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SOL Width Expansion driven by Fluctuation Energy Intensity Flux

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The pulsed heat load due to large ELMs is an existential problem for future devices of ITER size and FPPs because that load would produce unacceptable damage to the divertor plates. Simultaneously controlling large ELMs and divertor heat loads in H-mode plasma is crucial for achieving steady-state operation of a tokamak fusion reactor. Recently, both experiments and simulations have shown that H-mode plasma regimes with small/grassy ELMs can help to reduce the ELM size and broaden the SOL width λ_q, while maintaining high plasma confinement compared to type-I ELMs [1-3]. Investigating how turbulence spreading affects edge profile evolution and the SOL width is essential. Turbulence simulations using BOUT++ were conducted to investigate the effects of turbulence spreading on ELM size and the broadening of the divertor heat flux width (λ_q) in small ELM regimes [4,5].

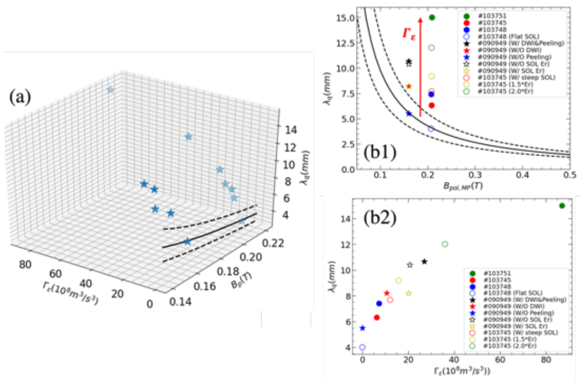

Fig. 1. (a) 3D plot of heat flux width λ_q vs poloidal magnetic field B_p and fluctuation energy intensity flux Γ_ε; 2D plot of heat flux width λ_q vs poloidal magnetic field B_p (b1) and fluctuation energy intensity flux Γ_ε (b2).

This study is motivated by EAST experiments, where the pedestal is near marginal stability for small ELMs and relaxes into a linearly stable state after the initial ELM crash. In small ELM regimes, the ELM size is significantly smaller than that of the large ELMs, but it can still increase with a corresponding increase of the inward penetration depth. The results from BOUT++ nonlinear simulations indicate that turbulence energy intensity flux Γ_ε is a crucial factor in the broadening of the SOL width λ_q [6]. As the fluctuation energy intensity flux Γ_ε at the last close flux surface (LCFS) increases, λ_q expands. The transition from ELM-free to small ELM regime leads to a significant broadening of λ_q, due to the strong radial transport of turbulence energy, which is consistent with EAST experimental results that λ_q is broadened as the upstream density fluctuation intensity increases.

The outward turbulence spreading from pedestal to the SOL is shown to be sensitive to pedestal parameters, such as pedestal pressure gradient ∇P_0 and pedestal collisionality υ^*_{ped}. The fluctuation energy density flux Γ_ε increases for increasing ∇P_0 and decreasing υ^*_{ped}. Peeling modes are seen to be especially effective for spreading on account of their large radial extent, which endows them with a large mixing length. The fluctuation energy density flux Γ_ε induced by low-n peeling modes, which dominate at low collisionality, is larger than for high-n ballooning modes, which occur at high collisionality, on account of the wider mode structure of the former.

Operating in H-mode with small ELMs has tremendous potential to address two of the most critical problems for Tokamak fusion reactors: significantly reducing the ELM size and substantially broadening the SOL width.

References

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