

# DESIGN OF THE SECONDARY PARTICLE PRODUCTION BEAM LINE AT KOMAC\*

Hyeok-Jung Kwon<sup>†</sup>, Jeong-Jeung Dang, Han-Sung Kim, Young-Gi Song, Sang-Pil Yun, Yong-Sub Cho,  
KOMAC, KAERI, Gyeonju, Republic of Korea

## Abstract

A 100-MeV proton linac is under operation since 2013 at KOMAC (Korea Multi-purpose Accelerator Complex) and provides proton beam to various users from the research institutes, universities and industries. To expand the utilization fields of the accelerator, we are planning to develop a target ion source to produce secondary particles such as  $^8\text{Li}$  based on the existing linac. A test beam line was designed in order to supply proton beam to target ion source. Details on the beam line design are presented.

## INTRODUCTION

The layout of the 100-MeV proton beam line is shown in Fig. 1. Three beam lines are operating for user service at KOMAC, one is a general purpose beam line for 20-MeV beam users (which is not shown in the Fig. 1), another is a general purpose beam line for 100-MeV beam users, both of which have been operating since 2013 [1], and the third is the radio-isotope (RI) production beam line using 100-MeV proton beam, which was commissioned in 2016 and starts beam service in 2017 [2]. The fourth beam line, whose main purpose is to supply low flux proton beam to users from application fields such as simulation of the space radiation, development of the radiation detector, was developed in 2016 and is under commissioning in 2017 [3]. The total number of projects for beam service was 131 in 2016. Among them, 37% were researches related with the material science including nano-science and semiconductor research, 26% were researches related with the bio-science, 13% were researches related with the basic science including nuclear physics and astrophysics. About 64% of the users come from the universities, 24% come from the research institutes, and 12% come from industries. Up to now, all the users use proton beam directly irradiated on the target. But it is well known that many kinds of secondary particles such as neutrons and ions come from the target when proton beam hits the target. And those secondary particles can be used equally valuable compared with the primary proton beam. Researches based on the secondary particle are planned at KOMAC. At first stage, two kinds of secondary particles, pulse neutron and radio-isotope beam based on  $^8\text{Li}$ , are considered. As is well known, pulse neutron produced by the high energy proton beam is a main application field of the high power proton accelerator. Therefore, it is planned to do the research not only on the pulse neutron user facility but also on the high energy

accelerator and neutron production target. Meanwhile,  $^8\text{Li}$  radio-isotope beam will be used for beta-NMR research, whose main advantage is its high sensitivity compared with the conventional NMR, but there are few user facilities in the world [4]. Here, a test bench including beam transport system and target for the  $^8\text{Li}$  production is described. A system for the production of the pulse neutron is presented elsewhere [5].

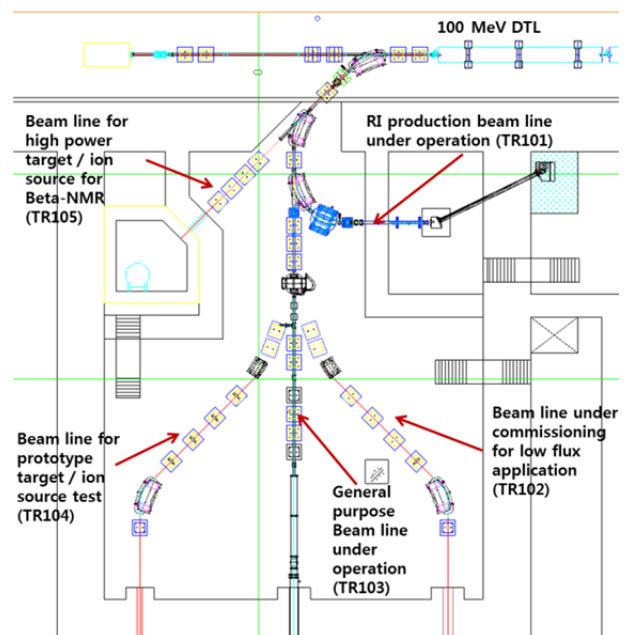


Figure 1: Layout of KOMAC 100-MeV proton beam line.

## $^8\text{Li}$ PRODUCTION TARGET / ION SOURCE PROTOTYPE

We are going to use a target room number TR104 as shown in Fig. 1 for testing the prototype of the target / ion source for  $^8\text{Li}$  production because the accessibility to the target room TR104 is easy. But the high power target / ion source will be installed at TR105 which has a vertical penetration into the ground. We are going to build a secondary particle experimental building beside the TR105 target room and install the beta-NMR facilities there. The neutron guide and the pulse neutron user facilities will be installed there too.

### Prototype Target / Ion Source

The design requirement of the prototype target / ion source is summarized in Table 1. A prototype target / ion source is developed to study the  $^8\text{Li}$  production by using 100-MeV proton beam. The target material to produce  $^8\text{Li}$  is beryllium oxide ( $\text{BeO}$ ). The  $^8\text{Li}$  is produced by the  $^9\text{Be}$

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<sup>†</sup> hjkwon@kaeri.re.kr

(p, 2p)  $^8\text{Li}$  nuclear reaction. In order to estimate the production rate, FULKA code was used [6]. The calculated production rate was  $1.1 \times 10^{10}$  pps inside the BeO by  $1 \mu\text{A}$  of 100-MeV proton beam as shown in Fig. 2.

Table 1: Design Specifications of Prototype Target / Ion Source

Parameters	Values
Proton energy	100 MeV
Proton peak / average current	20 mA / 10 uA
Target	BeO
$^8\text{Li}^+$ beam production rate	$> 10^6$ pps
$^8\text{Li}^+$ beam energy	30 keV

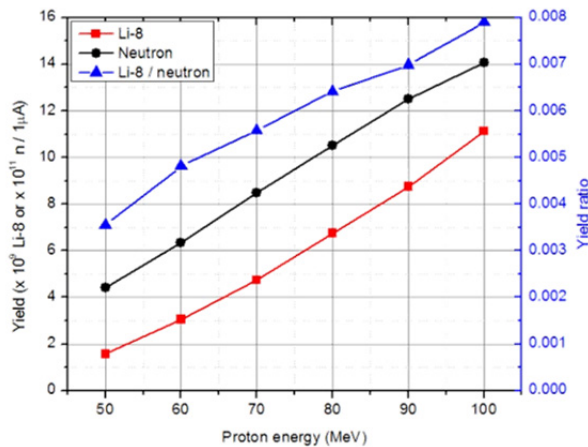


Figure 2: Production yield of  $^8\text{Li}$  and neutrons in BeO target depending on proton energy.

Based on the calculation results, prototype target / ion source was designed. The radius and thickness of the single BeO target are 25 mm and 1 mm respectively. Total 27 BeO disks are installed at rhenium (Re) target holder and aligned along the proton beam path inside graphite target container. The graphite target container encloses the BeO target and target holder, and guides the Li-8 into a transfer line which is connected with the ion source. The target and target container are heated by a tantalum (Ta) heater. Ta heater is a cylindrical tube with 60 mm in inner diameter and 1 mm in thickness. Both sides of the heater are opened. Heating power is supplied to the heater via a Ta wing and water-cooled high current feed through. The ion source adopts a surface ion source type. The inner diameter and the length of the surface ion source are 3 mm and 30 mm, respectively. The material of the ion source is rhenium which can ionize lithium more efficient than tungsten and tantalum. The designed prototype target / ion source is shown in Fig. 3.

A collimator, diagnostics box, insulator are installed in front of the prototype target / ion source. After the prototype target / ion source, an insulator, electrostatic triplet, velocity filter and  $^8\text{Li}$  beam diagnostic box are installed to

measure the  $^8\text{Li}$  beam production rate and to study the beam properties.

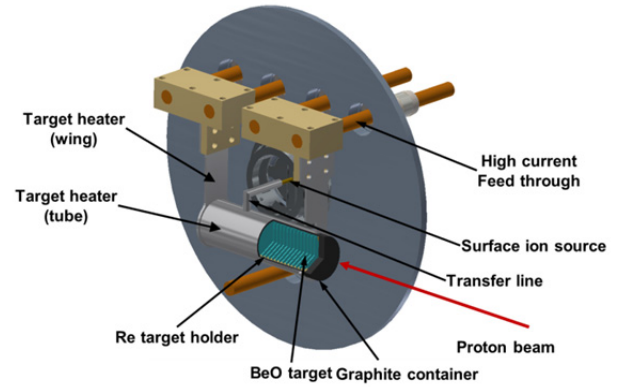


Figure 3: Prototype target / ion source.

### BEAM TRANSPORT SYSTEM

The 100-MeV proton beam transport system to the prototype target / ion source located in TR104 consists of beam focusing and bending elements, vacuum system, beam diagnostics.

#### Beam Optics and Beam Line Components

The beam transport system shares common elements from the DTL output to AC magnet with other beam lines such as general purpose beam line (TR103) and low flux beam line (TR102). The beam optics was calculated by using TraceWin code [7]. The output beam from the DTL was used as the input beam parameter to the code. The dispersion after the two 45 degree bending magnets was adjusted to zero by using the two quadrupole magnets between bending magnets. The beam size at the target position was increased by using the dispersion and downstream quadrupole magnets to target size. The beam trajectories along the beam transport system and beam distribution at the target position are shown in Fig. 4 and Fig. 5 respectively.

Based on the beam optics design, the elements of the beam transport system were designed. The purpose of the AC magnet is to distribute the beam into three downstream beam lines simultaneously at maximum 7.5 Hz sweep frequency. The 7.5 Hz AC magnet was already installed but the fast sweep power supply is not installed yet. A set of DC power supply and automatic transfer switch is used to guide the beam into three directions. The bending angle of the AC magnet is 20 degree and another 25 degree bending magnet is installed after the AC magnet and the total bending angle is 45 degrees. The last 45 degrees bending magnet directs the proton beam into the target room. The bending radius of the 25 degrees and 45 degrees bending magnet are the same and both are C-type magnet. The maximum pole tip field is 0.8 T and the pole gap is 90 mm with shim to satisfy the good field requirement of 0.1% within 100 mm width. There are 7 quadrupole magnets from the AC magnet to the target room. The aperture diameter of the quadrupole magnet is 110 mm, the maximum field gradient is 5 T/m and the effective length is 400 mm. Two sets of steering magnets are used.

It is a double steering magnet with rib to increase the field uniformity [8]. The kick angle of the 100-MeV proton beam is 4 mrad and aperture of the steering magnet is 136 mm. The field uniformity is 2% within 100 mm width.

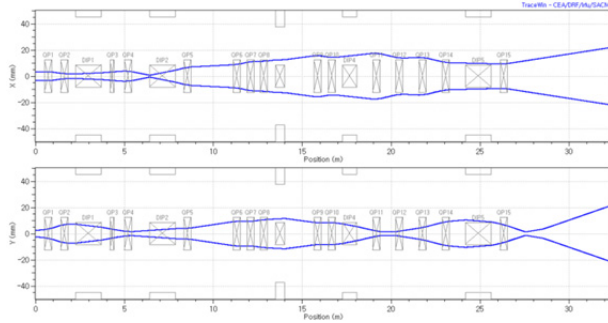


Figure 4: Beam envelope along the beam line.

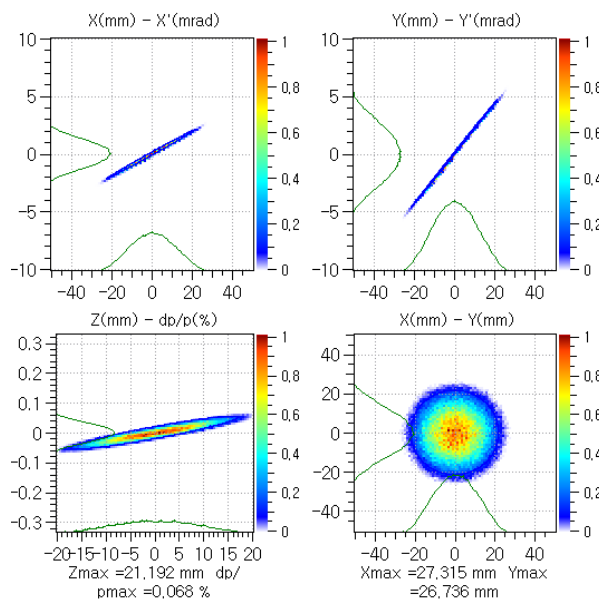


Figure 5: Beam at the target.

The beam pipe is 100mm in diameter. The vacuum requirement of the beam transport line is less than  $10^{-6}$  Torr. A set of turbo molecular pump (TMP) and ion pump (IP) is installed in the common beam line from the DTL output to the AC magnet. Another one set of TMP and IP is installed to evacuate the beam transport line at the middle of the beam line between 25 degrees bending magnet and 45 degree bending magnet. Two gate valves are installed, one is at the downstream of the AC magnet, and the other is in front of the target room penetration. A pressure sensor is installed behind the second gate valve to activate the fast closing valve which is installed in the middle of the two 45 degrees bending magnets at the downstream of the DTL to protect the accelerator from the sudden vacuum leak at the target room.

Two sets of AC current transformers (ACCT), beam position monitors (BPM) and wire scanners are installed. The BPM is strip-line type and the aperture diameter is 100 mm. Proportional type beam loss monitors are installed at the exit of the bending magnet which will be

used as a signal source to activate the machine protection system (MPS) to stop beam.

## CONCLUSION

Two kinds of secondary particle researches are planned at KOMAC to expand the application area of the 100-MeV proton linac. One is the pulse neutron and the other is  $^8\text{Li}$  RI beam. A beam transport system and prototype target / ion source to produce  $^8\text{Li}$  beam were designed. The target to produce  $^8\text{Li}$  is BeO with 50 mm in diameter. The surface ionization ion source is designed to ionize the  $^8\text{Li}$  particles at the surface of hot Re. A 100-MeV proton beam transport system to the prototype target / ion source was designed. Details of the elements including bending magnets, quadrupole magnets, a vacuum system, and beam diagnostics were designed based on the beam optics.

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