Pedestal structure and transport in the EPH and VH-modes

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We report on a comparative study of two enhanced confinement regimes: the VH-mode observed at DIII-D [1], and the NSTX Enhanced Pedestal (EP) H-mode [2]. These regimes are characterized by excellent energy confinement, with confinement times enhanced by a factor of more than three over L-mode scaling. This makes them potentially very attractive as operational regimes in future devices, with higher confinement allowing for a more compact device. However, both regimes tend to be transient (although long-lived EP H-modes have been observed). The present work aims to improve the physics understanding of these two regimes, with a goal towards producing and controlling them reliably so that they can be developed as steady-state operating scenarios.

Both the VH and EP H-modes show changes in the edge pedestal structure, with increases in temperature and rotation above the equivalent H-mode levels that are qualitatively quite similar. This is illustrated in Figure 1, with shows pedestal profiles for the VH (left) and EP H-mode (right), along with H-mode profiles in each case (dashed curves). For both the VH and EP H-mode cases, the edge density profile is similar to that in H-mode. The pedestal electron temperature profile shows a modest increase over H-mode for both enhanced confinement regimes, while a stronger increase is observed in the ion temperature. The VH and EP H-modes also show an increase in the toroidal rotation across the edge, and an increase in the rotation gradient above the H-mode level.

It has been shown that, in the EP H-mode, the ion temperature gradient near the edge strongly correlates with the gradient in the toroidal rotation, with the pedestal ion temperature increasing approximately linearly with rotation shear [2]. A similar trend has been found from analysis of recent VH experiments. As shown in Figure 2, the ion temperature gradient in the edge generally increases with

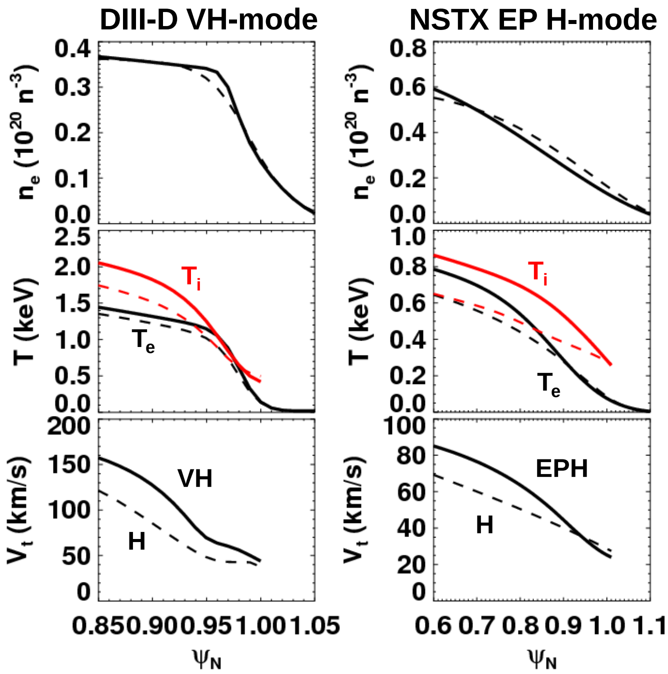

Figure 1: Profiles of a,d) electron density, b,e) electron (black) and ion (red) temperatures, and c,f) toroidal rotation during VH (a-c, solid curves), and EP H-modes (d-f, solid curves). Dashed curves indicate H-mode profiles.

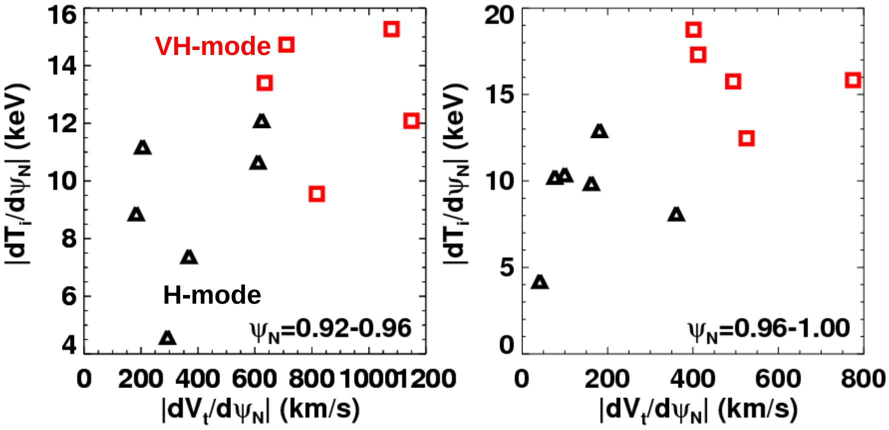

Figure 2: Dependence of ion temperature gradient on toroidal rotation shear in DIII-D H- (black triangles) and VH-modes (red squares), averaged over radial regions of a) ψ_N=0.92-0.96 and b) ψ_N=0.96-1.0

toroidal rotation gradient, with VH-mode discharges (red squares) showing higher values of both than H-mode discharges (black triangles). This correlation suggests that increasing shear stabilization of turbulence may be playing a role in the enhanced confinement of both the VH and EP H-mode (although, in NSTX, initial analysis suggests that both the H- and EP H-modes show near-neoclassical ion transport). The apparent importance of rotation also suggests that these enhanced confinement regimes could potentially be controlled by influencing the rotation profile via, e.g., 3D magnetic perturbation.

The EP H-mode does not appear to be associated with a strong reduction in turbulence, as might be expected if turbulence suppression due to flow shear were responsible for reduced transport. Fluctuation measurements from a variety of diagnostics generally show similar (and often modestly higher) fluctuation levels, without a clear trend differentiating H- and EP H-modes (see, for example, the measurements using Beam Emission Spectroscopy (BES) shown in Figure 3). However, measurements may indicate a change in the nature of the turbulence, with an increase in magnetic fluctuations often (though not always) observed, suggesting a trend towards more electromagnetic-dominated modes; BES has also measured a reduced poloidal correlation length in EP H, again suggesting a change in the nature of the turbulence even though the fluctuation level is not dramatically affected.

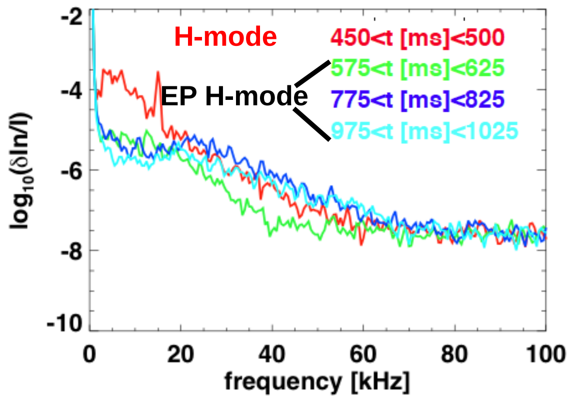

Figure 3: Density fluctuation amplitude spectra from a near-edge BES channel during H-mode (red) and EP H-mode phases (green, blue, cyan) of an NSTX discharge

Analysis of the transport and turbulence characteristics, calculations of the edge macro- and micro-stability, and the results of recent experiments aimed at controlling these enhanced confinement regimes, will be presented.

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