

# Foreword

## Special Issue on Fusion Neutronics

*Editor*

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Fusion neutronics serves as the essential framework for the design, safety, and operation of nuclear fusion systems. It is a field of remarkable breadth, bridging the gap between fundamental nuclear physics and complex engineering challenges related to large fusion facilities such as ITER, DEMO, and IFMIF-DONES. This special issue showcases the broad multidisciplinary scope of modern neutronics research, ranging from the intricate shielding of diagnostic systems to the fundamental investigation of nuclear analysis requirements and operational safety protocols for future fusion pilot plants and powerful charged-particle accelerators (e.g., the LIPAc deuteron accelerator) used for fusion materials irradiation.

A primary objective of this collection is to demonstrate the ongoing effort to increase the accuracy of fusion neutronics analyses. As reactor geometries and radiation fields become more complex, the margins for error in shielding, tritium breeding, and material activation shrink. The papers within this issue address these challenges through high-fidelity computational modeling—utilizing industry-standard transport codes like MCNP and PHITS and inventory codes like FISPACT alongside emerging open-source tools like OpenMC. By refining nuclear data and benchmarking integrated multiphysics solvers, these contributions provide a more reliable foundation for the global fusion program.

This special issue focuses on advancing precision in fusion neutronics, expanding analysis to include the emerging requirements of fusion pilot plants, and highlighting recent milestones in experimental validation. Its papers can be sorted into four sections.

*System integration, safety, and preliminary design drivers.* This section focuses on the requirements defined for fusion systems and includes the first three papers.

1. “Overview of Indian Domestic Agency Neutronics Activities” (Gajjar et al.) details the shielding optimization for ITER-India’s diagnostics. It demonstrates how beam dump geometry optimization ensures the survival of electronics by reducing flux at shielded cabinets.

2. “Compact Fusion Pilot Plant: Drivers for Nuclear Analysis Requirements” (Maya et al.) investigates the early-stage neutronics drivers for a 300-MW fusion pilot plant, focusing on modular maintenance and space constraints.

3. “Shutdown Dose Rate Evaluation Around the High-Power Beam Dump for 5-MeV and 9-MeV Deuteron Beam Operations in the Linear IFMIF Prototype Accelerator (LIPAc)” (Kumagai et al.) applies high-accuracy activation modeling to the LIPAc accelerator to establish safe maintenance windows. It integrates operational safety as a primary design driver for high-power deuteron beam facilities.

*Computational advancements and code synchronization.* The four papers in this section highlight the software tools and coupling methods used to increase the precision of modern neutronics simulations.

4. “Synchronization of the OpenMC and MCNP Models for ITER Neutronics” (Afanasenko et al.) establishes a synchronization workflow between MCNP and OpenMC, facilitating collaborative, high-fidelity modeling of complex ITER geometries.

5. “Applicability Analysis of FLUKA for SDDR with FNG-ITER Benchmark” (Tong et al.) validates FLUKA for “single-step” shutdown dose rate calculations,

offering a more streamlined alternative to traditional multistep methodologies.

6. “Application and Coupling of NEUTRO, a Deterministic Neutron Transport Solver for Fusion Applications in the Alya Multiphysics Environment” (Goldberg et al.) advances multiphysics integration by coupling the NEUTRO deterministic solver with fluid and thermal solvers to simulate real-time thermal responses in reactor walls.

7. “FNG HCPB Tritium Breeder Module Mock-Up Benchmarking of OpenMC and Uncertainty Quantification” (Novais and Peterson) benchmarks the OpenMC code against experimental data from the Frascati Neutron Generator facility to quantify uncertainties in tritium production rate predictions.

*Experimental validation and nuclear data accuracy.* The two papers in this section focus on refining the fundamental data that reinforce all neutronics calculations through rigorous benchmarking.

8. “Validity Examination of Benchmark Experiment for Large-Angle Scattering Cross Section with Two Shadow Bars Using 14-MeV Neutrons” (Fukui et al.) resolves discrepancies in 14-MeV neutron scattering data by examining shadow bar arrangements, increasing the accuracy of streaming models using the MCNP6.2 code.

9. “A Benchmark Experiment for  $^{180}\text{Hf}(n, n')^{180\text{m}}\text{Hf}$  Activation Reaction Cross Section with  $^{252}\text{Cf}$  Neutron Source” (Araki et al.) uses the  $^{252}\text{Cf}$  neutron source to reveal a 20% overestimation in current hafnium activation

data, a critical finding for shield design and waste management.

*Novel materials and breeding blanket research.* This section’s three papers explore the broader area of material science in the context of fusion neutronics.

10. “Neutronics Analysis of CILiF: An Alternative Molten-Salt Tritium Breeder” (Dunn et al.) investigates CILiF as a safer alternative to FLiBe, using OpenMC to demonstrate that  $^{37}\text{Cl}$  enrichment can balance tritium breeding needs with lower toxicity.

11. “Design and Performance of Metal Hydride Composite Neutron Shields for Compact, High-Power Fusion Reactors” (Fletcher et al.) proposes hafnium hydride composites that can reduce fast neutron flux to superconducting magnets by 93%.

12. “Neutronics and Activation Analysis of Aluminized RAFM Steel” (Rizk et al.) confirms that aluminum coatings for tritium barriers do not compromise the overall neutronic performance or activation profile of structural steel.

I hope that you enjoy this special issue on fusion neutronics and that these papers spark your imagination for future works in this and related areas of fusion science and engineering.

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