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The Preliminary Design of Prototype Target Stack and the Investigation of Radionuclide Inventory at the 100 MeV Isotope Production Facilities at PEFP

Sang-pil Yoon*, In-seok, Hong, Yong-sub Cho
Proton Engineering Frontier Project, Korea Atomic Energy Research Institute
1045 Daedeok Street, Yuseong-gu, Daejeon 305-353, Korea
**Corresponding author: spyun@kaeri.re.kr*

1. Introduction

The Proton Engineering Frontier Project have a plan to construct 100-MeV Proton Linear accelerator and also, will construct radioactive isotope production facility using 100MeV proton beam for medical application. Sr-82, Cu-67 and Ge-68 were selected as the objective radioisotope in this facility, they are promising radioisotope for the PET imaging and cancer therapy.

To produce Sr-82, Cu-67 and Ge-68, RbCl, Zn metal and Ga metal were chosen as a target materials which they have capsulation of Inconel and also to produce these radioisotopes at the same time, we have introduced target stack in tandem [3].

Table 1. indicated the general characteristics of the designated radio-isotopes.

Table 1. Characteristics of the designated radio-isotope

Isotope	material	Nuclear reaction	Half-life	Emitting radiation
Sr-82	RbCl	natRb(n,xn)82Sr	25.5d	Positron
Cu-67	Zn	68Zn(p,2p)67Cu	2.6d	Electron
Ge-68	Ga	natGa(n,xn)68Ge	270d	Positron

2. Methods and Results

To design RI target, we have derived the optimum thickness of target materials considering the beam energy loss by the beam window, cooling water and target material through SRIM calculation [1].

In order to determine maximum beam current and maximum beam exposure time, we have calculated all generated radionuclide activities by using MCNP calculation [2].

2.1 the Determination of the optimum beam energy for RI production

Figure 1 shows the schematics of the prototype target stacks. When the proton beam passes through the target they lose its energy. Thus the target thickness determine the proton beam energy which bombardment at each the target.

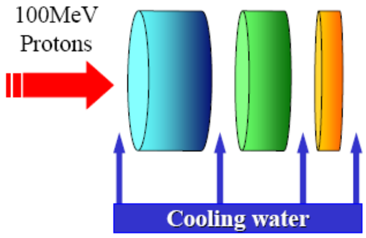
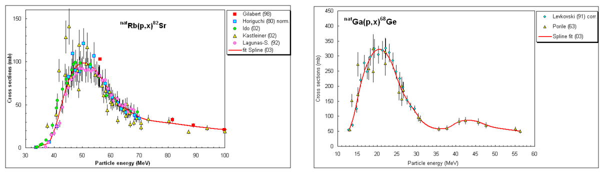
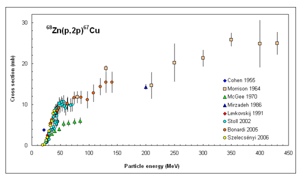


Fig.1 Target configuration

To determine the optimum target thickness, we have investigate the proton induced the nuclear reaction cross-section data which produce the designated radioactive isotope such as Sr-82, Cu-67 and Ge-68 from the IAEA nuclear data service. Figure 2 shows the the production cross-section for the Sr-82, Cu-67 and Ge-68.



(a) Sr-82 (b) Ge-68



(c) Cu-67

Fig 2. The production cross-section induced by proton

Considering these the production cross-section and the proton beam energy of 100-MeV, we derived the optimum beam energy.

Table 2. the optimum beam energy for RI production

isotope	Optimum beam energy	Actual beam energy
Sr-82	98MeV ~ 41MeV	95MeV ~ 70MeV
Cu-67	> 40MeV	65MeV ~ 40MeV
Ge-68	30 ~ 10 MeV	30MeV ~ 10 MeV

2.2 the Determination of the optimum thickness of target materials

The prototype targetary system consists of inconel beam window, target stacks and cooling channels. The prototype target stacks to produce Sr-82, Cu-67 and Ge-

68 are consisted of RbCl, Zn metal, Ga metal, the inconel alloy capsulation for RbCl and Niobium capsulation for the Ga metal.

First we fixed the thickness of the inconel beam window, each cooling channel and target capsulations as 0.5 mm, 5 mm and 0.3 mm. and then, we optimized the thickness of target materials such as RbCl, Zn metal and Ga metal by using iterative SRIM calculation.

The table 3 and figure 3 indicated the optimized target thickness and the energy loss of proton beam as function of target thickness.

Table 3. Target thickness and beam energy

Layer	Thickness [mm]	Energy
Beam window	0.5	103~100.88
cooling water	5	100.88~97.17
Inconel capsule	0.3	97.17~95.85
RbCl	17	95.84~69.67
Inconel capsule	0.3	69.67~68.01
cooling water	5	68.01~62.9
Zn metal	4	62.9~41.93
cooling water	5	41.93~34.92
Nb capsule	0.3	34.92~30.99
Ga metal	3	30.99~2.96
Nb capsule	0.3	0
cooling water	5	0

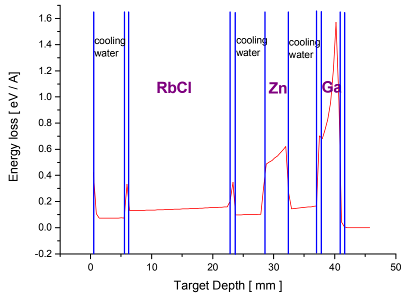


Fig. 3. the energy loss of proton beam at target stacks

As a result of SRIM calculation, we optimized the thickness of RbCl, Zn metal and Ga metal as 17 mm, 4 mm and 3 mm. and this result also indicated the energy loss of 20MeV occurred at each target stacks. Thus we can estimate the quantity of heat dissipation at each target.

2.3 radionuclide inventory and total radioactivities

To estimate what nuclides generate during proton beam irradiation and total radioactivity of irradiated target, this paper introduce the use of Monte Carlo code MCNPX.

We set up the typical beam parameters as 300 µA beam current and 95 hours irradiation time. Though the MCNPX calculation, we can obtain the list and the quantity of all generated radionuclide by using used the residual nuclei option of F8 pulse height tally.

From the result of MCNPX calculation, 93 species of radionuclide are generated at end of irradiation, and indicate most of generated nuclide have ß+,ß-,EC decay mode. Thus the energy of dominant gamma was 511 KeV. Figure 4 shows the partial section of the radionuclide inventory.

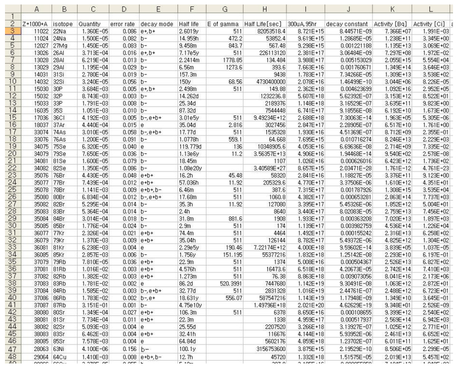


Fig 4. the screen shot of the generated radionuclide list

Also, the result of MCNPX shows total radioactivity of prototype target stacks. After 60 hours, their activity was about 1600 Ci. That result was shown as Figure 5.

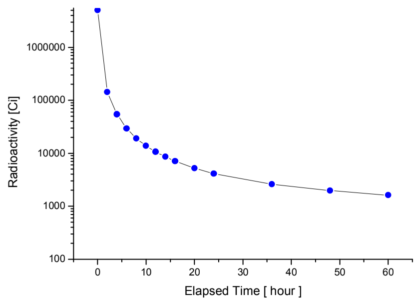


Fig 5. The time variation of radioactivity

3. Conclusions

In this paper, we optimized the thickness of target materials by using SRIM calculation for preliminary designing RI target. And we have investigated the radionuclide inventory at the end of proton beam irradiation. If beam current is 300 µA and irradiation time is 95 hours, we estimated 92 species of radionuclide generated and their total radioactivity is 1600 Ci.

Acknowledgement

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