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Advanced Computational Approaches and Tools for High-Fidelity Nuclear Analyses of Fusion Facilities

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The nuclear design and optimisation of fusion facilities and their components rely on the data provided by neutronic calculations. Suitable computational approaches, tools, and data, qualified and validated for design applications are required to enable reliable design analyses and ensure a sufficient prediction accuracy of the results. Recent efforts aim at extending the capabilities of the simulation tools for the provision of high-fidelity neutronic results on meshes generated on the basis of engineering CAD geometry models. Such meshes can be adapted to the requirements of subsequent thermal-hydraulic (TH) and structural mechanics (SM) calculations and can be also used for the results visualisation.
At the Karlsruhe Institute of Technology (KIT), Institute for Neutron Physics and Reactor Technology (INR), the development efforts lately focused on various computational schemes coupling, on the one hand, the MC radiation transport simulation to the CAD geometry, and, on the other hand, to high resolution activation calculations, TH/ SM simulations and the visualisation of the results on the CAD geometry. The related development works have been mainly performed in the framework of the Power Plant Physics and Technology (PPPT) programme launched initially by the European Fusion Development Agreement (EFDA) and integrated now into the new Eurofusion projects.
This paper presents the recent progress achieved at KIT on (i) the related development of a multi-physics coupling approach for neutronics, TH and SM analyses, (ii) the extension and improvement of the conversion software tool McCad for the generation of MC geometry models from CAD geometry data, and (iii) the further enhancement of a coupled programme system for the MC based calculations of high-resolution shut-down dose rate distributions. The paper includes application examples on ITER and DEMO showing the suitability of the tools for real design analyses.

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