Kinetic simulations of W impurity transport by ELMs

D.C. van Vugt\textsuperscript{1,3}, G.T.A. Huijsmans\textsuperscript{1,2}, L.P.J. Kamp\textsuperscript{1}, N.J. Lopes Cardozo\textsuperscript{1}, A. Loarte\textsuperscript{3}

\textsuperscript{1} Eindhoven University of Technology, Eindhoven, The Netherlands
\textsuperscript{2} CEA Cadarache, IRFM, 13108 St. Paul Lez Durance Cedex, France
\textsuperscript{3} ITER Organization, 13067 St. Paul Lez Durance Cedex, France

Impurity accumulation in the core plasma leads to fuel dilution and increased radiative losses that can lead to the loss of the H-mode and to thermal collapse of the plasma and a disruption in tokamaks. The issue is particularly challenging for high-Z impurities such as W, which is used as plasma-facing material in present tokamaks. Concentrations in the range of a few $10^{-5}$ are expected to significantly decrease fusion performance in ITER and next step devices [1].

In present experiments, ELMs at sufficiently high frequency are required to prevent W accumulation in the core [2], by expelling impurities from the edge plasma region [3] and thus prevent their penetration in the plasma core; this effect is more pronounced for high-Z impurities given the large inwards pinch that they are subject to and the ensuing edge impurity density peaking. The effect of ELMs on high-Z impurity outflux in ITER remains uncertain given the expected impurity screening in the plasma pedestal [4].

In this work we present an extension of the MHD code JOREK [5], that allows the simulation of impurity transport during ELMs and thus can provide an evaluation of their effectiveness for impurity expulsion. It includes full-orbit tracking of impurities in time-varying electromagnetic fields and ionization, recombination and radiation processes for impurities with ADAS rates.

This extended model has been applied to a JET-like plasma, where we have quantified the displacement of W particles across flux surfaces during an ELM, depending on their position in phase space ($E, \mu, \psi$, toroidal and poloidal angles $\phi$ and $\theta$ and gyrophase). The particle displacements are found to form a continuous distribution mostly between -0.01 and 0.01 in $\psi$. Different groups of particles with large displacements can be identified, all having a large parallel velocity. This indicates that most radial transport is parallel along ergodic field lines.

Future steps will include modelling the ELM-resolved W source by including sputtering and prompt redeposition effects, and the implementation and verification of neoclassical transport due to impurity-background plasma collisions. This will allow us to perform simulations on longer timescales and simulate impurity accumulation.

References