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A higher fidelity model for ELM onset in spherical tokamaks

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We present developments towards a higher fidelity model to consistently predict edge-localized mode (ELM) onset in spherical torus (ST) configurations, such as NSTX/-U and MAST/-U. The formation of the edge pedestal in H-mode operation is connected with periodic sudden relaxations of the edge pressure gradient (ELMs). These instabilities cause expulsion of particles and heat [1] towards the plasma facing components, which can cause serious damage in reactor-scale devices. Avoidance and control of ELMs is therefore crucial. ELMs are typically associated with macroscopic peeling-ballooning (PB) modes in the edge pedestal, which arise due to strong pressure and current density gradients [2]. In large aspect ratio devices these modes have ideal character and are well understood [3]. However, a long-standing problem has been the reliable modeling of such stability boundaries in some ST scenarios, where ideal-MHD models often predict stability for ELMing discharges [4]. We investigate current- and pressure-driven stability limits in ELMing discharges in NSTX and MAST, as well as ELM-free wide-pedestal H-mode and enhanced pedestal H-mode scenarios in NSTX. In simulations with the state of the art extended-MHD code M3D-C1 [5], it is found that plasma resistivity can significantly alter macroscopic edge-stability in ELMing H-mode discharges in NSTX [6]. These discharges are limited by resistive kink-peeling modes, while both ELM-free scenarios appear limited by ideal ballooning modes [7]. While MAST discharges are often seen to be unstable to ballooning modes, recent results in MAST-U indicate the presence of kink-peeling modes. We investigate whether the impact of resistivity on PB stability is a result of aspect ratio or profile alterations due to Li coating in NSTX. We find that the simulation predictions are consistent with experimental observations in the considered discharges. The model thus enables higher fidelity predictions for ELM thresholds and presents a valuable basis in the quest for a predictive model for ELMs in low-aspect ratio tokamaks. This is an important step towards a compact fusion power plant.

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References

[1] H. Zohm, Plasma Phys. Control. Fusion **38**, 105 (1996)
[2] P. B. Snyder et al., Physics of Plasmas **9**, 2037 (2002)
[3] P. Snyder et al., Nuclear Fusion **51**, 103016 (2011)
[4] A. Diallo et al., Nuclear Fusion **53**, 093026 (2013)
[5] S. C. Jardin, N. Ferraro, J. Breslau, and J. Chen, Computational Science & Discovery **5**, 014002 (2012)
[6] A. Kleiner, N. Ferraro, A. Diallo, and G. Canal, Nuclear Fusion **61**, 064002 (2021).
[7] A. Kleiner, N. Ferraro, G. Canal, A. Diallo, and R. Maingi, Nuclear Fusion **62**, 076018 (2022).

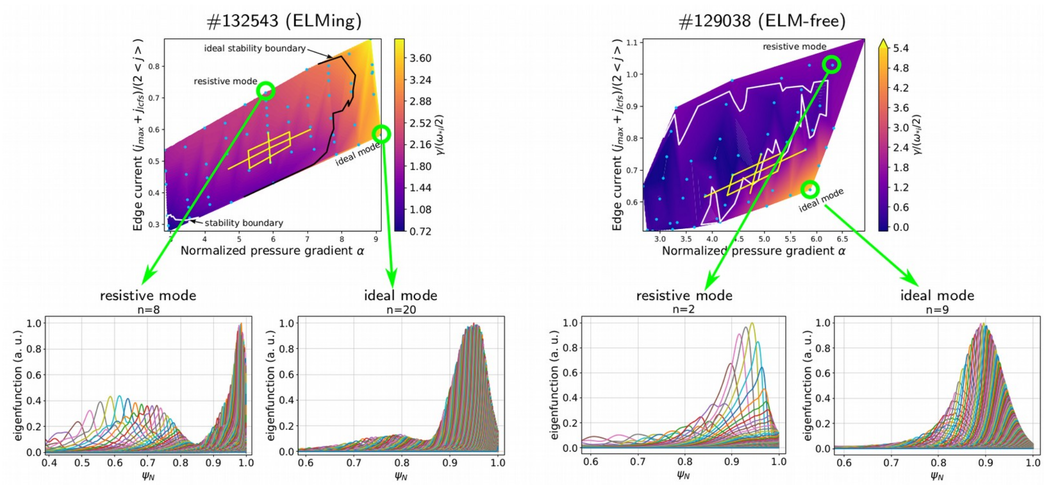

Figure 1: Poloidal spectrum of resistive and ideal peeling-ballooning modes in NSTX. Resistive modes exhibit a strong scaling with resistivity and are crucial to capture the stability limits. (left) ELMing discharge 132543. (right) ELM-free wide pedestal H-mode discharge 129038.