I. 4. Study of Neutron Induced Nuclear Reactions at CYRIC


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Data measured by neutron-induced reactions are useful to explore the nuclear isospin structure in comparison with investigations with proton beams. Until now, they have been limited because of difficulties to use clean- and intense-monoenergetic neutron source in the intermediate energy region. The scarcity of neutron-induced reaction data makes the understandings of the nuclear isospin structure to be ambiguous. In order to settle the questions in isospin-related problems, we are going to focus to accumulate the neutron-induced reaction data, especially in the few nucleon system. In this article, we report the brief summary of the neutron beams and the proposed $^2\text{H} + n$ experiments$^{1,2}$ in the wide kinematical range. In this project, we are going to try to make the nucleon-nucleon interaction clear in nuclei.

One of the most realistic way to produce quasi-monoenergetic neutron beams in an energy range up to 100 MeV is the use of $(p, n)$ reactions on light elements such as $^2\text{H}$, $^3\text{H}$, $^6\text{Li}$, $^7\text{Li}$ and $^7\text{Be}$. Among these elements, $^7\text{Li}$ is frequently used for the neutron production target material due to the simpler handling than other elements$^{3,5}$. In the $^7\text{Li}(p, n)^7\text{Be}$ reaction, the neutron beam is consisted of two neutron groups leading to ground and the 0.43 MeV first excited state in the residual $^7\text{Be}$. They are usually unresolved and limits the energy width of the neutron beam in several hundreds keV. When we assume 1 watt the energy loss in the Lithium target, the obtainable neutron beam intensity is shown in Figure 1. It is a typical situation for the neutron beam experiments, where the achievable neutron beam intensity becomes about 1 MHz on the nuclear reaction target.

The neutron beams used to perform the study of the neutron-induced reactions are produced via the $^7\text{Li}(p, n)^7\text{Be}$ reaction. A proton beam accelerated by Type-930 Cyclotron$^6$ is transported and incident upon an enriched $^7\text{Li}$ foil of 6 mg/cm$^2$ at Experimental Hall-5 (EH-5). In Figure 2, the floor plan of EH-5 is presented. The protons incident upon an enriched $^7\text{Li}$ foil of 6 mg/cm$^2$ placed in the scattering chamber, which is located at the end of the beam swinger system. The produced neutrons are collimated and impinge on the target placed at 3 m (first target position) and 10 m (second target position) downstream from the neutron
production target. A typical time profile of the neutron beam at the second target position is shown in Figure 3, where the incident proton energy was 20 MeV and the typical time spread of the beam bunch was 1 nsec corresponding to about 0.3 MeV in the neutron energy resolution. The spatial distribution of the neutron beam is also monitored by using a beam profile camera called GAMERA/NAMERA\(^7\) in front of the first target.

In order to obtain efficient event triggers and reduced background for the \(^2\text{H}(n, \gamma)\) and \(^3\text{H}(n, n)\) measurements, a live deuteron target consisting of a deuterized liquid scintillator is examined\(^7\). The main component of this scintillator is the deuterized benzene \((\text{C}_8\text{D}_8)\), which was fabricated by ELJEN Technology Ltd (EJ315). A cylindrical aluminum can with internal dimensions of 10.6 cm in diameter and 13.1cm in length is utilized to contain the scintillation material. The density and volume of EJ315 are 0.954 g/cm\(^3\) and 1000 cm\(^3\), respectively. The proton contamination in deuteron is approximately 0.7%. The scintillator is optically coupled to a R1250 (HAMAMATSU Photonics) photomultiplier tube. A pulse shape discrimination technique was employed to separate hadron signals from photon- and electron-signals. In Figure 4, an analyzed pulse shape spectrum is shown. We can observe an enough separation between the electron and hadron events for the live deuteron target.

To summarize the present development of the neutron beam and the experimental equipments for the measurements of the \(n + ^2\text{H}\) reactions, we carried out to investigate the performance of the neutron beams and detectors for the \(^2\text{H}(n, \gamma)\) and \(^3\text{H}(n, n)\) experiments at CYRIC. Installed apparatuses to produce the monoenergetic-neutron beams have been tested. We found that the quality of the neutron beams satisfies the requirement to carry out the study of the neutron-induced reaction. The detectors for the proposed neutron beam experiments on deuteron target have been equipped and tested. In conclusion, the neutron-related nuclear physics including the presently described projects are still actively in progress at CYRIC.

References

7) Kobayashi Y., Master thesis (Tohoku University), 2000.
Fig. 1. Neutron yields at the reaction target position by using the $^7$Li$(p, n)^7$Be reaction. The energy loss in the Lithium target is assumed 1 watt corresponding to $\Delta E = 1$ MeV at $I_p = 1$ $\mu$A.

Fig. 2. Floor plan of Experimental Hall-5.

Fig. 3. Time-of-flight spectra, where signals from a neutron detector and RF signals from the cyclotron are used for the start and stop signals.

Fig. 4. PSD spectrum for EJ315 scintillation counter.