Dependence of the H-mode Pedestal Structure on Aspect Ratio

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We report on a set of experiments between NSTX, MAST, and DIII-D to determine the aspect ratio dependence of the pedestal. The dimensionless parameters of electron collisionality ν_e^* and normalized ion gyroradius ρ_i*were matched at the top of the outboard pedestal, and the widths and gradients were assessed. An accurate prediction of the ITER H-mode pedestal parameters is key in performance projections, e.g. high pedestal temperature is linked to sufficient core energy confinement, while ideal MHD stability appears to set the maximum edge pressure gradient in the pedestal before large edge-localized modes (ELMs) are encountered. Explicit determination of the dependence of the pedestal heights, widths, and gradients on the device inverse aspect ratio ($\varepsilon = a/R$) is receiving increasing attention, because many of the machines in the international database used for scaling to ITER have different aspect ratios. In this regard, a strong dependence of the pedestal on aspect ratio would not be surprising, because variation of the aspect ratio primarily affects the edge magnetic topology. Determination of the effect of aspect ratio can take the form of an explicit aspect ratio term in the pedestal scaling[1], or a multi-machine comparison as reported here.

Previous studies have confirmed the possibility of a strong aspect ratio dependence of the pedestal. For example, a scaling study of the H-mode T_e pedestal width (Δ_{Te}) between DIII-D and JT-60U showed clear differences in the pedestals; specifically $\Delta_{Te} \sim \varepsilon^{0.5}$ if solely attributed to the aspect ratio difference[2]. More recently, stability calculations with the ELITE code rather robustly showed[3] that the pedestal pressure was expected to increase with decreasing major radius at moderate shaping, i.e. triangularity $\delta \sim 0.3$-0.4 (Figure 1). Note that this calculation was done assuming a fixed pedestal width, so that the prediction is effectively of the critical pedestal gradient. Also, the minor radius was held constant, such that the aspect ratio decreased with decreasing major radius. Thus the prediction equates to an increase of the pedestal pressure gradient with inverse aspect ratio. NSTX, MAST and DIII-D are ideal aspect ratio scan candidates, with the first two machines providing a low aspect ratio comparison with $\varepsilon \sim 0.7$, as compared with the DIII-D $\varepsilon \sim 0.35$. We note that the actual NSTX and MAST major radii lie to the left of the x-axis in Figure 1, leading to the prospect of a measurably large difference in the pressure gradient limit before the onset of intermediate-n peeling/ballooning modes.

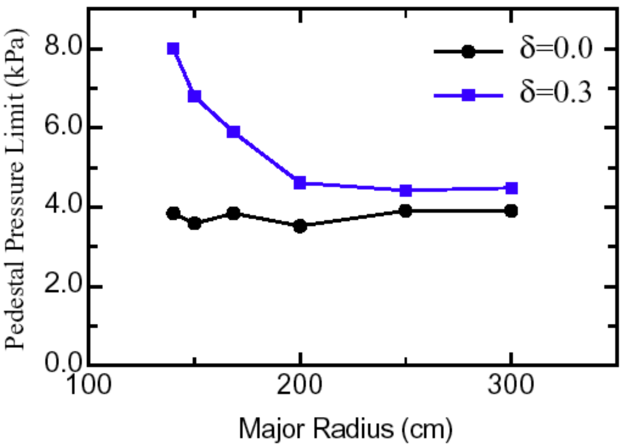

Fig. 1. Dependence of pedestal pressure limit in major radius at a fixed minor radius of 0.603m, i.e. an aspect ratio scan, from Ref. [3].

To test the ELITE calculations, a common double-null shape was developed for these experiments with δ~0.5 and κ~2. Figure 2 shows that small differences in the shape (particularly the squareness, which varied from about 0.0 to 0.2) were difficult to eliminate; however, a squareness scan in DIII-D showed little impact on the pedestal parameters in this experiment. The toroidal fields and plasma currents used were 0.45-0.55 T and 0.6–0.8 MA in all three machines. The dimensionless parameters $\nu_e^* \sim 1$ and $\rho_i^* \sim 0.01$ were matched at the top of the outboard pedestal by variation of the target density and neutral beam heating power while maintaining ELMy H-mode. The pedestal widths and gradients were analyzed in each machine using a 'standard' modified hyperbolic tangent function[4]; the ranges of pedestal top parameters obtained in this manner were n_e^{ped}: 3-5 × 10^{19} m^{-3}, T_e^{ped}: 100-250 eV (e.g. Figure 3), and P_e^{ped}: 0.4-1.5 kPa.

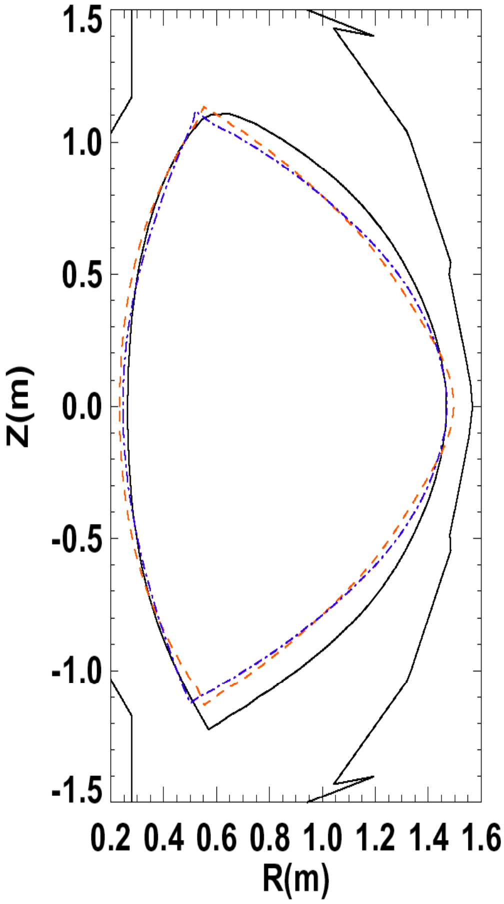

Fig. 2. Common double-null shape developed for aspect ratio scan. Color code: NSTX (black), MAST (red), and DIII-D (blue). The DIII-D shape was shifted inward by 0.81m.

The pedestal n_e, T_e and P_e widths measured in DIII-D for these discharges were between 6-8% in ψ_N (normalized poloidal flux), i.e. almost twice as large as the normal range of widths at the normal B_t=2.1 T. In comparison, the pedestal widths in MAST were between 1.5-4% in ψ_N, and final assessment of the widths in NSTX is still in progress. Stability analysis with the ELITE code is commencing on all machines and will be presented at the conference.

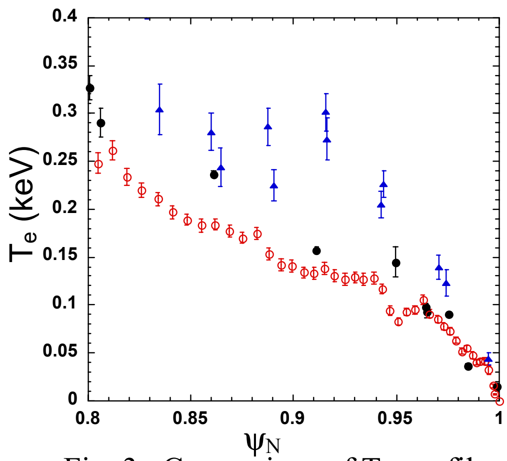

Fig. 3. Comparison of Te profiles with color code: NSTX (black), MAST (red), and DIII-D (blue).

References

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