Parameter dependences of the experimental nitrogen concentration required for detachment in ASDEX Upgrade and JET

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Substantial seeding of impurities into the divertor 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. There have been attempts to predict how the impurity concentration required for detachment should scale with different plasma parameters, such as the power crossing the separatrix, P_{sep}, and the upstream separatrix density, $n_{e,sep}$ [1-3]. In [2] there is a concerning absence of any machine size scaling, while including the LH threshold scaling shows a dependence on $B_T^{0.88}R^{1.33}$[3]. Since there are no experimental results to test these scaling laws, this work uses spectroscopy to measure the divertor nitrogen concentration, c_N, to examine the parameter dependencies both within and across the ASDEX Upgrade (AUG) and JET tokamaks.

From a database of AUG N-seeded H-mode discharges, spanning P_{sep}=3.5–12 MW and $n_{e,sep}$=1.8–4x10^{19} m^{-3}, with line averaged core densities from 7–10x10^{19} m^{-3}, and plasma currents from I_p=0.8–1.2 MA, the c_N measurements at the onset of detachment will be presented and shown to scale as $P_{sep}I_p n_{e,sep}^{-2.63}$; a result in good agreement with [2] but with a moderately stronger dependence on $n_{e,sep}$. A similar database of JET pulses will be used to further investigate the parameter dependencies found on AUG and to investigate the impact of machine size with regards to scaling law comparisons.

This work will also examine the robustness of the measurement and provide comparisons to a simple approximation of c_N derived from the ratio of the impurity and fuel gas valve fluxes. In steady state scenarios with fully saturated vessel surfaces, the two measurements agree; however, when this condition is not satisfied the two measurements can differ by an order of magnitude. While the gas valve ratios provide a good proxy for the impurity concentration in the divertor neutral domain, spectroscopy provides a direct, line-integrated measurement in the outer divertor plasma. Moreover, modelling and inverted camera images place the N II emission in a thin, localised layer in the private flux region (PFR). This is also consistent with N II line ratios which show electron temperatures mostly between 3-4 eV, close to the zero-transport prediction of maximum fractional ion abundance. This work will discuss how this PFR c_N measurement relates to both an outer divertor and average SOL quantity, with the latter relating directly to the scaling law predictions.

[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

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