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LOCUST Predictions of Fusion Alpha-Particle Transport Due to Static 3D Magnetic Perturbations in ITER

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This work presents simulations of alpha-particle transport due to static 3D magnetic field perturbations in ITER, specifically those arising from Toroidal Field (TF) Ripple, ferromagnetic materials, and Resonant Magnetic Perturbations (RMPs) arising from edge-localized mode (ELM)-control coils, which have been reported to significantly increase losses in existing devices [1].

We employ the Lorentz-Orbit Code for Use in Stellarators and Tokamaks (LOCUST) [2]. This GPU-based code tracks the orbits of fast ions subject to the Lorentz force and Monte Carlo collisions with bulk plasma. The aim is to predict alpha-particle transport and associated power loads, with a focus on providing Fast Ion Loss Detector (FILD) diagnostic simulations in support of its design.

The simulations are performed using a detailed representation of the ITER plasma-facing components (PFCs). LOCUST tracks the orbits of one million markers representing alpha particles, starting from their production by the DT reaction, until they thermalize or collide with the PFCs. The markers are resampled [3] at an intermediate stage of the simulation, resulting in a deposit of over one billion markers on the PFCs. This approach minimizes the GPU usage while produces smooth heat load maps of complex structures, such as the cooling pipes under the dome, and improve the statistical accuracy of FILD synthetic strike maps.

The results are consistent with previous simulations performed using the ASCOT code [4]. The plasma response to the RMP strongly mitigates the passing particle transport, while enhancing the trapped particle transport. The alpha losses do not affect plasma performance, and the power loads on the divertor region and outer wall remain well below the designed maximum values. While the RMP is dominant in terms of the overall alpha transport, the FILD captures localized losses strongly influenced by the TF-ripple. Therefore, there is no direct correlation between RMP-induced alpha losses and the FILD signal.

[1] K. G. McClements et al., The effects of resonant magnetic perturbations on fast ion confinement in the Mega Amp Spherical Tokamak, 2015, *Plasma Phys. Control. Fusion* **57** 075003

[2] S.H. Ward et al., Verification and validation of the high-performance Lorentz-orbit code for use in stellarators and tokamaks (LOCUST), 2021, *Nucl. Fusion* **61** 086029

[3] R.J. Akers, et at. High fidelity simulations of fast ion power flux driven by 3D field perturbations on ITER, 2016, *IAEA Fusion Energy Conference*, TH/4-1

[4] K. Särkimäki et al., Mechanics of ELM control coil induced fast particle transport in ITER, 2018 *Nucl. Fusion* **58** 076021