Modelling and interpretation of micrometric dust behaviour in tokamaks

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As tokamak devices approach more closely and reliably the technical conditions required for confinement of a deuterium-tritium burning plasma, it becomes clear that optimization of the plasma performance requires better understanding of important physics processes occurring in the scrape-off layer which is actually a "composite" plasma, consisting of multiple ion species and heterogeneous dust with variable charge and mass. A number of questions are addressed by numerical models, concerning the mobilization of dust from the plasma facing components, its migration and redeposition in the tokamak configuration and eventually its destiny of ablation and plasmoid formation. A brief overview of selected problems is presented here, with an assessment of the most interesting results and open questions, especially focused on the tungsten and beryllium dust particles in the tokamak JET-ILW (ITER-like wall).

The performance of magnetic confinement nuclear fusion systems, like tokamaks, depends significantly on the "purity" of the reacting mixture (Z_{eff} not » 1). Realistic confinement implies some interaction of the thermonuclear plasma with the tokamak's wall thorough the plasma facing components (PFCs), mainly leading to PFCs sputtering and eventually to the production of mobilizable solid particulate or dust [1].

The expected number density of these particles is low, but they can be important sources of plasma contamination through input of high Z elements, causing strong radiative losses (observed often as transient impurity events, TIEs) and also gross magnetohydrodynamic instabilities eventually evolving in disruptions. Alternatively, their impact and interaction with the PFCs can cause the damage of their surface, instantaneous and cumulative. Moreover, these meso-sized dust particles can retain the radioactive tritium (T) and, moving almost freely within the vessel, could significant affect the T inventory of the tokamak.

Validated numerical modeling tools such as dust trajectory calculators [2-4], can provide qualitative and quantitative description of the mobilization and fate of selected bunches of dust grains. Key issues are addressed here in a first investigation of tungsten (W) and beryllium (Be) dust mobilization, redeposition and plasma pollution in the tokamak JET-ILW (i.e. ITER-like wall).

The results presented are produced by the dust trajectory code DUSTTRACK [2,3] of IFP-CNR, based on real and realistic background plasma configurations of JET-ILW. Figure 1 shows a pragmatic example of the output of the code relative to the motion of several tungsten dust particles mobilized from the JET-ILW's full-W divertor. On one hand, it is clear that several dust particles can reach the hot and confined plasma (the region inside the last closed magnetic surface, LCMS) significantly polluting it. On the other hand, one can see that the dust particles could be transported and finally deposited in places far away from their mobilization spot. In case of dust particles with a high fraction of T, this can be particularly relevant since their behaviour possibly affects the tokamak's inventory of tritium.

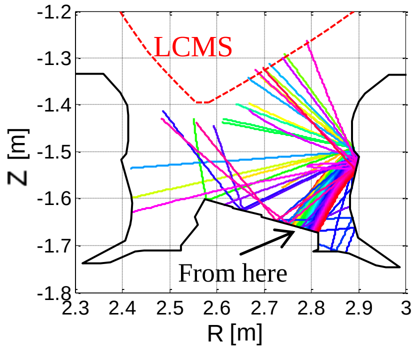

Fig.1: Poloidal trajectories of 101 W dust particles launched from the divertor of JET-ILW.

References

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