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Recent joint experiments on DIII-D and JET have explored the dependence of the H-mode edge transport barrier (ETB) width and Type I edge localized mode (ELM) characteristics on plasma dimensionless parameters at the top of the H-mode pedestal. The highlights of these studies are the observation of at most a weak inverse dependence of the density and temperature pedestal widths on the ion gyroradius ($\rho^*=\rho/a$), and agreement between the measured width of the H-mode edge steep gradient region and the predictions of the EPED1 model [1] in which the width scales as $(\beta_P^{PED})^{1/2}$. These are both favorable results for projections of performance in ITER.

The dependence of the ETB width and ELM size on ion gyroradius, $\rho^*=\rho/a$, is an important consideration since ρ^* in ITER will be smaller than existing tokamaks. Some theories based on a balance between *ExB* velocity shear and drift wave growth rate suggest the width should decrease as $(\rho^*)^{1/2}$, while theories based on ion orbit loss mechanisms for rotation drive suggest a linear dependence on ρ_{POL}. For ELM size scaling no theoretical basis has thus far been established.

The determination of the experimental dependence of the ETB width and ELM size on ρ^* [2,3] exploits the size difference of JET and DIII-D to achieve a factor of 4 variation in ρ^*, keeping other dimensionless parameters at the top of the H-mode pedestal fixed. JET results include data from the recently installed high resolution Thomson scattering system [4]. A strong positive dependence of the ETB width on ρ^* is ruled out by these experiments. The width of the steep gradient region of the electron temperature (T_e) and density (n_e) profiles varies as $w_{Te} \propto (\rho^*)^{-0.17\pm08}$ and $w_{ne} \propto (\rho^*)^{-0.10\pm0.08}$ respectively (Fig. 1). A scaling of $w_{Te} \propto (\rho^*)^x$ with $x \geq 0.25$ is ruled out to a 95% confidence level, and to 80% confidence for $x \geq 0.1$. These observations are consistent with beam emission spectroscopy measurements on DIII-D that show no change in the radial correlation lengths of density fluctuations in the ETB as a function of ρ^*. Although the density width is relatively independent of ρ^*, for DIII-D a shift of the density vs temperature profiles is observed, which is consistent with what would be expected from the variation in the depth of neutral particle penetration. For JET no variation in the relative temperature and density pedestal position is observed.

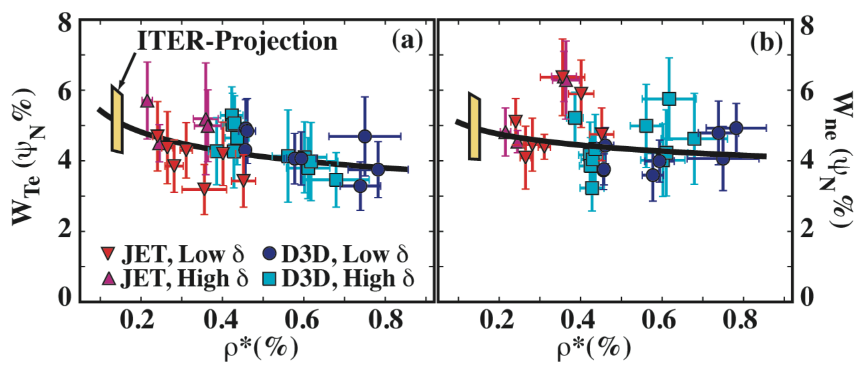

Fig. 1. Variation of the width of the H-mode edge steep gradient region in the electron temperature, w_{Te}, (a), and density, w_{ne}, (b), in normalized poloidal flux space as a function of ρ* for JET and DIII-D discharges at both low and high plasma triangularity.

The ELM size, measured as the ratio of the energy loss at an ELM to the H-mode pedestal energy, increases dramatically with ρ^* on DIII-D, but the trend is not continued to smaller ρ^* discharges on JET. Although the inward shift of the pedestal density versus temperature profile at large ρ^* (and lower n_e) on DIII-D produces some broadening of the width of the region with high pressure gradient, the associated broadening of the peeling-ballooning mode eigenfunction was too small to account for the large increase in ELM size with ρ^*. The ELM energy loss in the large ρ^* discharges greatly exceeds the value expected based on an established scaling with collisionality [5], but it correlates with the proximity to the critical density for transition to the low density L-H power threshold regime [6] (Fig. 2). The ELM size is generally observed to increase when the heating power is near the L-H threshold on both JET and DIII-D. We will discuss the scaling of the ELM energy loss as a function of other parameters from a more extensive database of JET and DIII-D discharges.

In DIII-D discharges covering a range of plasma shapes and pedestal pressures, the width of the H-mode edge steep gradient region is in agreement with the predictions of the EPED1 model [1] in which the width scaling is derived from the magnetic shear dependence of the kinetic ballooning mode critical pressure gradient. We will present results of the scaling of the ETB width and ELM size as a function of pedestal β, and a more extensive comparison with EPED1 (which predicts optimistic pedestal temperatures of 3.5-5 keV for ITER [1-3]), based on a broader database of discharges from both tokamaks.

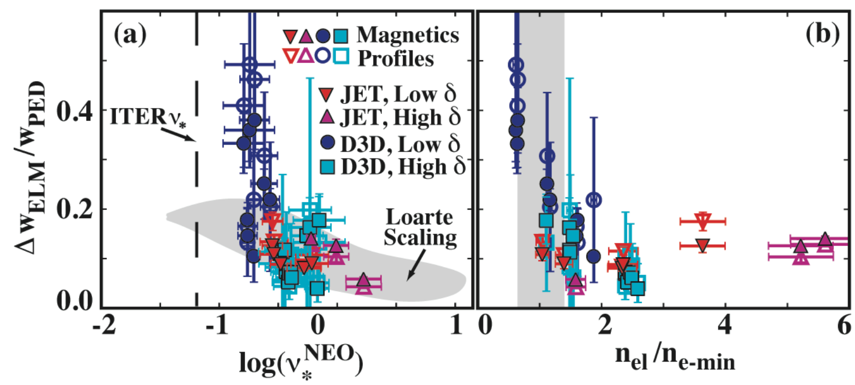

Fig. 2. Scalings for Type I ELM energy loss, $\Delta W_{ELM}/W_{PED}$, for ρ^* scan discharges. (a) $\Delta W_{ELM}/W_{PED}$ vs collisionality, previous data for several tokamaks is shown in the gray region [5], (b) vs ratio of the line averaged density to density for transition into the low density L-H power threshold regime [6], gray region representing uncertainty in $n_{e\text{-min}}$.

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[1] P.B. Snyder *et al.,* Phys. Plasmas **16** (2009) 056118
[2] M.N.A. Beurskens *et al.,* Plasma Phys. Control. Fusion **51** (2009) 124051
[3] T.H. Osborne, *et al*., "Scaling of H-mode Pedestal and ELM Characteristics with Gyro-radius in the JET and DIII-D Tokamaks," submitted to Nucl. Fusion.
[4] M.N.A. Beurskens *et al.*, Nucl. Fusion **48** (2008) 095004
[5] A. Loarte *et al.,* Plasma Phys. Control. Fusion **45** (2003) 1549
[6] Y. Martin *et al.,* J. Phys. Conf. Ser. **123** (2008) 12033