Calculation of Independent Fission Product Yield and Fission Spectrum with the Statistical Decay Theory (2) Prompt Fission Neutron Spectrum

*Toshihiko Kawano[1], Shin Okumura[2], and Satoshi Chiba[2]

[1]Los Alamos National Laboratory, [2]Tokyo Institute of Technology

We applied the Hauser-Feshbach statistical decay theory to the excited fission fragments formed just after fission to calculate the fission product yield, and the prompt fission neutron and gamma-ray spectra. We included a large number of fission fragment pairs produced in the ^{235}U(n$_{\rm th}$,f) reaction. The neutron kinetic energy was converted into the laboratory-frame and aggregated.

Keywords: prompt fission neutron spectrum, independent product fission yield, Hauser-Feshbach theory

1. Introduction

The Monte Carlo Hauser-Feshbach technique is a recent attractive method to evaluate the prompt fission neutron spectrum, where all the neutrons from possible fission fragments are aggregated in a stochastic way. In contrast to some analytical methods employed in the evaluated nuclear data files, the Monte Carlo technique has a wider model parameter space, and it is often time-consuming. Instead of performing the Monte Carlo sampling, we developed a deterministic method, yet a large number of fission fragments are involved in the Hauser-Feshbach calculation, and demonstrated feasibility of applying this to the fission product yield (FPY) evaluation. Constraining the model parameters by several fission observables, we are able to calculate the prompt fission neutron spectrum by converting the neutron energy into the laboratory-frame, which is consistent with the FPY evaluation.

2. Method

We calculate the Hauser-Feshbach decay of compound nuclei that are formed in fission. The fission fragment yields are given by the five Gaussian form based on several experimental data, together with Wahl's Z_p model. The most important model parameters that define an initial configuration of a compound nucleus are, (1) the anithothermal parameter to determine the energy split into two fission fragments, and (2) the spin distribution of the populated states. These are estimated by some fission experimental data, and we report this in our series talk.

Since the Hauser-Feshbach decay from each fission fragment is performed in the center-of-mass frame, the kinetic boost due to the moving fragment for the CMS spectrum $\phi(J,\Pi,E_x,\epsilon)$ from a specific initial state labeled by the spin J, parity Π and the excitation energy E_x is calculated as

$$\chi(E) = \int dE_x \int_{(\sqrt{E}-\sqrt{E_k})^2}^{(\sqrt{E}+\sqrt{E_k})^2} \sum_{J\Pi} \frac{1}{4\sqrt{E_k \epsilon}} \phi(J,\Pi,E_x,\epsilon) R(J,\Pi) G(E_x) d\epsilon \, , \tag{1}$$

where, ϵ is the neutron outgoing energy in CMS, E_k is the kinetic energy of the fragments per nucleon, E is the neutron energy in the laboratory frame, $R(J,\Pi)$ is the spin and parity distribution, and $G(E_x)$ is the distribution of excitation energy. E_x and E_k are connected by the energy conservation. $\chi(E)$ is given for a pair of fission fragments, and the final neutron spectrum is the sum of $\chi(E)$ weighted by the fission fragment yield. The same technique can be applied to the prompt fission γ-ray spectrum, while no kinematic boost.

3. Results and Discussions

The calculated prompt fission neutron spectrum for the thermal neutron-induced fission on ^{235}U is shown in Fig. 1 as a ratio to the Maxwellian spectrum with the temperature of 1.32 MeV. We emphasis that this calculation was not adjusted the experimental data of fission spectrum, but it was derived from the model parameters tuned to other fission observables such as $\overline{\nu}$. The calculation well reproduces the experimental data up to 6 MeV of the neutron outgoing energy, and drops faster than the data. This tendency is also seen in our previous study using the Monte Carlo technique.

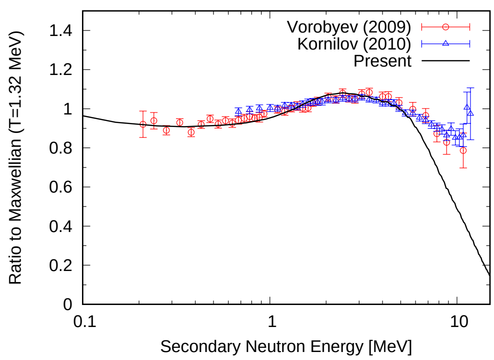

Fig. 1: Prompt fission neutron spectrum for the thermal neutron induced fission on ^{235}U, shown as a ratio to Maxwellian of $T = 1.32$ MeV.