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Using variations in divertor magnetic topology and geometry to optimize divertor detachment

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Total flux expansion, a divertor magnetic topology design choice embodied in the Super-X divertor, is predicted through simple analytic models [1] and SOLPS calculations [3] to reduce the plasma and impurity density detachment thresholds as the outer divertor target strike point position, Rt, is increased. Since the total magnetic field, |B| ~ 1/R, |B| at the target is lowered as Rt is increased. Those predictions are contradicted by recent TCV experimental results [2]. The SOLPS-ITER code was utilized to both match TCV results and determine, more generally, the relative effect of detachment threshold by 'magnetic topology'(in this case, total flux expansion) and 'divertor geometry', for which we vary a) the separatrix incidence angle to the divertor surface and b) the effect of physical baffles that retain more neutrals in the divertor.

We quantify the role of those neutral effects through applying a definition of neutral trapping in form of the fraction of the total target ion flux that is re-ionized in a divertor flux tube which is just outside the separatrix - eta_RI. The analysis for TCV showed that neutral trapping was reduced as Rt was increased, negating the effect of total flux expansion on the detachment threshold.

This study has pointed a path towards more quantitative divertor design tools. Quantitative prediction of the effect of total flux expansion on the detachment threshold [1] and target temperature [3-4] already exist. The relationship between divertor geometry and the detachment threshold has been more qualitative: The angle between the separatrix and the target (effect a) is well known to affect the detachment threshold [5,6]. Baffling the divertor (effect b) is oft-used to protect the core from neutral effects as opposed to maximize divertor ionization. The quantitative relation between eta_RI and the detachment threshold for the two divertor geometry design choices will be shown and contrasted to that of total flux expansion. We will also discuss how the same design tools might affect other divertor design criteria - e.g. detachment control.

[1] B. Lipschultz et al, Nucl. Fusion 56 (2016) 056007
[2] C. Theiler, B. Lipschultz , et al., Nucl. Fusion 57 (2017) 07200
[3] D Moulton, J Harrison, B Lipschultz & D Coster, Plasma Phys. Control. Fusion 59 (2017) 065011
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[5] B. Lipschultz et al., Fusion Science Tech., 51, (2007) 369
[6] M. Groth et al, J. Nucl. Materials 463 (2015) 471

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