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First-Principle Theory-Based Scaling of the SOL Width in Limited Tokamak Plasmas, Experimental Validation, and Implications for the ITER Start-up

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The steady-state heat load onto the plasma facing components of tokamak devices depends on the SOL width, which results from a balance between plasma outflowing from the core region, turbulent transport, and losses to the divertor or limiter. Understanding even the simplest SOL configurations, like circular limited plasmas, is a stepping-stone towards more complicated configurations, with important implications for the ITER start-up and ramp-down phases. Here we present a first-principle based scaling for the characteristic SOL pressure scale length in circular, limited tokamaks that has been obtained by evaluating the balance between parallel losses at the limiter and non- linearly saturated resistive ballooning mode turbulence driving anomalous perpendicular transport. It is found that the SOL width increases with the tokamak major radius, the safety factor, and the density, while it decreases with the toroidal magnetic field and the plasma temperature. The scaling is benchmarked against the flux-driven non-linear turbulence simulations that have been carried out with the GBS code. This code solves the drift-reduced Braginskii equations and evolves self-consistently plasma equilibrium and fluctuations, as the result of the interplay between the plasma injected by a source, which mimics the plasma outflow from the tokamak core, the turbulent transport and the plasma losses to the vessel. GBS has been subject to a verification and validation procedure unparalleled in plasma physics. The theoretical scaling reveals good agreement with experimental data obtained in a number of tokamaks, including TCV, Alcator C- MOD, COMPASS, JET, and Tore Supra.

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