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MODIFICATION OF EDGE PLASMA TURBULENCE BY EXTERNAL MAGNETIC PERTURBATIONS

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Modification of Edge Plasma Turbulence by External Magnetic Perturbations

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Magnetostatic perturbations applied to the DIII-D plasma using a n=3 coil set have significant impact on the plasma edge, such as edge localized mode (ELM) suppression [1], but also affect the background turbulence levels. Discharges with parameters R=1.75 m, a=0.56 m, B_T~1.6 T, I_p~1 MA and $n_e \sim 3\times10^{13}$ cm^{-3} - $n_e \sim 7\times10^{13}$ cm^{-3} (low, $\nu_e^* \sim 0.1$ and moderate, $\nu_e^* \sim 1$ electron pedestal collisionality) were used as a target for the perturbation, [applied at 3 s Fig. 1(a) and 2 s Fig. 1(b)]. The global density and energy content, among many other parameters, are unaffected, raising the issue of what mechanism replaces the particle and heat exhaust otherwise mediated by ELMs. Mixed ELMs (high frequency, low amplitude Type II ELMs interspersed with Type I) in the moderate collisionality regime and Type I ELMs in the low collisionality regime, are replaced by intermittency and broadband turbulence or semi-periodic events. t is important to notice that the coils can be energized in high poloidal mode spectra (upper and lower coils produce fields in the same direction) or odd configuration (upper and lower coils produce fields in the opposite direction) and also rotated 60 deg toroidally. Although we will focus on scanning probe [2] data obtained in the scrape-off layer (SOL), other

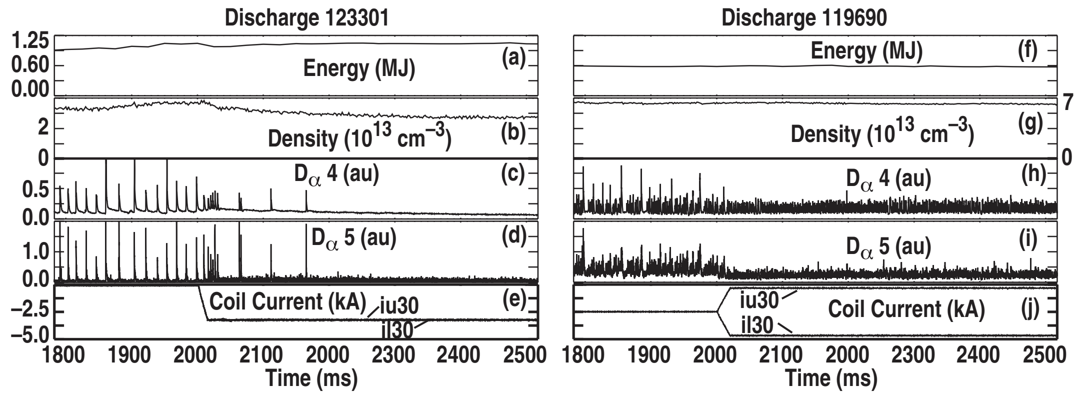

Fig. 1. Timeline of low (123301) and moderate (119690) collisionality DIII-D discharges. The I-coil spectrum is high in 123301 and low in 119690. ELMs are promptly suppressed as shown in the D_α signals (c,d,h,i) while the density dips slightly or stays constant, see (b,g).

diagnostics, beam emission spectroscopy (BES), reflectometry [3], were used to study the changes in the plasma turbulence when the ELMs are suppressed and the underlying turbulence and transport change. Thomson scattering n_e and T_e profiles (Fig. 2) accumulated over 200 ms before (red) and during (blue) I-coil perturbation are fitted with $y = a + b^* \tanh\left[(r-c)/d\right]$ resulting in a,b staying constant while d varies from -0.009 to -0.011 and c from -0.013 to -0.009, i.e. the profiles mostly broaden and shift outward, changes which may be connected to an increase in radial turbulent transport assuming no deformation of the separatrix. This broadening is seen in both low and high collisionality regimes and in the high spatial resolution probe data (Fig. 2 inset).

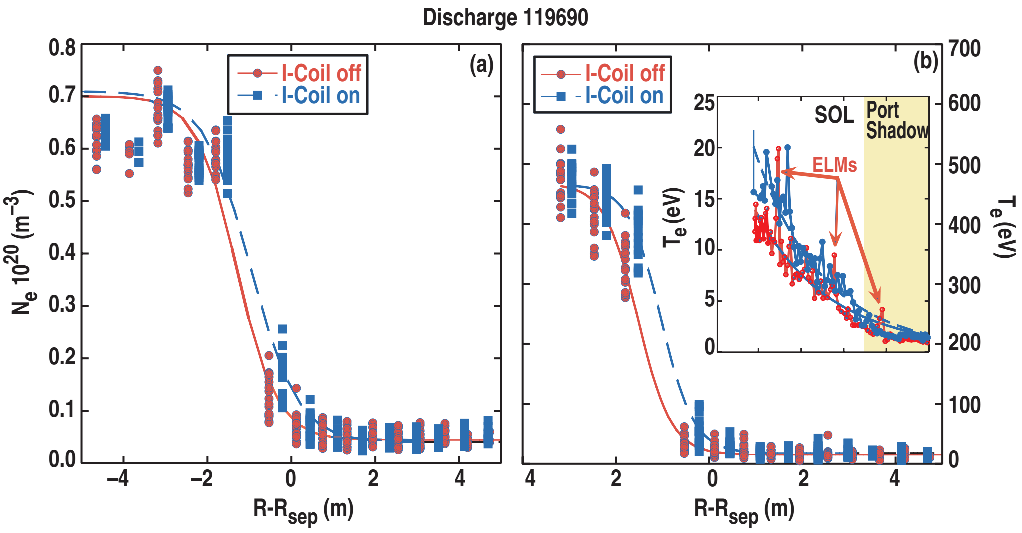

Fig. 2. Thomson scattering profiles of n_e (a) and T_e (b) with a tanh fit to the data to highlight the profile changes. Insert shows high-resolution probe data in the SOL.

Probe data shows an increase in the rms levels across the SOL (Fig. 3). The rms levels for saturation current (I_{sat}) and poloidal electric field (E_θ), indicative of density and radial velocity fluctuations respectively, were calculated by a running 1024 point window in the probe data,

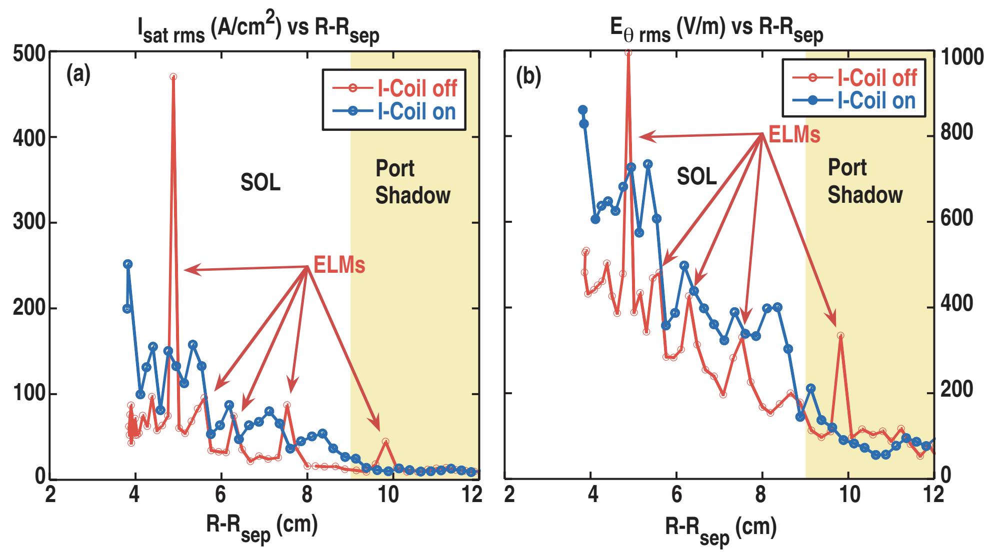

Fig. 3. Profiles of rms levels for I_{sat} (a) and E_θ (b) from probe data using a 1024 point running window. The inter-ELM rms level increases 30%-100% when the I-coil is turned on.

which is sampled at 1-3 Ms/s. The rms profiles (Fig. 3) show an increase of the background (in between ELMs) fluctuations of 30%-100%, however detailed inspection of the raw data shows that much, if not all, of the increase seems to arise from enhanced intermittent transport. In order to separate changes in broadband turbulence from intermittent transport changes, conditional averaging performed on n_e (Fig. 4) and E_θ (not shown) from probe measurements reveal that both the density of the filaments and their radial velocity increase by factors of 1.5 and 3 respectively, resulting in a 5-fold radial flux increase locally. The conditional averaging was performed over the probe data (~ ms) divided on 5 ms time series. Over those 5 ms, events ≥2.5 rms in amplitude are clipped in 10 μs segments and binned. Since the probe is moving, each 5 ms series corresponds to an average radius.

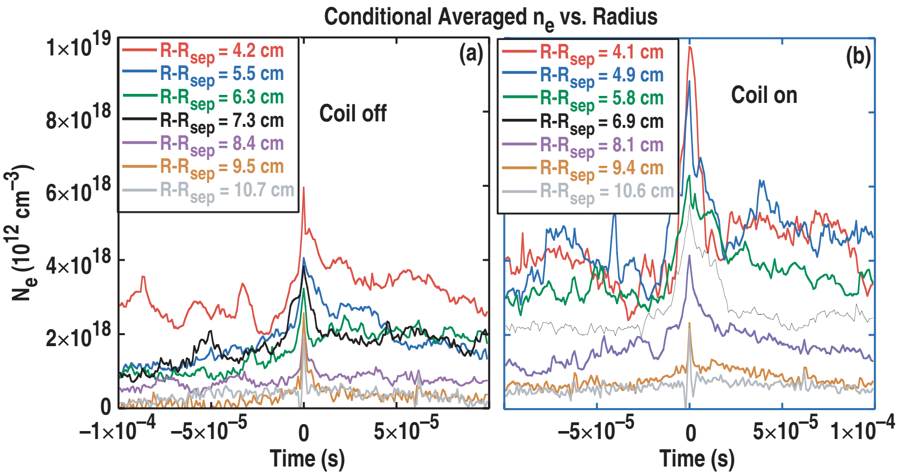

Fig. 4. Conditional averaging results vs conditional average window width for coil off (a) and on (b) showing greatly increased density in the filaments for a given radius when the I-coil is turned on.

Increased SOL transport is consistent with globally stable particle and energy inventories in the sudden absence of ELMs, however increases in turbulence/transport in the pedestal region, where the confinement region ends, must also be present. To examine this, other fluctuation diagnostics were used, namely BES and reflectometry. BES measurements straddling the pedestal are shown in Fig. 5 for a high collisionality discharge. There is little change in Channels 11 and 12 after the I-coil is turned on (indicated by the shaded background) except for the suppression of ELMs, whereas channel 13 shows a large increase in the fluctuation level after 3000 ms. This later channel is the closest to the separatrix (LFCS) and the SOL. BES data is also shown for a low collisionality discharge in Fig. 6. The four channels shown are straddling the pedestal (EFIT inset) and the fluctuation increase in all of them (seen most clearly in channels 24 and 25 after t~2,190 ms when occasional ELMs end) upon energizing the I-coil at 2000 ms (shaded background). IWe observed that changes in the applied perturbation fields due to rotation or poloidal mode spectra result in different turbulence behavior and location in the pedestal.

The dominance of intermittent transport in the pedestal and scrape-off layer in tokamaks is widely accepted, therefore, methods that allow a degree of control of the intermittent transport may be useful in the control of divertor and particle fluxes. Thus, understanding how the application of a static magnetic perturbation leads to increased intermittency [4] is of potential great importance. Recent simulations [5] have achieved an initial degree of understanding in simplified geometry.

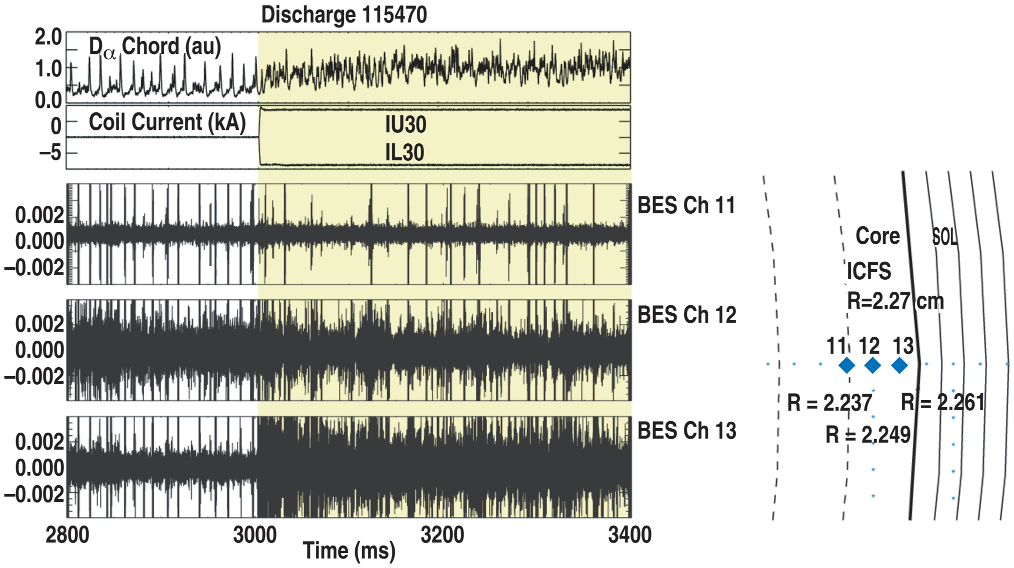

Fig. 5. BES data for a moderate collisionality discharge at three radial locations straddling the pedestal (Channels 11, 12, 13) as seen in the EFIT insert (right). Channel 13 shows a clear increase in turbulence after the I-coil is turned on with the low mode spectrum.

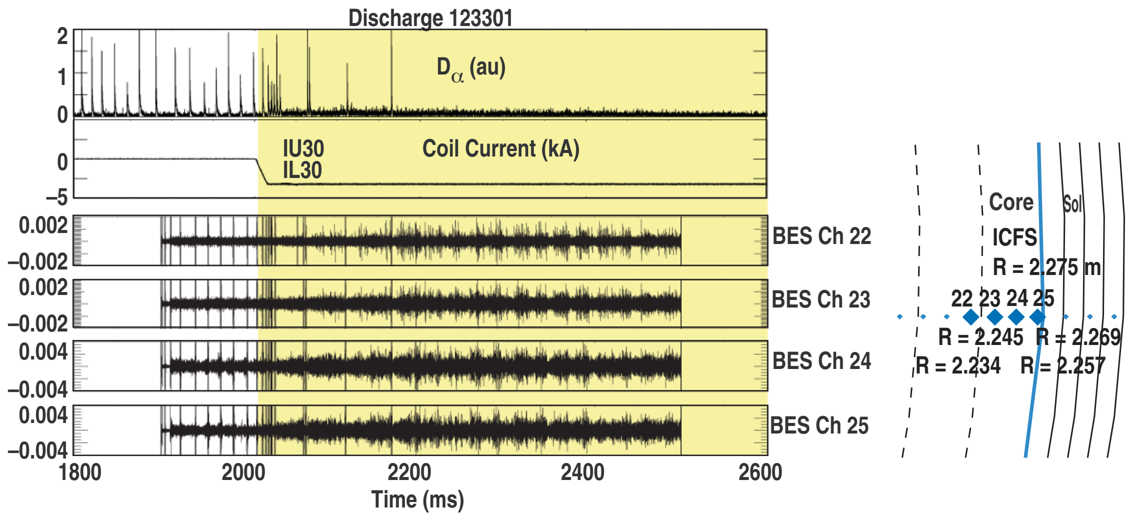

Fig. 6. BES data for a low collisionality discharge at four radial locations straddling the pedestal (Channels 22, 23, 24, 25) as seen in the EFIT insert (right). Channels 24 and 25 show a clear increase in turbulence after the I-coil is turned on. Even configuration is used with the high mode specrum.

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