Interaction between a self-generated reversed radial electric field and turbulence in 3D global flux-driven fluid edge plasma simulations

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The formation of a strongly reversed radial electric field in the pedestal region of a tokamak plasma is of particular interest for the modelling of improved confinement regimes, as the related sheared flow appears to strongly impact turbulence, by stabilizing it [1], leading to the formation of an edge transport barrier and to the transition to high-confinement “H-mode” [2]. Numerous studies have highlighted the essential role of an edge-localized poloidal E × B flow structure on confinement improvement; however the mechanism underlying its interplay with turbulent transport is still debated.

Here, the dynamics of a self-generated reversed radial electric field (Er) and its interaction with edge turbulence are investigated via global flux-driven simulations in three-dimensional geometry with the electrostatic fluid turbulence code TOKAM3X [3,4]. Systematic spontaneous generation of a reversed radial electric field in the proximity of the separatrix of a tokamak plasma is found in TOKAM3X anisothermal turbulence simulations in a limited circular plasma, encompassing both the closed field lines edge region and the Scrape-Off-Layer (SOL).

Interestingly, the Er shear maximum at the outer midplane is systematically arising at a few Larmor radii outside the separatrix, in the near SOL region, similarly to [5]. Besides, by performing a scan in the injected heating power, it is found that the reversed Er spike strongly increases with increasing injected power, consistently with experimental observations. Coherently, a concomitant steepening of the global plasma density and temperature profiles is observed in the same radial region outside the separatrix, with the creation of a strong gradient in the near SOL reminiscent of the narrow \( \lambda q \) feature.

We will discuss the interplay of the shear flow with edge and SOL turbulence and how it affects turbulence reorganization. First analyses show an effect of the increased Er shear in an evident shearing of the turbulence structures. Further, we will discuss how the charge balance determines the shear region and characterize the herein generation of parallel currents between the plasma and targets.


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