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3D heat and particle fluxes in Wendelstein 7-X

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Many present and future large magnetic fusion experiments need to consider the 3D topology of the heat and particle exhaust either due to application of external magnetic perturbations to mitigate type-I ELMs or because it is typically inherent to the magnetic configuration of the device (e.g. LHD or W7-X). In both cases, the scrape-off layer forms heterogeneous 3D structures of field lines with different connection lengths. A key question to future and present devices is in how far the presence of 3D boundary affects the plasma-wall interaction whith toroidal symmetry not preserved anymore. W7-X in its recent campaign with an uncooled fine-grain graphite divertor investigated for the first time in full detail a concept of an island divertor, which uses intrinsic large, low resonance island chains at the plasma edge to form heat and particle exhaust channels. The measured strike line width is of up to 10 centimeters with its 3D geometry strongly depending on the magnetic configuration. Similar findings are observed at LHD, whch is typical for any device with a stochastic boundary independent if it is a tokamak or a stellarator.

In steady state operation, assumptions that power loads follow the periodicity of the device cannot be made, therefore 10 high-resolution infrared/visible systems are installed to monitor the heat and particle fluxes over the whole divertor surface. We have developed new methods to characterize the local and global heat and particle loads based on recent experimental observations, e.g. by projecting the measured heat flux onto the geometry of the islands forming island divertor. The energy of particles deposited at the strike line varies strongly with plasma density as shown by floating potential. At very low densities a strong negative potential (<-60 V) has been measured by divertor Langmuir probes, whereas at higher densities it goes even slightly positive. In addition, the electron temperatures at the strike line vary strongly depending on the plasma parameters from below 5 eV during divertor heat flux detachment to ca. 100 eV at very low plasma collisionalities.

The data from LHD, W7-AS and W7-X shows that the measured heat and particle flux patterns are rather sensitive to magnetic configuration, changes in finite plasma beta and arising toroidal currents.

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