Alternative Divertor Configurations in the future upper divertor of ASDEX Upgrade

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Power exhaust is a major challenge of a future fusion reactor based on the Tokamak design in single-null (SN) configuration. As a potential solution, alternative divertor configurations (ADCs) are currently discussed and investigated by many laboratories in the world [1]. In order to study a series of ADCs [2] in a machine with a high heating power (30 MW) compared to its size (R=1.65 m) and compare them to the conventional SN configuration, the installation of a couple of in-vessel coils in the close proximity of the upper outer strike-point of ASDEX Upgrade (AUG) is currently in preparation [3]. Compared to the SN SOLPS simulations predict an access to a detached divertor regime for the Snowflake (SF) configuration [4] at lower upstream density and/or impurity seeding rate, accompanied by a substantial reduction of the power and particle fluxes. In order to characterize the edge plasma conditions experimentally, optimize the reference equilibrium and make predictions for the realistic (3D) future divertor coil geometry, a series of USN discharges were carried out in AUG recently and analyzed by the 3D edge transport code EMC3-EIRENE. With 10 MW of total power the discharges are in a small-ELM H-mode regime and approach partial detachment at the end of the flattop phase due to N2 puffing and a fueling ramp. Although the outboard limiters are about 35 mm away from the separatrix, i.e. about ten times the measured near-SOL power fall-off length (λ_q^{near}=3.8 mm), substantial amounts of power are deposited on their surfaces. This is explained by a substantially larger far-SOL power fall-off length λ_q^{far}=25 mm [5] measured by high spatial coverage IR thermography in the open divertor, and the formation of a density shoulder [6] upstream. The EMC3-EIRENE simulations, now including volumetric recombination, but not yet drifts, are able to reproduce quantitatively the in-out asymmetry, the collapse of the target electron temperature and the flattening of the upstream density profile. In the detached state the outboard limiters receive more power (8% of the total injected power) than the outer target (4%) and contribute substantially (23% of the total) to the particle fueling of the main plasma according to the simulation.
Apart from an analysis of the current experiments an extrapolation to the future ADCs in detachment will be shown including a power deposition pattern for the realistic (3D) geometry of the upper divertor coils and current feeds.

[1] V. A. Soukhanovskii, PPCF 2017, [2] T.Lunt, et al., NME 2017, [3] A.Herrmann, et al., FED 2019, [4] O.Pan, et al., PPCF 2018, [5] T.Lunt, et al., in preparation, [6] D.Carralero, et al., PRL 2014