

## Long-pulse operation of Wendelstein 7-X in attached scenarios

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An important benefit of fusion reactor based on a stellarator design is an easier access to long pulse scenarios. In fact, one of the main goals of Wendelstein 7-X (W7-X), largest superconducting stellarator in the world, is to demonstrate steady-state capabilities of the stellarator line. Since the next campaign, all plasma-facing components will be water-cooled, which should enable pulse duration of up to 30 minutes with up to 10 MW of input power. In the previous campaign, different experiments were performed in order to prepare long pulse operation, incl. scenario control, control of the heat and particle exhaust and influence of leading edges on plasma stability. Although a robust detachment scenario has been discovered at W7-X [1], at the moment it works in relatively narrow operational space and it is necessary to consider long pulse attached scenarios as well. This contribution will report on the results of those studies.

The heat and particle exhaust in W7-X is realized with the help of an island divertor [1], which utilizes magnetic islands at the plasma boundary. We have measured very efficient heat flux spreading (wetted area of up to 1.5 m<sup>2</sup>) with favorable scaling with input power. In standard configuration peak heat fluxes at the strike line of up to 4 MW/m<sup>2</sup> at input power of 5 MW were measured in the scenarios with middle range plasma densities (5-6·10<sup>19</sup> m<sup>-3</sup>). Error fields, which emerged from non-perfect manufacturing of superconducting coils, are reduced from a level of ca. 50% below 30% by help of trim coils. The asymmetry is also affected by edge drifts, which in typical scenario put more loads on lower divertors. The standard configuration projects well towards steady state operation with 10-12 MW of  $P_{\text{ECRH}}$ . Looking at other steady state candidate configuration - so called "high iota" configuration with 5/4 island chain forming island divertor, we see smaller wetted area (of up to 1 m<sup>2</sup>) and high peak heat flux (of up to 10 MW/m<sup>2</sup> at similar conditions as in the standard configuration. This configuration, however, is inherently robust against error fields, which reduces technical requirements when thinking about future devices. As W7-X is a low shear device, edge islands are affected by plasma dynamics e.g. changes in toroidal current. Several measures to counter-react to strike line movement were tested, i.e. by use of external coils or ECCD.

An essential issue of long pulse operation is impurity control, a series of experiments were performed to study behavior of intrinsic impurities as well as seeding low and highly recycling species to enhance plasma radiation. Overall W7-X shows very good impurity control in low and high density discharges. Moreover, we have found that in spite of high influx of carbon into SOL during discharges with on purpose overloaded leading edges plasma remained stable. Line-of-sight averaged  $Z_{\text{eff}}$  stayed throughout the discharge below 1.5 and radiation increased at the plasma edge only.

[1] Pedersen, T. S. et al. First results from divertor operation in Wendelstein 7-X. Plasma Phys. Control. Fusion 61, 014035 (2019).