**Using Neural Networks to Predict the Density Profiles of Isotopes.**

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**155Tb**

- **155Tb** is a promising isotope for Theranostics; figure 1
- Has computationally complex nucleus
- Unknown reaction probabilities (cross sections)
- Difficult to produce with high purity
- Auger electrons have low penetrative power, and travel between 0.7 and 33 μm, smaller than human cells,
- High promise for highly precise cancer treatment
- Gamma rays are utilized in SPECT Imaging to diagnose tumors,

**156Gd**

- Used in current, direct method of producing **155Tb**; eqn 1
- High overlap of cross sections with **155Tb** and **156Tb**,
- Poor yield
- Novel method uses indirect production with the decay of **156Gd** via electron capture; eqn 2

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**155Tb**: The Future of Auger Therapy

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**JAX**

- Accelerated learning algebra (XLA) application programming interface (API) that uses the Python language,
- Uses GPUs and TPUs which hold multiple discs
- Designed for construction and implementation of computationally large programs such as neural networks.
- Stax is a built-in library that efficiently constructs the architecture of neural networks.

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**Neural Networks**

- A type of machine learning that are functionally digital brains; figure 2
- With/without batches
- Factors which affected the accuracy of the network the greatest; figure 3
- Can be used to find patterns and be trained to predict with high accuracies
- Base network used to evaluate the effects of differing network architectures
- Developed different combinations of hidden layers, number of neurons, loss functions, and initialization seeds; figures 5 and 6

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**Objective**

- Create a neural networks capable of predicting the density profiles of isotopes
- Demonstrate the design of new neural networks on the prediction of density profiles
- Optimize the network’s architecture for accuracy and run time.
- Predict the density profiles of **155Tb** and **156Gd**

**Results & Discussion**

- Factors which affected the accuracy of the network the greatest; figure 3
- Number of inputs
- Number of hidden layers
- Most affective:
  - initialization seed: 119; figure 5
- Lesser performance for nuclei with A & Z numbers approaching the end of the data set

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**Methods**

- Known data set of 80 nuclei, 60 for training, and 20 reserved for testing.
- Additional density profiles of nuclei calculated using 2pF, 3pF, and 3pG models
- Created the architecture of a basic neural network for proof of concept (termed Original in figures)
  - Inputs: A and Z numbers
  - Number of inputs
  - Number of hidden layers
  - Hidden layer
  - 64 neurons per layer
  - Tanh used for the activation function
  - Cross Entropy function for calculating loss (error from predicted training data)
  - Improved accuracy of network through the addition of a third input: Ground State Values
  - Cross Entropy loss function
  - 1000 steps with a learning rate of 0.0001

**Conclusion and Further Research**

- Testing different architectures of the neural network, the optimal configuration was found, producing the lowest loss value, and providing sufficient predictions. With the optimal network created (dubbed “final”) predictions for **155Tb** and **156Gd** were made; figures 7 and 8.
- High accuracy can be achieved with large enough data set
- Greater number of hidden layers
- Greater number of neurons per layer
- Run time can be decreased with access to more-or-larger GPUs

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**References**

https://doi.org/10.1002/cmdc.202100135.

This work was supported in part by Department of Energy Isotope Program’s Grant DE-SC0022550, the Horizon-Broadening Isotope Production Pipeline Opportunities (HIPPPO) program. This research was supported by the U.S. Department of Energy Isotope Program, managed by the Office of Science for Isotope R&D and Production and Argonne National Laboratory under U.S. Department of Energy contract DE-AC02-06CH11357. Presented at Los Alamos National Laboratory at the culmination of the Summer 2022 HIPPPO program.