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The physics basis for a solution to the power and particle exhaust problem of a next step device

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This contribution presents an overview how research in power and particle exhaust studies relevant to next step devices have advanced our quantitative understanding. For a future fusion reactor, such as the european DEMO, a dissipative power fraction, f_{diss}, of $90\% - 97\%$ would simplify the engineering demands on plasma facing components, PFCs. A quantitative understanding of the impact of f_{diss} on confinement is being developed. It is e.g. unclear if ITER could operate with a higher degree of detachment than the currently envisaged and achieve its fusion performance.

Seeding of impurities will be mandatory to accomodate the engineering limits of the PFCs. Here, the quantitative understanding of the enrichment of the seed impurities in the divertor is of the essence. The interaction of the plasma with the PFCs together with the volumetric dissipative processes leads to a complex physical system. Based on example cases it is shown how a significant improvement of our qualitative and quantitative understanding of detachment physics has been achieved. The combination of experiments in devices with full metal PFCs, improved diagnostic capabilities and the use of numerical tools with a comprehensive set of physical models provided a major step forward in interpreting experimental data. A steady improvement lead to the identification of missing elements in the models, most prominently the interaction of the numerically expensive drift terms with enhanced far SOL transport. Thus our uncertainty about the highest achievable f_{diss} of the SOL narrows down to the largest extent to a quantitative obscurity about the nature of perpendicular SOL transport. While selected positive example cases of a successful numerical validation against experimental data exist they remain an exception.

The certainty with which we can apply our models to interpret experimental data and thus allow for a more general quantitative statement is just starting to be looked at and will need more attention in the future. In view of the complexity of numerical modeling with fluid transport codes, reduced models are being investigated on the basis of experimental data or numerical simulation results. Validated reduced models of various levels of complexity may then be used in system codes to determine the performance of future devices and to specify their design.

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