Measurement of double-differential neutron yields for 345 MeV/nucleon ^{238}U incidence on Cu†

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The validation of Monte Carlo simulation codes on radiation shielding with a uranium beam is required for future upgrades of RIBF. Experimental data of double-differential neutron thick target yields (TTY) are desired as a neutron source term in the radiation shielding design. We have started to measure neutron energy spectra by the time-of-flight (TOF) method.

The experiment was carried out around the F10 chamber at the ZeroDegree Spectrometer. The experimental arrangement is shown in Fig. 1.

The 345 MeV/nucleon ^{238}U beam which was not pulsed irradiated a Cu target. The bunch width of the beam was less than 1 ns and its repetition rate was about 18 MHz. The thickness of the target was 10 mm, which was longer than the range of the beam ion.

Neutrons produced in the target were measured with two sizes of NE213 liquid organic scintillators. The small scintillator with a length and diameter of 5.08 cm was set at 0°. The large ones with a length and diameter of 12.7 cm were located at 45° and 90°. To determine the threshold level, light outputs of the scintillators were calibrated with γ-ray sources, ^{60}Co, ^{241}Am-Be and ^{244}Cm-^{13}C. A 2 mm thick plastic scintillator was set as a veto detector to distinguish non-charged particle events in front of each neutron detector. Neutron kinetic energy was determined by the TOF method in which the start and stop signal came from the neutron scintillator and the RF signal of the superconducting ring cyclotron. The flight path lengths from the target to the detectors were shown in Fig. 1.

Figure 2 shows the TOF spectrum at 90°. The horizontal axis is the time difference between the RF signal and the neutron detector. The TDC resolution was 0.027 ns/ch. The peak at 1350 ch was the prompt γ-ray from the uranium incident reactions. Neutron energy will be determined with the use of the time difference between each neutron and the prompt γ-ray event. Low-energy neutrons from the preceding beam bunch were overlapped in the TOF gate. The contribution of these neutrons was about 2% at the highest neutron energy point for 0° and substracted from the TOF spectrum.

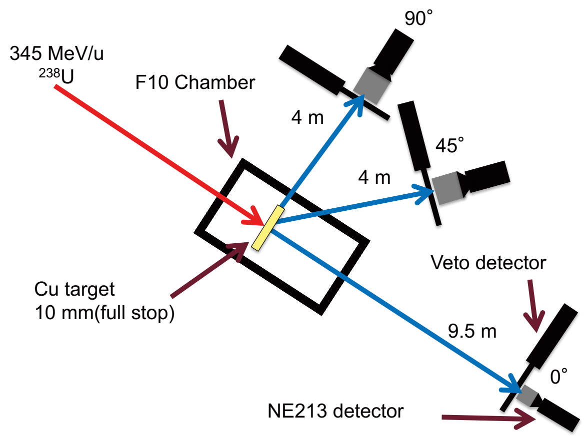

Fig. 1. Experimental arrangement.

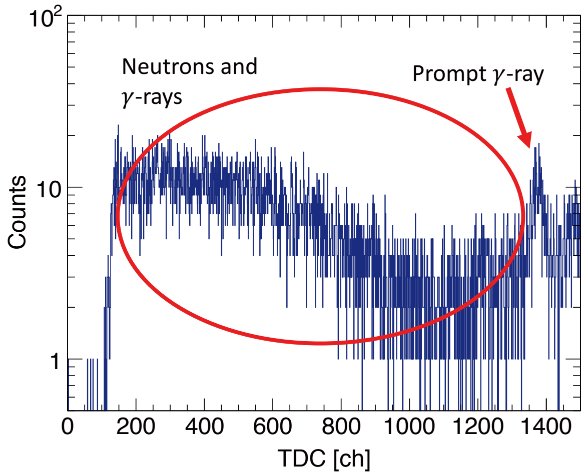

Fig. 2. TOF spectrum.

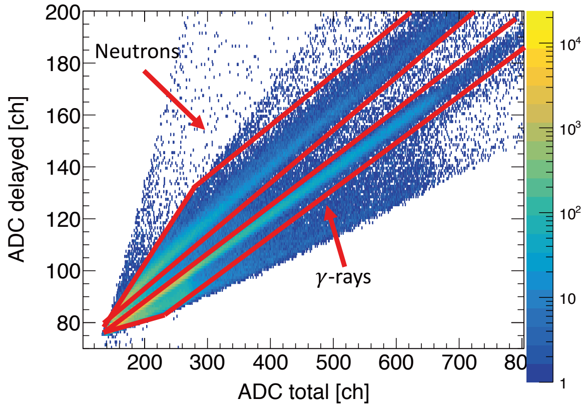

Fig. 3. Separation of neutron and γ-ray events.

Neutron events were extracted by using the difference of the decay part of the signal pulse between the neutron and γ-ray[1)] because the NE213 scintillator was sensitive to not only neutrons but also γ-rays. Figure 3 illustrates the two-dimensional plot of the total pulse of scintillator light output signal (horizontal axis) and the decay part of it (vertical axis). Neutron and γ-ray events are clearly separated in the low light output region.

The neutron TTY is under analysis and will be compared with calculation results by Monte Carlo codes.

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Reference

1) T. Nakamoto *et al.*, J. Nucl. Sci. Technol. **32**, 827 (1995).