Nonlinear dynamics of ELMs with E_r shear and collisionality trends*

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The latest 3-field 2-fluid BOUT++ simulation results demonstrated the linear and nonlinear characteristics of ELMs at different collisionality & electric fields E_r shear via a density scan. The BOUT++ simulation results show an emerging understanding of dynamics of ELM crashes and the consistent collisionality scaling of ELM energy losses with the world multi-tokamak database [1,2]. Recently, we have successfully expanded this understanding with large electric fields E_r shear as shown in figure 1. For various densities n_0 with pressure profile and small Er shear fixed, the linear simulations show that as the edge density (collisionality) decreases, the maximum growth rates of the peeling-ballooning (P-B) modes are almost the same, but the width of the growth rate spectrum $\gamma(n)$ decreases rather dramatically [2]. The reason is that the bootstrap current plays a complex dual role in the pedestal. On the one hand, increasing currents drive peeling instabilities at low n; while at the same time the increasing pedestal current increases the local magnetic shear at outside mid-plane even though it decreases the global magnetic shear, which stabilizes high-n ballooning modes, in addition to a strong density dependence of the ion diamagnetic stabilization, and leads to a large ELM energy loss. However, by decreasing collisionality with a increasing Er, nonlinear simulations show that (1) power spectrum becomes narrower and linear growth rate increases, the dominant mode decreasing from n=35 ballooning modes to n=6 peeling modes; (2) Bispectrum analysis shows that nonlinear mode coupling becomes weaker, resulting in the dominant filamentary structures and increasing ELM energy loss. The impact of radial electric field E_r shear on low-n peeling and high-n ballooning modes is different. The increase E_r shear significantly enhances the linear growth rate of low-n peeling modes at low density, but only weakly impacts on nonlinear saturation amplitudes. In contrast, the increasing E_r shear leads to large suppression of nonlinear peeling-ballooning saturation amplitudes at high density, but only weakly impacts on their linear growth rates [3]. These results are consistent with a systematic study of the effects of plasma rotation on the ELM characteristics performed using a combination of tangential and perpendicular neutral beam injections in JT-60U [4]. Furthermore, the increasing E_r 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, depending on the level of ExB flow shear, magnetic geometry and pedestal plasma profiles, which is reminiscent of the DIII-D ExB flow experiments, where a transition can be made from EHO to a regime with broadband turbulence, leading to a reduced pedestal pressure gradient, allowing the development of a broader and thus higher transport barrier in QH mode without ELMs [5].

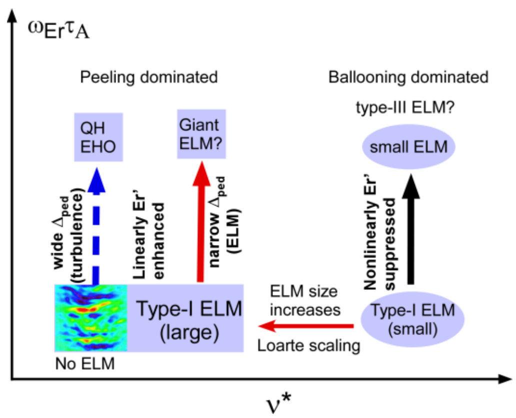

Fig.1 A sketch for ν^*–ω_{Er} operational space for type-I ELMs, type-III ELMs, giant ELMs, and QH-mode/EHO.

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