Detection efficiency of segmented neutron detector at 200 MeV

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Nucleon-knockout (p, pN) reactions at intermediate energies (200–300 MeV) provide a powerful probe of the nature of single particle states (SPSs) in nuclei[1]. The goal of our study is to determine the neutron separation energy with a high resolution of about 500 keV at full-width at half-maximum (FWHM) via the (p, pn) reaction. This is technically challenging because a high position resolution is necessary for neutron detection which cannot be achieved with a conventional design.

At RIKEN RIBF, we are developing a segmented neutron detector consisting of 64 scintillating fibers. Each fiber has dimensions of 3.75 mm (W) $\times$ 3.75 mm (D) $\times$ 1 m (H) and has two multi-anode photomultiplier tubes (Hamamatsu H7546B) at both ends. Using this setup, we confirmed that the position resolution of 3.75 mm in the total width, corresponding to the fiber size, was actually realized by performing a neutron irradiation experiment at the Cyclotron Radioisotope Center (CYRIC), Tohoku University in November 2012. Furthermore, we determined the neutron detection efficiencies at 50 and 68 MeV to be $1.6 \pm 0.4\%$ and $2.0 \pm 0.5\%$, respectively[2].

For higher neutron energies, we performed another experiment using neutron beams at 200 MeV at the Research Center for Nuclear Physics (RCNP), Osaka University in November 2013. Monoenergetic neutron beams at 199 and 181 MeV were produced from ^{7}Li(p, n) and ^{12}C(p, n) reactions using a proton beam at 200 MeV. The Li and C targets, each with natural isotopic abundance, had thicknesses of 0.94 and 2.1 mm, respectively. Neutrons flew in the neutron time-of-flight (NTOF) tunnel and, were then detected by the segmented neutron detector placed at a distance of 50 m from the target position. The intensity of the proton beam was about 100 nA and the rate of neutrons bombarding on the detector was typically 10^4 particles per second.

A preliminary analysis shows that the detection efficiencies for 181- and 199-MeV neutrons were $2.6 \pm 0.4\%$ and $2.5 \pm 0.4\%$, respectively. The threshold for neutron detection, 4.2 MeV electron equivalent (MeV$_{ee}$) was applied to the light output information obtained from the charge amplitude of the dynode signal.

Figure 1 shows the distribution of the detection position, which is defined as the most upstream fiber hit. When there are several hit fibers at the same depth, the fiber with largest light output is selected. Here, the threshold of each channel was set to 0.5 MeV$_{ee}$. The distribution was found not to be uniform near the surface. Along the beam direction, most events were concentrated on the first plane, and the fibers on the left and right sides had a larger number of events than the inner fibers. This enhancement in the number of events near the surface, which was not observed clearly in the previous experiment because of the lack of the uniformity on the threshold of each channel, is still not understood and is being investigated for details. The inner array of 6×6 fibers had a uniform distribution within 10%, possibly reflecting the uniformity of the neutron flux.

The most downstream fibers had a smaller number of events compared to upstream fibers. For these fibers, the light output deposit by recoil protons can be small because the protons go out of the detector volume within a short distance.

In summary, we are developing the segmented neutron detector with a high position resolution for the study of SPSs via the (p, pn) reaction. The detection efficiencies of neutrons at 181 and 199 MeV were determined to be $2.6 \pm 0.4\%$ and $2.5 \pm 0.4\%$, respectively. The distribution of the detection position shows a large enhancement in the number of events at the surface which is being analyzed.

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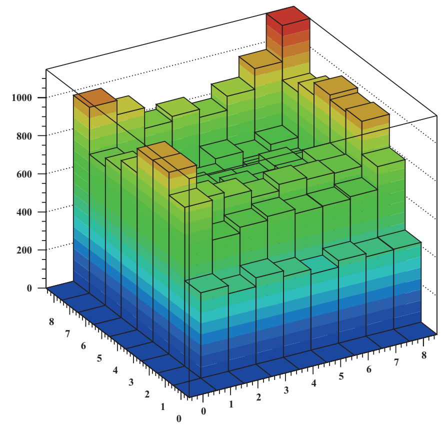

Fig. 1. Distribution of detecting positions indicated by the heights of the 8×8 blocks. The neutron beam travelled from top left to right bottom.

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