A Fast Neutron Experimental System at RAON

Cheolmin Ham[a*], CheongSoo Lee[a], Geonhee Oh[a], Kwang-Bok Lee[a], Donghyun Kwak[a], Jaesung Kim[a, b], Seong Jae Pyeun[a], Sangjin Lee[a], EunHee Kim[a], Changwook Son[a], Dong Geon Kim[a], Minsik Kwag[a], Jae Cheon Kim[a], Mi Jung Kim[a], Young-Ouk Lee[a, c], Do Gyun Kim[a], Jinho Lee[a], and Kyoungho Tshoo[a]

[a]*Institute for Rare Isotope Science, Institute for Basic Science, Daejeon 34000, Republic of Korea*
[b]*Department of Nuclear Engineering, Seoul National University, Seoul 08826, Republic of Korea*
[c]*Nuclear Data Center, Korea Atomic Energy Research Institute, Daejeon 34057, Republic of Korea*
[*]*Corresponding author: cmham@ibs.re.kr*

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1. Introduction

RAON (Rare isotope accelerator complex for on-line experiments) [1-4] is a heavy ion accelerator which provides both stable and rare isotope beams ranging from protons to uranium ions over a wide energy range. The superconducting linear accelerator 3 (SCL3) accelerates ion beams from the electron cyclotron resonance (ECR) ion source and delivers them experimental systems such as Korea broad acceptance recoil spectrometer and apparatus (KoBRA) [5, 6] or Nuclear data production system (NDPS).

A fast neutron experimental system, called Nuclear data production system (NDPS) [7-10], has been constructed at RAON in Korea. While NDPS was primarily designed to measure neutron-induced cross sections at energies above 20 MeV using the neutron Time-of-Flight (TOF) technique, it can also be utilized in a variety of other applications, such as radiation shielding, semiconductor testing, neutron imaging, materials science, and biomedical research. Various ion beams, especially protons and deuterons, can be provided from SCL3 to generate high energy neutrons in the range of a few tens of MeV. The installation of NDPS was completed in 2022 and the first neutron beam test was conducted in 2024 using ^{40}Ar ion beams.

2. Nuclear data production system (NDPS)

Nuclear data production system (NDPS) is a neutron experimental system that generates neutron beams with energies up to 100 MeV using various ion beams from SCL3. For neutron TOF experiments, a pre-bunching system is installed in the low energy beam transport (LEBT) line, as described in Refs. [10] and [11]. Ion beams are accelerated by radio frequency quadrupole (RFQ) and SCL3 and delivered to the NDPS target room for neutron production.

In the NDPS target room, magnets, beam diagnostics, and neutron production target chambers are installed as shown in Fig. 1. Thin targets with various thicknesses are installed in the middle of the target room to generate quasi-monoenergetic neutrons, while a thick target is installed at the end of the ion beam line to generate continuous (white) neutrons with higher intensity. The neutrons produced from the target pass through a 4-meter-long neutron collimator which is installed between the target room and TOF room at 0° to the ion beam axis.

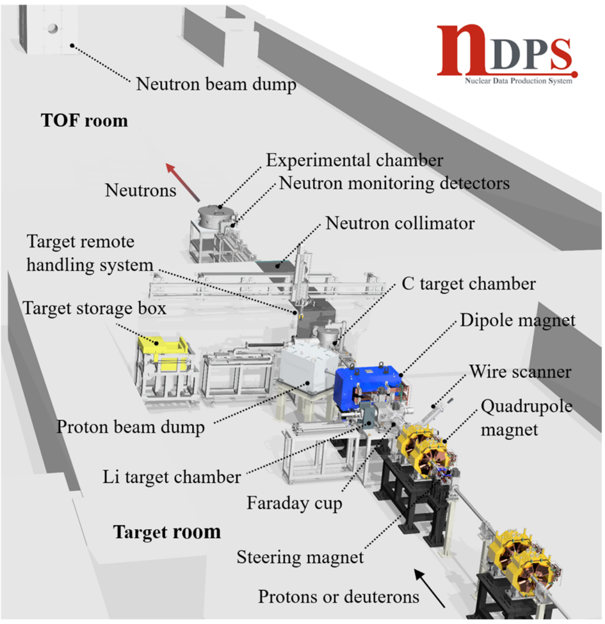

Fig. 1. Schematic view of nuclear data production system (NDPS) at RAON.

Neutrons passing through the neutron collimator are delivered to the NDPS TOF room, where experiments are conducted using neutron beams. The neutron collimator has a 4 cm inner diameter at its downstream end, which determines the neutron beam size. In the TOF room, various neutron detectors are installed to monitor the neutron beam, such as the parallel plate avalanche counter (PPAC) and the EJ-301 liquid scintillation detectors, as described in Ref. [12].

At NDPS, the first neutron beam production test was conducted in 2024, using ^{40}Ar ion beams at around 16 MeV/nucleon. After $^{40}Ar^{8+}$ beams are accelerated by SCL3, they pass through a thin carbon foil and are stripped to $^{40}Ar^{18+}$, because the dipole magnets in the SCL3–NDPS transport beamline have a maximum magnetic rigidity limited to 2.0 T·m. In the NDPS target room, a 28-mm-thick graphite target was used for neutron production, which is installed at the end of the ion beam line in the NDPS target room. As shown in Fig. 2, the neutron energy distribution was calculated using the PHITS [13] simulations, which exhibits a peak at approximately 8 MeV with a long tail extending into the tens of MeV range.

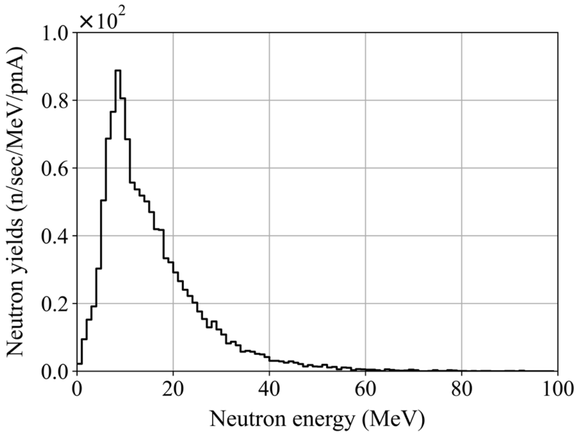

Fig. 2. Calculated neutron yields at the neutron collimator exit (4.8 m from the neutron production target) using PHITS [13] simulations when 16 MeV/nucleon ^{40}Ar ion beams bombard a 28-mm graphite target.

3. Summary

NDPS is a fast neutron experimental system installed at the Institute for Rare Isotope Science (IRIS) in South Korea. NDPS employs two neutron production methods: (1) quasi-monoenergetic neutron beam production using a thin target, and (2) white neutron beam production using a thick target. Both pulsed and continuous beams will be delivered to NDPS for neutron experiments as well.

At NDPS, the first neutron production test was conducted in 2024 using ^{40}Ar ion beams at around 16 MeV/nucleon. As shown in Fig. 3, neutrons generated from a 28-mm-thick graphite target were successfully measured using the EJ-301 scintillation detector, and neutrons with energies up to a few tens of MeV were observed. Starting in 2025, NDPS is scheduled to be available for non-proprietary experiments such as nuclear physics and other application fields [14].

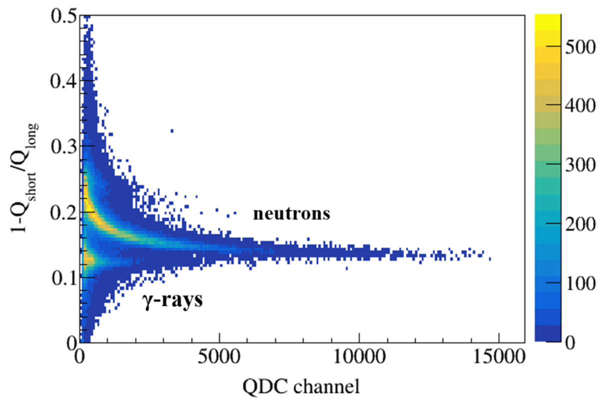

Fig. 3. A pulse shape discrimination (PSD) plot measured using the EJ-301 scintillator: Q_{short} and Q_{long} represent the charge collected with short and long integration gates, respectively.

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