

# Multi-physics tritium transport modelling of the ARC breeding blanket with FESTIM

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Complex multi-physics simulations are required to evaluate tritium transport in fusion breeding blanket concepts, since only such approaches can capture the coupled neutronics, thermo-fluids, and tritium transport phenomena and provide the quantitative results needed by system designers (eg. Tritium inventory, residence time, throughput...). An integrated digital workflow has been developed for simulating tritium transport in the ARC reactor breeding blanket. Neutronics analyses were performed using OpenMC, and thermo-fluid simulations were conducted with OpenFOAM. To enable coupled tritium transport studies, two new open-source tools, `openmc2dolfinx` and `openfoam2dolfinx`, were created to convert simulation results into `dolfinx` functions, a format directly usable by the tritium transport code FESTIM. This allows different physics domains to be brought together and enables the inclusion of effects such as turbulent diffusion in full three-dimensional blanket geometries.

Application of this workflow to a simplified representative ARC blanket segment provides new insights into tritium behaviour. The total tritium inventory was estimated at 0.39 g, with transient simulations indicating a characteristic time of 1 h to reach steady state. The analyses can help identify stagnation zones in the coolant flow that act as local accumulation sites for tritium. In addition, the tritium leaving the blanket outlet was quantified, with a flux of 1.4 mg/s and a concentration of  $3 \times 10^{-4}$  mol/m<sup>3</sup>. Such information is of direct relevance to system designers, providing boundary conditions and input data for connected fuel cycle components such as tritium extraction systems for which tritium concentration is paramount.

This work demonstrates how digital engineering approaches can accelerate the evaluation of blanket concepts by combining state-of-the-art simulation tools into an extensible multi-physics workflow, while also highlighting the value of using dedicated, domain-specific codes for their respective physics within a common framework. Work is currently underway at MIT to validate this workflow using data from smaller experimental platforms.

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