Plan/Design/Predict in the Pedestal: Results and Lessons Learned from Experiments to Test Pre-Experiment EPED Predictions*

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Developing a validated predictive capability is critical to the design, optimization and successful operation of fusion experiments. However, in part because of the coupled, multi-physics nature of tokamak plasmas, it can be challenging to isolate physics and control an experiment sufficiently to precisely test predictions. Here we report on experience with planning, execution and analysis of experiments designed to test pre-experiment predictions from the EPED pedestal model [1,2], beginning with a set of experiments on DIII-D in 2008, and continuing with more recent experiments on DIII-D and Alcator C-Mod. EPED predicts the H-mode pedestal height and width based upon two fundamental and calculable constraints: 1) onset of strongly non-local peeling-ballooning (P-B) modes at low to intermediate mode number, 2) onset of more weakly non-local kinetic ballooning modes (KBM) at high mode number. Model inputs are a set of scalar parameters specifying plasma shape, field, current, pedestal density and global beta (ie global Shafranov shift). In addition to broad statistical tests on several tokamaks [1–6], an important test for the model was to predict pedestal structure before particular experiments were conducted. This was first undertaken on DIII-D, identifying strong parameter dependencies (shape, field, and current) in the model, and then designing experiments to vary them over as broad a range as possible. An initial experiment found fairly good agreement with pre-experiment predictions, though there was some significant variation between planned and achieved input parameters. Uncertainty analysis in these experiments also identified that increased Thomson resolution would be beneficial for pedestal width comparisons, and resolution was later improved by a factor of ~2. More recent DIII-D experiments have used feedback control of density and global beta to more precisely achieve desired input parameters. Maintaining ELMy H-Mode across a broad range of conditions on Alcator C-Mod proved challenging, but a significant data set was obtained which enabled successful tests of the model and identification of the importance of an accurate model of diamagnetic stabilization [5]. EPED was also used to predict the existence of the Super H-Mode regime, and to design experiments which eventually led to its discovery [7]. Coupled core-pedestal modeling enables self-consistent prediction of global beta, and is a promising avenue for future "predict first" experiments.

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