The physics of neutrals and impurities in the new Small Angle Slot (SAS) divertor in the DIII-D tokamak

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Detachment at lower density than for an open divertor has been achieved in the new Small Angle Slot divertor (SAS) installed at DIII-D and designed to enhance power losses by controlling recycling neutrals. The full-slot detachment is manifested by the simultaneous observation of plasma cooling on the multiple diagnostics sampling the SAS slot. The behavior of neutrals and impurities are further explored by SOLPS modelling which reveals how trapping of recycled neutrals and impurities in the slot can increase divertor heat flux dissipation and reduce target erosion. SOLPS simulations indicate a strong correlation between Te and the molecular density at the divertor targets. The Monte Carlo trajectories of neutrals computed with the EIRENE code show that, compared to a matched open divertor case, the synergy of closure and target shaping leads to changes in the neutral ballistic trajectories that enhance volumetric losses facilitating detachment. Both experiments and simulations exhibit a divertor cooling dependence on strike point location supporting the potential for concave targets to focus neutrals. It is notable that discharges with ∇B drift away from SAS achieve dissipative divertor conditions with Te < 10 eV, as measured by LPs, at the lowest densities achievable in DIII-D H-modes. This is significant because a) the AT scenarios in DIII-D are operated with the ∇B drift away from the main divertor, and b) Next step steady state devices are designed with ne/nGW~0.6 for which no divertor solution is presently available. In this context, a SAS divertor concept with ∇B drift away from the divertor may provide a potential solution for future steady-state fusion devices. Additional important features of the SAS divertor include 1) higher pedestal performance and core confinement than a matched open divertor, and 2) a broad H-mode operational window due to access to dissipative divertor regimes at a much lower density with X-point MARFE formation at a significantly higher density, thus widening the window for detachment control and facilitating core-edge integration. Finally, since impurity radiation promotes detachment, the coupling of closure and impurity seeding is also evaluated. First impurity seeding experiments in SAS indicate that nitrogen injection correlates well with the detachment onset measured by all the boundary diagnostics: these discharges feature exceptionally cold temperature as measured by DTS (Te~0.3 eV) and Jsat reduction of 85% as N2 is puffed into the plasma. CER measurements indicate low nitrogen core leakage, suggesting possible impurity trapping in the SAS. A small but monotonic increase in the pedestal fluctuation magnitude is also found. Discharges with neon puffing show that neon stays in SAS throughout the discharge without leading to a radiation collapse. An increase in the pedestal density gradient is also found. These encouraging results suggest that the coupling between closure and impurity seeding may be promising for creating unique favorable conditions for detachment and target power removal. This material is based upon work supported by the Department of Energy under Award Number DE-FC02-04ER54698.