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# STATUS OF A 70 MeV CYCLOTRON SYSTEM FOR ISOL DRIVER OF RARE ISOTOPE SCIENCE PROJECT IN KOREA*

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*Abstract*

A 70 MeV $H^-$ cyclotron commercially available for medical isotope production will be used as an ISOL driver for rare isotope science project in Korea. The cyclotron is scheduled to be installed in 2021 for beam commissioning in the following year. In fact the building to house the cyclotron is currently almost complete so that the cyclotron system newly contracted needs to fit into the existing building, which brings some challenges in equipment installation and adaptation to utilities. Two beam lines to transport high-current proton beams into ISOL targets have been designed and are described along with other issues associated with the interface of the ISOL system.

## INTRODUCTION

A 70 MeV cyclotron system was contracted with a company in May 2017 to be used as the driver of the ISOL system for rare isotope science project (RISP) in Korea [1, 2] and a building to house the system has been constructed since 2017. However, the contract was broken in early 2019 while the building is near completion. A new contract was made with IBA in July 2019 after reviewing the building interface and the design of ISOL beam lines. It was then mutually confirmed no major modification of the present building is needed to accommodate the cyclotron system of IBA [3].

The major parameters of cyclotron are listed in Table 1. The cyclotron size is slightly smaller than the previous one so that minor modifications are sufficient for installation. The primary use of cyclotron will be to provide ISOL target with proton beams in a diameter of 2-5 cm. with a beam power up to 10 kW for RISP. A wobbler magnet will be installed in the cyclotron vault and then the drift length to the target is over 8 m, which may cause some instability of the beam spot at the target.

Table 1: Main Cyclotron Parameters

| Item | Value |
|---|---|
| Beam energy range | 30 – 70 MeV |
| Max. beam current | 0.75 mA |
| Extraction port number | 2 |
| Weight | 140 tons |
| Beam size at ISOL target | 20-50 mm |

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## BUILDING INTERFACE

Construction of the cyclotron building is nearly completed in 2019 with its design fit for the cyclotron of BEST Cyclotron Systems, Inc. [4, 5]. Hence, the building design was checked before the new contract was made whether any major modification of the current building is needed such as new penetration holes on the walls designed for radiation shielding, but no significant work was found.

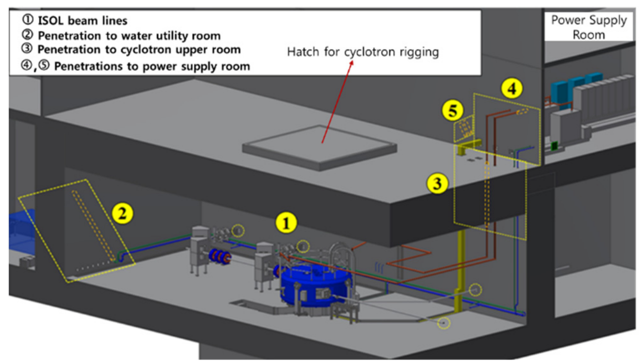


Figure 1: Penetration holes and a hatch in the cyclotron vault and in the upper room. The vault is located in B1. In ④ there are holes for rf transmission line of the final amplifier located in the power supply room, which is not needed for the IBA cyclotron.

The cyclotron will be rigged and installed through the hatch shown in Fig. 1 with one or two cranes anchored outside of the building. Also shown in Fig. 1 are utility connections through the shielding walls, which are grouped into four depending on their usage as denoted. A major difference in cyclotron component is that the final RF amplifier is directly attached to the cyclotron dee rather than placed in the power supply room. Hence, two high-power transmission lines of over 10 m long and their penetration holes are saved.

In the current building, there is no crane inside the vault so that it is expected to have some difficulty during installation and maintenance later. To relieve this issue we plan to install a simple jib crane near the cyclotron, which can also cover some beam line components.

The cyclotron pit was constructed to accommodate the ion source and injection beam line located under the cyclotron, but the IBA system has them on the top of the cyclotron. The lower space will be utilized to house some components such as for vacuum, so it is actually thought to be useful.

The beam loss inside the cyclotron and along the beam line is expected to be less than the loss used for the design of shielding walls. At the maximum current of 750 μA,

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the beam delivered to the target vault will be around 700 μA if the loss by the beam collimator is not included. The loss inside the cyclotron by magnetic and gas stripping during acceleration is calculated to be less than 3%.

## TWO ISOL BEAM LINES

Two target bunkers are prepared for the ISOL system as shown in Fig. 2 but only one beam line to cave 1 will be extended up to the target during RISP. For high-power beam test the beam will be delivered to cave 2 bombarding a beam dump cooled by flowing water to carry away up to 50 kW at 70 MeV.

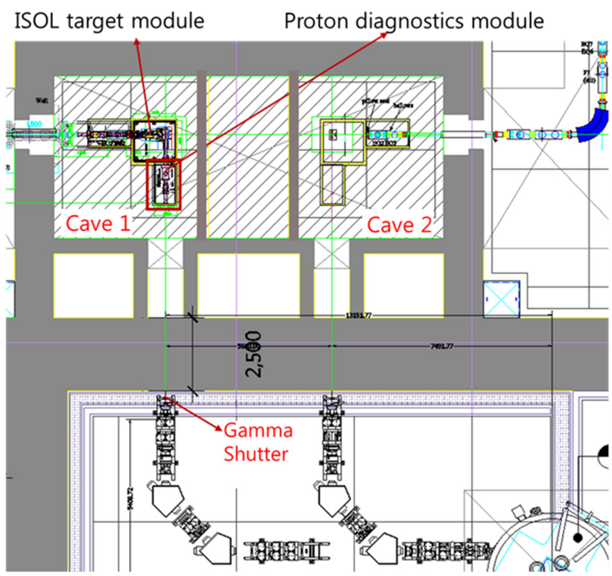


Figure 2: Two caves for the ISOL target. Two modules called as ISOL target and proton diagnostics will be installed with remote handling capability.

A concern in the target room design is the distance between a multi-slice ISOL target and wobbler magnet is over 8 m due to a long tunnel in between. An AC beam formed by the wobbler should travel the distance without any active beam steering component due to high radiation inside the cave, which requires sophisticated remote handling capability for maintenance. As indicated in Fig. 2 only two modules adapted to remote handling will be installed in the cave. Each module has gate valves and pillow seals, which are connected to the upper plate of the module for detachable connections. As a result any jittering of the wobbler can induce significant shift of the beam.

A gamma shutter will be used to enter the cyclotron vault when ISOL target being irradiated stays in the target cave. The ideal location of the shutter is near the wall inside the cave, but then its maintenance is not easy without resorting to complicate remote handling. Therefore the proper location considered is to be close to the wall inside the cyclotron vault as indicated in Fig. 2. A movable thick steel plate in vacuum will be used to shield gamma radiation

Figure 3 shows the layout of three beam components in the diagnostics module. The Faraday cup is retractable while the wire scanner needs to be further evaluated for the maximum beam power density sustainable without direct cooling. The 4-jaw collimator physically shapes the beam with a maximum cooling capacity of 15 kW. In addition, a beam position detector will be needed to monitor the beam shift non-destructively, which is not shown in Fig. 3.

As site acceptance, the beam line in cave 1 will be tested using the components of the diagnostics module and also with radio-chromic film at the target location for beam wobbling with two diameters of 2 cm and 5 cm. The beam jitter, which is worsened by the long drift distance, will be measured. A current plan is to install a collimator in front of target with a maximum power handling of 1 kW to remove stray beam.

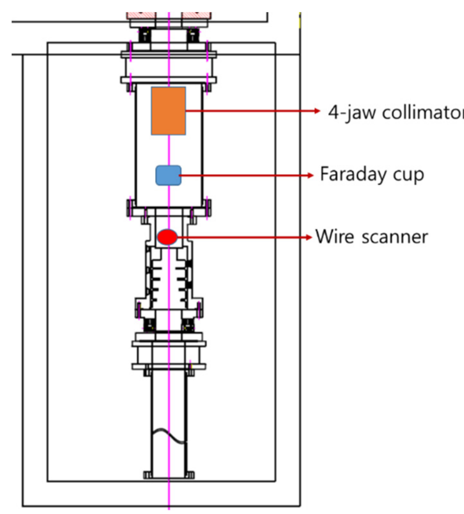


Figure 3: Layout of the proton diagnostics module including three beam components.

## ISOLATION OF ISOL TARGET VACUUM

The beam energy of 70 MeV is rather too low to install a beam window to isolate the ISOL target vacuum from the beam line and cyclotron. We plan to use a fast protection valve which can react within tens of ms in case of vacuum failure. However, there is concern of continuous molecular flow during irradiation, which will contaminate the entire system.

A couple of options have been thought to reduce the flow as follows [6]: 1) cold trap using liquid nitrogen, 2) a thin rotating target with vacuum pumping system. Other possibility may be to apply plasma window with a high-voltage system to isolate the vacuum almost non-interactively. Difficulty is a small aperture of a few mm while we need an aperture of over 10 mm. Further consideration including the possibility of plasma window will be made.

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## CONCLUSIONS

A 70 MeV $H^-$ cyclotron is recently contracted with a new vendor IBA to be used as the ISOL driver. The design of existing building and its interface were reviewed, which are fit with the previously contracted cyclotron system. Especially, utilities, wall penetrations and control system have been checked and no major modification required was found.

The initial design of two beam lines for ISOL targets has been performed also identifying the beam diagnostic components to be located inside the target cave. A long distance between the wobbler and the target may cause some difficulty in the stability of high-power beam. A non-destructive beam position monitor will be used close to the target to compensate for beam jitter, which may cause severe thermal stress problem. A beam collimator will be added in front of the target with a maximum power handling capacity of 1 kW.

The cyclotron system will be delivered to the RISP site in 2021 for installation and beam commissioning will follow.

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