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Improving Accuracy of Fission Product Yields by Bayesian Neural Network/ベイジアンニューラルネットワークによる核分裂生成物収率の高精度化

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Fission product yields (FPY) is one of the most important nuclear data, which provide information necessary for applications like burn-up calculation in nuclear reactors, environmental assessment of radioactive waste disposal and evaluation for production of valuable isotopes such as ^{99}Mo for medical imaging. Traditionally, major nuclear data libraries (such as JENDL, ENDF, JEFF, etc.) have established FPY databases for neutron-induced fission at only thermal energy, 0.5 MeV, and 14 MeV where many experiments have been carried out, and the data in the energy range lacking experimental data are obtained by an interpolation in linear-linear basis, which is not consistent with energy dependence of experimental data for many FPY. Therefore, evaluated data on FPY are still insufficient. However, consistent and systematic evaluations of energy dependence of the FPY have been proven to be quite challenging by both theoretical calculation and experimental measurement. In order to improve this situation, we utilized a two hidden-layer Bayesian neural network (BNN) model with data augmentation technique to train and predict evaluated and experimental fission product yields with high accuracy to obtain energy dependence of mass distributions of the FPY. Similar to the normal deep learning, the JENDL-5 FPY data were divided into 2 groups, 80% for training and 20% for validation. Additionally, the training data included several experimental cumulative yields and theoretically calculated values. The number of units in each layer and activation function were selected carefully to reproduce the global and fine structure of the mass distribution data. Additionally, the data augmentation is particularly valuable for enhancing the accuracy of specific nuclides. Finally, the predicted results for energy dependence of mass distribution for ^{232}Th, ^{233,235,238}U and ^{239,241}Pu for incident energy ranging from 1MeV to 5MeV in BNN model exhibited certain peak structures at fission product mass numbers A = 134 and A = 140-144, which agreed with enhancement due to the shell and even-odd effects, and the standard I and II asymmetric modes of fission from Brosa model [1]. The capability of our BNN to reproduce the mass distributions including the fine structure is evaluated to be an advancement of the similar approach by a group of Beijing University [2], which aims at description of an overall 2-peak structure of the FPY and the fine structure.

References

[1] Brosa U, Grossmann S, Muller A. Nuclear scission. Physics Reports. 1990;197(4):167–262.

[2] Wang ZA, Pei J, Liu Y, et al. Bayesian evaluation of incomplete fission yields. Physical Review Letters. 2019 09;123.

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