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Accessibility and Properties of ELMy H-mode and ITB Plasmas in TCV

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High confinement regimes are obtained in tokamaks when transport barriers are formed in the plasma. Transport barriers located close to the edge lead to H-mode while transport barriers in the plasma core are simply referred to as Internal Transport Barriers (ITBs). In diverted tokamaks, H-mode are generally obtained when enough additional power is injected into the plasma, while ITBs are traditionally formed by applying additional power during the initial plasma current ramp. All transport barriers are characterised by steep, localised temperature gradients, small local transport coefficients and a subsequent increase in the global energy confinement time.

In TCV, plasmas with H-mode or ITB are regularly obtained even if their accessibility differs from the scenarios generally used elsewhere. H-mode plasmas are readily obtained in ohmically heated discharges. The threshold power increases with the plasma density in accordance with the multi-machine ITER scaling, but its absolute value is observed to be twice that deduced from this scaling. A small region of the large, multidimensional operational space of TCV gives access to ohmic H-mode plasmas with Edge Localised Modes (ELMs). Once established, this regime is robust against changes in plasma parameters, allowing us to widen the working operational domain. ELMy H-mode plasmas are also produced using Electron Cyclotron Heating (ECH). The required power exceeds the ITER scaling as well. The ELM frequency decreases with increasing additional power, indicating the type III nature of the ELMs. The energy confinement time is greater than 50ms in ELMy H-mode plasmas. In ohmically heated discharges, a periodic magnetic perturbation of the plasma vertical position has a strong effect on the timing of ELMs.

A steady-state electron Internal Transport Barrier (eITB) is obtained in TCV during the current plateau when ECH is applied off-axis and Electron Cyclotron Current Drive (ECCD) is applied at the centre in the direction opposite to the plasma current. The improvement in confinement reaches 3.5 times the RLW scaling and lasts longer than 100 confinement times.

An eITB is also obtained in non-inductive plasma discharges. In this case, the inductive current is replaced by off-axis Co-ECCD. The injection of on-axis ECH or Counter-ECCD produces a safety profile with reversed shear and a strong eITB is formed. Due to the large pressure gradient, the bootstrap current makes an important contribution to the total plasma current. Under these conditions the volume of plasma inside the ITB can be enlarged and H-factors close to 4.5 are obtained.