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A gyrokinetic model for pedestal width-height scaling across aspect ratio

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We find the pedestal width-height scaling for multiple tokamaks using a new kinetic ballooning mode (KBM) gyrokinetic threshold model, GKPED. 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]. We reproduce the square root pedestal width-height scaling at regular aspect ratio 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

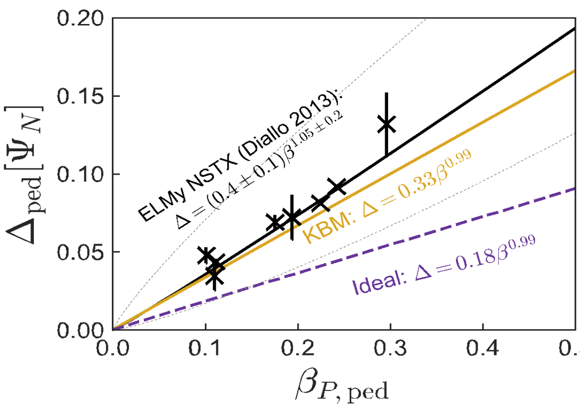

Figure 1:NSTX Δ_{ped} versus $\beta_{P,ped}$ KBM (GCP) scaling, ideal (BCP) scaling, and ELMy H-mode experimental points.

agreement between ideal and kinetic ballooning mode width scalings. In addition to device-specific results, we report the effect of aspect ratio and plasma shaping on width-height scalings, showing the dependence on various shaping parameters. 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. This work is an important step towards a unified predictive capability of pedestal stability and transport across tokamak equilibria across a range of operating space.

We combine linear local gyrokinetics with a self-consistent variation of pedestal width $\Delta_{\rm ped}$ and height $\beta_{\rm P,ped}$ to predict the critical pedestal scaling $\Delta_{\rm ped}=C(\beta_{\rm P,ped})^{\gamma}$ 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 $\Delta_{\rm ped}$ $=0.33(\beta_{\rm P,ped})^{0.99}$ and the BCP $\Delta_{\rm ped}$ $=0.18(\beta_{\rm P,ped})^{0.99}$, shown in Fig. 1. The maximum $\beta_{\rm P,ped}$ 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.

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