Spectroscopic investigations of detachment on the TCV tokamak

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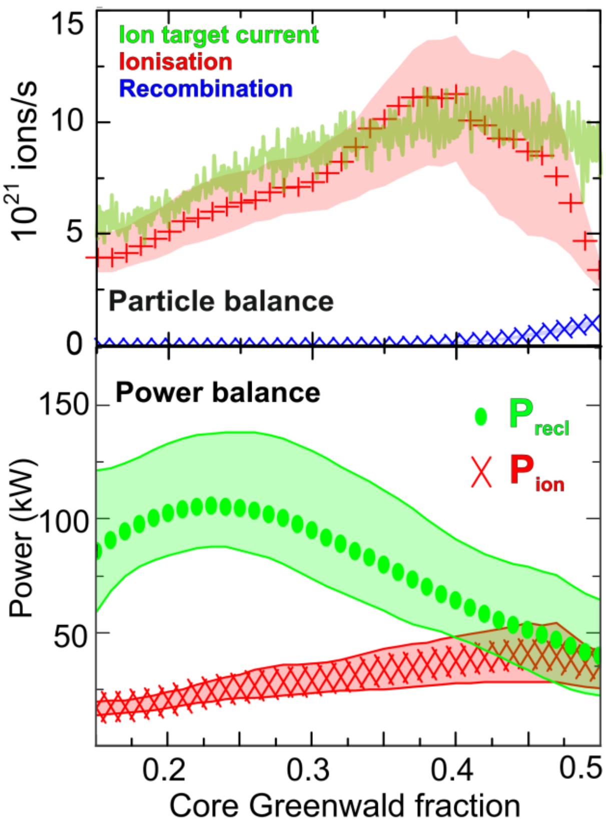
Divertor detachment, facilitated through a range of atomic and molecular processes, is essential for a tokamak fusion reactor. There is no consensus, as yet, regarding the precise role and sequence of the relative importance of physical processes for detachment. It remains unclear whether the target ion flux (I_t) reduction, seen during detachment, results from reductions in ion sources (I_i); increases in ion sinks (I_r) [2], or both. We have addressed this by developing new spectroscopic analysis techniques to facilitate the first quantitative power/particle balance measurements throughout the detachment process [1]. SOLPS simulation results [2] agree quantitatively with these TCV detachment measurements [3].

Based on the analysis (see figure) we find that volumetric electron-ion recombination to be negligible during the initial detachment phase at TCV [4,3] and not a detachment requirement. Instead, a reduction in divertor ionisation causes the initial ion current loss to the target as the power entering the ionisation region (P_{recl}) starts to limit the power expenditure of ionisation ($P_{ion} = E_{ion} I_i$) [3]. This 'power limitation' starts when $P_{recl} \sim 2\, P_{ion}$ and target temperatures of $T_t \sim E_{ion}/\gamma$ ~ 4-6 eV are reached – in quantitative agreement with detachment threshold predictions from improvements in analytic models from this work [3]. Reaching power limitation conditions enables volumetric momentum loss processes and plasma-molecular interactions, and (when $P_{recl} \sim P_{ion}$) volumetric recombination, which only then becomes important in further increasing the loss in target ion current.



[1] K. Verhaegh, et al. Plasma Phys. Control Fusion, 2019, **61**(125018) [2] A. Fil, et al. Contributions to Plasma Physics, 2017 [3] K. Verhaegh, et al. Nuclear Fusion, 2019, **59** (126038) [4] K. Verhaegh, et al. Nuclear Materials and Energy, 2017, **12**: p. 1112-1117. ** See the author list of S. Coda et al. 2019 Nucl. Fusion, 59 112023 ** See the author list of B. Labit et al. 2019 Nucl. Fusion, 59 086020 *** Currently based at Culham Centre for Fusion Energy, Culham, United Kingdom.*