Prediction of Independent Fission Fragment Isomeric Yields using Machine Learning

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Physics and Astronomy

1. **RATIONALE:**

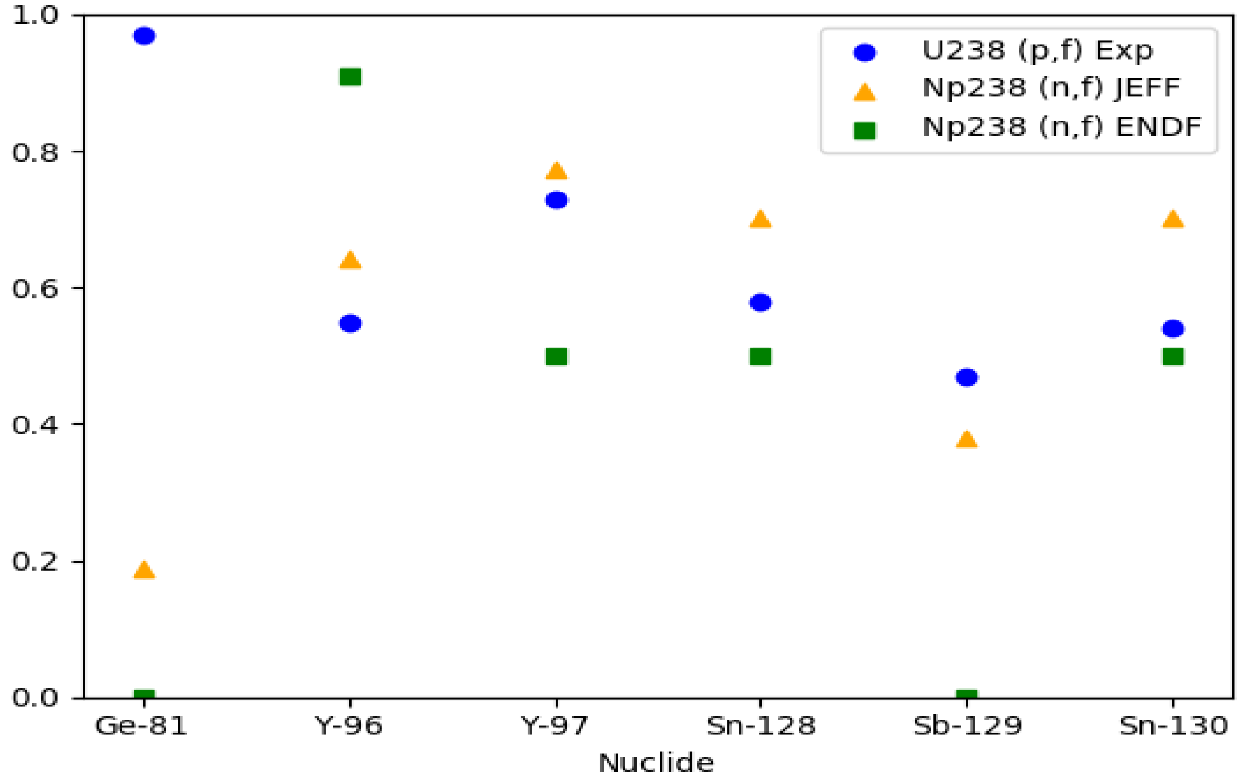

Figure 1: Comparison of ENDF and JEFF 3.3 Neptunium 238 yields, and experimental data for isomeric yield ratios of proton induced fission of Uranium-238. Both reactions result in the same compound nucleus [2][3][4] (Figure was created by author).

In the process of fission, a heavy compound nucleus breaks into two excited β-unstable fission fragments. These fragments first deexcitate through prompt sequential neutron and gamma emissions which result in independent fission yields. Figure 1 displays the independent isomeric yield ratios of the same compound nuclear system, Np-239, for several isomers. A compound nucleus is formed by the target nucleus absorbing the projectile. Isomers are excited nuclei that reach a metastable form, meaning that they remain in this excited state. These isomers are significant because they are the only source for post fission spin distribution data. Figure 1 shows that there is incomplete and inconsistent data within the ENDF and JEFF 3.3 evaluations compared to experimental U-238. Obtaining accurate data provides necessary information for determining the antineutrino spectrum. In beta decay, antineutrinos are formed as a result of the launched neutrons decaying through the weak force. The antineutrino spectrum (the number of antineutrinos per outgoing energy) has applications for nonproliferation and the understanding of the Standard Model of particle physics. Two of the largest contributors of uncertainty in the reactor antineutrino spectrum are the fission products Rubidium-92 and Yttrium-96. While Rb-92 production has been studied in great depth, Y-96 has not. Therefore, understanding the production of Yttrium-96 and its isomer will reduce the uncertainty in the antineutrino spectrum [1].

Machine learning is a tool in data analysis which enables a user to extract hidden relationships within data for classification or regression based tasks [6]. There are many forms of machine learning such as neural networks, classification algorithms, and reinforcement learning algorithms. These different forms of machine learning enable users to find new insights into data that were otherwise unable to be seen. The machine learning field has clear potential for all fields in science to help develop models to better understand scientific phenomena.

Furthermore, there is clear potential for machine learning to greatly help the field of nuclear data by extracting hidden interdependencies. Fission is a complicated nuclear process which produces many radioactive products. Experiments are challenging and observables do not provide enough insight into these interdependencies. As experimental data is limited, any tool that can provide insight with incomplete data is useful. The benefit of understanding the Yttrium-96 isomeric ratio as well as applying machine learning models to nuclear data leads to the proposal of the creation of the following model: A machine learning model that estimates isomeric ratios.

2. **RESEARCH QUESTION(S), HYPOTHESIS(ES), ENGINEERING GOAL(S), EXPECTED OUTCOMES:**

Research Question(s): Is there a hidden relationship in the features of independent isomeric fission yields that can be used to create a model?

Hypothesis: It is hypothesized that a regression model should be able to extract the correlations to accurately predict the yield ratios.

Expected Outcome: It is expected that a regression model will be constructed which can accurately predict the isomeric fission fragment yield ratio for a given set of parameters.

3.

a. **Procedures:**

The EXFOR library is a nuclear database which contains all experimental nuclear reaction results taken since the Manhattan project [5]. Therefore, the library is the most complete and authoritative source for fission product yield data for training. I will compile all possible data entries into a comma separated values file or CSV. I will also develop a data structure and parser to automate the system, accounting for key fission fragment data such as the target projectile, incident energy, type of projectile, and compound nucleus. The data structure will enable easy access to key features of a data entry as well as the labeled data, being isomeric yield and their uncertainties.

From this data structure, multiple machine learning models will be constructed and trained with a fraction of the data entries available from EXFOR. The models will then be tested with reserved data entries to determine the models' accuracy.

c. **Risk and Safety**:

Since this is a purely computational project, meaning that there is no risk or safety concerns in this project.

d. **Data Analysis:**

After completing the machine learning model and the automation of EXFOR data into a usable form for the model, approximately three fourths of data entries will be used as training data to train the neural network. After completing training, the model will infer the values for isomeric ratios from the testing data and will be compared to the actual data, providing a statistical analysis of the accuracy of the data.

4. **BIBLIOGRAPHY:**

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No Addendum Exists