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Experimental studies of the nitrogen concentration required for divertor detachment in ASDEX Upgrade

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Substantial seeding of impurities into the divertor volume has been used for a long time in tokamaks to reduce the power and particle fluxes impacting on the divertor targets and is one of the main techniques to be utilised on ITER to allow safe, steady state divertor operation. Since the amount of power radiated by the impurity species varies directly with the electron and impurity ion density, the impurity concentration in the scrape-off layer (SOL) is therefore a necessary input for predictive scaling of divertor detachment in future devices.

There has been a recent effort to develop scaling laws [1-3] to predict the impurity concentration required for detachment and to assess how these concentrations vary with different plasma parameters, such as the power crossing the separatrix, Psep, the separatrix density, ne,sep, and the poloidal magnetic field. However, due to the difficulty of the measurement itself, currently there are no experimental studies to validate these predictions and guide expectations for ITER and DEMO. To try and address this, the work presented here builds on previous preliminary measurements of the nitrogen concentration in the divertor volume, cN, determined from chord-averaged N II line emission [4,5] and examines the specific parameter dependencies and trends with respect to the detachment state.

From a database of ASDEX Upgrade N-seeded H-mode discharges, spanning Psep=4 –11 MW and ne,sep=1.5 – 3x10^19 m-3, with total injected powers ranging from 6 –14 MW, line averaged core densities from 7 –8x10^19 m-3, and plasma currents from 0.8 –1 MA, the cN measurements at the onset of detachment will be presented and shown as a function of Psep, ne,sep, and scaling law calculations. The measurements suggest that the concentrations scale approximately linearly with Psep and inversely with the square of ne,sep; however the absolute values are approximately four times lower than scaling law predictions. A detailed comparison of the plasma scenarios chosen in this database will be presented, with a focus on the strike-point position along the outer divertor target plate and how this effects the length of the N II emission volume along the line-of-sight. The time window relative to the detachment state through which the cN is averaged will be assessed, providing data before and during divertor detachment. Finally, the relevance of the measurement in the divertor compared to the average SOL quantities used in scaling predictions will be discussed.

[1] A. Kallenbach et al. 2016 Plasma Phys. Control. Fusion 58 045013
[2] R. Goldston et al. 2017 Plasma Phys. Control. Fusion 59 055015
[3] M. Reinke 2017 Nucl. Fusion 57 034004
[4] S. Henderson et al. 2018 Nucl. Fusion 58 016047
[5] S. Henderson et al. 2019 NME 18 147-152

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