Impact of Drifts on Divertor Power Exhaust in DIII-D

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Radiative divertor experiments and 2D fluid simulations show strong impact of cross-field drifts on the low field side (LFS) divertor target heat flux and volumetric radiation profiles through the transition to detachment in DIII-D high confinement mode (H-mode) plasmas. This code model validation by direct comparison to data increases physics understanding and confidence in predictions of detachment in ITER and future reactor scenarios.

Operating with the $\mathbf{B}\times\nabla$B-drift towards the X-point (fwd. B_T) with deuterium and nitrogen injection, the LFS divertor radiation front is observed to rapidly shift from the target to near to the X-point at the onset of detachment. In contrast, operating with the $\mathbf{B}\times\nabla$B-drift away from the X-point (rev. B_T), the radiation front is observed to remain closer to the target plate and to be radially shifted towards the far SOL. Consistently, flat target heat flux profiles, q_{LFS}, with the peak reduced by ~5x relative to the attached conditions are measured in fwd. B_T. In rev. B_T the q_{LFS} profile remains peaked and the peak is reduced only by ~3x.

UEDGE simulations optimized to reproduce experimental measurements from multiple diagnostics, indicate that these observations can be largely explained by the poloidal and radial $\mathbf{E}\times\mathbf{B}$-drifts in the divertor. In fwd. B_T, the poloidal $\mathbf{E}\times\mathbf{B}$-drift in the private flux region (PFR) drives the main ions from the LFS divertor to the high field side (HFS) divertor, thereby reducing n_e and increasing T_e in the LFS divertor. At the detachment onset, the reduction of the radial T_e and potential gradients diminish this $\mathbf{E}\times\mathbf{B}$-drift sink in the LFS divertor, such that the LFS divertor can evolve into a high n_e, low T_e, strongly detached state with the same upstream separatrix n_e. In rev. B_T, on the other hand, the poloidal $\mathbf{E}\times\mathbf{B}$-drift in the PFR drives the main ions from the HFS divertor to the LFS divertor, thereby increasing the LFS divertor n_e and facilitating radiative divertor conditions. However, the radial $\mathbf{E}\times\mathbf{B}$-drift in the LFS common SOL in rev. B_T competes with this mechanism, driving ions from the strike line region towards the far SOL. As a result, n_e at the strike-line becomes depleted, limiting the degree of detachment next to the separatrix, while leading to a formation of a high n_e, radiation front in the far SOL. A similar comprehensive physics picture is also emerging from SOLPS-ITER simulations including drift effects. These observations are consistent with 2D divertor Thomson scattering volumetric n_e and T_e data, 2D radiation distributions from bolometer and visible emission reconstructions, and target Langmuir probe measurements. New divertor EUV emission data, capable of directly identifying the contributions of the primary species contributing to the total radiated power, will also be presented. Collectively, these sets of multiple code simulations validated by data from multiple diagnostics significantly increases physics understanding of detachment and confidence in predictions of heat flux and radiation profiles for future devices.

Work supported by the US DOE under DE-FC02-04ER54698 and DE-AC52-07NA27344, and LLNL LDRD project 17-ERD-020.