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Experimental study and interpretative modelling of the power exhaust in configurations with multiple divertor X-points in TCV

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Power exhaust remains a major challenge in magnetic confinement fusion, as the unmitigated heat flux reaching the wall in future reactors is predicted to greatly exceed material limits. Alternative divertor configurations are being developed to reduce target heat loads, should the standard Single Null (SN) not scale to reactors such as DEMO [1]. Additional divertor X-points, such as in the Snowflake-minus (SF-) configuration [2], can increase the plasma wetted area by diverting the scrape-off layer (SOL) towards multiple divertor targets, and can greatly increase the parallel connection length ($L_{||}$) by enlarging the region of traversed low poloidal field.

SF- experiments in TCV have demonstrated a reduction of the peak parallel target heat flux by up to 66% compared to the SN, while being able to control the heat flux reaching each active target by varying the distance between the two X-points [3]. Interpretative modelling of these plasmas with the coupled fluid plasma and kinetic neutral code EMC3-EIRENE suggests that the redistribution of power to the far-SOL strike-point (and corresponding reduction of peak target heat flux) is due to increased cross-field transport. Simple analytical models propose that divertor radiative cooling capability increases with $L_{||}$ [4]. However, these low density SF- experiments and simulations do not indicate any significant increase in radiated power compared to the SN configuration. An increased core effective charge in the SF- compared to the SN indicates a degradation in divertor impurity retention, which would reduce the impurity radiation. In an effort to increase SOL-core plasma screening, further SF- experiments were performed at higher core density, for which a small increase in divertor radiated power is observed in the SF-.

To accentuate the effect of additional X-points and enhanced connection length on power exhaust, an extreme divertor shape was developed in TCV, named the Jellyfish (JF). The JF features three divertor X-points and 4x longer $L_{||}$ than in the SN, bringing strong target heat flux reductions in regions of enhanced $L_{||}$ with respect to the SN and SF- geometries. Remarkably, the JF shows no increase in divertor radiated power with respect to the SN, despite the extreme connection length enhancement. A reduced 1D SOL model will be used to study the effect of connection length on divertor power exhaust in isolation from effects of impurities and other geometrical aspects.

References

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