Systematic Study on Fission Yields, Fission Product Nuclear Data and Fission Mechanisms (4) Prompt Neutron and Photon Emissions from Fission Fragments with the Hauser-Feshbach Theory

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

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

We present the statistical Hauser-Feshbach approach to the prompt neutron and γ-ray emissions from the fission fragments, and discuss some recent theoretical advances. As an example, the technique is applied to the thermal neutron induced fission on ^{235}U.

Keywords: fission neutron, fission gamma-ray, Hauser-Feshbach theory

1. Introduction

Nuclear fission produces two highly excited fragments, which decay by emitting several prompt neutrons and γ-rays. We interpret this de-excitation process by the Hauser-Feshbach (HF) theory without an incident particle channel. The decay of a compound nucleus, assuming its spin and parity can be specified, is characterized by the neutron and γ-ray transmission coefficients, and the nuclear structure properties of residual nucleus. This decay process continues until the nucleus arrives at its ground state, or a long-lived meta-stable state. Depending on the physical quantities we are looking at, the HF calculation is performed either in the standard deterministic mode, or with the Monte Carlo (MC) technique.

2. Monte Carlo Hauser-Feshbach (MCHF) Technique

The decay probability P of the n-th compound nucleus at the i-th state to the m-th nucleus at the j-th state is written as

$$P(n_i, m_j) = \frac{T(m_j \to n_i)}{\sum_{m_j} T(m_j \to n_i)} , \qquad (1)$$

where T is the transmission coefficient; $n = m$ for the γ-ray and $n \neq m$ for the neutron. The summation runs over all the possible final states. The states i and j can be a discrete level or a discretized continuum state. Starting with the initial compound nucleus at a given excitation energy, a sequential decay of the compound state is stochastically governed by Eq. (1). From each MC simulation the multiplicity distributions for the emitted neutrons and γ-rays are constructed. When Eq. (1) is numerically integrated, it will be the standard HF calculation, and we obtain the average neutron and γ-ray multiplicities.

3. Application to Fission Observable

A joint-distribution of the atomic number Z, the mass number A, and the total kinetic energy TKE, for the thermal neutron induced fission on ^{235}U is estimated by combining experimental data and systematics. We adjust the initial spin distribution of fission fragments to reproduce the average number of neutron per fission, $\overline{\nu}$. Fig. 1 shows the neutron multiplicity distributions $P_\nu(Z, A)$ for ^{90}Ba, ^{118}Rh, and ^{136}Xe. The arrows are the average multiplicities.

When correlated information, such as P_ν, is not required, we perform the standard HF calculation. The HF method can be applied to estimate the isomeric-state production, from which we can infer the initial spin distribution. However, such a calculation will be very sensitive to the γ-ray branching ratio data employed.

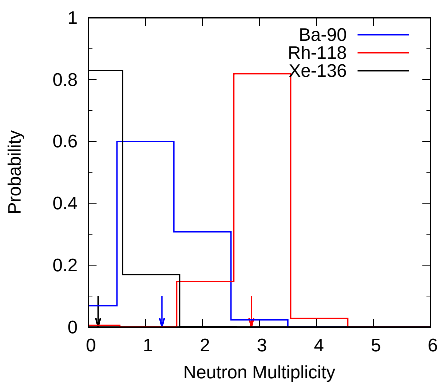

Fig. 1: Neutron multiplicity distribution from the selected fission fragments for the thermal neutron induced fission on ^{235}U.