

8-2 Accurate Prediction of Nuclear Fragmentation by Energetic Radiation

— Fragmentation Cross Section Measurement by New Method and Theoretical Model Development —

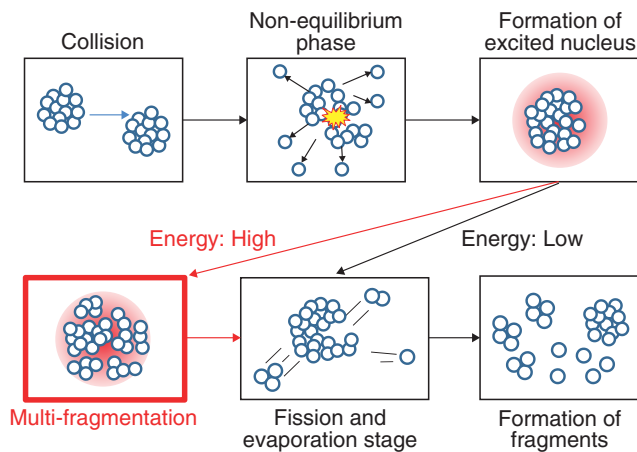


Fig.8-5 Simulation flow of high-energy nuclear fragmentation reactions

A model for simulating the multi-fragmentation process, indicated in red, was added in this research. In the revised simulation flow, energetic nuclei form fragments through a reaction that forms multiple fragments.

In accelerator facilities, various radioactive fragments are produced by spallation of nuclei by high-energy radiation. Because radioactive fragments become radiation sources in accelerators after the operation period, the fragments must be considered, e.g., for safety management in maintenance. However, the radiation transport simulation codes used for shielding calculations cannot accurately predict fragment production from heavy elements.

To solve this problem, we measured the fragment production cross sections of lead bombarded by carbon ions at the National Institute of Radiological Sciences heavy ion therapy facility, HIMAC, and revised the reaction models of the Particle and Heavy Ion Transport code System (PHITS) on the basis of the experimental data. In the experiment, cross sections in a wide energy range (from 50 to 400 MeV/nucleon) were measured by a new method, in which stacked lead plates were irradiated and the fragments in each plate were measured. Calculation by the previous version of PHITS underestimated the cross sections by a factor of 100 at the maximum. We assumed that the underestimation was attributed to the absence

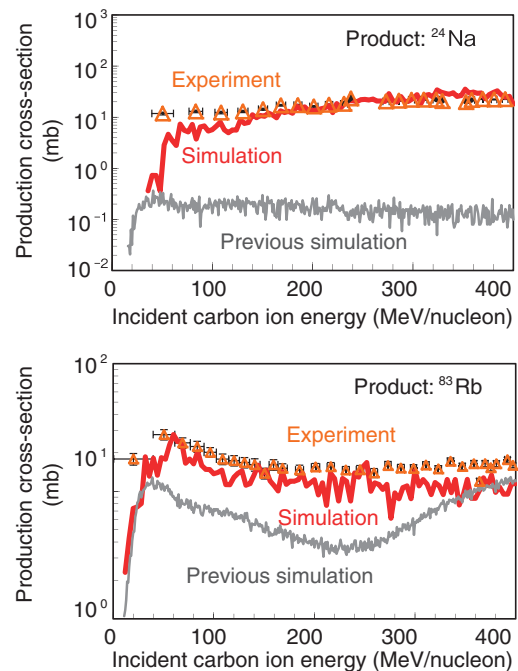


Fig.8-6 Comparison of fragment production reaction cross sections (upper: ${}^{\text{Nat}}\text{Pb}(\text{C},\text{x})^{24}\text{Na}$ reaction, lower: ${}^{\text{Nat}}\text{Pb}(\text{C},\text{x})^{83}\text{Rb}$)

The previous simulation underestimates the cross sections by a factor of 10 to 100 compared to the measurement data, whereas the new calculation using PHITS as revised in this research agrees with the measurement data very well.

of a multi-fragmentation process. In this process, nuclei are disintegrated into multiple small fragments, whereas the old PHITS assumes that all the excited nuclei undergo a fission/evaporation process to form fragments. Therefore, a new model, the statistical multi-fragmentation model, was added to the calculation model of PHITS; it determines the partition of nuclei on the basis of the probabilities of various partitioning patterns calculated using statistical mechanics (Fig.8-5). The fragment production cross sections calculated by the revised PHITS reproduced the measured ones accurately (Fig.8-6).

In this research, accurate prediction of the radioactive fragment production cross sections by PHITS was realized; this contributes remarkably to the precise evaluation of radiation safety in high-energy accelerator facilities.

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Reference

Ogawa, T. et al., Analysis of Multi-Fragmentation Reactions Induced by Relativistic Heavy Ions using the Statistical Multi-Fragmentation Model, Nuclear Instruments and Methods in Physics Research A, vol.723, 2013, p.36-46.