Influence of suprathermal electrons on ionization, transport and radiation properties of fusion plasma with high-Z impurities

Tokamaks represent currently one of the most promising options to achieve controlled nuclear fusion as a safe and abundant energy source. Very recently, several world records have been established: by different tokamaks in terms of sustained fusion power, fusion energy released and long pulse operation.

Unfortunately, the issue of plasma contamination by high-Z impurities like tungsten (W), due to wall erosion of the tokamak, is becoming a major source of concern for the stable and efficient operation of these fusion devices. Indeed, W impurities radiate a lot of energy from the plasma by X-ray radiation, which is detrimental for the fusion performance. A potential solution to mitigate W impurity accumulation in the plasma core is to apply central electron heating. However, in the presence of dominant electron heating, the electron velocity distribution function stops to follow a Maxwellian distribution and a significant suprathermal tail arises.

Therefore, the main goal of this project is to investigate how a fast electron population can affect ionization, transport and radiation properties of fusion plasma with high-Z impurities.

The first objective is to develop theoretical and numerical tools allowing to calculate the ionization equilibrium of high-Z impurities in plasma with non-Maxwellian electron velocity distribution and with moderate particle transport, as experienced in tokamaks with strong electron heating.

The second objective is to estimate the new impurity cooling rates in the presence of these effects and quantify how much they differ from the reference ones (without a suprathermal fraction of electrons nor transport effects). The emphasis will be especially put on W impurities since it is the main element foreseen for modern tokamaks (ITER, WEST).

A direct consequence, that will be studied as the third objective of this project, is to determine in which cases the perturbation of impurity cooling rates is sufficient to change significantly plasma power balance and should therefore be included in integrated tokamak simulator codes used to develop plasma scenarios.

Finally, the last objective is to conduct or participate to plasma experiments on the WEST tokamak, Cadarache (France) and analyse radiation diagnostic data, to test the hypothesis, numerical predictions and validate diagnostic tools developed during the project.

This project will be part of the existing international collaboration with IRFM, where is operated the WEST tokamak. The involved Polish and IRFM research teams will bring their complementary expertise in terms of theory, numerical modelling, analysis of the simulation outputs and of experimental diagnostic data.