Particle-in-cell simulations of Langmuir Probes at COMPASS Tokamak

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Langmuir probes are a widespread tool for measuring the electron temperature $T_e$, plasma density $n_e$, floating potential $V_{fl}$ and other plasma parameters. Their values are typically obtained from a fit to a $I–V$ characteristic of the probe. To find the correct value of these quantities, one should account for various instrumental effects affecting the measured data. The principal one is the sheath expansion due to finite Larmor effects, which is addressed by introduction of the fourth parameter to the fitted function. Additionally, the expression for calculating the value of plasma density, depends on geometry of the probe, particularly on the area of the probe surface. In the un-magnetized plasmas with high Debye shielding, the geometrical calculation of exposed area can be used. When the magnetic field is introduced, this approach is no longer applicable, and the correct collecting area needs to be determined by other means. This influence of the magnetic field on the area is still not precisely understood, although the usage of these probes in tokamaks is widespread.

In this work, the effect of magnetic field on probe area is studied by the means of fully 3D particle-in-cell model SPICE3 which allows us to closely observe particles subjected to Larmor gyration. Parameter scans based on plasmas properties at the COMPASS tokamak for a particular probe pin mounted on horizontal reciprocating manipulator are performed. The results of simulations show that the influence of magnetic field is inversely proportional to Larmor radius, which is mainly caused by presence of magnetic pre-sheath in the vicinity of the probe head. This effect is present within entire simulated range of densities. However, the differences in absolute values are within 3 $\sigma$ and are comparable to the probe cross section. The simulated data are compared to experiment results from real probe, which is benchmarked against the density measurement of beam emission spectroscopy and the comparison suggests that influence of the probe head in real device is not as eminent as in the simulated case due to obvious difficulties with proper alignment of the probe and magnetic field.