Studies of impurity transport in tokamak edge and SOL using tracer particle simulations

Shrish Raj[1,2], Nirmal Bisai[1,2], Vijay Shankar[1,2], Souvik Mondal[1,2], and Abhijit Sen[1,2]
[1] Institute for Plasma Research, Bhat, Gandhinagar, Gujarat, 382428, [2] Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai, 400094, India
e-mail (speaker): shrish.raj@ipr.res.in

In tokamak plasmas, the behavior of impurity ions is crucial for understanding and controlling plasma performance. Impurities can originate from various sources, such as from the walls of tokamak or impurity injection for diagnostic and heat load controlling purposes [1]. These impurities, particularly in the edge and scrape-off-layer (SOL) regions are ionized by electron impact ionization and move by the influence of interchange plasma turbulence. The movement of impurity ions is associated with E×B, diamagnetic, and ion polarization drifts of the plasma turbulence. To determine the movement, we have performed a two-dimensional (2D) tracer particle simulation in slab geometry using Python code which involves solving the trajectories of individual impurity ions by the various drifts. However, the modification of the plasma turbulence by impurity ions has been ignored and is one of the limitations of this method. We have also neglected the influence of ion diamagnetic drift of impurity ions assuming the impurity ions are not in thermal equilibrium with the plasma and the impurity density so low that the impurity pressure is negligibly small.

In the present study, the background low frequency interchange plasma turbulence has been generated by solving the 2D drift reduced Braginskii equations using input parameters related to Aditya-U and ITER tokamak using BOUT++ code [2,3]. It is found that the edge turbulence provides the impurity screening as the zonal flows move the impurities mainly toward the poloidal direction in the SOL which reduces the impurity concentration in core as the zonal flows reduce the poloidal electric field generation. It is found that the background plasma moves radially with velocities between 200-600 m/s in primarily due to the E×B drift as shown in Fig.1. As a consequence of the background plasma turbulence, the impurity ions (N^+) have been found to move in the edge and SOL regions within the few microseconds as shown in Fig.2. A small contribution to the movement of impurity ions is observed from the polarization drift as ion polarization drift is mainly low frequency. Similar studies related to heavier impurities like Ar (Argon) and W (Tungsten) will be reported. It has been also found that under certain conditions, impurities can become trapped in turbulent eddies [4], affecting their overall transport properties. An interesting observation associated with the motion of the impurity ions in the presence of the finite plasma ion temperature gradient will also be presented.

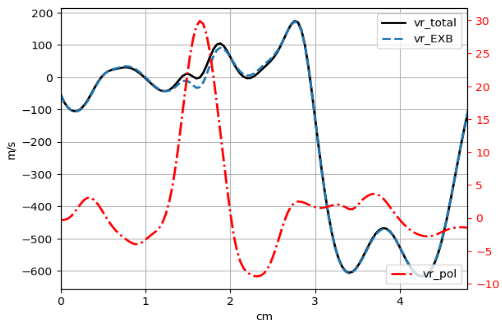

Fig.1: Radial variation of the background plasma drifts

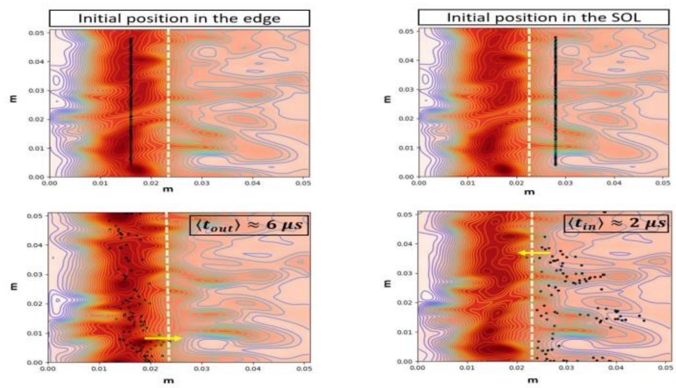

Fig.2: Impurity ion transport in the influence of background plasma turbulence. The vertically dotted line indicates the last closed flux surface.

References

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