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Nonlinear dynamics of ELMs with Er shear and collisionality trends

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Simulations with the BOUT++ code have been used to study the energy loss for edge localized modes (ELMs) at different collisionality & electric field Er shear and to investigate the controls of transition to different ELM and quiescent H-mode (QH-mode) regimes. The simulation results indicate that by development of a flexible Er control capabilities, it is conceivable that tokamak operation regime access can be achieved through a control of edge fluctuation spectrum via the radial electric field and its shear. By decreasing collisionality with a increasing Er for a narrow pedestal, nonlinear simulations show that (1) power spectrum becomes narrower and linear growth rate increases, the dominant mode decreasing from high-n ballooning modes to low-n peeling modes; (2) Bispectrum analysis shows that nonlinear mode coupling becomes weaker, resulting in the dominant filamentary structures and increasing ELM energy loss. The increasing Er shear at high collisionality with a narrow pedestal leads to strong nonlinear coupling and reduced ELM energy loss, In contrast, the increasing Er shear at low collisionality with a wide pedestal can modify the stability boundary to drive stable low-n peeling modes unstable, leading to enhanced pedestal transport due to either a saturated low-n peeling modes or a broadband turbulence, therefore leading to a reduced pedestal pressure gradient, allowing the development of a broader and thus higher transport barrier in QH mode without ELMs.

To validate BOUT++ simulations against experimental data for inter-ELM fluctuations, the BOUT++ simulations are performed based on a set of C-Mod and DIII-D experiment data, the overall signatures of simulation results for quasi-coherent fluctuations (QCF) show good agreement with C-Mod and DIIID measurements. QCFs are localized in the pedestal region having a predominant frequency at f $\approx$300–400kHz and poloidal wavenumber at k⊠$\approx$0.7/cm, and propagate in the electron diamagnetic direction in the laboratory frame. (2) The pedestal profiles giving rise to QCFs are near the marginal instability threshold for ideal peeling-ballooning (P-B) modes for both C-Mod and DIII-D. (3) Particle diffusivity is either smaller than the heat diffusivity for DIII-D or similar to the heat diffusivity for C-Mod.

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