Correlation between the increase in the L-H power threshold and the alignment of externally applied non-axisymmetric magnetic perturbations

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ITER will likely rely on the application of externally applied non-axisymmetric magnetic perturbation (MP)-fields to suppress edge localized modes (ELMs) in low collisionality H-mode plasmas. To suppress even the first ELM, it is foreseen to use MP-fields prior to the transition to H-mode (L-H transition). Since the initial auxiliary heating power of ITER will be marginal above the predictions for the L-H power threshold (P_{LH}) from a multi-machine database [1], strategies are needed to optimise the MP-coil configuration for ELM suppression while avoiding an increase in P_{LH}.

A comprehensive series of experiments at ASDEX Upgrade, including 34 L-H transitions, shows that P_{LH} increases by up to $\approx 80\%$ when the external $n = 2$ MP field is aligned to maximise the associated plasma response at the edge. This alignment deviates from the equilibrium field pitch and is similar to the one needed in H-mode to suppress ELMs by MPs. The relative perturbation amplitude $\delta B_r/B$ has to exceed a critical value, roughly 2×10^{-4}, to cause an increase in P_{LH}. This is above the value needed to sustain ELM suppression and is favourable for ITER. Predictions from plasma response calculations combined with the empirical critical value capture very well the measured dependencies of P_{LH} on the alignment of the applied MP-field.

State-of-the-art diagnostics probing the edge $E \times B$ velocity (v_{ExB}) like Doppler reflectometry, charge exchange recombination spectroscopy and a novel active He^+ spectroscopy measure a reversal and flattening during the application of MPs. This change is primarily attributed to a spin-up of the fluid velocity into the co-current direction leading to a positive v_{ExB}. To develop a well in the v_{ExB} profile, more heating power is necessary to additionally drive the main ion diamagnetic velocity v_{dia} by the ion temperature gradient. The resulting edge v_{ExB} profile at the L-H transition has roughly the same shear as without MPs [2], but with a more positive rotation direction and a larger fraction of the main ion diamagnetic velocity. Several models to describe the phenomenology like 3D NTV, resonant $J \times B$ torque and ergodisation are discussed.

[1] Y. R. Martin *et al*, Journal of Physics: Conference Series, 123(1):012033, 2008.
[2] M. Cavedon *et al*, submitted to Nucl. Fusion, 2020