Study of (n,2n) reaction cross section of fission product based on neural network and decision tree models

Xiaodong Sun[1], Zihao Wei, Yuan Tian, Duan Wang, Ruirui Xu

[1] China Institute of Atomic Energy, P. O. Box 275, Beijing 102413, China

1214518959@qq.com

Abstract:
The neutron induced nuclear reaction cross section of fission products is related with the neutron flux and the reactor burnup, which plays an important role in accurately designing nuclear engineering. To predict (n,2n) reaction cross sections especially those without experimental data, the relevant features were analyzed and the experimental data set were established on the basis of sorting out the experimental data recorded in EXFOR library. This work includes 5294 (n,2n) cross section measured results, among which a lot of experimental data concentrate around 14 MeV incident energy. Moreover, there may be divergence between measurements due to system error and negligence error. Faced with these real and defective data, researchers discovered laws behind them and established the compound nucleus reaction models. However this means a heavy workload. It would be surprising if machine learning could reach a quantitative level close to the evaluation results. The 8 features include the proton number Z, the mass number A, the single nucleon separation energy of both proton and neutron, the Casten factor, the level density, the pairing correction, and the incident energy. The back propagation artificial neural network (ANN) and decision tree (DT) models were built to learn the experimental data set, respectively, adopting PyTorch and XGBOOST toolboxes. Draw lessons from the variational auto-encoder network, the 2 sub-networks with the same internal structure, which contains 128 neurons in 2 hidden layers, were designed to learn the mean and variance respectively. The boosting model integrates 16 decision trees. The training set includes 4 000 uniform and randomly selected data, while the remaining data constitutes the test set. The results show that both ANN and XGBOOST models describe the experimental cross section data well, moreover model gives a smooth and continuous curve, indicating a certain predictive ability. For the case of lack of experimental data, the predictions are also basically consistent with the evaluation nuclear reaction data libraries. Compared with the XGBOOST model, the ANN model has somewhat better generalization ability in the range of neutron incident energy above 20 MeV. In the test set, the ANN predictions with a mean absolute percentage error (MAPE) deviation less than 10% from the experimental data account for more than 85%. Therefore we successfully established machine learning models to analysis and predicate (n,2n) reaction cross section. On the other hand, through traditional nuclear reaction models, one can intuitively understand the relationship among physical quantities and build a picture of the reaction mechanism. However, machine learning models are often regarded as difficult to understand black boxes, which is questionable for physicists. In future it is planned to further apply machine learning for the nuclear data research to verify the rationality of the method.