

NSTX Research on the Physics of High-Performance ELM-Free Regimes

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One focus of recent analysis of discharges from the National Spherical Torus Experiment (NSTX) has been on quasi-steady regimes devoid of large ELMs. Three targeted areas were the enhanced pedestal H-mode (EP H-mode), transport and

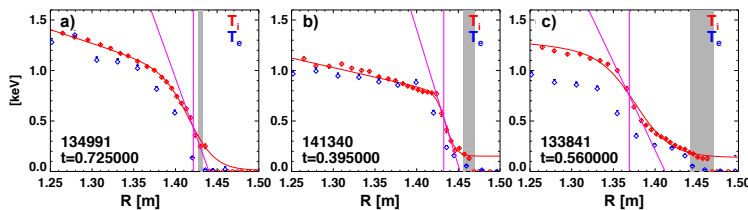


Fig 2: T_e and T_i profile shapes for three EP H-mode examples.

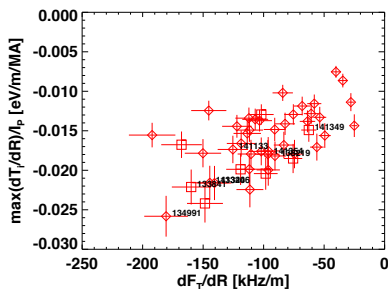


Fig. 3: Correlation between the T_i gradient on the local toroidal rotation shear.

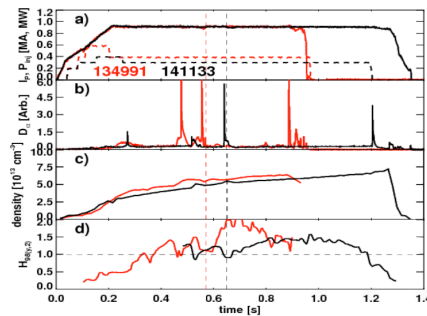


Fig 1: EP H-mode discharges, including a recently observed, near-stationary EP H-mode example (141133). The EP H-mode transition is triggered by ELMs at the times indicated by dotted lines.

turbulence dynamics in the ELM-free H-mode pedestal, and cases where low-amplitude edge harmonic oscillations (EHOs) were observed.

EP H-mode: The EP H-mode is a confinement regime characterized by

having a region of very steep ion temperature gradient at the plasma edge, coincident with a region of strong toroidal rotation shear. Long-pulse EP H-mode plasmas have been observed (Fig. 1), including a case exhibiting very high confinement (134991 [1]), and a very quiescent case that is sustained through the available heating duration (141133). Examination of many cases (Fig. 2) shows that the region of steep ion temperature gradient can be located very near the separatrix, or shifted substantially inwards. However, these cases share a common dependence of the ion temperature gradient on the local rotation shear (Fig. 3). Fluctuation amplitudes in the EP H-mode pedestals have been assessed using beam

emission spectroscopy (BES): no ubiquitous reduction in fluctuation amplitudes compared to H-mode has been observed. However, some changes in the fluctuation characteristics may be present, including a small increase in magnetic fluctuation levels and a reduction in the poloidal correlation length. The ion thermal transport is found to be close to neoclassical, as determined by the Chang-Hinton, NCLASS, and NEO calculations. Reliable EP H-mode triggering has been observed at low q_{95} , but these cases have been difficult to extend to long pulse.

Pedestal Transport and Turbulence in Lithium Conditioned ELM-free H-modes [2-4]: The lack of ELMs, along with changes to the carbon transport due to modifications of the main-ion temperature and density profiles, explains the core carbon accumulation in discharges with lithium PFC conditioning, though anomalous carbon transport in the pedestal is required to explain the details of the profile shapes. The enhancement of neoclassical lithium diffusivities due to the high

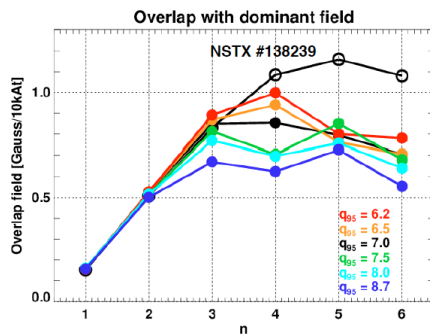


Fig. 5: Overlap of the applied field with the dominant field component as a function of toroidal mode number, for an NSTX-U q_{95} scan. The results for an NSTX case are illustrated as the topmost black curve.

carbon concentration is partly responsible for the low lithium core concentration. Experimental analysis of pedestal turbulence amplitudes from BES show trends consistent with TEM/KBM turbulence drives; the trends are notably inconsistent with ITG driven turbulence. These trends are consistent with linear microstability calculations made with the GENE code.

Low-Amplitude EHOs: Low-amplitude EHOs have been previously observed in NSTX [5]; these have proven too low in amplitude to modify the transport, but may conceivably be driven to larger amplitude. Recent research using the BES diagnostic has confirmed that the modes are localized in the pedestal (Fig. 4). ELITE calculations show that the pedestals in these plasmas are near the peeling boundary, similar to QH-mode cases in DIII-D that exhibit EHOs. The efficacy of driving these perturbations with the HHFW antenna has been assessed using model NSTX-U equilibria (Fig. 5) and the IPEC code. It is found that the optimal coupling occurs at lower q_{95} .

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[1] R. Maingi, et al., Phys. Rev. Lett., **105**, 135004 (2010).

[2] F. Scotti, et al., Nuclear Fusion **53**, 083001 (2013)

[3] D.R. Smith, et al., Physics of Plasmas **20**, 055903 (2013).

[4] D.R. Smith, et al., Nuclear Fusion **53**, 113029 (2013).

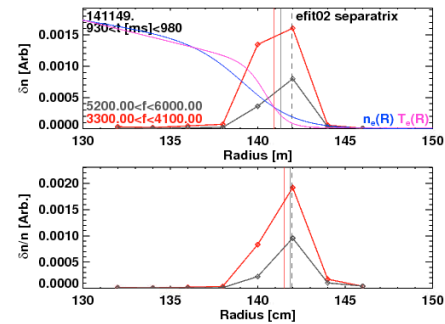


Fig. 4: Profiles of the BES fluctuation amplitude (proportional to δn_e) (top), and the amplitude normalized to the DC level (proportional to $\delta n_e/n_e$) (bottom). The top frame additionally shows the tanh fit to the density and temperature profiles during this time period. The red curve is for an $n=3$ mode, while the black curve is for the $n=4$ EHO.

[5] J.K. Park, et al., submitted to Nuclear Fusion.