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Behavior of Density Fluctuations and Electron Temperature Profiles in JET Density Limit Disruptions

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Previous studies of density limit disruptions in small [1] and medium [2] size tokamaks found that degradation of the plasma energy confinement, characterizing major density limit disruptions, initiates in the neighborhood of the $m/n = 2/1$ island. A flattening of the electron temperature profile was observed spreading inwards, to the center of the plasma, from the outboard O-point of the 2/1 mode. This event initiates the global destruction of the plasma energy confinement, that if complete results in a major disruption, otherwise only a minor disruption occurs. Generally if the plasma is left to evolve alone then a major disruption will follow after one, or sometimes a few, minor disruptions. Here we report on the observation of this sequence of events, also in JET density limit disruptions. The observation of the same phenomena in three distinct size tokamak plasmas indicates that it may be an intrinsic characteristic of this type of disruptions.

Low elongation limiter ohmic plasmas with $I_p = 2$ MA, $B_\phi = 3$ T and $q_a = 3.8$ were used in these experiments. Density limit disruption were provoked by puffing Ne or Ar gas on a D plasma in order to lower the density limit. Such procedure allowed optimization of the use of the radiometer, avoiding cut-off of the central channels. Nonetheless these disruptions show features common to precursors and postcursors of JET density limit disruptions as reported in e.g. [3]. In this paper a discharge with Ne gas puff where the density limit was 5×10^{19} m^{-3}, is discussed.

The time evolution of the temperature profile was measured with the ECE heterodyne radiometer that has been upgraded to 96 channels. Channel separation varied between 1 to 2 cm, and the time resolution was 100 μs. The evolution of density

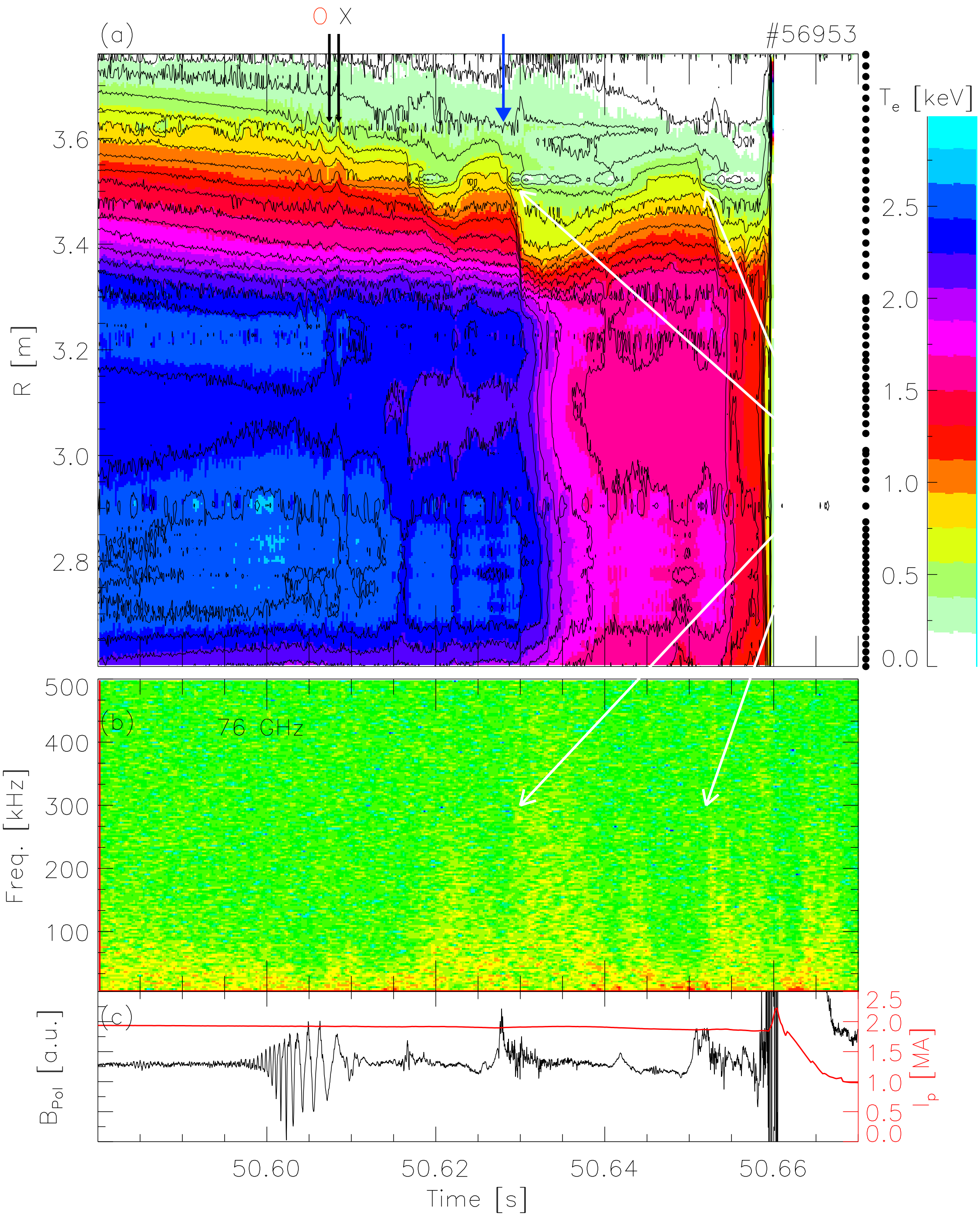

Figure 1: *Synchronized time evolution of some plasma parameters during disruption. (a) T_e measured with ECE radiometry. Dots at right indicate channels positions. (b) Spectrogram of fluctuations from 76 GHz X mode LFS reflectometer channel. The blue arrow in (a) indicates position of cut-off layer. White arrows indicate clear correlations between variations in the signals of the radiometer and the reflectometer. (c) Perturbed poloidal magnetic field measured inside the vessel at the LFS and plasma current.*

fluctuations was measured from the low field side (LFS) with a fixed frequency, X mode, reflectometer at 76 and 78 GHz with 1 μs time resolution. These two diagnostics are at the same toroidal position.

Cooling of the plasma edge is observed in Fig. 1(a), as a result of the increased edge radiation, enhanced by the Ne gas puff and as the density limit was reached. This radiative contraction of the current profile destabilizes an $m/n = 2/1$ tearing mode (see Fig. 1(a) and (c)). After a fast growth during approximately 20 ms the mode stops rotating and stays locked. The first abrupt degradation of the energy confinement is observed 15 ms after the $m = 2$ mode locks to the wall. This one is relatively minor when compared with the three that follow at 50.630 s, 50.652 s and the final and major one at 50.660 s. A common feature to all of them is that they initiate with an abrupt flattening of the T_e profile, from the neighborhood of the $m = 2$ mode towards the plasma core.

In figure 1(b) is shown the spectrogram of fluctuations from the LFS 76 GHz X mode reflectometer channel. The blue arrow if Fig. 1(a), indicates the position of the cut-off layer, that was calculated from a LIDAR electron density profile measured at that time, and shown in Fig. 2. Up to the time the mode locks, is observed a slow decrease of the power spectrum of the high frequencies. This behavior starts already a few hundred milliseconds before and shows a correlation with the edge cooling. After the mode locks, an abrupt increase of the frequency of the fluctuations occurs at the onset of every minor disruption. That is particularly clear in the cases indicated by

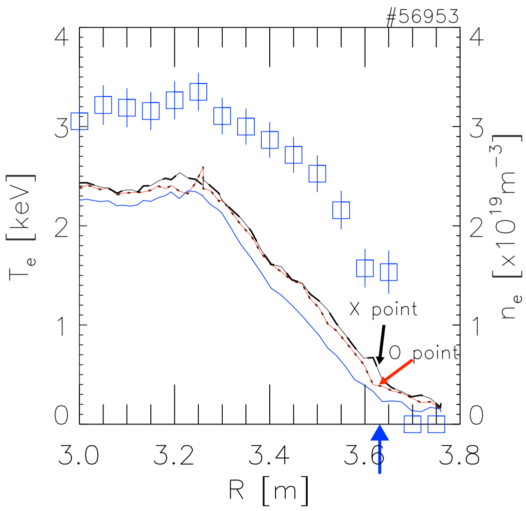

Figure 2: *T_e ECE profiles (lines) and n_e LIDAR profile (squares). Profiles in blue were measured at 50.6276 s. In red and black at 50.6074 s and 50.6085 s, respectively (see black arrows in Fig. 1(a)). The red and black T_e profiles are shown to indicate the radius of the $m/n = 2/1$ island. Just like in Fig. 1(a) the blue arrow indicates the position of the 76 GHz cut-off layer.*

the white arrows in Fig. 1(a),(b)).

The only cases where there is no visible correlation with the T_e erosion (at least as measured by the ECE radiometer) are at times 50.642 s and 50.663 s, the last one occuring already after the major disruption. An intense (6.7 KeV) and localized ($R = 3.65\ m$) burst of ECE radiation is observed just previously to the sudden vanishing of ECE signal (50.660 s), similarly to what was observed at RTP [1] where it was found that from this time onwards T_e measured by ECE was always lower than measured by Thomson scattering. The current quench initiates at this phase where runaway electrons have been observed [4, 5].

The calculated radial position of the cut-off layer for 76 GHz coincides with the position of the $m/n = 2/1$ mode, as shown in Fig. 2. The LIDAR n_e profile shows a small plateau that coincides with the island radius. The low spatial resolution of this profile impedes a comprehensive observation of the density behavior. However it is recalled that high spatial resolution Thomson scattering n_e profiles measured in similar behaved discharges [1] revealed n_e perturbations and that an abrupt increase of the electron density was observed by fast (35 μs) broadband reflectometry in ASDEX Upgrade major disruptions [2]. Connecting this with the fact that the evolution of the T_e profiles measured in these three distinct size tokamaks by the common technique of ECE radiometry, shows the similar features described before, one can conjecture that electron density fluctuations in the neighborhood of the $m/n = 2/1$ island are involved in the onset of the fast destruction of energy confinement in tokamak plasmas. At JET, measurements of fluctuations at higher frequencies will allow clarification of the behavior of these fluctuations deeper into the plasma core.

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