Overview on the Rare Isotope Science Project in Korea

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Abstract

In this write-up, we briefly summarize the Rare Isotope Science Project in Korea.

Keywords: *Rare Isotope Science Project; neutron rich rare isotope beams*

1 Introduction

With the goal of creating world-class institute in basic sciences, Institute for Basic Science (IBS) has been launched in November of 2011 [1]. IBS is located in Daejeon, Korea. The core project of IBS is "Research Group Configuration" and "Rare Isotope Accelerator." IBS will host about fifty research centers and affiliated institutes. The rare isotope accelerator is one of key research facilities to secure innovative successes in basic sciences such as nuclear physics, astrophysics, and atomic physics. The rare isotope accelerator will be designed and constructed under Rare Isotope Science Project (RISP) of IBS. Currently RISP is a project team in IBS. Later, RISP will become an affiliated institute of IBS. The accelerator of RISP/IBS is officially named RAON, previously it was called KoRIA. RAON is a pure Korean word, meaning *delightful*. This name implicates a wish that the rare isotope accelerator of RISP/IBS would be a delightful gift for scientists all over the world and for the bright future of mankind.

In this briefing, we present a bit on the history of RISP, its present status, and its future plans. For more details on RISP, we refer to [2]. Some overviews on rare isotope physics are given in [3, 4, 5].

2 Rare Isotope Science Project

We start with a brief history of RISP and its future plan. RISP of IBS started in December of 2011 to perform technical design of RAON and to construct it. Currently, RISP consists of five divisions: Experimental Systems, Accelerator Systems, Construction, Theory, and Administration. The division of experimental systems consists of three teams: ISOL system, Spectrometer and Detector development, and Application facility teams. The division of accelerator system is composed of three teams: Injector and beam Physics, Superconducting Linac (SCL), In-flight Fragmentation (IF) and RF (Radio Frequency) teams. The theory division contains nuclear physics and particle/astrophysics teams. At the beginning stage, the utmost goals of RISP were to determine main scientific research fields at RISP, to establish the concept of the accelerator, and to review/revise/improve the Conceptual Design report (CDR) of RAON [6] made from March 2010 to February 2011. The Baseline Design

Summary [7], which is an upgraded version of the CDR summary, was completed in June 2012.

Below is the development plan of RISP for RAON:

– The Technical Design Report of RAON will be completed by 2013.

– Main component production will start from 2014.

– Installation will start from 2016.

– Day-1 experiments are expected to be embarked in 2017.

Now we touch a bit on accelerator systems.

RAON is planned as a world class multi-purpose accelerator facility to provide exotic rare isotope beams of various energies. The accelerator complex has three accelerators: two heavy ion linear accelerators (Driver Linac, Post Linac) and one cyclotron. The main heavy ion accelerator, Driver Linac, is designed to accelerate ions from proton to Uranium to be used as the driver for 400 kW in-flight (IF) system and for 400 kW isotope separation on-line (ISOL) system with the proton beam. In addition, it can be used as a post accelerator for isotopes, which will be accelerated up to 250 MeV/u, produced by the ISOL system.

As to rare isotope productions, RAON utilizes the IF system for fragmentation and the ISOL system for target spallation and fission. To produce more exotic rare isotope beams, a unique method, a combination of ISOL and IF systems in which the RI beams generated by the ISOL facility will be accelerated to a higher energy by the in-flight fragmentation Linac, will be also used.

Before we move onto experimental systems, we sketch main research fields and subjects at RISP. A variety of basic and applied science can be studied with RI beams. Especially high intensity RI beams with high purity near the drip lines offer much opportunities to explore every facet of our universe. The research at RISP is categorized into four science fields: Nuclear Science, Atomic and Molecular Science, Material Science, and Medical and Bio Science.

Major scientific research fields at RISP are:

– Nuclear astrophysics and nucleosynthesis;

– Nuclear structure and matter;

– Nuclear data;

– Nuclear theory;

– Precision mass measurements and laser spectroscopy;

– RI material research;

– Medical and Bio applications.

The highest priority research subjects of RISP are:

– Nuclear reaction experiments important to nuclear astrophysics;

– Search for super heavy elements: $Z > 113$;

– Nuclear structure of n-rich RI near $N = 126$;

– Nuclear symmetry energy at sub-saturation density, and its important scientific applications are:

- Precision mass measurement and Laser spectroscopy;
- Material science: β-NMR, μSR;
- Medical and bio science;
- Nuclear data for Gen-IV NPP and nuclear waste transmutation.

Now, we have a glance over the experimental systems of RAON.

The Korea Recoil Spectrometer (KRS) is a main facility for nuclear structure, nuclear astrophysics, and super heavy elements search.

The Large Acceptance Multipurpose Spectrometer (LAMPS) is designed to explore the nuclear symmetry energy and equation of state (EOS) of nuclear matter with various neutron-proton asymmetries.

For the super heavy element research, we plan to use two types of separators: gas-filled separator such as FLNR at Dubna and GARIS at RIKEN and vacuum type separator such as SHIP at GSI.

Ion trap and laser spectroscopy are to do precise mass measurements and offer spectroscopic information of rare isotopes.

In addition, the experimental apparatus of RAON includes β-NMR facility, μSR facility, and neutron Time-of-Flight (n-ToF).

In a nutshell, essential experimental systems for the main scientific research fields could be summarized as:

- Nuclear physics ⇒ Large Acceptance Spectrometer;
- Nuclear astrophysics ⇒ Korea Recoil Spectrometer (KRS), Gas filled Separator for SHE;
- Atomic physics ⇒ Atom and Ion Trap System;
- Nuclear data by fast neutrons ⇒ neutron Time-of-Flight (n-ToF);
- Material science ⇒ β-NMR/NQR, μSR, Laser Selective Ionizer;
- Medical and Bio sciences ⇒ Heavy Ion Therapy research, Irradiation Facility.

Finally, we show the selected rare isotope beams that are summarized on the Baseline Design Summary in Table 1.

3 Summary

RISP will be establishing rare isotope accelerator, RAON, experimental systems, and the theoretical foundation for basic sciences. The Technical Design Report for the accelerator and experimental apparatus will be published by the end of 2013.

Acknowledgement

This work was supported by the Rare Isotope Science Project funded by the Ministry of Education, Science, and Technology (MEST) and National Research Foundation (NRF) of KOREA.

Table 1: Selected RI beams in the Baseline Design Summary. Here, NS — nuclear structure; NA — nuclear astrophysics; MS — material science; SE — symmetry energy; NSPT — nuclear study with polarized target; NSPRI — nuclear study with polarized RI beam; SHE — super heavy elements; AP — atomic physics; MBS — medical and bio science.

RI beam species	Energy range	Desired intensity [pps]	Research fields
^{132}Sn, ^{144}Xe	> 100 A MeV	10^8, 10^6	NS
^{15}O	< 10 A MeV	10^{10}	NA
^{15}O	< 30 keV	10^8	MS
^{26m}Al	< 15 A MeV	10^7	NA
^{45}V	0.6–2.25 A MeV	10^7–10^9	NA
^{68}Ni, ^{106}Sn, ^{132}Sn, ^{140,142}Xe	10–250 A MeV	10^9	SE
^{6,8}He, ^{12}Be, $^{24-30}$O	50–100 A MeV	10^9	NSPT
^{17}N, ^{17}B, ^{12}B, $^{14-15}$B, $^{31-32}$Al, ^{34}K	50–100 A MeV	10^9	NSPRI
^{64}Ni, ^{58}Fe (stable)	a few MeV/A	10^{12}	SHE
^{8}Li, ^{11}Be, ^{17}Ne	< 30 keV	10^8	MS
$^{133-140}$Sn	< 60 keV	1	AP
^{8}B, $^{9-11}$C, ^{15}O	≥ 200 A MeV	10^7–10^9	MBS

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