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Research on DEMO Physics Issues at High Density on ASDEX Upgrade

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Conceptual design studies of DEMO, the step that should bridge the gap between ITER and an FPP, heavily rely on the physics assumptions for its operational scenario. Usual DEMO designs exceed the parameters of the ITER Q=10 baseline scenario in a number of points, such as β_N, n/n_{GW} and $f_{rad,core} = P_{rad,core}/P_{tot}$. Research on present day devices cannot address these issues simultaneously at the high density and low collisionality that will occur in ITER or DEMO. In the last years, work on the ASDEX Upgrade tokamak has therefore mainly focused on the high density regime, consistent with the operational range set by the unique all-W wall of ASDEX Upgrade. In this contribution, we will report in particular on the following results:

- ELM mitigation with magnetic perturbation coils at high densities: ASDEX Upgrade has demonstrated reliable ELM mitigation using $n = 1$, $n = 2$ and $n = 4$ coil configurations at high density with no loss in confinement, in contrast to RMP ELM suppression at low density in DIII-D. We will discuss differences and commonalities.

- H-Mode operation at line averaged density well above the empirical Greenwald limit: small ELM regimes, lead to good pellet fuelling efficiency and have allowed achieving stationary H-modes at $n/n_{GW} = 1.5$ with peaked density, the pedestal top density staying below n_{GW}. These findings may open a route to operation of DEMO beyond the empirical Greenwald limit.

- Upper density limit for H-mode operation: recent studies reveal the coupling of an energy loss and the saturation of the density increase, which lead to the degeneration of the H-mode at high edge densities. Hence, also this limit can be viewed as an edge density limit.

- Exhaust at high P_{sep}/R or high $f_{rad,core}$: both ITER and DEMO will have to operate with (semi)detached divertor at $P_{sep}/R \geq 15$ MW/m to stay in H-mode. We show stationary operation at 7 MW/m with average divertor heat flux below 5 MW/m^2 and $T_{e,div} \sim 5$ eV by simultaneous feedback control of two seed impurities. In DEMO, this regime calls for $f_{rad,core} > 70\%$; we have also shown this, albeit necessarily at lower P_{sep}/R values.

While these studies target DEMO operation parameters, they have a high relevance for the exhaust problem in ITER as well, which faces the same challenges as DEMO in terms of P_{sep}/R and the need to mitigate ELMs.