Topic: EX-C

L-H Threshold Studies in NSTX

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The National Spherical Torus Experiment (NSTX) has recently carried out a series of L-H threshold experiments in support of the high priority ITER and ITPA needs, addressing such issues as effect of plasma ion species, applied 3D fields, wall conditioning, plasma current and plasma shape/X-point position on the L-H power threshold and local parameters leading up to the transition. The high-confinement, or H-mode[1], in which broader density and temperature profiles lead to both enhanced MHD stability and higher stored energies, is the preferred operating regime for ITER. The power threshold for this transition has been characterized to date using a small subset of global parameters[2], although it is well-recognized that a wider set of both global and local parameters play a critical role in determining the conditions necessary for the L-H transition. NSTX is a low aspect ratio tokamak with R/a=0.85/0.65 m ~1.3, which has run with neutral beam and High Harmonic Fast Wave (HHFW) heating powers up to 7 MW and 4 MW respectively. NSTX typically operates at toroidal fields of ~0.45 T. NSTX has implemented an external coil set capable of applying n=1 to 3 fields at the plasma edge, and it also has conditioned the plasma facing graphite tiles with evaporated lithium.

High Harmonic Fast Wave Heating (HHFW) was used to study the scaling of the L-H power threshold in helium and deuterium discharges It was found that to within the uncertainties of the HHFW heating efficiency for the injected wave number, k_θ=-8 m^{-1}, which was on average 30% of the power at the antenna, the quantity $P_{LH}=P_{HHFW,heat}+P_{OH}$ was the same for the two species. When the dW/dt term was included in the heating power, $P_{LH}'=P_{LH}-dW/dt$ where W is the plasma stored energy, the helium discharges exhibited threshold powers that were approximately 30% greater than that for the deuterium discharges. These results are shown in Fig. 1. Also shown in the figure are the powers at the H-L back-transition, which is less than that for the L-H transition for P_{LH}, indicating hysteresis, but are comparable to P_{LH}', indicating no hysteresis. Here, the powers were normalized to line-averaged density to compensate for the modest variation in density (~20%) among the discharges.

The power threshold was also found to depend critically on other global conditions. There was a ~35% reduction in the threshold power normalized by line-averaged density for discharges using lithium evaporation to coat the plasma facing components than for those that did not. Application of largely non- resonant n=3 fields at the plasma edge, potentially critical for suppression of ELMs in ITER, resulted in about a 65% increase in density-normalized threshold power. In these discharges, the increase appears to be a 3D effect in that the edge rotation, rotation shear and E_r were the same with and without application of 3D fields. The plasma current in NSTX has a controlling factor in the L-H transition, with normalized threshold powers almost a factor of two greater at 1 MA than at 0.7 kA. XGC0

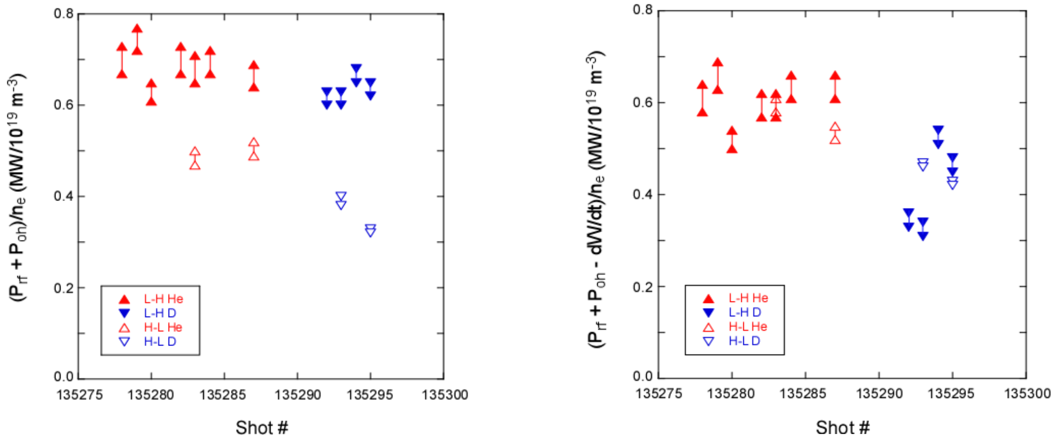

Fig. 1 Heating power normalized by density required at the L-H and H-L transitions for helium (red) and deuterium (blue) discharges. The heating power is defined as the absorbed HHFW plus Ohmic power (left panel). The dW/dt term is included in the definition in the data show in the right panel.

neoclassical calculations support this result in that the in that the edge E_r well is predicted to be greater at lower current than at higher current in NSTX. Finally, motivated by XGC0 calculations which show strongest ion loss and largest edge E_r and E_r' when the X-point is at large R, experiments indicate that the lowest auxiliary heating power to transition into the H-mode is required at low triangularity, although the results are less well-ordered when the ohmic and dW/dt terms are considered[3].

Careful attention was paid to how the local parameters at the edge differ for discharges that transition into the H-mode as compared to those at slightly lower power that remained in the L-mode. To within the constraints of temporal and spatial resolutions, no systematic difference in T_e, n_e, p_e, T_i, v_ϕ or their derivatives was found.

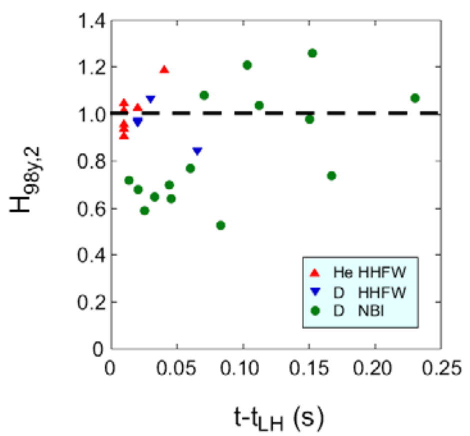

Fig. 2 Confinement quality as a function of time after the L-H

Finally, the confinement quality of discharges transitioning into the H-mode was examined. It was found that the HHFW heated discharges, in both helium and deuterium, could attain values of $H_{98y,2}$~1 in ELM-free conditions for powers just above the power threshold. Furthermore, NBI heated, ELM-free H-modes could also achieve $H_{98y,2}$~1, but only after a sufficient time after the L-H transition, as is seen in Fig. 2. Within 50 ms after the transition, however, H98y,2 was < 1.

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References:

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