RCNP EXPERIMENT E

PROPOSAL FOR EXPERIMENT AT RCNP

12 February 2016

TITLE:
Test of Neutron Detectors for Future Rare-Isotope Collision Experiments at RAON

SPOKESPERSON:

Full Name	Kyong Sei Lee
Institution	Department of Physics, Korea University
Title or Position	Research Fellow
Address	Anam-ro 145, Seongbuk-gu, Seoul, 02841, Republic of Korea
Phone number	+82-2-3290-4277
FAX number	
E-mail	kslee0421@korea.ac.kr

EXPERIMENTAL GROUP:

Full Name	Institution	Title or Position
Byung-sik Hong	Department of Physics, Korea University	Professor
Jung Keun Ahn	Department of Physics, Korea University	Professor
Tatsushi Shima	RCNP, Osaka University	Assistant Professor
Sun Young Ryu	RCNP, Osaka University	Specially-appointed Assistant Professor
Young Jin Kim	RISP, Institute for Basic Science	Scientist
Hyo Sang Lee	RISP, Institute for Basic Science	Scientist
Jong Won Lee	Department of Physics, Korea University	Postdoctoral Fellow
Min Ho Kim	Department of Physics, Korea University	Ph.D Student
Shin Hyung Kim	Department of Physics, Korea University	Ph.D Student
Woo Seung Jung	Department of Physics, Korea University	Ph.D Student
Jun Lee Kim	Department of Physics, Korea University	Ph.D Student
Young Jun Kim	Department of Physics, Korea University	Ph.D Student

RUNNING TIME:	Installation time without beam	0.5 days Development of
	device	0
	Test running time for experiment	0.5 hour
	Data runs	4 hours
BEAM LINE:		Ring : N0 course
BEAM REQUIREMENTS:	Type of particle	n
	Beam energy	80 MeV, 400 MeV
	Beam intensity	$\approx$ 10 nA

BUDGET:	Experimental expenses	0 yen

SAFETY CONTROLLED ITEMS:

TITLE:
Test of Neutron Detectors for Future Rare-Isotope Collision Experiments at RAON

SPOKESPERSON: Kyong Sei Lee

SUMMARY OF THE PROPOSAL

We propose to use neutrons at N0 beam line to validate the performance of a mini array of prototype neutron detectors with dedicated signal-processing and data-transfer electronics, which will be operated for future rare-isotope collision experiments at RAON in Korea. The mini neutron-detector array is composed of three detector layers, each equipped with four plastic scintillator bars with dimensions of $10 \times 10 \times 200$ cm^3. Energies and hit positions of neutrons in an energy range from 10 to 400 MeV will be determined by using a time-of-flight method. We install the array at a distance of 10 m from the neutron production target. Then, the expected time resolution for neutrons with a typical energy of 100 MeV with the present detection system is about 300 ps, which will guarantee quality measurements of neutrons with an energy resolution of about 3%. Furthermore, the neutron hit reconstruction algorithm will be tested in the proposed beam test.

1 Scientific Motivation

LAMPS, the Large Acceptance Multi-Purpose Spectrometer, has been designed to measure important observables essential to perform various researches on nuclear symmetry energies at supra-saturation densities. As shown in the schematic diagram in Fig. 1, LAMPS planned to be constructed in the high-energy beam experimental hall at RAON are composed of a solenoid magnet equipped with an large-acceptance TPC and Si-CsI detectors, a dipole spectrometer, and a neutron-detector array placed in forward direction. LAMPS with these three major detector components will be one of powerful experimental apparatuses existing for systematic researches on nuclear symmetry energies. Various particle species including charged pions and their clusters will be measured by the TPC with a large kinematic acceptance. Furthermore, beam fragments and neutrons knock-out from the heavy-ion collisions are measured by the Si-CsI array and the neutron detector array, respectively, in the forward angular range. The present configuration of LAMPS will allow us to perform comprehensive analyses for many important observables in nuclear symmetry-energy studies, such as the production ratio of mirror nuclei, the pion ratio, the collective flow, and the isospin diffusion parameters.

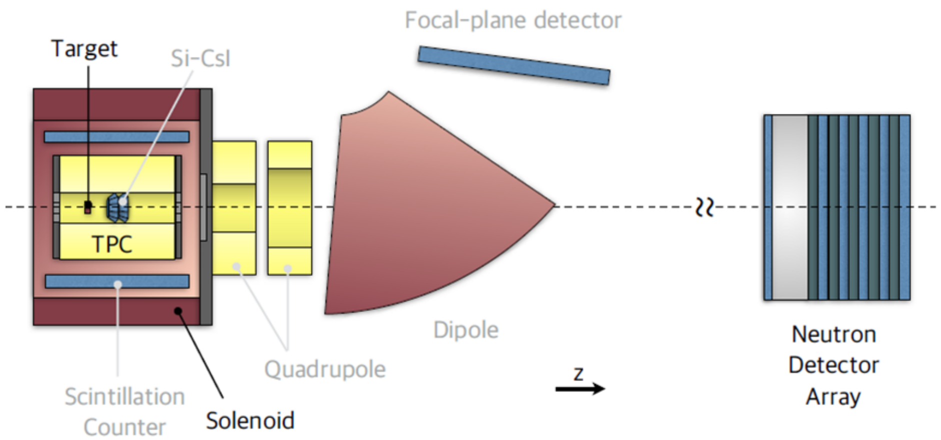


Figure 1: Schematic view of the LAMPS system at RAON.

The current design of the neutron detector array for the LAMPS system consists of eight layers in total that are aligned along the beam direction, and each layer consists of twenty scintillator slats. In addition, every two layers are paired, and the gap between the two consecutive pairs is larger than 30 cm. For each pair, the longest side of each slat follows the vertical direction in the first layer and the horizontal direction in the second layer (or vice versa), so as to provide the two-dimensional hit-related information. The dimensions of each scintillator slat are $0.1 \times 0.1 \times 2.0$ m^3. A veto detector is positioned in front of the most upstream layer. The structure and the dimensions of the veto detector layer are exactly the same as those of a single layer of the neutron detector array, except the thickness, which is 5 cm. The signals from each scintillator slat are read out by the PMT at both ends. In order to minimize the loss of light, the light guide is placed in between the scintillator bar and the PMT.

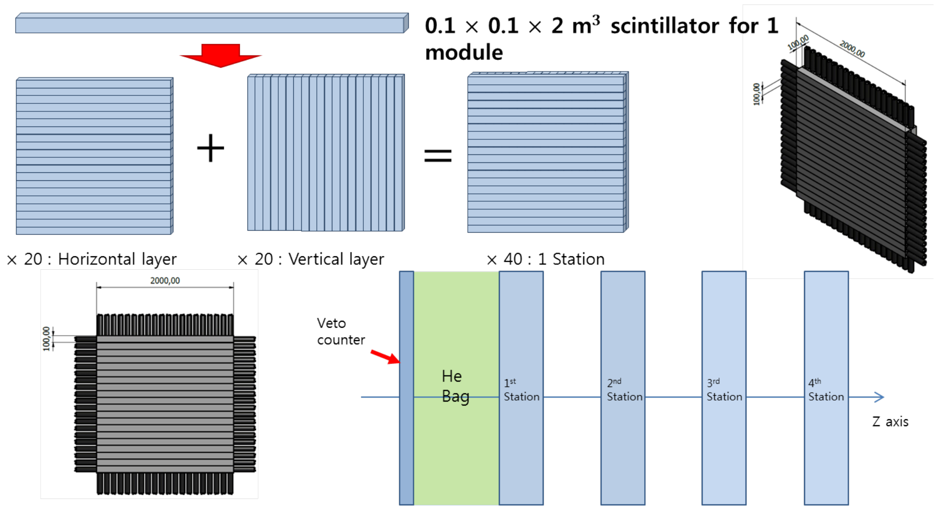
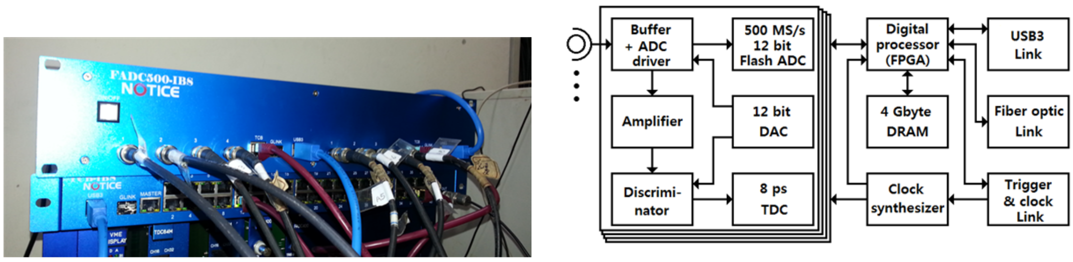


Figure 2: Schematic view of the LAMPS neutron detector array.

2 A Mini-array of Neutron Detectors

We have developed prototype modules of the neutron detector and tested the basic performance using a ^{252}Cf source and cosmic rays. We also developed a custom-made readout electronics system, which accommodates 12-bit flash ADC with 500 MHz sampling rate and 8-ps resolution TDC circuit. This new readout module communicates with internal trigger circuits, which accept both internal and external triggers, and also transfers data to the storage through fiber optic links, as shown in Fig. 3. Neutron hit reconstruction algorithm has been tested with Geant4-simulated events. A typical simulated event is displayed in Fig. 4(left) and the number of reconstructed neutron hits is plotted in Fig. 4(right) for the energy of 60 MeV and 200 MeV, respectively.

The test array consists of three stations, each equipped with four slats of plastic scintillators. Each station has the effective area of 40×200 cm^2, as shown in Fig. 5. Four of them are now ready and rest of them will be available in May.



(a) (b)

Figure 3: (Left) Custom-made readout module and (right) a circuit diagram

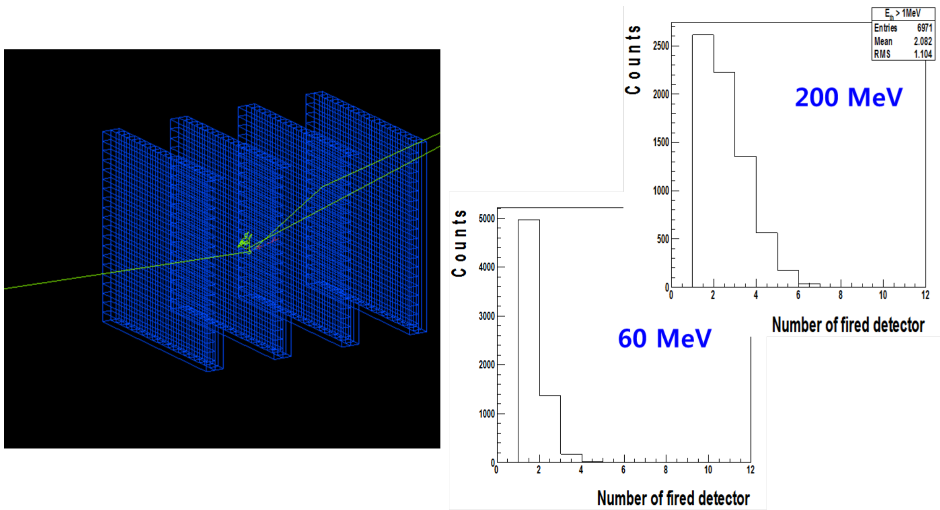


Figure 4: (Left) Simulated neutron hits and (right) number of neutron hits for neutrons at 60 MeV and 200 MeV.

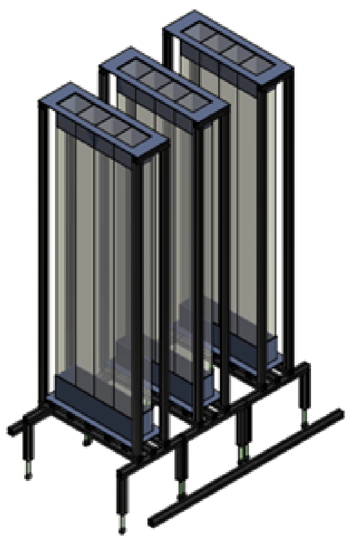


Figure 5: A mini-array of the neutron detectors

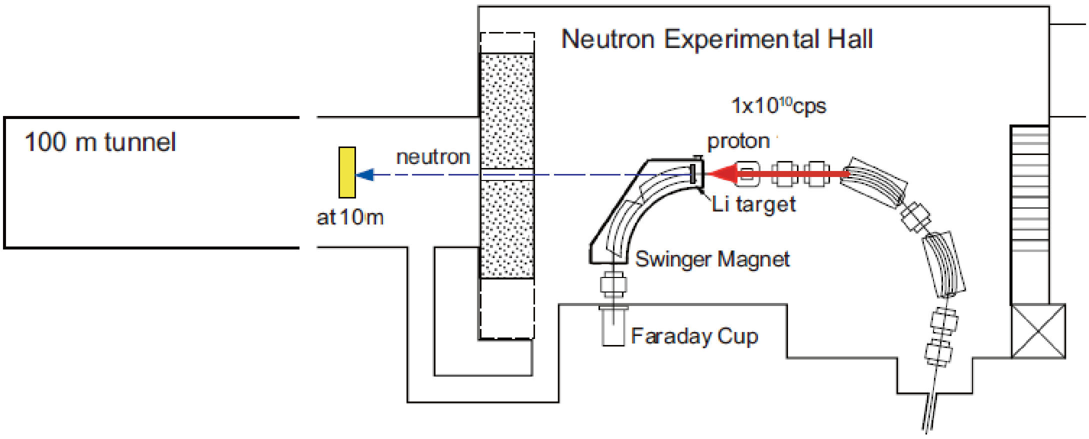


Figure 6: Proposed experimental setup in the N0 course

Work Item	Time	Note
Detector Setup	1 day	Installation and Cabling
Calibration Run	0.5 hour	Trigger/DAQ test
400 MeV Run	2 hour	
80 MeV Run	2 hour	

Table 1: Proposed schedule and request beam time

3 Experimental Consideration

We propose this test using neutrons of 80 MeV and 400 MeV at the N0 course. The ^{7}Li$(p, n_{0,1})^7$Be ($Q = -1.644$) MeV reaction reaches both the ground state of ^{7}Be(n_0) and the first excited state at 0.429 MeV(n_1). The neutron beam intensity of the high-energy peak(n_0) at 0^o is approximately 10^{10} n/sr/μC and the quasi-monoenergetic peak has almost equal probability with other contributions [2].
Our test array covers a solid angle of 8×10^{-3} sr at a distance of 10 m away from the neutron production target. For a proton beam current of 10 nA, the expected neutron intensity is then estimated to be 8×10^5 n/s. However, quasi-monoenergetic neutrons pass through the collimator hole with an exit dimension of 14×14 cm^2 at a distance of 8 m away from the production target. The highest energy neutrons can concentrate only on two central slats of the first scintillator layer. Therefore, we need to change once the horizontal position by one slat width. We plan to ship the whole detector components to RCNP. We expect to spend a full day for the detector installation at the N0 course, including cabling for about 30 readout channels. Our request beam time for this test is a total of 4 hours, except an additional 0.5 h beam time for calibration. First two hours are the beam test with quasi-monoenergetic neutrons of 400 MeV, and the next two hours with 80 MeV neutrons. The beam time can be optimized according to the actual neutron fluence at the proposed distance of 10 m. A short summary of our beam test schedule is summarized in Table 3.

References

[1] B. Hong, Eur. Phys. J. A **50**, 49 (2014).

[2] Y. Iwamoto, Progress in Nuclear Science and Technology **4**, 657 (2014).