The dual role of the plasma boundary in tokamaks

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One of the paths to achieving nuclear fusion on earth is the confinement of hot plasma in a magnetic device, called a tokamak. In the largest one, ITER, which is currently being built in the south of France, a burning deuterium-tritium plasma will require core ion temperatures above 10 keV (100 Mio ºC) at densities around 10^{20} m^{-3}. The dominant transport mechanism in the core of a tokamak plasma is turbulence which limits the temperature gradient length. Therefore, the first role of the plasma edge is to act as boundary condition to the core, and its temperature value is a crucial quantity that determines the performance of a tokamak plasma. In steady state conditions, all of the heat, which is deposited or produced in the centre, is transported across the plasma edge towards the wall. Thus, the second role of the plasma edge is to provide conditions for safe operation that prevents damage to the plasma facing components by too high local heat loads or high energy bursts.

The plasma edge region (around 5% of the plasma radius) is characterised by different physical properties, such as extremely strong pressure gradients in an edge transport barrier that create strong flow shear. This combination can simultaneously reduce background turbulence as well as drive magneto-hydrodynamic and turbulent modes. The interplay between these processes determines the transport from the core to the wall. In present day experiments it is impossible to combine reactor relevant conditions at the foot and at the top of the edge transport barrier simultaneously. This makes the validation of theoretical models essential for reliable predictions of the plasma boundary in large tokamaks.

In this talk the most important physical properties of the plasma edge will be explained together with open research questions, and possible options for the operation of the plasma edge in large devices will be illustrated.