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Impact of X-point geometry and neutrals recycling on edge plasma turbulence

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In tokamaks, heat and particle exhaust as well as confinement depend on the interplay of multi-physics phenomena occurring in the boundary of the plasma. A comprehensive modelling of the physics at play should involve a consistent description of plasma transport - including turbulence -, plasma-wall interaction, atomic and molecular physics, all treated in realistic magnetic and wall geometries. Due to the complexity of such modelling, the state of the art has for long been compartmentalized between mean-field codes, lacking a self-consistent description of transverse transport, and turbulence codes, ignoring neutrals physics and most often in simplified geometries. However, experimental results point out that the decoupling between turbulence physics and other aspects of edge plasma physics cannot properly account for observations. One can take as an illustration the difference between scrape-off layer (SOL) widths in limiter and divertor geometry [1,2] or the now well documented shoulder formation at high densities [3].

As part as an effort to bridge the gap between these two facets of edge plasma physics, we report recent results from edge plasma turbulence modelling with the TOKAM3X code. In a first part, we focus on the impact of X-point geometry on edge turbulence and transport. Our simulations exhibit a strong impact of the magnetic geometry. On the one hand, turbulent transport appears extremely sensitive to the magnetic flux expansion, leading to an absolute level of transport larger in areas of large flux expansion, typically at the top of the machine. The X-point itself is found to quench turbulence in its direct vicinity, leading to a quiescent zone along the outer separatrix below the X-point and a deconnection of turbulent filaments between the mid-plane and the divertor, thus impacting near SOL profiles and heat flux spreading in the divertor.

In a second part, we present the results of first principle simulations including self-consistently turbulence and neutrals physics. For that purpose, TOKAM3X was coupled to the EIRENE kinetic neutrals code in order to account self-consistently for neutral particles recycling from the target plates and their interaction with the plasma. Comparison is made between simulations driven by a gas puff and including neutrals recycling and simulations classically driven by an arbitrary core particle influx. Results demonstrate that the change of location of the particle source from the core to the edge fundamentally changes the natures of heat transport in the closed field lines region. Non-linear interactions are also found between the neutrals and the plasma, leading to an amplification of poloidal asymmetries in the SOL, in particular an increase of intermittency in the immediate vicinity of the targets.

[1] J. Gunn et al., J. Nucl. Mater. 438, S184-S188 (2013).
[2] A. Scarabosio et al., J. Nucl. Mater. 438, S426–S430 (2013).
[3] D. Carralero et al., Nuclear Materials and Energy, 1189-1193 (2017).

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