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Core-edge integration studies in negative triangularity in TCV

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Negative Triangularity (NT) configurations exhibit higher energy confinement compared to the conventional Positive Triangularity (PT) configurations. Experiments on TCV [1] and DIII-D [2] have shown that NT L-Mode plasmas can achieve confinement comparable to H-mode, with β_N up to 2.8 (2 in stationary state) demonstrated in TCV. This suggests the potential for high-confinement L-Mode reactors that circumvent H-mode challenges, including ELMs and power thresholds. In this contribution, we investigate power exhaust in Ohmic and high-power NT configurations to demonstrate the compatibility of NT plasmas with reactor relevant operation and core-edge integration.

In Ohmic L-Mode TCV discharges, detachment in NT configurations is challenging [3,4], with the outer target difficult to cool to electron temperature below 5 eV using core density ramps, compared to PT. Increasing the divertor closure with divertor gas baffles [5] decreases the outer target temperature, but detachment remains more difficult to achieve than in PT [6]. In Lower Single-Null (LSN), changing the upper triangularity (u) from positive to negative, whilst matching the divertor geometries, still results in harder detachment. This is, at least partially, explained by the role of the SOL width (λ_q), which is smaller in NT than in L-Mode PT [7,8], in agreement with theoretical and numerical predictions. These experiments with matched divertor geometries furthermore exhibit a typically lower divertor neutral pressure in NT than in PT, even with increased divertor closure [6]. Using extrinsic impurity seeding (N2), NT detachment was achieved, with reduced core confinement, and still exhibiting higher difficulty to detach as compared to PT.

These Ohmic studies have been extended to high-input power scenarios. The scenario is a 170kA LSN with favourable ion grad-B drift, with negative δ_u and positive δ_l, to maintain compatibility with divertor baffles, employing Neutral Beam Heating (NBH). High performance is achieved, with β_N up to 1.8 (H_{98} near 1), at a Greenwald fraction of about 0.4, sustained in stationary conditions, for the duration of the NBH. Even without extrinsic impurity seeding, the divertor is relatively cold, as evidenced by the CIII front retreating from the outer target, a low outer target temperature (Te ~ 6 eV, measured by Langmuir probes) and a significant radiated power fraction. When N_2 seeding in the divertor is introduced, an X-Point Radiator forms. This, however, leads to reduced β_N. Real-time β-control can recover performance by increasing the NBH power, and enabled the demonstration of fully detached, high-performance (β_N = 1.6) L-mode NT plasmas, comparable to ELMy H-mode, which suffers from reattachment during ELMs.

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