Progress Toward Divertor Detachment in TCV H-mode Discharges

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The operation of future high-power density fusion reactors such as ITER and DEMO requires avoiding damaging plasma-facing surfaces and good core confinement. The former requirement necessitates operating in the detached divertor regime, and the latter is met by operating in the high confinement (H-) mode. Recent experiments on the TCV tokamak have explored access to H-mode and divertor detachment in neutral beam heated ELMy and ELM-free scenarios in conventional and alternative divertor configurations using fuelling and N_2 seeding. The impact of the divertor geometry on detachment access was explored in variations of the single null configuration where the poloidal flux expansion at the outer divertor ranged from 3.5 to 10 and the major radius from 0.75m to 1.03m. The approach toward detachment and its evolution has been extensively diagnosed to characterise the divertor particle and power loads, radiation losses and spectral line emission profiles. This work builds on previously reported studies of ohmic H-modes where Ne injection was applied, resulting in a reduction in divertor power and particle loads [1].

The heating power required to enter H-mode was measured in a range of divertor configurations, finding that, in the vicinity of the minimum of the $P_{L\text{-}H}/n_e$ curve, the threshold power is largely independent of the poloidal flux expansion and major radius of the outer divertor.

A factor 2 reduction in the outer divertor power load was achieved in ELM-free (using N_2 seeding and D_2 fuelling) and ELMy scenarios (using N_2 seeding only). No significant reduction in the outer divertor particle flux was observed in the ELM-free scenarios, compared with ~30% reduction in the most strongly detached ELMy cases, which is thought to be due to a reduction in the particle source in the divertor due to ionization, which is also observed in L-mode [2]. Unlike L-mode plasmas, a broadening of the emission profiles after the onset of detachment is not observed. The deposited ELM heat flux is found to decrease with increasing seeding. Nevertheless, at all depths of detachment explored, ELMs led to attachment of the divertor followed by prompt re-detachment following the ELM. Increasing poloidal flux expansion was found to result in a deeper detachment. These observations will be interpreted via SOLPS-ITER simulations.

Work supported by RCUK [grant number EP/I501045] and Euratom.

[1] R. A. Pitts et al., J. Nucl. Mater **266-269** 648-653 (1999) [2] K. Verhaegh et al., NME **12** 112-117 (2017)