Mapping irradiation effects in fusion reactors with 3D Monte Carlo simulations

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High temperature superconducting (HTS) magnets are one of the key components for the development of compact fusion reactors, and represent a large fraction of the total cost of these prototypes and devices [1].

Due to the compact design, the magnets are close to the plasma and limited space is available for neutron shielding. For this reason, HTS radiation damage and heating need to be carefully examined and neutron shielding needs to be optimized to minimize such effects.

Monte Carlo (MC) codes allow estimating the relevant quantities: neutrons and secondary particles fluxes and spectra, damage in terms of dpa, deposited power, primary knock-on atom (PKA) spectra.

Here we present the use of the MC code PHITS with parallel computing schemes on the CINECA-MARCONI and ENI-HPC4 high performance computers to analyze these aspects. The study exploits 3D geometries of fusion reactors [2] and HTS cable designs [3] from CAD files via a tethragonal meshing scheme to obtained detailed maps of the quantities of interest, allowing for a careful evaluation of weak spots that require neutron shielding optimization.

Moreover, this approach allows for the coupling of the MC results with molecular dynamics simulations for the evaluation of radiation damage at the atomic scale [4] and with finite element method softwares for the analysis of thermal and mechanical effects induced by the irradiation [5].

References

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