A User-Friendly OpenMC-Based Workflow for CAD-Driven Fusion Neutronics and Engineering Design

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High-reliability neutronics simulations are a critical component in the design and optimization of fusion systems. However, the complexity of modern Monte Carlo tools such as OpenMC often presents a significant barrier to their efficient use within fast, iterative engineering workflows. In this contribution, we present a user-friendly application developed at Marvel Fusion that simplify and automates OpenMC-based neutronics calculations, with the goal of enabling rapid and consistent engineering assessments by both neutronics specialists and non-expert users.

The application provides an integrated workflow that enables rapid neutronics assessment directly of CAD-based designs, with a particular emphasis on fusion-relevant neutronic quantities. It allows our engineering team to efficiently evaluate the impact of geometry and material modifications on neutron multiplication, tritium breeding ratio (TBR), spatial neutron flux distributions, and neutron interaction rates in structural materials. In addition, the tool quantifies volumetric nuclear heating and the resulting power deposition, thereby supporting coupled neutronics thermal analyses. The application enables consistent, reproducible neutronics studies within fast engineering design iterations, making advanced Monte Carlo neutronics accessible to non-expert users while preserving physical precision and reliability.

While the application has been developed to support laser-driven fusion concepts at Marvel Fusion, its methodology is broadly applicable to fusion neutronics problems that require tight coupling between neutronic performance, thermal constraints, and CAD-driven design changes. Overall, this work demonstrates how lowering the usability barrier of advanced Monte Carlo neutronics tools can significantly accelerate fusion engineering design cycles, enabling physics-driven decisions to be made earlier, faster, and more reliably across multidisciplinary teams.

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