Plasma regime with small ELMs as access to dissipative exhaust scenarios

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The tokamak scenario with high shaping and high separatrix pressure always exhibits increased transport stemming from ballooning modes in a narrow region just inside the separatrix. This scenario can be optimised such that no type-I ELMs occur and the confinement factor H_98 stays high, i.e. H_98 ≥ 1. The separatrix conditions lead to interchange like transport, and fast filaments carry particles and heat into the far scrape-off layer, such that the heat flux pattern in the divertor is broadened and a density shoulder occurs. Moreover, the scenario can be combined with impurity seeding and thus developed into a discharge in which both, the inner and outer divertor are detached.

The physical mechanism can be understood in the following way: A high separatrix pressure can only be achieved via high density, i.e. gas fuelling, because the temperature at the separatrix is limited due to the fast parallel heat flux to the divertor. The high shaping allows reaching a high separatrix pressure before type-I ELMs become unstable. The ballooning modes modify the pedestal pressure shape, such that the width of the steep gradient region is narrower and thus more stable against coupled peeling-ballooning modes. The shaping close to double null leads to a lower shear, additionally destabilising the ballooning modes. For each plasma current (0.6 – 1 MA at ASDEX Upgrade) an optimum combination of shaping, fuelling and heating can be found, such that good confinement is achieved without any type-I ELM. For a discharge at 0.8 MA, we show that the heat flux decay length is increased by a factor of four with respect to the multi-machine power width scaling. The filaments in the SOL are measured with the thermal helium beam diagnostic and exhibit a velocity of around 500 m/s, which is faster than typical inter-ELM filaments but slower than filaments stemming from a type-I ELM.

This scenario, optimised for confinement, can be further developed into a semi-detached or even detached scenario by adding impurity seeding. Nitrogen seeding was explored, a high recycling regime in the outer divertor with a detached inner divertor was achieved with H_98 = 0.9 with heating power as high as 15 – 20 MW. As soon as the outer divertor is detached, an X-point radiator can be seen. Such radiative scenarios are DEMO relevant, because they do not show any type-I ELM, have highly dissipative exhaust and a significant radiation fraction inside the confined region.

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