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A FIRST PRINCIPLES PREDICTIVE MODEL OF THE PEDESTAL HEIGHT AND WIDTH: DEVELOPMENT, TESTING, AND ITER OPTIMIZATION WITH THE EPED MODEL

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This effort develops and tests a model for the H-mode pedestal height and width based upon two fundamental and calculable constraints: 1) onset of non-local peeling-ballooning (PB) modes at low to intermediate mode number, 2) onset of nearly local kinetic ballooning modes at high mode number. Calculation of these two constraints allows a unique, predictive determination of both pedestal height and width. Recent versions of the model are first principles, with no parameters taken from observation, and include important kinetic effects. Extensive successful comparisons to existing experiments, and ITER prediction and optimization are presented.

The pressure at the top of the edge transport barrier (or "pedestal height") strongly impacts global confinement and fusion performance. Accurately predicting the pedestal height in ITER is an essential element of prediction and optimization of fusion performance. Investigation of intermediate wavelength MHD modes (or "PB" modes) has led to improved understanding of important constraints on the pedestal height and the mechanism for ELMs. The combination of high-resolution pedestal diagnostics, including substantial recent improvements, and highly efficient stability codes, has made edge stability analysis routine on several major tokamaks, contributing both to understanding and to experimental planning and performance optimization. Extensive testing has led to substantial confidence in the accuracy of the calculated PB constraint on the pedestal height [e.g. 1,2].

Calculation of the PB stability constraint over a broad range of toroidal mode numbers (typically *n*~3-30), with an efficient MHD code, such as ELITE [3], which has been developed and optimized specifically for this purpose, provides a constraint on the pedestal height, as a function of the edge barrier width (or "pedestal width"). By using model equilibria with a small set of parameters, it is possible to calculate the PB constraint predictively [1], both for future experiments on existing devices and for future devices such as ITER. However, an additional constraint is needed in order to predict both the pedestal height and width. The EPED series of models employ local onset of the kinetic ballooning mode (KBM), as a second constraint. A simplified form of the KBM constraint is developed using a "ballooning critical pedestal" (BCP) technique, in which an edge barrier profile is taken to be ballooning critical when the inner half of it is at or beyond the local ballooning threshold. BCP studies on a broad range of typical equilibria find a dominant dependence of the pedestal width (in poloidal flux) on the value of poloidal beta at the top of the pedestal, yielding the relation $\Delta_{\psi_N} = c_1 \beta_{p,ped}^{1/2}$, where c_1 is weakly varying, with typical values in the range ~0.07-0.09. A value of c_1=0.076 was chosen for definiteness in EPED1 [4]. This simple KBM relation is then combined with direct calculations of PB stability on model equilibria, to yield a unique prediction of the pedestal height and width, as shown by the filled circle in Fig. 1(a), which can then be compared to a past or future experiment [open square in Fig. 1(a)].

The newly developed EPED1.5 model improves upon EPED1 by calculating both the PB and KBM constraints directly for each case, using sets of model equilibria, and the BCP technique. This yields a prediction which is fully first principles, in the sense that no parameters are taken from observations, and it also takes into account the weaker parameter dependencies in the KBM relation, beyond the poloidal beta dependence emphasized in EPED1. The pedestal height and width are again predicted via the intersection of the PB and KBM constraints, similarly to Fig. 1(a).

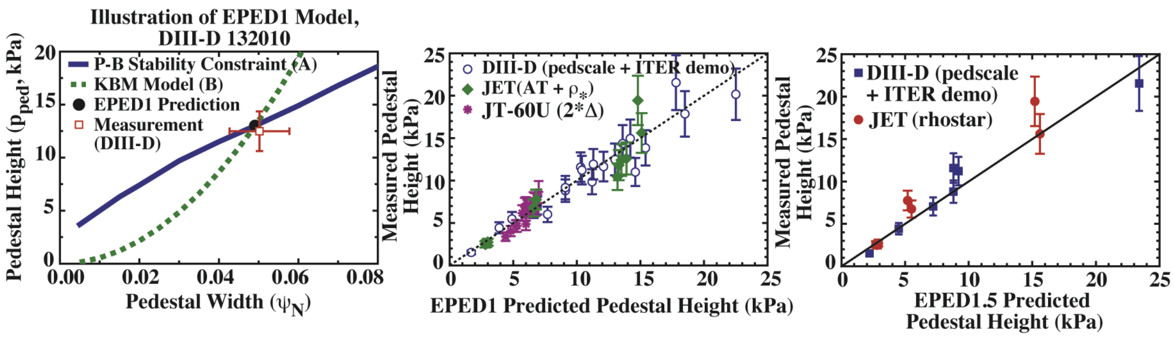

Fig. 1. (a) The EPED model predicts a pedestal height and width (solid circle) from the intersection of peeling-ballooning (solid line) and KBM (dashed line) constraints. This can then be compared with observations, here shown by an open square, for DIII-D discharge 132010 (b) The EPED1 predicted pedestal height is compared to observations on DIII-D, JET [6] and JT-60U [7], finding good agreement (c) The new EPED1.5 model is compared to an initial set of DIII-D and JET observations, finding good agreement.

The EPED model has been extensively tested across a range of experiments on several devices. A dedicated experiment to test the model was conducted on DIII-D, in which EPED1 predictions were made before the experiment, and plasma current, toroidal field and triangularity were varied by a factor of 3, to yield more than an order of magnitude variation in the pedestal height, and a factor of three variation in the pedestal width. The EPED1 model was found to be in good agreement with the observations, with a ratio of predicted to observed pedestal height of 1.03±0.13, and of width of 0.93±0.15 in 17 discharges [4,5]. A comparison across a set of 21 DIII-D, 16 JT-60U [7] and 11 JET [6] discharges found a similar level of agreement (1.02±0.14) as shown in Fig. 1(b). The model was also found to recover the observed variation of the pedestal height with time on JT-60U, a phenomenon attributed to relatively small variations in density and global Shafranov shift by EPED1. A recent experiment on Alcator C-Mod, where EPED1 predictions were made before the experiment, has produced good initial agreement, with further analysis underway. Initial tests of the new EPED1.5 model have also been conducted. The new model is found to accurately predict the observed pedestal height in a set of 7 DIII-D and 7 JET discharges, with a ratio of predicted to observed pedestal height of 0.97±0.19, as shown in Fig. 1(c). The EPED model is also consistent with the observation of the lack of a positive correlation between pedestal width and gyroradius [5-7]. Additional ongoing tests on several devices, with multiple parametric variations, will be presented. Development of the EPED2 model, which will include arbitrary aspect ratio and additional kinetic effects in its KBM calculations, is ongoing, with planned comparisons to observations on NSTX and MAST.

Predictions for ITER from both EPED1 and 1.5 yield a high pedestal ($\beta_{N,ped}$~0.6) due to strong shaping, and are used to explore optimizations of both pedestal, and, in conjunction with core transport and MHD studies, global performance in ITER.

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