【Grant-in-Aid for Specially Promoted Research】

Study of pure-neutron nuclei explored by innovative neutron detectors

Principal Investigator	Tokyo Institute of Technology, School of Science, Professor NAKAMURA Takashi	Researcher Number : 50272456
Project Information	Project Number : 24H00006	Project Period (FY) : 2024-2028
	Keywords : Multi-neutron systems, Unstable Nuclei, Neutron Star, Neutron Detector Array	

Purpose and Background of the Research

●Outline of the Research

Can neutral nuclei composed exclusively of neutrons exist”? This project is dedicated to investigating “neutral nuclei”, focusing on ^{2}n, ^{4}n, and ^{6}n, existence of which has been a subject of controversy or remains unknown, by introducing a novel neutron detector.

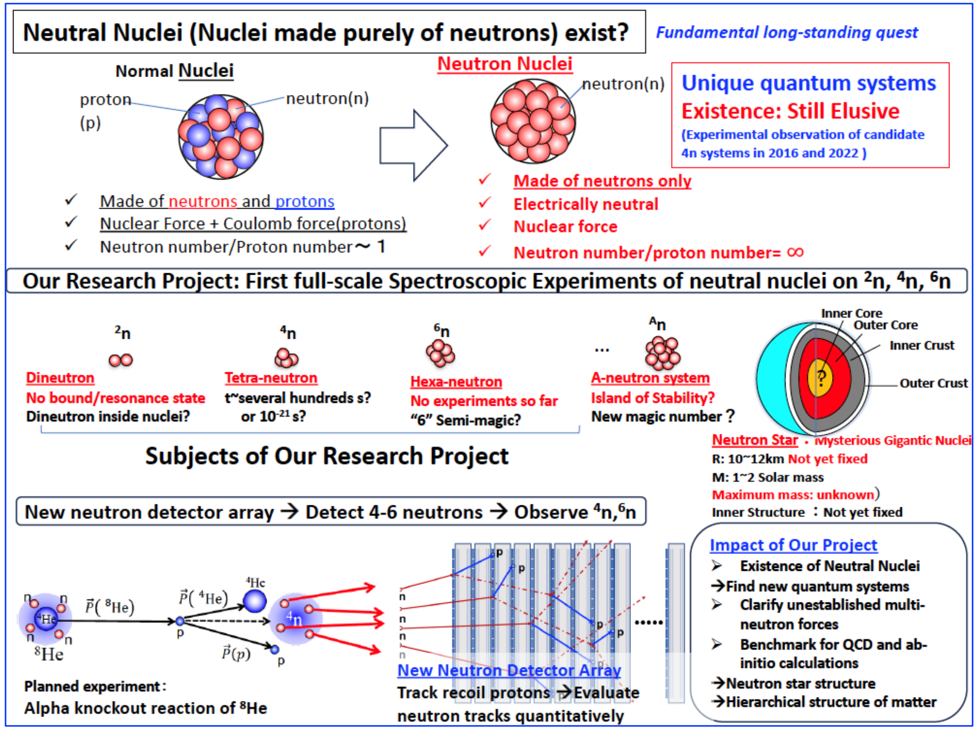

Figure 1. Outline of the Project

●Background and Purposes of the Project : The quest for neutron nuclei dates back to the 1960s, yet evidence such as the existence of ^{4}n, has only recently been obtained (e.g. Our collaboration (SAMURAI collaboration) Nature 606, 678 (2022).). However, theoretical/experimental inconsistencies remain regarding the existence of ^{4}n, necessitating further investigations. Moreover, the intriguing ^{6}n, potentially linked to a semi-magic number (6) remains unexplored experimentally. This project aim to address this subject by simultaneously detecting emitted 4(6) neutrons, crucial for elucidating the states and decay scheme of ^{4}n(^{6}n) nuclei. To achieve this, we propose the utilization of a novel neutron detector array employing a tracking technique for recoil protons.

● Novel Neutron Detector Array We develop and construct a novel neutron detector array that can distinguish and measure multiple neutrons (up to six) with high accuracy. With such measurements one can determine precisely the mass (invariant-mass) and decay scheme of the 4n and 6n states. However, the detection of more than two neutrons have so far been nearly impossible due to the cross-talks as shown in Figure 2 a). A neutron in the detector (plastic scintillator) can be scattered which may cause the second signal, mimicing the “two neutron” event. In our new detection scheme, we track the recoil protons from the scintillator, with which one can evaluate the direction of the scattered neutron. Accordingly one can measure multiple neutrons.

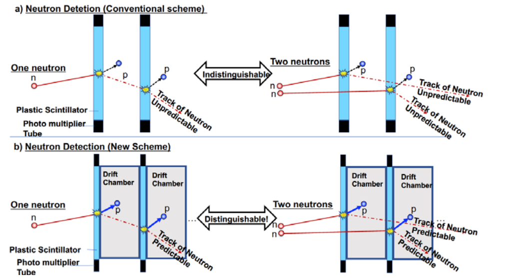

Figure 2. Neutron detection schemes: a) conventinal; b) new

Expected Research Achievements

●Research Goals and Our Competitiveness

Our objective is to pioneer full-scale spectroscopic experiments on neutral nuclei, such as ^{2}n, ^{4}n, and ^{6}n, for the first time in the world. Our key mile-stones encompass the confirmation of ^{4}n with precise mass measurement and decay scheme, and the first observation of the 6n system. The point is that we use the invariant mass method which has advantages in having higher mass resolution and capability of measuring decay scheme compared to the missing mass method used previously for studying ^{4}n. To achieve our objectives, we develop and construct a cutting-edge neutron detector array (see Fig.3) tailored to discern and measure multiple neutrons with exceptional precision at the Radioactive Isotope Beam Factory (RIBF) at RIKEN, a world-leading research center for unstable nuclei (Fig.4). Leveraging this detector array, we anticipate achieving resolutions of 30-70 keV (kilo-electron-volt) in measuring ^{4}n and ^{6}n with unprecedented accuracy. Moreover, our system enables positional detection with a remarkable 2mm accuracy, a significant improvement over conventional detectors which typically offer only centi-meter level precision. This breakthrough opens avenues for neutron imaging applications, with potential applications in medical diagnostics and engineering.

We have some advantages over competing facilities such as FRIB and FAIR, given that our neutron detection scheme remains at the forefront. While the construction of FAIR and the large-acceptance spectrometer (HRS) at FRIB is ongoing, our method offers immediate benefits, positioning us a leaders in this frontier of nuclear research.

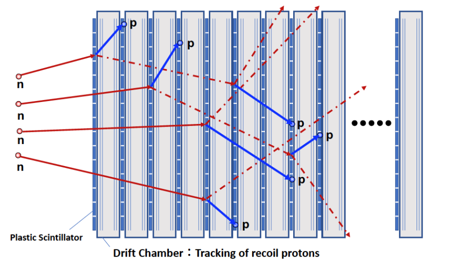

Figure 3. Schematic Figure of our new neutron detector array

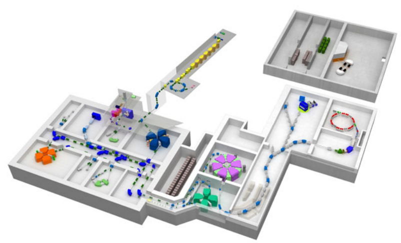

Figure 4. RIBF at RIKEN

Homepage Address, etc.	The web-site of this project is under construction. Publication list of PI (Prof. Takashi Nakamura, google scholar) is seen at