Multi-Device Study of Pedestal Width Scaling Using a Gyrokinetics-Based Model

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Using a new kinetic ballooning mode (KBM) gyrokinetic threshold model, GKPED, we find the pedestal width-height scaling for multiple tokamaks. At tight aspect ratio, GKPED reproduces NSTX's experimental linear pedestal width-height scaling for ELMy H-modes [1] , overcoming previous issues with tight aspect ratio pedestal prediction [2]. At regular aspect ratio, we reproduce the square root pedestal width-height scaling for previously published DIII-D discharges [3]. Our model uses EFIT-AI [4] to calculate global equilibria with self-consistent bootstrap current, and can be applied to any H-mode equilibria. For ELMy NSTX discharges, KBM physics is needed to match the experimental data: we find that infinite-n MHD stability overpredicts pedestal pressure. For regular aspect ratio, however, we find closer agreement between ideal and kinetic ballooning mode width scalings. Combined with peeling ballooning mode (PBM) stability [5,6], our model will calculate a maximum inter-ELM pedestal width and height based on KBM and non-ideal PBM stability. GKPED also makes quasilinear predictions for turbulent pedestal transport during pedestal evolution including the effects of increasing pressure with varying temperature and density contributions. This work is an important step forward towards a unified predictive capability of pedestal stability and transport across tokamak equilibria across a range of tokamak operating space.

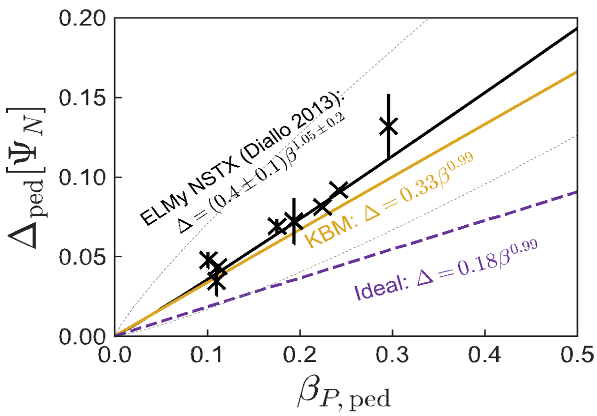

Figure 1:NSTX Δ_{ped} versus $\beta_{P,ped}$ KBM (GCP) scaling, ideal (BCP) scaling, and ELMy H-mode experimental points.

We combine linear local gyrokinetics with a self-consistent variation of pedestal width Δ_{ped} and height $\beta_{P.ped}$ to predict the critical pedestal scaling $\Delta_{ped}=C(\beta_{P.ped})^{\gamma}$ across devices [7]. Our prediction imposes the Gyrokinetic Critical Pedestal (GCP) pressure gradient constraint, obtained from KBM stability. The KBM critical gradient is always lower than the ideal mode, whose stability we calculate to produce a Ballooning Critical Pedestal (BCP) width constraint. For NSTX, the GCP gives $\Delta_{ped} =0.33(\beta_{P.ped})^{0.99}$ and the BCP $\Delta_{ped} =0.18(\beta_{P.ped})^{0.99}$, shown in Fig. 1. The maximum $\beta_{P.ped}$ at any given width also depends on how the pedestal pressure is varied, due to the bootstrap current's differential dependence on density and temperature gradients [9]. We discuss transport implications of the dependence of pedestal width on density and temperature, and show pedestal scalings for additional tokamaks. This work was supported by US Department of Energy Contract No. DE-AC02- 09CH11466.

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