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Capture cross-section measurement at J-PARC: ^{61}Ni case

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Abstract. ^{61}Ni(n, γ) cross-section has been measured at ANNRI, using the TOF method. ANNRI is an outstanding neutron facility based on spallation in MLF at J-PARC. In this cross-section measurement, we used HPGe detectors covering a substantial fraction of solid angle. In this paper, we focused the analysis on the capture rate to extract the corresponding cross-section. The dead-time correction, the overlapped neutrons correction and the background estimation were discussed.

1 Introduction

Several facilities in the world aim at measuring nuclear data for neutron-induced reactions, such as capture or fission cross-section. Those data are important for developments of innovative nuclear reactors. For this aim, Accurate Neutron-Nucleus Reaction measurement Instrument (ANNRI) was developed recently in the Materials and Life science experimental Facility (MLF) in the Japan Proton Accelerator Research Complex (J-PARC). Neutron-capture cross section for ^{63}Ni is very important for the slow neutron-capture process in astrophysics. However, a ^{63}Ni sample usually contains high quantity of Nickel stable isotopes. These isotopes affect the ^{63}Ni cross-section measurements. Therefore, to obtain accurate cross-section data for ^{63}Ni, a series of measurements for all stable nickel isotopes is required. In this paper, we mainly present the ^{61}Ni data which has been measured with ANNRI.

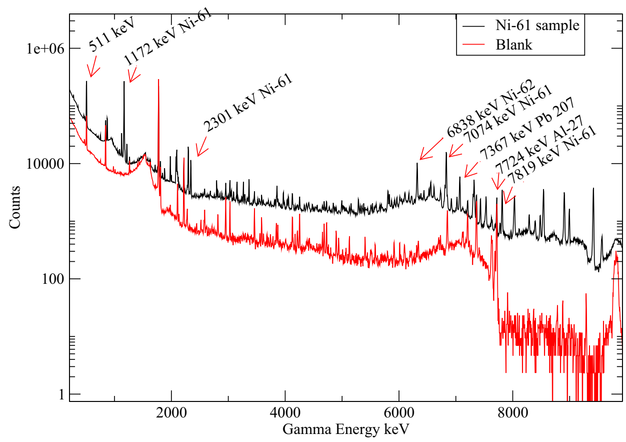

Figure 1. γ-ray pulse-height spectra for ^{61}Ni sample (black curve) and Blank (red curve).

2 Experiment setup

ANNRI is equipped with an array of large Ge detectors for multiple gamma-ray detection, located at 21.5 meter position from the center of the moderator. This spectrometer consists of 14 Ge crystals and BGO anti-Compton shields. The array is placed around the aluminium beam pipe where the target was put on the center. A LiF plate and LiH plate are placed in front of the detectors for the scattered neutrons shielding. In general, we put a lead plate to reduce the detection rate. The beam condition and set-up were described in [1] and [2] respectively. The ^{61}Ni sample weight is 401 mg, the dimension is 232 mm^3.

3 Analysis

γ pulse height spectrum of ^{61}Ni compared to the measurement without sample is shown in the figure 1. The peaks of ^{61}Ni are observed and it is possible to identify the impurities, such as ^{62}Ni and ^{64}Ni.

To obtain an accurate neutron cross-section data, we have to perform several corrections: the dead-time correction by using the random pulse generator; subtraction of the overlapping neutrons and the estimation of the background by scattered neutrons.

3.1 Dead-time correction

The dead-time of Ge spectrometer setup varies in the range of several to hundreds of microseconds. We developed a new dead-time correction method by using time-random pulse generator. First, the random pulses are injected into each Ge pre-amplifier, separated from the capture events gamma. Therefore, the dead-time affects similarly both the pulses from the gamma of capture reaction and the signals from the generator. At the end, we can calculate the dead-time from the ratio of random pulse number generated and the number actually recorded in the experiment. The figure 2 shows the ^{61}Ni TOF spectrum with the correction of dead-time compared to the previous raw data.

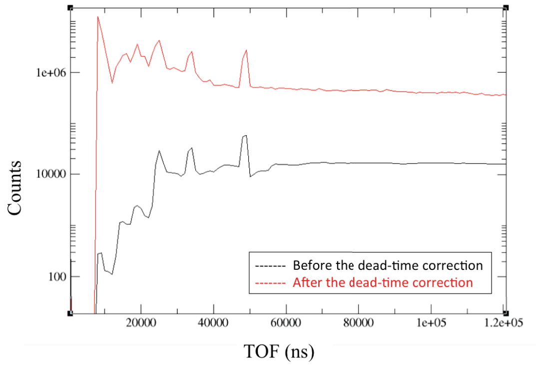

Figure 2. The ^{61}Ni capture yields with dead-time correction (black curve) compared to the previous raw data (red curve).

3.2 Overlapped neutrons correction

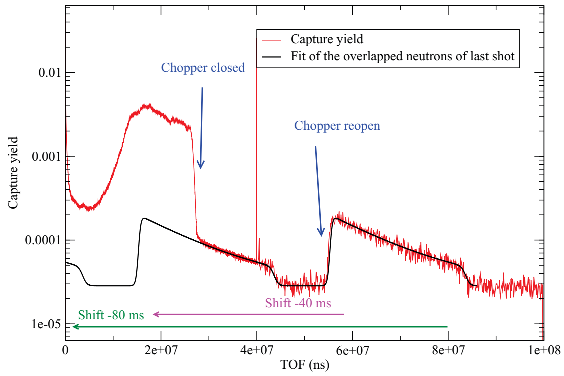

Figure 3. Subtraction of overlapped neutrons of the fit of the last tail (40 ms to 80 ms) (black curve) from the ^{61}Ni TOF spectrum (0 to 40 ms)(red curve)

The beam repetition frequency is 25 Hz (40 ms range). As the neutrons of each shot cover more than 100 ms in time of flight, some low energy neutrons overlap to the next shots. However, one cycle (3 s) always contains N pulses, from which n pulses are sent to ANNRI facility and (N-n) to the other facility. The last shot (n^{th} pulse) lasts more than the longest time of flight, thereby allowing to evaluate the tail of neutrons coming from previous shots (overlapped neutrons). In the experiment, 71 neutron shots were provided to MLF, and the other 4 were sent to other facilities. Figure 3 shows a ^{61}Ni TOF spectrum up to 100 ms. A sudden downward step in the spectrum around 25 ms, and similarly an upward step at around 55 ms, are due to a chopper, with the scope of stopping the slow neutrons, reduce overlapped neutrons and allow to evaluate the background. In this case, the subtraction of the fit the tail from the previous data permits to correct the overlapped neutrons effect.

3.3 Preliminary results

To obtain the capture cross-section, we need to subtract the background and calculate the neutron spectrum. The background of the ^{61}Ni measurement in this experiment is mainly due to the scattered neutrons. Therefore, we used carbon as a reference to estimate the background because the capture cross-section of carbon is negligible in comparison with scattering cross-section. Regarding the relative neutron spectrum, it was measured by using the 478-keV γ rays from the ^{10}B$(n, \alpha\gamma)$ ^{7}Li reaction. Therefore, once the background has been subtracted, the relative cross-section was obtained with the normalization to the relative neutron spectrum [2]. Preliminary results of the

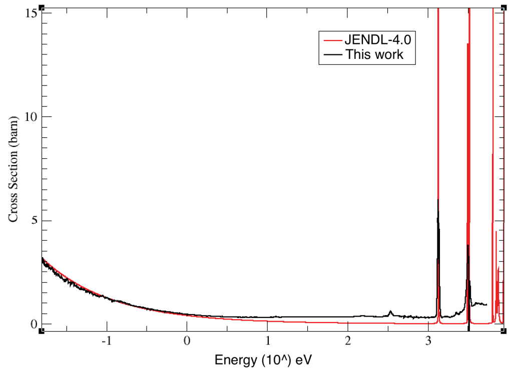

Figure 4. ^{61}Ni capture cross-section by the relative yield to JENDL-4.0

neutron-capture cross-section for ^{61}Ni were obtained by normalizing the relative cross-section to JENDL-4.0 [3] in the energy range from thermal energy to 10 eV, as shown in figure 4. The preliminary data are lightly discrepant to the library in the energy range from 10 eV to 1000 eV. It might due to underestimation of the background subtraction. Multi-scattering neutron corrections are planned.

Ackowledgement

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References

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