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Finite gyro-radius and mean-free-path layers on tokamak walls

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Controlling the energy flux to the wall of tokamaks and stellarators is crucial for magnetic confinement fusion energy. Since the width over which the exhausted power is spread depends on the turbulent cross-field transport, among other physics, there has been an increasing interest in developing fluid, gyro-fluid and gyrokinetic codes that can describe that turbulence.

In this talk, we will describe layers of the order of the gyro-radius and of the collisional mean-free-path that form over the wall where the gyrokinetic and fluid descriptions are not valid. In these layers, which appear in addition to the well-known Debye sheath, electrons are repelled away from the wall to ensure quasineutrality. The layer with a width of the order of the ion gyro-radius, known as the magnetic presheath or Chodura sheath [1], appears because ions are lost to the wall when their guiding centers are a gyro-radius away from the wall. For sufficiently large collisionality, the layer with a width of the order of the collisional mean-free-path appears because ions, upon colliding with the wall, return as neutrals rather than ions. Thus, ions with velocities away from the wall must be the result of collisions that reverse the direction of the ion velocities. These layers provide the boundary conditions for the gyrokinetic and fluid equations: the potential difference with the wall, the distribution function of electrons moving away from the wall, and an integral condition on the ion distribution function (the Chodura condition).

Using the smallness of the angle between the magnetic field and the wall, we have developed models to calculate the magnetic presheath with low computational cost [2, 3, 4]. We will discuss our most recent results with these models, showing that there is a critical angle between the wall and the magnetic field below which the Debye sheath physics change significantly. We will also describe a new model for the collisional layer, presenting new analytical results regarding the Chodura condition mentioned above, and new numerical results that connect fluid equations in the bulk of the plasma with the distribution of ions hitting the wall, needed to calculate sputtering among other relevant quantities.

References

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