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

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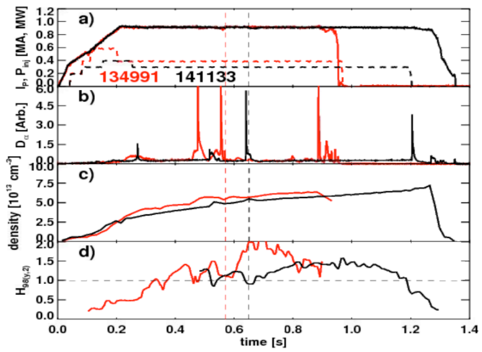

Fig 1: Time traces for EP H-mode discharges, including a recently observed, near-stationary EP H-mode example (141133). The EP H-mode transition is triggered by ELMs at the times indicated by the dotted lines.

As part of the research for the 2013 OFES Joint Research Target on high performance stationary ELM-free regimes, the National Spherical Torus Experiment (NSTX) assessed three topics. These were the enhanced pedestal H-mode (EP H-mode), transport and 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. Examination of many cases (Fig. 2) shows that the region of steep ion temperature gradient can be located at near the separatrix, or shifted substantially inwards. However, these cases share a common dependence of the ion temperature gradient on the local rotation sheer (Fig. 3). Fluctuation

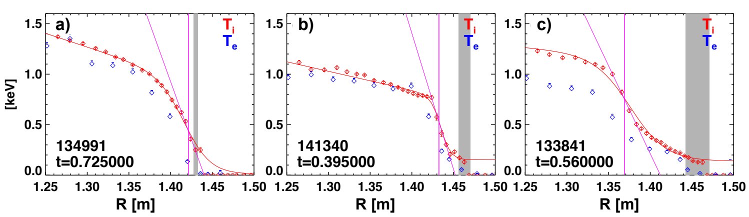

Fig 2: T_e and T_i profile shapes for three EP H-mode examples.

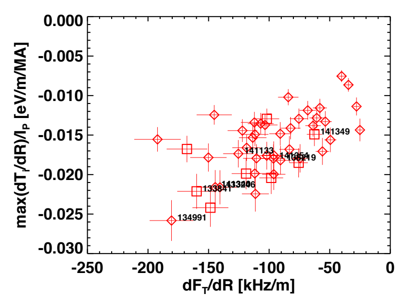

Fig. 3: Correlation between the ion temperature gradient on the local toroidal rotation shear.

amplitudes in the EP H-mode pedestal have been assessed using BES, and no 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 as measured by BES. The ion thermal transport is found to be close to neoclassical, as determined by the Chang-Hinton model, NCLASS, and NEO. Reliable EP H-mode triggering has been observed at low q_{95}, but these cases have been difficult to sustain.

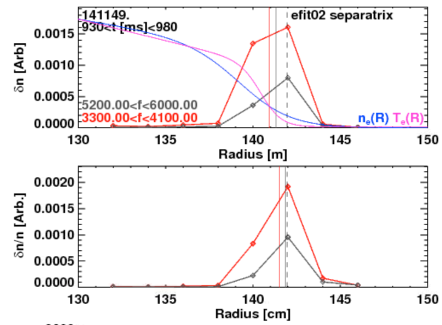

Fig. 4: Profiles of the BES fluctuation amplitude (proportional to δn_e) (top), and the amplitude normalized to the DC level (proportional to $\delta n_e/n_e$) (bottom). The top frame additionally shows the tanh fit to the density and temperature profiles during this time period. The red curve is for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

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

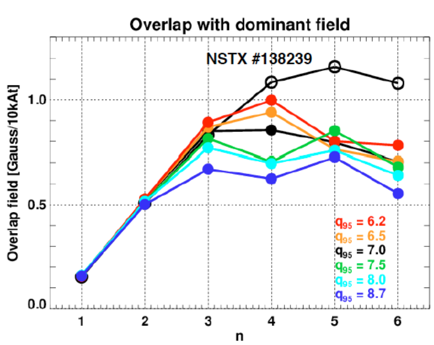

Fig. 5: Overlap of the applied field with the dominant field component as a function of toroidal mode number, for an NSTX-U q_{95} scan. The results for an NSTX case are illustrated as the topmost black curve.

Low-Amplitude EHOs: Low-amplitude EHOs have been previously observed in NSTX [5]. 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). It is found that the coupling to the plasma is less than for NSTX equilibria, with the optimal coupling at lower q_{95}.

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