Dependence of particle transport on collisionality, rotation and MHD in NSTX

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The NSTX spherical torus (ST) is a low-aspect ratio tokamak (A<1.5) that is able to sustain a high plasma β. NSTX operates with B_ϕ~0.35-0.55 T, I_p~0.7-1.1 MA and neutral beam injection (NBI) heating power up to 7.0 MW, leading to core toroidal velocities of the order of 100-300 km/s and $E\times B$ shearing rates up to ~1 MHz. This shearing rate can be up to a factor of three to five greater than typical linear growth rates of long-wavelength ion temperature-gradient modes, suppressing these instabilities partially if not completely. One of the ST predicted benefits is therefore the reduction of the anomalous ion transport, resulting in low core (r/a<0.7) particle diffusivities in good agreement with the values predicted by neoclassical transport theory [1]. Particle and impurity transport properties at low-aspect-ratio remain important for extrapolation to future ST-based devices such as an NHTX and CTF as well as to conventional aspect ratio schemes such as ITER. This paper will describe the results obtained from H-mode experiments aimed at studying, a) impurity transport in a $\nu^*\sim 1/T^2$ scan of NBI heated H-mode plasmas, b) the relationship between particle transport and rotation and, as a by-product of a strong impurity seeding, c) the correlation between impurity radiation and the presence of neoclassical tearing modes (NTMs).

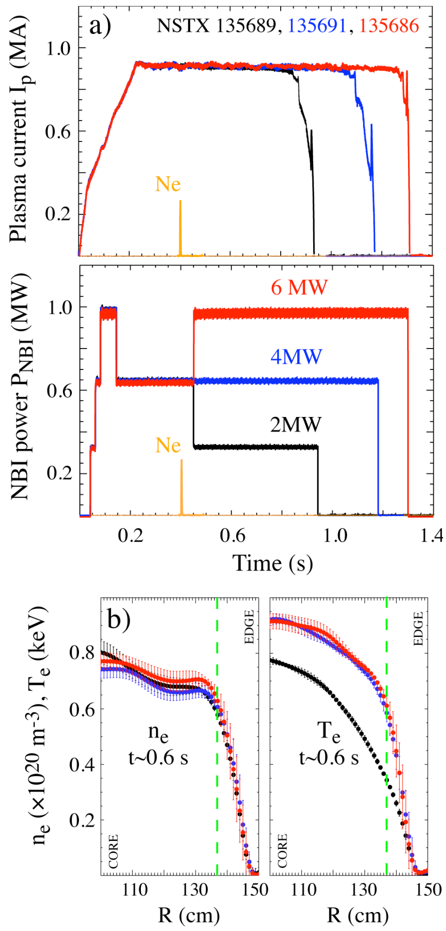

Fig. 1 ν* scan varying NBI power at constant density.

These impurity transport experiments used a transient neon puff as an impurity particle source. The neon has a strong spectral signature in the soft X-ray energy range, and the resulting emission was tracked by the Multi-Energy Soft X-ray (ME-SXR) imaging system developed for fast time and space-resolved measurements of the SXR emissivity profiles in multiple broadband energy ranges [1,2]. The main experiment included a ν* scan of NBI heated H-mode plasmas with n, I_p and B_ϕ held constant (see Figure 1); the high-power discharges have as much as twice the ion and electron temperatures in the gradient region (r/a~0.6-0.8) relative to that at low power, with an associated ν* varying up to a factor of four with nearly identical density profiles. First cut Abel reconstructions for the low-energy and high-energy SXR emissivities for the 2 and 6 MW cases are shown for comparison in Figure 2. The low-energy emissivities [see Figures 2-a) and b)] sensitive to line radiation from He- and H-like Neon ions indicate that the core emissivity decreases with NBI power while increasing at mid-radius. However, the high-energy emissivity [see Figures 2-c) and d)] indicate that both the core and mid radius emissivity increases with NBI power. It is therefore possible that the factor of two increases in electron temperature in the gradient region could be solely responsible for modifying the neon charge state distribution, without the need of changing the underlying diffusive and convective transport properties. Background subtraction will allow quantitative estimates of diffusivity and convective velocity as discussed in reference [1]. A 1D-radial transport code will be used to model the evolution of the neon charge states using the experimental time histories of n_e and T_e and assuming external profiles of charge-independent neon diffusivity and convective velocity. The core impurity diffusion will also be compared with that of the enhanced neoclassical Pfirsch-Schluter diffusivity due to toroidal rotation and associated centrifugal forces. It has been found [3,4] that heavy and not fully stripped impurities can experience a diffusion coefficient several times larger than that of the neoclassical transport for stationary plasmas without the need of invoking the presence of long wavelength electrostatic turbulence. The convective pinch velocity at the gradient region will also be compared with that obtained from momentum transport experiments.

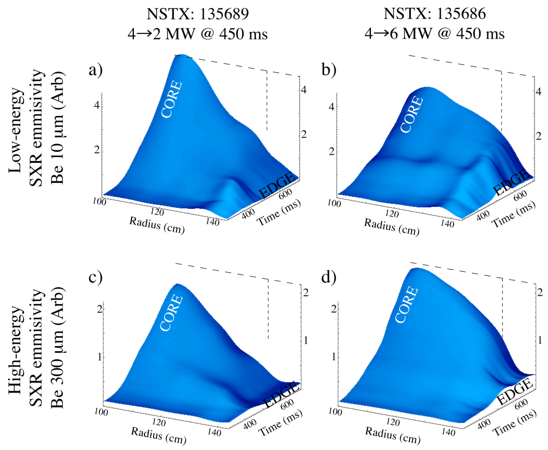

Fig. 2 Space-time history of low- and hi-energy SXR emissivities for 2 and 6 MW.

By the end of the current flattop for the discharges shown in Figue 1, we observed the development of m/n=2/1 NTMs as indicated in Figure 3 (w/o Neon injection). The appearance of the NTM ~100 ms earlier in the neon-seeded H-mode appear to be due to the enhanced radiated power; both the plasma density and temperatures profiles are similar before the NTM onset. Dedicated NTM scaling experiments have also been carried out in NSTX, making use of different impurity amount by extending the neon puff lengths, indicating a relationship between the strength of the radiation emitted and the appearance of the NTM. Verifying the linear scaling law between island growth rate and power radiated is important, as it predicts that an ST-based reactor and even ITER can be susceptible to NTM destabilization by impurity radiation, and that NTM control techniques must be implemented.

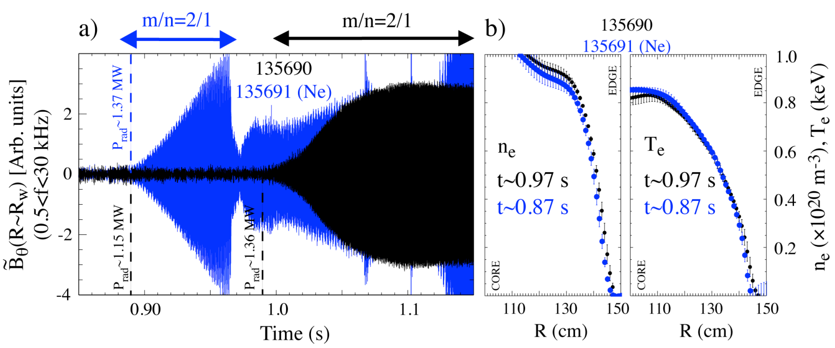

Fig. 3 a) dB/dt signatures of NTM at 4MW w/o Ne seeding

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