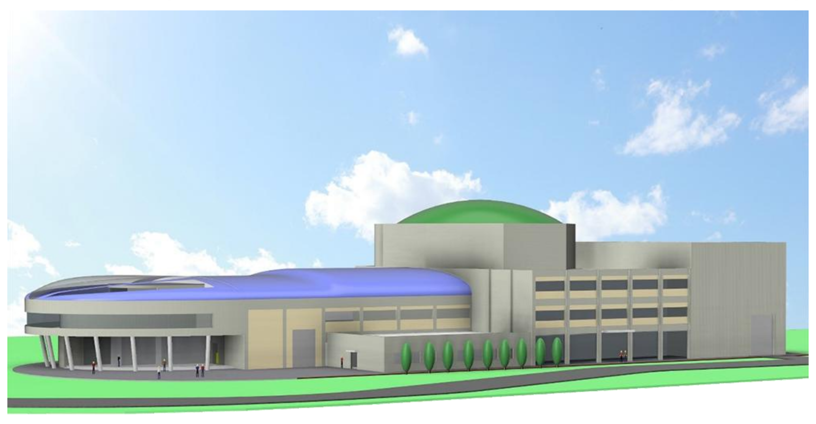
Towards the design of cold neutron source for the new research reactor at the "Monju" site

Yudai Takita[1], Mizuki Iriyama[1], Seiji Tasaki[1], Yutaka Abe[1], Masahiro Hino[2], Masaji Arai[3]
1: Kyoto University Graduate School of Engineering, 2: institute for Integrated Radiation and Nuclear Science, Kyoto University, 3: Japan Atomic Energy Agency

Introduction

The new research reactor will be built at the Monju site in Tsuruga city, of which thermal power is about 10MW and primary purpose is neutron beam utilization.

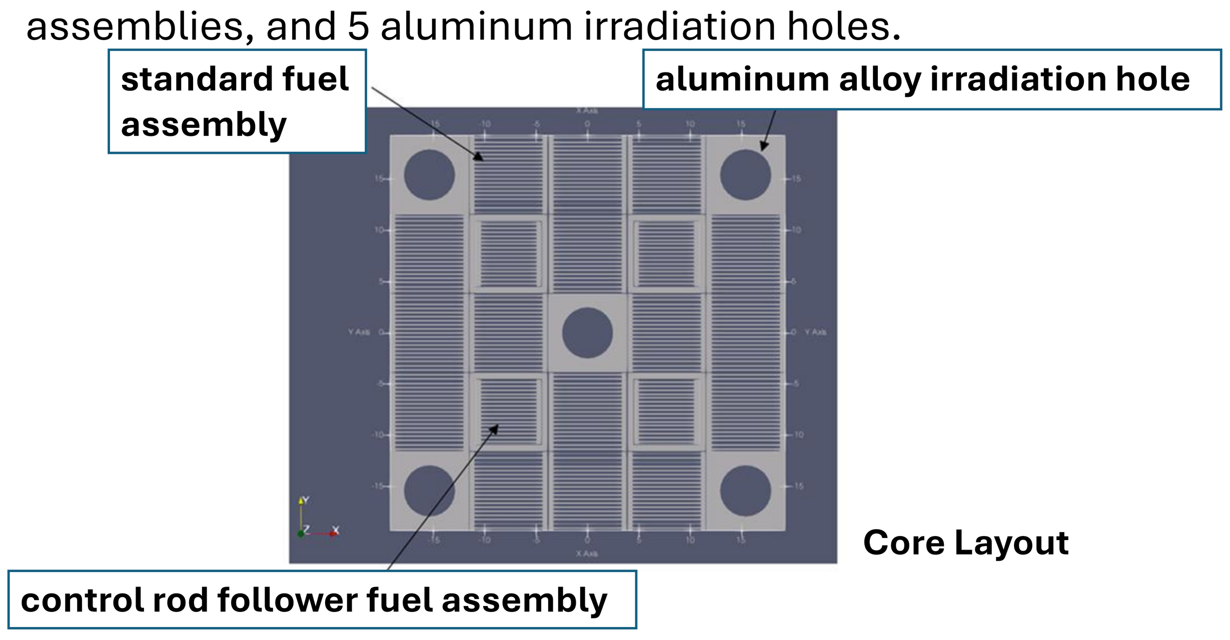


[1]

Recently, slower neutrons are more and more desirable, and cold neutron source (CNS) is used to product intense cold neutrons by slowing down from kinetic energy of thermal neutrons. The performance of CNS strongly depends on moderator material and shape. In this study, we investigates the optimal shape of CNS of which moderator material is deuterium.

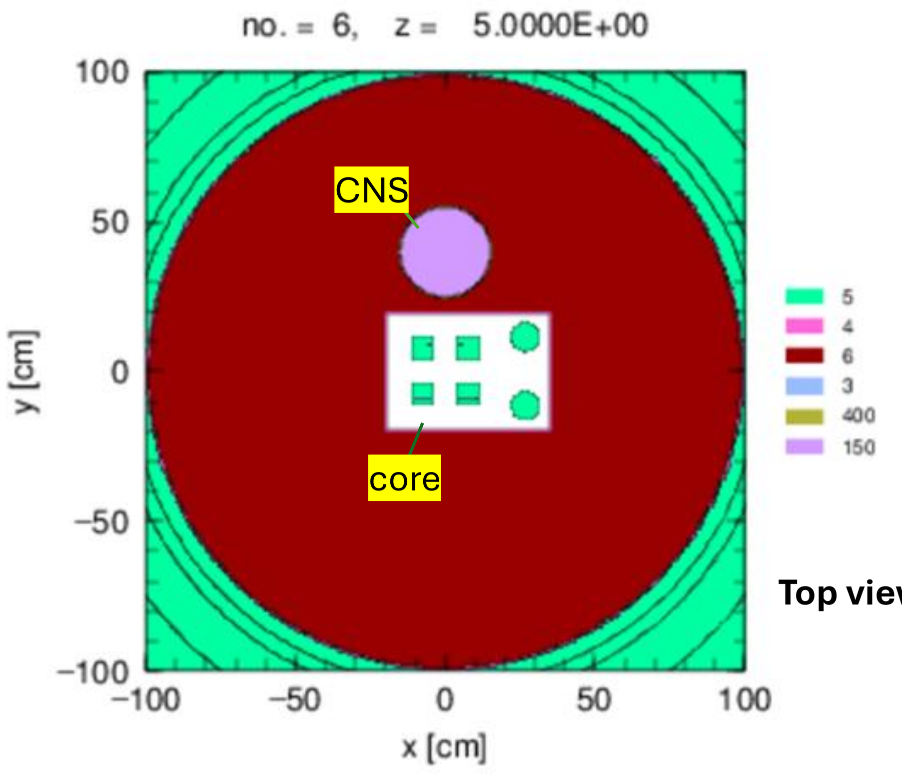
Deuterium is expected to be highly effective as a cold neutron source (CNS) material due to its large scattering cross section and small absorption cross section for neutrons.

In a previous study, the reactor core system modeled by the JAEA design group using MCNP was reproduced using PHITS 3.10[2].
In that (previous) study, we assumed a core configuration (Ce20) composed of a 5 × 5 lattice consisting of 16 standard fuel assemblies, 4 control rod follower fuel assemblies, and 5 aluminum irradiation holes.



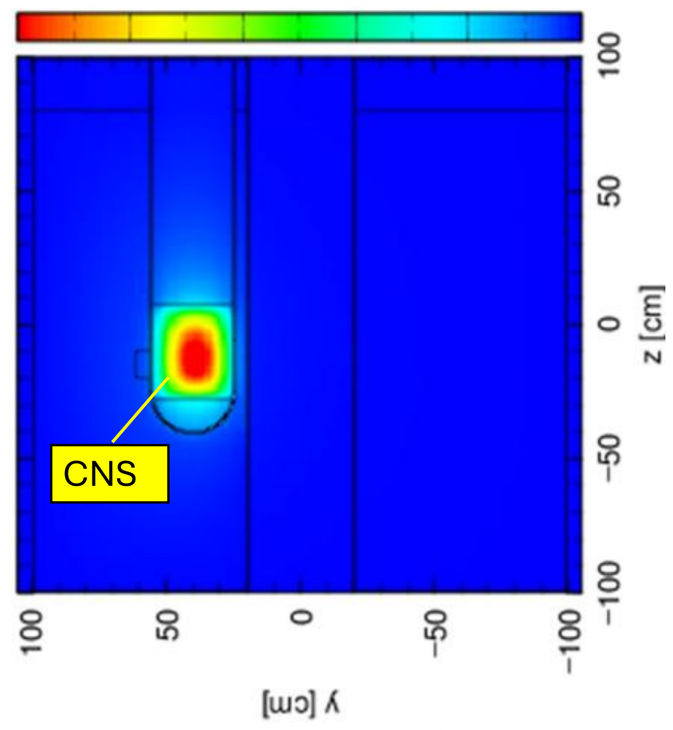
Core Layout

In that system, deuterium was used as the moderator in the CNS, and its diameter was 30 cm[3].



Top view of the reactor system

In that study, we examined the cold neutron flux distribution and found that cold neutrons were highly concentrated at the center of the CNS.



Cold neutron flux distribution in the reactor system

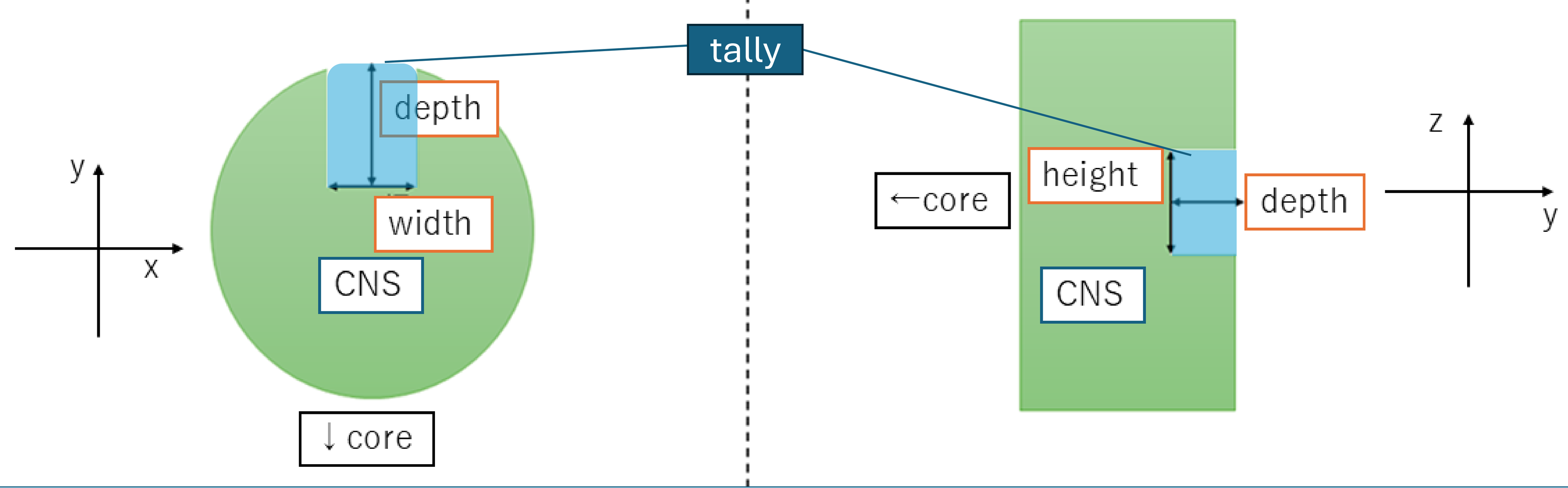
To extract cold neutrons from the center of the CNS, it is important to introduce a re-entrant structure—a shallow cavity on the CNS surface.

The objective of this study is to investigate how changes in the geometry of the re-entrant structure affect the extracted cold neutron flux.

Simulation Method (using PHITS 3.10)

A re-entrant structure was formed by adding a rectangular cavity on the side of the CNS opposite the reactor core.

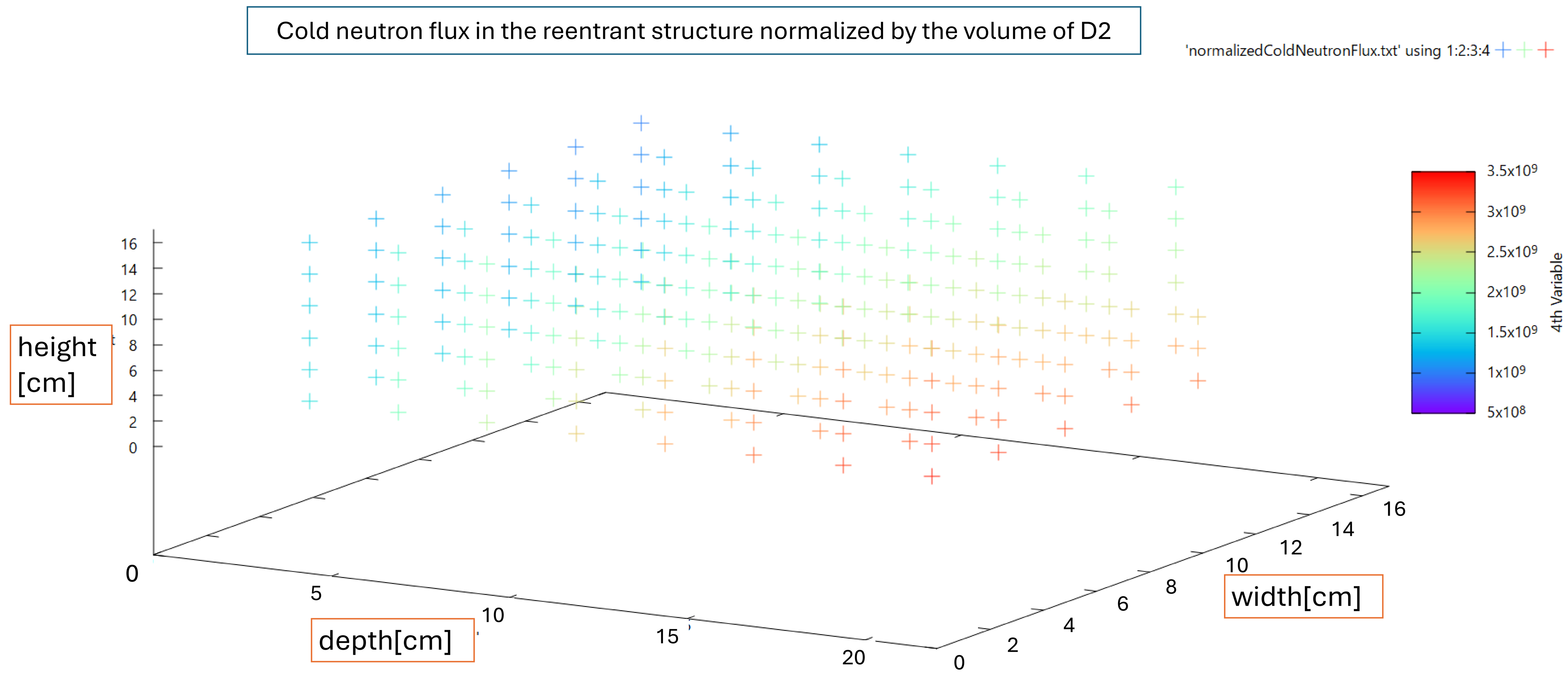
As shown in the figure, the depth, width, and height of the re-entrant structure were defined as variable parameters. Each dimension was varied in increments of 2.5 cm. The depth ranged from 2.5 cm to 20 cm, while the width and height ranged from 2.5 cm to 15 cm.
We placed a tally over the entire re-entrant structure to measure the cold neutron flux.



Results and Discussion

Increasing the width or height of the re-entrant structure resulted in a decrease in the cold neutron flux. In contrast, increasing the depth of the cavity led to a higher cold neutron flux, although the effect appeared to saturate around 20 cm. These results suggest that a narrow and elongated re-entrant structure that extends deep into the CNS is optimal.
This is because cold neutrons tend to accumulate near the center of the CNS, so a deeper cavity allows better extraction.
However, increasing the width and height reduces the volume of moderator material, lowering its moderating efficiency, which negatively affects cold neutron production.

Cold neutron flux in the reentrant structure normalized by the volume of D2



Summary and Next Plan

- The effect of the re-entrant structure's geometry on cold neutron flux was evaluated using PHITS 3.10, assuming a rectangular cavity in the CNS.
- Under the evaluation conditions used in this study, **greater depth** and **smaller width and height** of the cavity resulted in higher cold neutron flux.
- Future work will involve exploring more complex geometries beyond simple rectangular shapes and increasing the number of cavities to further optimize the structure.

[References]
[1]Japan Atomic Energy Agency New Research Reactor Promotion Office. "New Research Reactor To explore the scientific innovation". 2025. https://www.jaea.go.jp/04/nrr/en/index.html (reference:2025.06.05)
[2] T. Sato, Y. Iwamoto, S. Hashimoto, T. Ogawa, T. Furuta, S. Abe, T. Kai, Y. Matsuya, N. Matsuda, Y. Hirata, T. Sekikawa, L. Yao, P.E. Tsai, H.N. Ratliff, H. Iwase, Y. Sakaki, K. Sugihara, N. Shigyo, L. Sihver and K. Niita, Recent improvements of the Particle and Heavy Ion Transport code System - PHITS version 3.33, J. Nucl. Sci. Technol. 61, 127-135 (2024)
[3] M.Arai. Private communication