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Gyrokinetic prediction of microstability and transport in NSTX H-mode pedestals

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A large variation in pedestal structure was observed in NSTX H-modes. In particular, the wide pedestals ($\Delta\psi_N$=0.3-0.4) observed in low-recycling regimes (e.g. using lithium-coated divertor targets [1]) exhibit the high confinement ($H_{98}\leq1.8$) and bootstrap fraction ($f_{BS}\leq0.7$) required for 100% non-inductive scenarios in compact pilot plant concepts. Current state-of-the-art pedestal models like EPED [2], based on (i) peeling-ballooning stability limits and (ii) kinetic ballooning mode (KBM) transport limits, are so far unable to predict these pedestal structures at low aspect ratio. Previous gyrokinetic analyses for NSTX [3] predict that in addition to KBM there are other theoretical instabilities that may play a role including microtearing modes (MTM), trapped electron modes (TEM), and electron temperature gradient (ETG) modes, similar to recent analysis at conventional aspect ratio [4,5].

Gyrokinetic analysis (CGYRO [6]) has continued to further characterize the linear micro-stability thresholds and nonlinear transport of these various mechanisms that will eventually be required to form the basis of a predictive model. All the NSTX pedestals investigated thus far (narrow to wide, ELMy or ELM-free) are found to be within ~10% of the local KBM pressure gradient thresholds across the entire pedestal (Fig. 1), indicating that KBM remains a viable candidate for constraining the maximum pressure gradient at low aspect ratio.

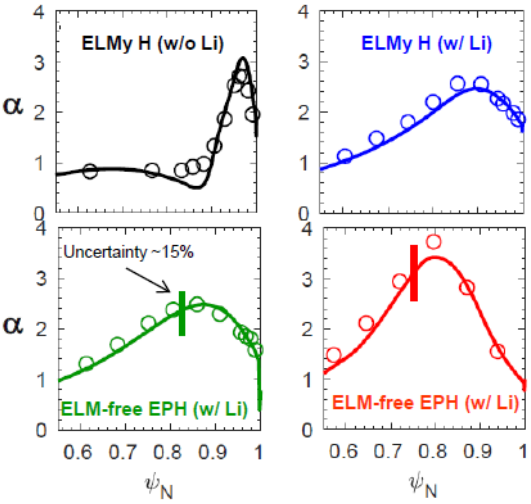

Fig. 1. (lines) Experimental profiles of $\alpha=-q^2 2\mu_0\nabla P/B^2$, compared with linear KBM thresholds predicted by CGYRO (symbols), for four NSTX H-mode pedestals.

However, the ratio of electron particle to thermal diffusivity predicted for KBM is much larger than experimentally inferred from SOLPS. Other transport mechanisms are instead likely responsible for establishing profiles prior to reaching KBM limits. Gyrokinetic analysis predicts that ion-scale MTM and TEM instabilities are unstable across the various pedestals. Electron-scale ETG is unstable in the outer half region of the pedestal where experimental values of $\eta_{e,exp}$ (ratio of normalized electron temperature and density gradients) are larger than predicted ETG thresholds $\eta_{e,ETG,crit}\approx1.4$-$1.6$.

Electron heat fluxes predicted from nonlinear ETG simulations approaches experimental values in some cases but are unlikely to robustly account for all the transport. An ETG pedestal transport model is presented, integrating similar recent results from conventional aspect ratio analysis [7], for use in future predictive modeling. Nonlinear MTM simulations are progressing to determine whether they can account for the remaining experimental transport. Neoclassical simulations (NEO) also predict substantial particle and ion thermal transport that must be considered to develop an integrated understanding of kinetic profiles within the pedestals.

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