public who access to the target room.

ACKNOWLEDGMENT

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