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TH/P7-13: Flux-driven Full-f Gyrokinetic Studies of the Influence of Edge Dynamics in Diverted Geometry on Tokamak Core Confinement

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A first principles-based understanding of the relationship between the ion temperature (Ti) at the pedestal top and that in the central core is critically needed to enable reliable predictions of fusion power efficiency in ITER. Utilizing petascale high-performance computers, the multi-scale (combined neoclassical, kinetic turbulence, and neutral physics scales), full-function ("full-f") gyrokinetic code XGC1 has produced new results showing that the ion temperature gradient driven (ITG) turbulence inter-connects the core and edge Ti through self-organized-criticality (SOC) and, thus, can account for the observed profile stiffness. The simulation domain is the entire tokamak volume, from the magnetic axis, through the separatrix, scrape-off layer and divertor, and out to the grounded material wall. Results from the XGC1 simulations are consistent with the experimentally observed rapid (much faster than diffusive) connection between Ti and the turbulence dynamics [1]. The underlying physics is turbulence spreading [2] through nonlinear avalanche dynamics. Smaller scale avalanches are self-regulated within a zonal flow staircase [3], while larger scale avalanches across the staircase are self-regulated when the zonal flow walls open up from time to time. This kind of non-diffusive, non-local behavior has also been observed in hot and cold pulse experiments [4] as well as in other tokamak experiments. XGC1 simulations of a separate cold pulse has cross-validated these experimental physics observations. Even though the central core is forced to stay at a subcritical value of ∇Ti, our simulation results show that the outer turbulence spreads into the central core in a specific way that produces efficient heat flux. Supporting experimental evidence can be found, e.g., in [5]). A strong ExB shearing layer is formed in the edge density pedestal region – with another one formed at a smaller minor radius, possibly giving rise to an internal transport barrier. The present discussion will focus on ITG and trapped electron mode turbulence, including their effects on pedestal structure and inward particle pinch physics in the presence of neutral ionization and charge exchange.

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