8-1 Challenge of Obtaining Accurate Nuclear Data for Radioisotopes
—Measurement of Neutron Capture Cross Sections of ^{244}Cm with ANNRI—

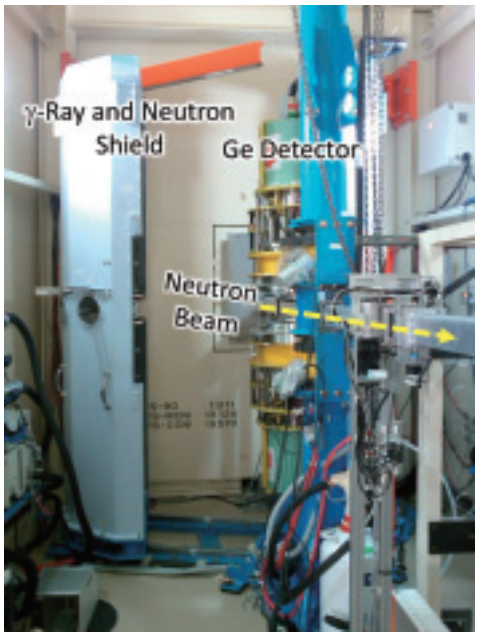

Fig. 8-4 Photo of an array of Ge detectors in ANNRI
Using the detectors, energies of prompt γ-rays are recorded together with a flight time of an incident neutron. An energy of the incident neutron is calculated from the flight time.

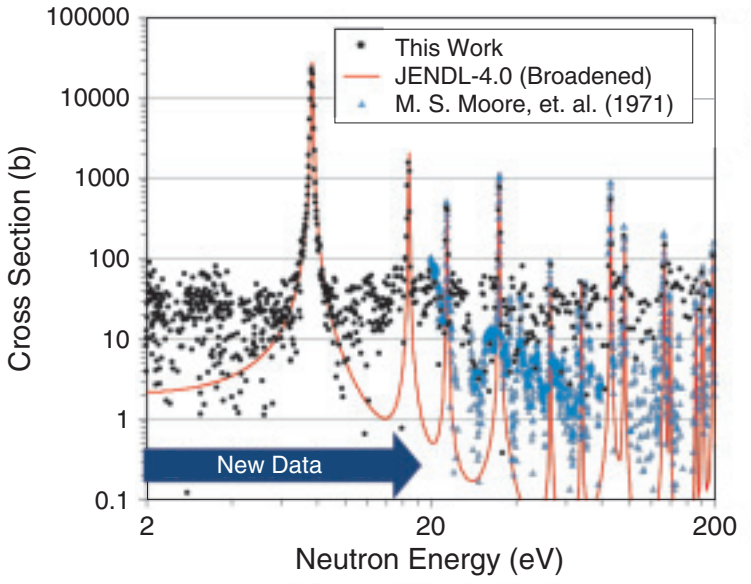

Fig. 8-5 Measured neutron capture cross sections of ^{244}Cm (●)
The results are compared with the data obtained by Moore (▲) and evaluated values in JENDL-4.0 (——). The resonances below 20 eV were observed in the capture reactions for the first time.

Accurate neutron capture cross section data for minor actinides (MAs) and long-lived fission products (LLFPs) are required in order to estimate the production and transmutation rates for developing innovative nuclear systems. To satisfy this requirement, the Accurate Neutron-Nucleus Reaction measurement Instrument (ANNRI, Fig.8-4) has been developed in the Material and Life Science Experimental Facility of the Japan Proton Accelerator Research Complex. A series of neutron capture cross-section measurements have been begun with ANNRI.

^{244}Cm is one of the most important MAs. However, there is only one reported experimental data set, which was obtained in 1969 using a nuclear explosion. The difficulties associated with experiments are as follows:

- Because strong decay γ-rays from ^{244}Cm produce a severe dead time, deduced cross sections have a large error due to the dead time correction. (The radioactivity of our sample was 1.8 GBq.)
- Because it is difficult to obtain and handle ^{244}Cm samples, uncertainties in the sample amounts become quite large. (The uncertainty of our sample was about 16%.)
- Because the detectors are sensitive to fission events, a ratio of the sensitivity to fission events to the sensitivity to capture events must be evaluated.

To overcome these difficulties, we have developed the following new techniques:

- An accurate dead time correction method using random timing pulses
- A normalization technique at the first resonance of ^{240}Pu, which is the daughter nuclide of ^{244}Cm, to reduce the uncertainty in the sample amount
- A method of evaluating the sensitivity ratio at the first resonance of ^{245}Cm, which has a large fission cross section

Using these techniques, we obtained the neutron capture cross sections of ^{244}Cm, as shown in Fig.8-5. The resonances at around 7.7 and 16.8 eV were observed in the capture reactions for the first time. An uncertainty of 5.8% was achieved at the top of the first resonance of ^{244}Cm.

Currently, in addition to ^{244}Cm, analyses of ^{246}Cm and ^{237}Np have been completed, and analyses of ^{241}Am, ^{129}I, ^{107}Pd, ^{99}Tc, and ^{93}Zr are in progress. These results will make significant contributions in the development of innovative nuclear systems.

The present study includes the results of "Study on nuclear data by using a high-intensity-pulsed neutron source for an advanced nuclear system" entrusted to Hokkaido University by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT). This project is partly supported by a JSPS Grant-in-Aid for Scientific Research (S), Grant No.22226016, and by a Grant-in-Aid Young Scientific (B), Grant No.22760675.

Reference

Kimura, A. et al., Neutron-Capture Cross-Sections of ^{244}Cm and ^{246}Cm Measured with an Array of Large Germanium Detectors in the ANNRI at J-PARC/MLF, Journal of Nuclear Science and Technology, vol.49, no.7, 2012, p.708-724.