Rare Isotope Science Project in Korea

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1. Introduction

A big picture was drawn for promoting basic science in Korea within a frame of International Science Business Belt (ISBB) by Korean Government in 2009. Thereafter a new world-class research organization in the ISBB, Institute for Basic Science (IBS) was created to provide a creative research environment for basic science in Korea. Rare Isotope Science Project (RISP) was launched at the end of 2011 with the budget of about 0.4 B$ for the construction of a heavy ion accelerator complex as a key research facility of IBS. At that time, the budget was only for constructing accelerators and experimental devices, but in the middle of 2014, the budget of about 1.44 B$ in total was finalized for the full construction of the facility, including civil engineering and conventional facilities as well as accelerators and experimental apparatus.

The goal of the accelerator complex, named RAON meaning joyful and happy in Korean, is to produce variety of stable and rare isotope beams to be used for researches in basic science and various applications [1, 2]. Prototyping of major accelerator components has been almost finished and their test is going on. Prototyping of experimental systems are mainly performed for light components like detectors. The details of the present status on the construction of RAON will be given in a special session during the period of this meeting. Some basics of RISP will be given here, instead.

2. Project Overview

2.2 Facility concept of RISP

The use of rare isotopes existing in the world only at a very short moment (radioactivity with short lifetime) is increasing nowadays in various research fields, not only for basic researches in nuclear physics investigating origin of matter, synthesis of new atomic elements, and exotic nuclear structure of rare isotopes but also for applied researches in medical-bio-life science, materials and nuclear sciences.

The degree of usability of various rare isotopes is largely relying on the development of particle accelerator facility for the effective production and on-line separation of rare isotopes. Two methods have been adopted separately in existing world-wide facilities, depending on the facility configuration; Isotope Separator On Line (ISOL) and In-Flight (IF) methods which are complementary to each other in character [3, 4].

The IF method uses an electromagnetic (EM) separator to select and guide rare isotope beams (RIBs) to experimental halls for further studies. Not only the projectile fragmentation of high-energy heavy-ions but also other reactions (e.g. transfer reactions and fission in-flight) with incident energies from a few MeV to a few GeV per nucleon have been used. There is no need to accelerate beams of all elements; fragmentations of the incident beam produce wide variety of elements equally energetic. Therefore, the facility configuration is relatively simple, requiring a heavy-ion accelerator and an EM separator. The technical issues for this type of facility are on the development of heavy-ion sources and high-power targets, allowing an incident beam with intensity as high as possible.

The ISOL method, often called reacceleration method, uses the ISOL technique to produce radioactive nuclei, then ionizes and accelerates desired nuclei to energies high enough for further studies. The ISOL technique has been mainly developed at CERN/ISOLDE in order to single out an radioisotope among the target fragments produced by bombarding heavy nuclear target (like UCx target) with high-energy proton beam (target fragmentation). This type of facility needs some more complicated systems including an ISOL-system and an accelerator of radioactive ions. High efficiencies are required in each step of the production, ionization, separation, and transportation. Those developments are inter-related and thus many developments are still necessary. Especially, one has to extract a rare isotope of interest from the bulk of production target. The rate-determining steps are diffusion and effusion of the rare isotope in the target materials, whose speed depends on the combination of a target material and an element to be extracted and often slow compared with the lifetime of a nuclide of interest. Therefore most of the efforts have been put in the developments of targets and ion sources.

For the production of radioactive nuclei, ISOL has much more advantage (about 10^4 times) than in-flight method in view of target thickness and primary beam intensity available for production. For the in-flight method, only an electromagnetic separator is necessary. More factors come in for the ISOL method; the efficiencies for extraction from target materials and ionization. In the case of the in-flight method the necessary separation time (<1 μs) is much shorter than lifetimes of any beta-decaying nuclei (>1 ms). Concerning the quality of produced RIB, the ISOL facility provides good quality; the energy spread and emittance of the beam is essentially same as those of stable heavy-ion beams. The admixture of other nuclides available in the ISOL-type facility is small in many cases as compared to the IF method in which the beam delivered is usually a mixture of different nuclides. The energy spread and emittance is wider for IF method.

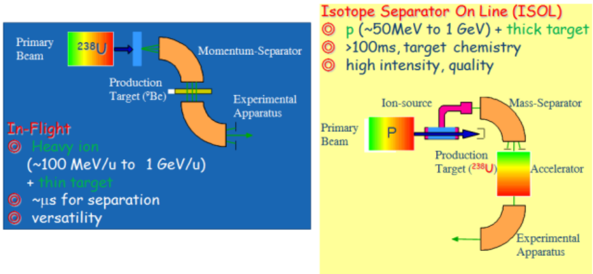

Fig. 1. Two RIB production methods are compared.

As summarized in Fig. 1, there exist advantages and disadvantages in detail in two types of facilities. Most of studies have been done by either of the facilities. However in any of the facilities, present and near future, it seems to be hard to work out investigation that highly requires more neutron-rich nuclei than ever. What if the ISOL-type facility connects to the IF-type facility? An ISOL system, probably with actinide target, is used to produce high-intensity beam of neutron-rich isotopes of easiest-to-extract elements (i.e. fast in diffusion and effusion in the target materials) then this RIB is accelerated to an energy high enough for projectile fragmentation. The in-flight technique for fast separation is applied to obtain beams of very neutron rich nuclei. This method is expected to give higher intensity neutron-rich nuclei than ever reached in any existing facilities. This is the one of the most important ingredients in the facility concept of RISP, as shown in Fig. 2.

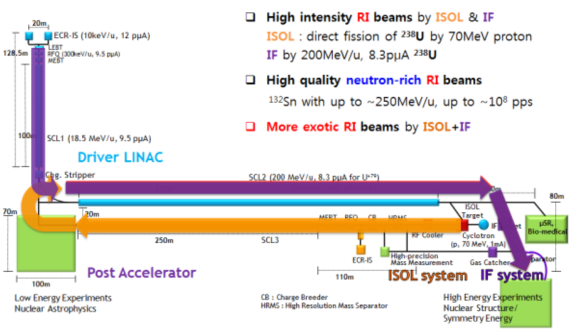

Fig. 2. Schematic view of RAON. The operation modes, namely flow of driving beams for RI production, are shown.

The accelerator complex to be constructed at Sin-Dong in Deajeon consists of three accelerator systems; a heavy ion superconducting linear accelerator as the driver for IF isotope separation system, a proton cyclotron as the driver for the ISOL system, and a post-accelerator for the ISOL system [1, 2]. The ISOL and the IF system can be operated separately and independently, as indicated by arrows in Fig. 2. In addition, the rare isotopes produced in ISOL can be injected into the driver linac for accelerating the RI beam even higher energies or for use in IF system to produce even more exotic rare isotopes. RAON has a unique feature of having both ISOL and IF system for the production of isotope beams. High intensity rare isotope beams provide opportunities for a wide range of basic science researches and applications.

The characteristics of RAON, in terms of production of neutron-rich isotope beams and of their neutron richness (ratio of mass number to atomic number; A/Z), are compared with the performance in other facilities that are present and under construction in Fig. 3.

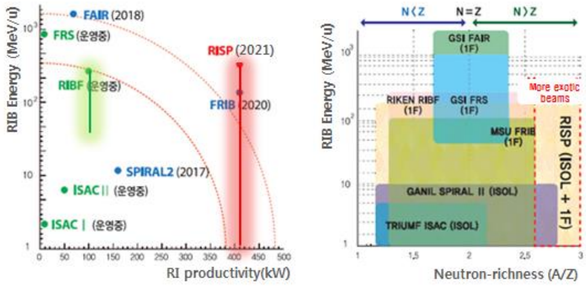

Fig. 3. Characteristics of RISP. RISP can provide RIBs with energies ranging from very low energy of tens keV to intermediate energy of around 200MeV/nucleon with a high intensity and neutron richness. (*FAIR and FRS in GSI, Germany; ISAC I and II in TRIUMF, Canada; RIBF in RIKEN, Japan; SPIRAL2 in GANIL, France; FRIB in MSU, USA.)*

2.2 Time plan and construction site

The period of RISP is from Nov. 2011 to Dec. 2021. The time schedule for the completion of the project by the end of 2021 is shown in Fig. 4, where some important milestones can be identified for subsystems of accelerator and experimental devices, and for conventional facilities. We extracted successfully stable beams from ion sources of Driver LINAC and ISOL at the end of 2015 at ion source test benches, and accelerated beams at the off-site test facility are expected in 2017. For the conventional facilities, the site will be available for constructing buildings accommodating accelerator complex at the beginning of 2017, utilities at the end of 2018. Installation and commissioning of accelerator and experimental system will be going on accordingly.

The construction site for the facility was finalized in the midst of 2014 as Sindong at about 10-km distance from the center of Deajeon. The purchase of the land is under progress and the site development work will start soon. The bird’s view of the complex is shown in Fig. 5.

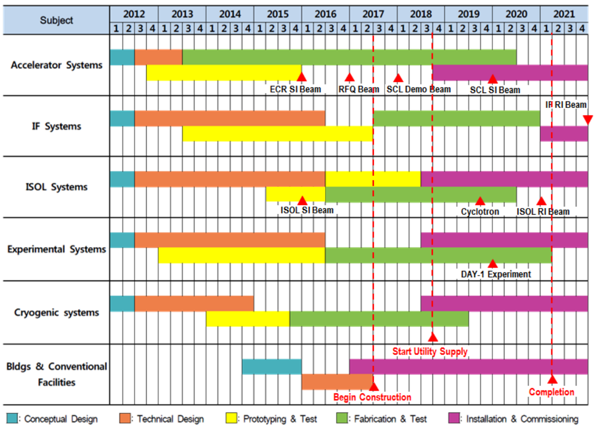

Fig. 4. Time plan of the project. Some important milestones are also given.

Fig. 5. Bird’s eye view of the facility to be constructed at Sindong in Deajeon.

3. Closing

The RISP launched for the construction of heavy ion accelerator to provide best opportunities for researchers in rare isotope science has come to meet half of the project period. We have overcome many difficulties through persistent efforts to address various R&D issues. We believe that the techniques and experience polished up during that period could be considered as a basis for the successful construction of a heavy ion accelerator with world's highest performance.

For further efforts until the completion of our mission, we expect continuous encouraging support from related academic communities and government, more importantly from people of taxpayer.

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