Study on accuracy improvement of fast-neutron capture reaction data of long-lived MA for development of nuclear transmutation systems
(2) Development of a neutron beam filter system at ANNRI in J-PARC

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The double-bunch mode of the J-PARC facility introduces serious ambiguities in the neutron induced cross-section measurement in the fast neutron energy region. The neutron filtering technique is applied in the ANNRI beamline in order to produce quasi-monoenergetic neutron beams. In this work, different filter configurations with Fe and Si were tested and their performance as neutron filter is presented.

Keywords: J-PARC, ANNRI, double-bunch, Time-of-flight measurement, Neutron Filter, PHITS, fast neutron energy.

1. Introduction

The Accurate Neutron-Nucleus Reaction Measurement Instrument (ANNRI) beamline was designed to accurately measure neutron-induced reactions using spallation neutrons. These neutrons are generated by protons coming from the Japanese Proton Accelerator Research Complex (J-PARC) impinging on a Hg target. Currently, the J-PARC accelerator is operated in double-bunch mode at a repetition rate of 25 Hz. This means that every 40 ms two 0.1 μs wide proton bunches are shot into the Hg target with a time difference of 0.6 μs. Although this time difference is negligible for thermal neutrons, it is quite problematic for fast neutrons as the 0.6 μs time difference can amount to an energy difference of several tens of keV. Hence, the double-bunch mode introduces severe ambiguities in the determination of the incident neutron energy from the time-of-flight method as it is impossible to separate the contribution from each proton bunch.

2. Neutron Filtering Principle

The neutron filtering technique was applied to the ANNRI beamline using materials that present a sharp minimum in the neutron total cross-section. By employing such materials, the incident neutron flux can be tailored into sharp neutron peaks with the energy of these "windows" created by the filter materials. In this work, ^{nat}Fe and ^{nat}Si were used in different thickness configurations to test their performance as neutron filters in order to produce quasi-monoenergetic peaks at the energies of 24 keV (Fe) and 54 and 144 keV (Si) (see Fig. 1).

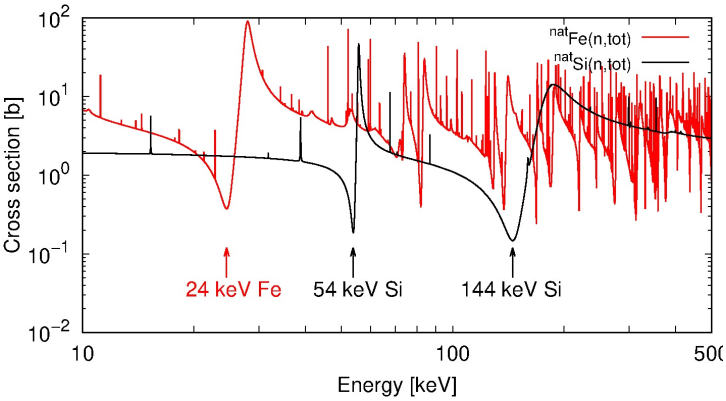

Fig. 1 Neutron total cross-section of ^{nat}Fe and ^{nat}Si from JENDL-4.0

3. Experimental Analysis

The performance of the filters was evaluated using a NaI(Tl) spectrometer and Li-glass detectors. The incident neutron flux was derived from the measurement with a NaI(Tl) spectrometer of the 478 keV γ-rays emitted from the ^{10}B(n,αγ)^{7}Li reaction from an enriched boron sample. Li-glass neutron detectors were also employed to measure the shape of the incident neutron flux through the filter material. In this work, filter assemblies consisting of 20 cm of Fe and 20 and 30 cm of Si were tested.

4. PHITS calculations

Monte-Carlo simulations with the PHITS code were essential for the final benchmarking of the neutron filtering system. The experimental results were reproduced by the calculations with the PHITS code. Moreover, since the energy and time of each incident neutrons is known, the energy distribution from the filtered neutron peaks can be determined. From these results, the performance of each of the neutron filters configurations can be determined by referring the energy distribution from each filter to that without the filter present.

5. Conclusions

The characteristic of the three neutron filter configurations of 20 cm of Fe and 20 and 30 cm of Si are presented and their viability as a neutron filter is discussed from the results of the present work.

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