Validation of JENDL-4.0 in PHITS using alpha particles in water at 0.001 MeV to 1000 MeV in BNCT

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ABSTRACT

Alpha particle is one of the by-products of neutron reactions, specifically in BNCT. With this concept, it is proposed that JENDL-4.0 can be utilized to simulate BNCT.

The simulation methods start with the simulation set-up, followed by the execution of the simulation, data calculation, data generation, and data analysis. The results generated in this study are then compared to the standard range values from the International Commission on Radiation Units and Measurements (ICRU) Report No. 49, *Stopping Power and Ranges for Protons and Alpha Particles*.

The range values from both measurements are plotted in a scatter graph and the JENDL-4.0 results are in agreement with the ICRU (1993) values. Moreover, the scatter plot that the values do not scatter much around each other and they have a positive, strong and linear correlation.

Finally, the alpha particle ranges from JENDL-4.0 agree to that of the standard ranges from ICRU and therefore, JENDL-4.0 is an acceptable data library for BNCT simulations.

INTRODUCTION

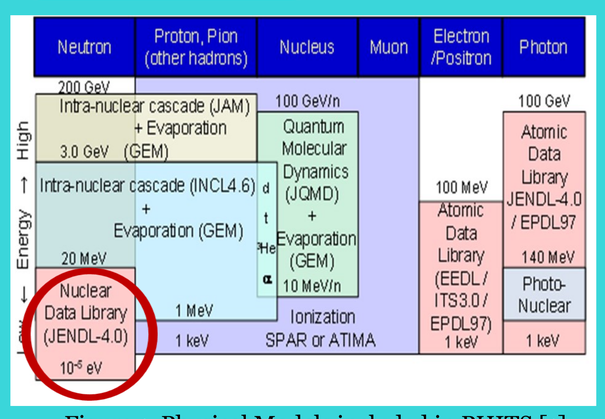

Figure 1. Physical Models included in PHITS [1]

JENDL-4.0, a data library under Particle and Heavy Ion Transport code System (PHITS), provides fast thermal reactions for neutrons [1].

WHAT DOES NEUTRON REACTION PRODUCE?

Alpha Particle:

- **Product of neutron reaction in BNCT (Figure 3)**
- **Has high linear energy transfer (LET) [2}**

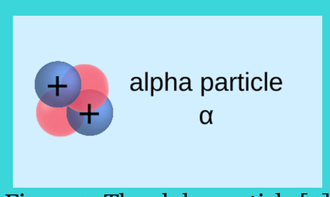

Figure 2. The alpha particle [3]

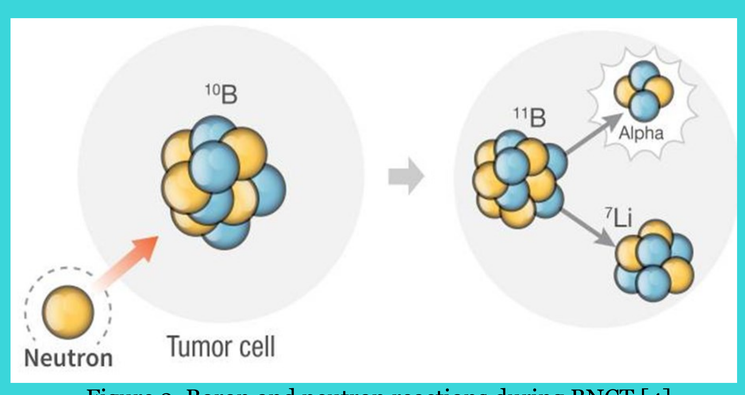

Figure 3. Boron and neutron reactions during BNCT [4]

Goal:

to validate JENDL-4.0 PHITS physics model in the simulation of alpha particle ranges at 0.001 MeV to 1000 MeV for BNCT

HOW TO DO THIS?

METHODS

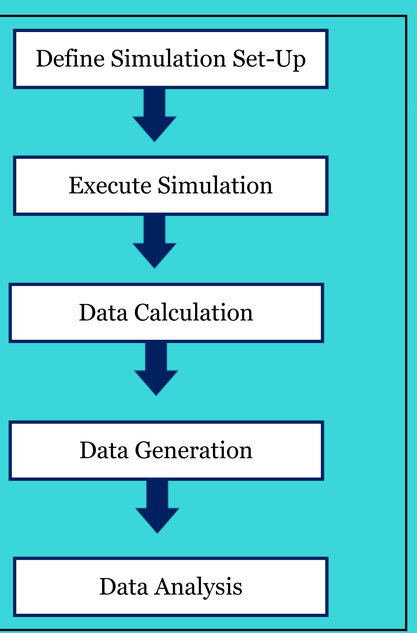

Figure 4. Schematic diagram of the simulation

Simulation Visualization

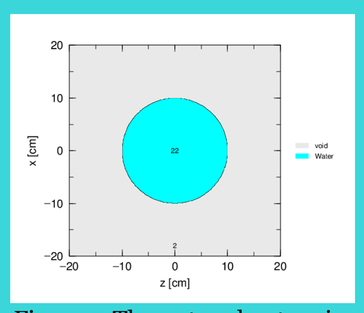

Figure 5. The water phantom in 10cm radius with the energy source in the center

RESULTS

- **As the energy increases, the range of alpha particle also increases (both results)**
- **The results also have positive, strong and linear correlation**
- **The results obtained from JENDL-4.0 is in agreement with the standard range values from ICRU, 1993 (Report No. 49, *Stopping Power and Ranges for Protons and Alpha Particles* [5].**

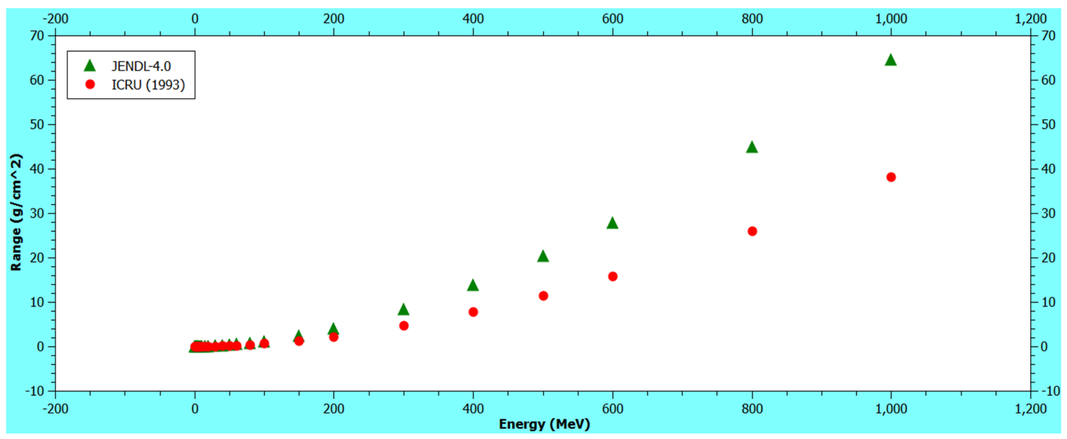

Figure 6. The alpha ICRU (1993) ranges comparison with ranges of alpha particle in water by using JENDL-4.0 with energies 0.001 MeV to 1000 MEV

The obvious deviation or difference in range values can be due to the difference in experimental environment. ICRU was obtained from an actual experiment while the results in this study are obtained from a simulation.

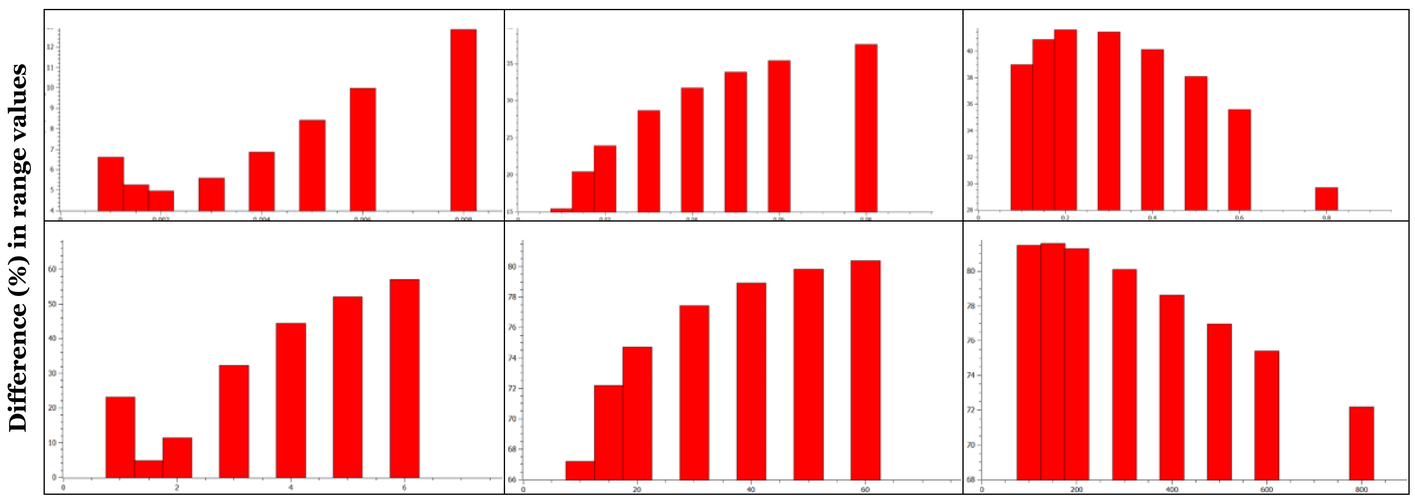

Figure 7. The percent difference in ranges of alpha particle for different energies in water between JENDL-4.0 and ICRU (1993).

Figure 7 shows the percent difference between the range values obtained from JENDL-4.0 and ICRU (1993). While JENDL-4.0 shows a general agreement to the trend of the range values from ICRU (1993), they still show evident differences at higher energy region.

CONCLUSION

It can be concluded that the alpha particle ranges from JENDL-4.0 are in agreement to that of the standard ranges from ICRU.
Therefore, JENDL-4.0 is an acceptable data library for BNCT simulations.

REFERENCES

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[2] "Alpha Radiation - an overview | ScienceDirect Topics." https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/alpha-radiation (accessed Oct. 24, 2022).
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[4] "Click on image to zoom." https://www.ncbi.nlm.nih.gov/core/lw/2.0/html/tileshop_pmc/tileshop_pmc_inline.html?title=Click%20on%20image%20to%20zoom&p=PMC3&id=5503652_oncotarget-08-39774-g001.jpg (accessed Jun. 22, 2022).
[5] "ICRU Report 49, Stopping Power and Ranges for Protons and Alpha Particles – ICRU." https://www.icru.org/report/stopping-power-and-ranges-for-protons-and-alpha-particles-report-49/ (accessed Sep. 28, 2022).

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