Overview of theoretical and experimental results on SOL profiles and transport

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Understanding scrape-off layer (SOL) and divertor heat-fluxes is essential for the success of ITER and next-step burning plasma experiments. In the present talk, we review our present theoretical and experimental understanding of the SOL plasma profiles, as well as the intervening transport processes. The power decay length $\lambda_q \approx -p/\partial_r p$ is of particular interest, since it impacts how much power reaches the plasma facing components. The SOL profiles are the result of a balance between parallel conduction, convection, and radial transport. Despite a challenging setting for theory and computation (large amplitude fluctuations, strongly non-linear behavior, etc) the radial transport is increasingly well understood. The latest generation diagnostics allow high-fidelity, detailed validation studies covering many aspects of the dynamics, including the SOL profile structure, its poloidal variation, and details about the nature of the transport. First principles fluid and kinetic simulations have recovered many significant features of the dynamics, going far beyond reproducing the experimental λ_q. Details such as the moments of the fluctuation PDF (amplitude, width, skewness, flatness) can routinely be predicted, approaching quantitative agreement. Interestingly, it appears that a lot of the variation of λ_q with the plasma parameters can be captured by simple 0D models such as the Eich scaling. It is here, in fact, where physical models substantially disagree. While neoclassical transport models give rather pessimistic projections for ITER and beyond, turbulence simulations suggest that λ_q can increase with the device size. Plasma detachment (e.g. parallel transport), a crucial need for ITER, is far less understood than cross-field transport. While the principal mechanisms (closure, collisions, connection length, divertor closure, flux expansion) are identified, our understanding lacks a robust, first-principles quantitative predictive capability. Even though significant headway has been made towards a comprehensive understanding of the scrape-off layer heat-fluxes, conventional divertor solutions may not scale beyond ITER. For this reason, new divertor configurations have been conceived, introducing potential benefits caused by increased connection length, flux expansion, divertor enclosure, and blobby transport. A full understanding of SOL profile formation in these new exotic configurations will require integrating our knowledge of the main plasma species behavior with the effects of the sheath, neutrals, particle fueling, impurities, and exotic plasma geometries.

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