DPP13-2013-000065

Abstract for an Invited Paper
for the DPP13 Meeting of
the American Physical Society

Edge ambipolar potential in toroidal fusion plasmas

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A series of issues with toroidally confined fusion plasmas are related to the generation of 3D flow patterns by means of edge magnetic islands, embedded in a chaotic field and interacting with the wall. These issues include the Greenwald limit in Tokamaks and reversed-field pinches (RFP), the collisionality window for ELM mitigation with the resonant magnetic perturbations (RMPs) in Tokamaks, and edge islands interacting with the bootstrap current in stellarators. Measurements of the 2D map of the edge electric field $E^r(r = a, \theta, \phi)$ in the RFX RFP show that E^r has the same helicity of the magnetic islands generated by a m/n perturbation: in fact, defining the helical angle $u = m\theta - n\phi + \omega t$, maps show a sinusoidal dependence as a function of u, $E^r = \tilde{E}^r \sin u$. The associated $\mathbf{E} \times \mathbf{B}$ flow displays a huge convective cell with $\mathbf{v(a)} \neq \mathbf{0}$ which, in RFX and near the Greenwald limit, determines a stagnation point for density and a reversal of the sign of E^r. Similar reversal of E^r at high collisionality is found also in Alcator C-mod. From a theoretical point of view, the question is how a perturbed toroidal flux of symmetry m/n gives rise to an ambipolar potential $\Phi = \tilde{\Phi} \sin u$. On the basis of a model developed with the guiding center code ORBIT and applied to RFX and TEXTOR, we will show that the presence of a m/n perturbation *in any kind of device* breaks the toroidal simmetry with a drift proportional to the gyroradius ρ, thus larger for ions ($\rho_i \gg \rho_e$). Immediately an ambipolar potential arises to balance the drifts, with the same symmetry as the original perturbation.