Integration of divertor detachment with optimized pedestal performance in the first impurity seeding studies in the SAS slot at DIII-D

L. Casali[1,2], T. H. Osborne[1], D. Eldon[1], B. A. Grierson[3], A. G. McLean[4], A. W. Leonard[1], J. Ren[2], M. W. Shafer[5], H. Wang[1], J. G. Watkins[6]
[1]General Atomics, [2]University of Tennessee-Knoxville, [3]Princeton Plasma Physics Laboratory, [4]Lawrence Livermore National Laboratory, [5]Oak Ridge National Laboratory, [6]Sandia National Laboratory
e-mail (speaker): lcasali@utk.edu, casalil@fusion.gat.com

Impurity seeding studies were performed for the first time in the slot divertor at DIII-D, revealing a strong relationship between both detachment onset and pedestal performance with target shaping and impurity species. Future reactors will need to operate with impurity seeding and detached divertor conditions to reduce erosion and power loads on divertor components. In this work we show that the combination of divertor closure [1] and impurity seeding can enable improved core-edge compatibility by controlling the neutral and impurity distribution through variations in strike point location in a closed slot divertor. This study has been enabled by unprecedented diagnostic coverage in the closed divertor, which enabled multiple independent observations of plasma cooling evolution. The experimental data show strong dependence of detachment and impurity leakage on strike point location [2]. For a database which includes power and density scans, the detachment onset consistently requires half the nitrogen amount when the outer strike point (OSP) is on the slanted inner surface, compared to the outer corner of the slot. Relative nitrogen contamination levels are reduced by 15-20% in the core under these conditions, as measured by CER and independently confirmed by core SPRED measurements of N-IV, when the OSP is on the slanted inner surface. SOLPS-ITER simulations with D+C+N, drifts and n-n collisions activated are performed in DIII-D for the first time to interpret this behavior. The results highlight an important dependence of the recycling source on target shaping. The inclusion of drifts in the simulations shows the importance of convection in moving particles towards the inner target (fig.1). Matched discharges with either nitrogen or neon injection show that Ne leads to increased pedestal pressure gradient and improved pedestal stability. Little N penetrates in the core, but a significant amount of Ne is found in the pedestal consistent with the higher ionization potential of Ne compared to N. Ne dissipates more upstream and thus removes the capability of the divertor to dissipate as confirmed by the 2-point model [3,4]. This work demonstrates the achievement of mitigated divertor heat flux with impurity seeding while maintaining good core and pedestal performance. This result is achieved by choosing appropriate radiative species for pedestal conditions, as well as by optimizing divertor geometry and tailoring drifts for particle entrainment, thus leading to enhanced divertor dissipation and improved core-edge compatibility which are essential for ITER and for future fusion reactors.

Work supported by US DOES under DE-FC02-04ER5698 (DIII-D), DE-AC52-07NA27344 (LLNL), DE-AC02-09CH11466 (PPPL), DE-AC05-00OR22725 (ORNL), DE-NA0003525 (SNL) and LDRD project 17-ER.

References

1 L. Casali et a. Nucl. Fusion 60, 7 076011 (2020)
2 L. Casali et al. Phys. of Plasmas 27, 062506 (2020)
3 L. Casali et al. "Impurity retention and pedestal performance in DIII-D closed divertor" Proceeding of the IAEA FEC 2021
4 L. Casali et al. "Impurity leakage and radiative cooling in the first nitrogen and neon study in the slot divertor at DIII-D" Submitted to Nuclear Fusion (2021)

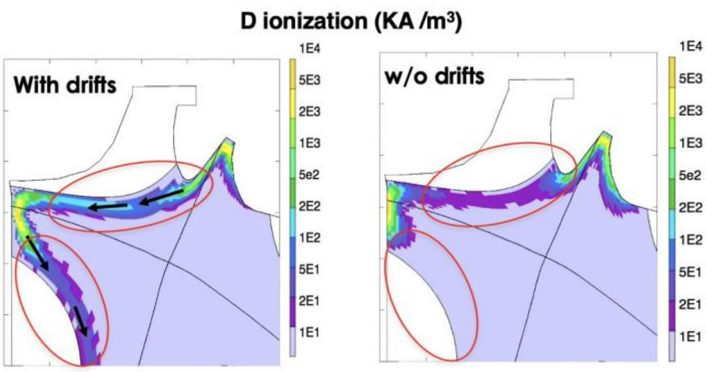

Fig.1: 2D ionization profile with drifts turned on in the simulations (left) and without drifts in the simulations (right).