Recent Update on RAON Neutron Science Facility for Neutron-induced Cross-section and Various Application

Jae Cheon Kim[a*], Jae Bum Son[a], Gi Dong Kim[a], Yong-Kyun Kim[b]
[a]*Rare Isotope Science Project. Institute for Basic Science, Daejeon 305-811*
[b]*Department of Nuclear Engineering, Hanyang University, Seoul 133-791*
[*]*Corresponding author: jaecheon@ibs.re.kr*

1. Introduction

The RAON accelerator complex plans to provide the first primary beam to the neutron science facility (NSF) in late 2017 for producing fast neutrons covering the 1-90 MeV energy range with a high intensity as well as a mono-energetic neutron source. 53 MeV deuterons and 88 MeV protons accelerated by a superconducting driver LINAC (SCL1) are delivered to the neutron production target to produce high energy neutrons. With up to 12μA, a pulsed beam should be sufficiently intense for measurements of neutron-induced cross-sections at the neutron time-of-fight (n-TOF) facility. The proton and deuteron beam frequency are variable from 1 MHz to 1 kHz while linac primary beam frequency is 81.25 MHz. The beam width is 10 ns. Our first interest is on fission (n,f), inelastic scattering (n,n') and neutron multiplicity (n,xn), all of which are known to play dominant roles beyond the 10 MeV energy region. In addition, we will consider capture (n,γ) reaction in order to maximize the capability of NSF. Our goal is to develop the main devices used in NSF that enable us to measure accurate neutron-induced cross-sections.

2. Methods and Results

We divided our works into four categories such as 1) target, 2) beam line, 3) nuclear data detection system, and 4) radiation protection. Figure 1 shows the conceptual design and potential location of neutron science facility.

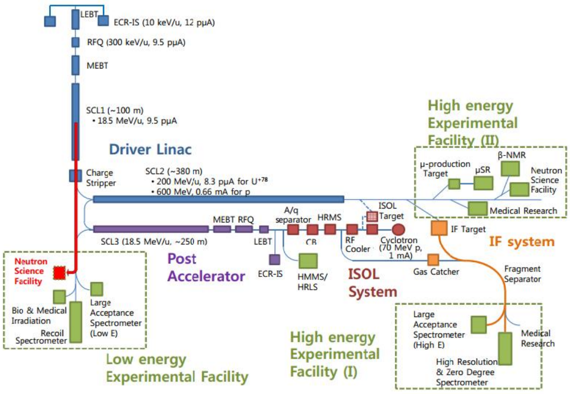

Fig. 1. Conceptual design of RAON and the location of neutron science facility

2.1 Target

In NSF, production of white neutrons will be used by C (graphite) thick target, while thin target made of Li are used to produce mono-energetic neutrons. The neutron spectra produced by the bombardment of targets with deuteron and proton beams have been reproduced with Monte Carlo codes. RAON will provide either up to 88 MeV protons or up to 53 MeV deuteron beams through the LINAC. Fast neutrons are produced when either protons or deuterons bombard a light target such as C and Li. Those fast neutrons have energies almost as high as those of the driver LINAC's primary beams.

Production of white neutrons will be used by C (graphite) thick target instead of Be. C target has more advantages than Be induced by heat deposition on the target. In addition, neutron yield of C target is almost ~70% of Be as shown in Figure 2 and it would be comparable for Be target [1].

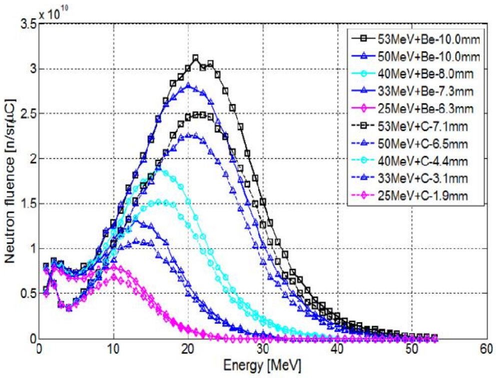

Fig. 2. Neutron spectral fluence at the direction of 0° produced by bombardment of a thick C and Be target as a function of incident deuteron energies.

2.2 Beam Line

NSF is divided into two main sectors, the target and TOF halls. The primary beam (either protons or deuterons) will be delivered into the target hall. For the production of white and mono-energetic neutron beams, the target system will be located either ahead of or behind a clearing magnet. For neutron time-of-flight (n-TOF) measurements in NSF, basically, two neutron beam lines will be designed at the direction of 0° and 30°. For neutron collimator, we referred to some world-leading neutron science facilities. From several Monte Carlo simulation, we have tried to find the most optimized material and composite for collimator that minimized the neutron background.

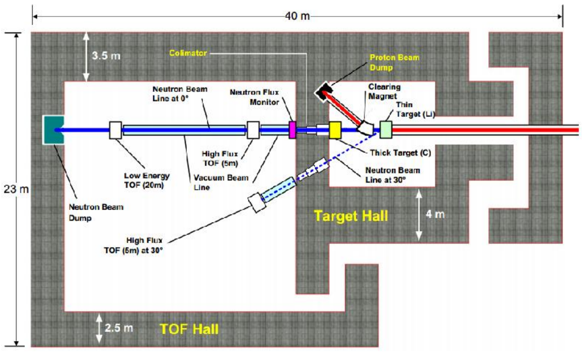

Fig. 3. Schematic layout of the neutron science facility

2.3 Nuclear Data Detection System

It has been reported that the cross-sections of neutron-induced reactions such as fission, inelastic scattering and neutron multiplicity are unknown or known with poor accuracy in the energy range above ~10MeV. NSF is well-suited for measuring neutron-induced reactions above ~10MeV. Our first goal is to measure fission cross-section with a few % uncertainty using conventional detector. In order to measure more accurate cross-section, we may consider employing the time projection counter (TPC) as an advanced fission detector system [2]. Low energy neutron measurements (below 1MeV) are also considered to maximize the utility. When proper moderators are applied to the target, it is possible for production of low energy neutrons to measure capture cross-section. 4 C_6D_6 detectors will be used to increase the gamma-ray detection efficiency for more accurate measurement results [3].

In order to understand the characteristics of detector systems used for fission, the Monte Carlo simulation have been performed by using Geant4. By measuring the particle range in addition to the total energy, we have confirmed that a TPC can clearly distinguish fission fragments among alpha particles, and nuclear recoils from neutron scatters in fission reaction.

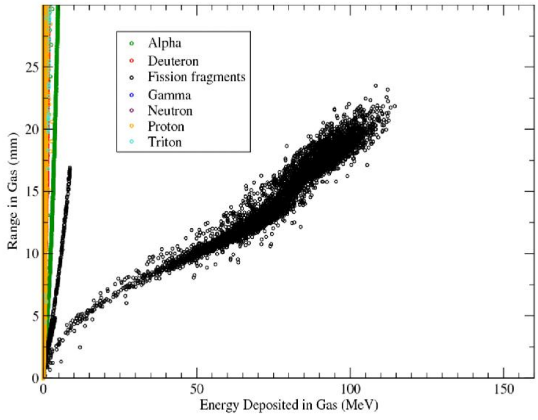

Fig. 4. Identification of fission fragments using the plot of particle range versus total energy deposition

2.4 Radiation Protection

Since NSF uses 53 MeV deuteron and 88 MeV proton beams to produce fast neutrons of similar energies, radiation protection guidelines must be adhered to rigorously for the safety of the workers. The two parameters related to radiation safety to be considered in the neutron experimental device are the external prompt dose rate and the residual gamma dose rate [4]. External prompt dose rate is immediate radiation dose caused by fast neutrons produced during operation. It acts as an important parameter in the shielding design for various buildings. Residual gamma dose rate is the gamma-ray dose from secondary radiation from various substances (concrete, accessories of the experiment, etc.) activated by the fast neutrons. After prolonged accelerator operation, it is an element that leads to constraints such as permissible working time and necessary cooling time of the experimental facility.

For radiation protection, we have developed the analytical procedures to evaluate the radiation risk from prompt fast neutrons and residual gamma-rays. We have determined the concrete thickness for radiation shielding. In order to effectively monitor gamma-rays in NSF, we have employed the gamma-ray imaging spectrometer called Polaris-H. Using standard gamma-ray sources, basic performance has been successfully checked.

3. Conclusions

In order to develop a wide range of applications such as next generation nuclear reactors, ADS for radioactive waste transmutation, fusion technology, medical diagnostics and various basic science research projects, accurate measurements for neutron-induced reaction is the key technology in neutron science. We will focus on constructing facility for neutron science and developing various nuclear data detection systems that enable us to measure neutron-induced reaction. This study will be used for development of main devices that will be used in NSF.

REFERENCES

[1] S. S. Mitja Majerle, Modeling d-be, d-c and p-li neutron sources for spiral2: Kit final report for the spiral2pp, tech. rep., Karlsruhe Institute of Technology, 2010.

[2] M. D. Heffner, P. D. Barnes, and J. L. Klay, Innovative fission measurements with a time projection chamber, tech. rep., Lawrence Livermore National Laboratory, 2005.

[3] P. Schillebeeckx, B. Becker, and Y. Danon, Determination of resonance parameters and their covariances from neutron induced reaction cross section data, Nucl. Data Sheets, vol. 113, p. 3054, 2012.

[4] R. H. Thomas and et al, Radiation protection for particle accelerator facilities, Tech. Rep. Report No. 144, NCRP, 2005.