Power exhaust in small ELM regimes at high separatrix density

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Power exhaust solutions for a next step device have to be in agreement with sufficient plasma core performance. Steady state divertor power loads are extrapolated to exceed material limits making significant impurity seeding necessary. The amount of injected impurities required depends critically on both the maximum achievable separatrix density and the scrape-off layer width. Transient power loads due to unmitigated type-I edge localized modes (ELMs) are additionally extrapolated to significantly reduce the life time of the first wall in e.g. ITER and have to be avoided completely for reactor-sized devices.

Active suppression of such large ELMs is widely studied, however, so far these suppression schemes are restricted to comparably low edge densities, leaving the steady state power loads as a remaining challenge. A promising regime combining all three aspects, high plasma core performance ($H_{98,\mathrm{y2}} \simeq 0.9$–$1.0$, $n_{\mathrm{e,core}} \simeq 0.9\,n_{\mathrm{GW}}$), high separatrix densities and small ELMs is achieved in ASDEX Upgrade at high triangularity, close to double null. Here, the edge plasma reaches a ballooning parameter close to the ideal-MHD limit. These conditions, a high separatrix pressure together with a lower magnetic shear, lead to ballooning modes at the separatrix being unstable causing increased radial transport and preventing type-I ELMs.

The divertor target power load profiles in the small ELM regime are characterized for the first time using a high resolution infrared thermography system at ASDEX Upgrade. This is possible due to the attached divertor conditions observed in this operational regime. The time averaged power load profile of this small ELM regime is successfully described by the well established divertor power load fitting function, derived originally for the inter type-I ELM profile. Most importantly, a significant broadening of the power fall-off length is measured, up to a factor of four compared to the ITPA-multi-machine scaling, reflecting the larger radial transport during the small ELM regime compared to inter type-I ELM periods. The current hypothesis is that the ballooning modes expected for $\alpha_{\mathrm{MHD}} \simeq 2.0$–$2.5$ lead to a radial convection of filaments carrying the heat much further into the scrape-off layer. The filamentary radial transport manifests also in the formation of a so-called density shoulder.

A possible route to the high confinement, high separatrix density and small ELM regime will be shown. Additionally, first results on impurity seeding as well as a plasma start-up into this regime without large ELMs are reported.