5–2 Transmission Nuclear Resonance Fluorescence Assay of a Spent Fuel Canister
— Demonstrating Feasibility in a Realistic Scenario —

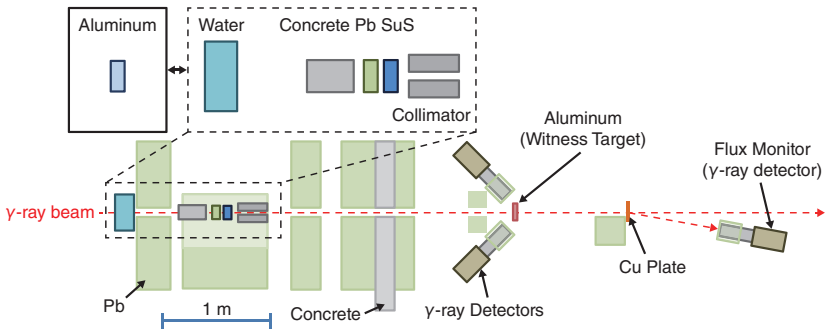

Fig.5-7 Diagram of the TMI-2 transmission nuclear resonance fluorescence experiment
In the experiment, the beam first traversed water, concrete, lead, and stainless steel absorption targets, and then continued to the aluminum witness target, where scattered NRF γ-rays were measured by four detectors. The γ-ray beam flux was determined by measuring the Compton scattering off of a Cu plate. A measurement was also done by changing the absorption target to a single aluminum target.

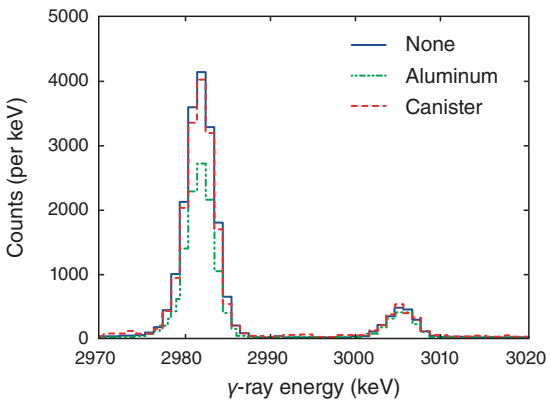

Fig.5-8 ^{27}Al nuclear resonance fluorescence peaks
The NRF peak areas in ^{27}Al measured at the witness station decrease in proportion to the amount of aluminum in the absorption target.

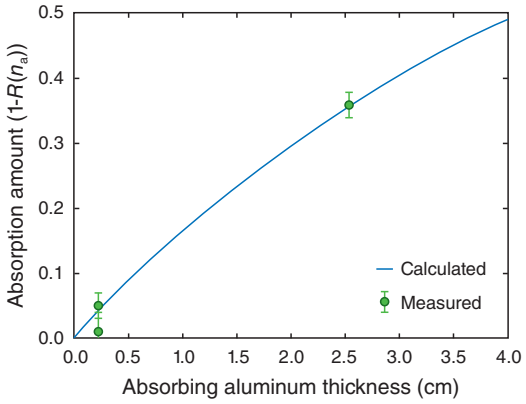

Fig.5-9 Absorption amount for the 2982 keV state
The 2982 keV state's calculated (——) and measured (●) absorption amounts (1-$R(n_a)$) for the following absorbers: canister, concrete (both 0.2 cm aluminum thickness), and aluminum (2.5 cm).

Transmission nuclear resonance fluorescence (NRF) is a promising method for precision non-destructive assay (NDA) of ^{239}Pu in spent fuel stored inside a canister. This method may be needed to assay the melted fuel from the TEPCO's Fukushima Daiichi NPS if the fuel were immediately placed in such a canister, an action that would minimize the possibility of future re-contamination. The Three Mile Island Unit 2 (TMI-2) canister, which was used to store the melted fuel from the Three Mile Island NPS, is one possible candidate. To demonstrate the feasibility of using transmission NRF to assay material inside of a TMI-2 canister, an experiment was conducted at the HIγS facility at Duke University in North Carolina, USA (Fig.5-7).

With transmission NRF, the decrease in NRF scattering from a ^{239}Pu witness target (normalized by flux), or, in other words, the absorption amount, $R(n_a)$, is proportional to the amount of ^{239}Pu through which the γ-ray beam is transmitted. This proportionality is guaranteed because of the resonant absorption nature of NRF. In the demonstration experiment, ^{27}Al was used in place of ^{239}Pu because of their similar NRF properties. The absorption amounts due to aluminum in a simulant TMI-2 canister and in other absorption targets were measured at a γ-ray energy of 2980 keV.

The flux normalized NRF spectra displayed resonant absorption (Fig.5-8), verifying assay feasibility. The measured absorption amount in each case was consistent with the expected absorption amount (Fig.5-9). This agreement demonstrates that overlapping resonances from competing isotopes in the TMI-2 canister should not interfere with the assay.

Reference

Angell, C. T. et al., Demonstration of a Transmission Nuclear Resonance Fluorescence Measurement for a Realistic Radioactive Waste Canister Scenario, Nuclear Instruments and Methods in Physics Research B, vol.347, 2015, p.11–19.