First principle modeling of the impact of Langmuir probes on turbulent transport in edge plasma of tokamaks

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Research in magnetic confinement fusion plasmas explores the possibility of producing power by using fusion in deuterium-tritium plasmas heated to temperatures of up to 10^7-10^8K. Particles are confined in the edge plasma by magnetic field in machines of toroidal shape known as tokamaks. Fusion requires optimizing temperature and density in order to maximize the fusion yield, while also minimizing the heat load on plasma wall. This optimization requires understanding and control of the main heat and particles transport mechanisms in the machine, namely turbulence. Exhaustive experimental studies have been carried out to measure fluctuations and time-averaged quantities (density, potential, electronic temperature…) in order to characterize the phenomenology associated with this turbulent transport. One of the most widely used tools to realize such measures in the Scrape-Off-Layer of tokamaks are Langmuir probes. However, these probes are active diagnostics and, when polarized, may locally influence the plasma and perturb local turbulence properties.

A first study [1], modelling this probe-plasma interaction by biasing the target plates in the 2D interchange code TOKAM2D, showed that the presence of a probe in ion saturation mode can significantly perturb the plasma beyond its radius, affect the current circulation even non-locally and alter the measured plasma properties. In this work, we are going one step further by studying the multi-probe cases with combinations of biased and floating probes (mimicking rake probes) to observe their mutual interactions. Due to their local impact on parallel current circulation, floating probes alone are shown to perturb the density and potential fields in their vicinity. Combined with the biased probes, these perturbations may lead to significant errors (up to 100% in worst case scenarios) on measured particles fluxes. Nevertheless, our model is based on some assumptions such as isothermal hypothesis and 2D turbulence model which relies on a parallel symmetry assumption. Consequently the next step is to look at the impact of temperatures fluctuations and to extend the test case to more-realistic 3D-slab geometries with the help of the 3D fluid turbulence code TOKAM3X [2].

[1] C. Colin et al., Contrib. Plasma Phys. 54, No. 4-6 (2014).

[2] P. Tamain et al., Contrib. Plasma Phys. 54, No. 4-6 (2014).