

## Electron density behaviour during Dynamo Relaxation Events in Virtual Shell operation in RFX-mod

R. Lorenzini, F. Auriemma, A. Canton, P. Innocente, S. Martini, D. Terranova

Consorzio RFX, Associazione Euratom-ENEA sulla Fusione, Padova, Italy

Magnetic field fluctuations play a double role in characterizing the Reversed Field Pinch (RFP) configuration: they are responsible for confinement degradation, but at the same time are the means by which the configuration itself can be sustained. Through the dynamo mechanism magneto-hydro-dynamical (MHD) tearing modes act against the resistive diffusion of the magnetic field following a cycle of destabilization and magnetic toroidal flux regeneration, the so-called dynamo relaxation event (DRE). This process can take place either in a discrete or a more continuous fashion depending on the magnetic boundary

of the experiment: in either case the current profile changes so that the modes are destabilized following a cascading process that propagates from the innermost resonant harmonics to outer ones. This mechanism was studied both theoretically [1,2] and experimentally on several RFPs [3,4,5] and was also observed in RFX [6] though not so often since the machine was characterized by a more continuous dynamo process. The situation has now changed on the new RFX-mod ( $R=2$  m,  $a=0.459$  m) where the magnetic boundary was modified with a thinner

shell and a system of 192 magnetic radial field active saddle coils [7] that are used to provide a virtual shell (VS) operational scenario that mimics a configuration close to an ideal wall. This configuration improved the confinement properties thanks to a significant reduction of the level of magnetic fluctuations [8,9,10]. In particular the plasma is now characterized by a discrete MHD activity with large DREs. As an example, in figure 1 we show the typical cascading process of the  $m=1$  toroidal field harmonics, and the evolution of the  $m=0$  toroidal field modes and the reversal parameter ( $F = B_i(a)/\langle B \rangle$ ).

In this framework, the strong DRE activity that is now observed did put into evidence a significant and peculiar phenomenology in the electron density time evolution during such

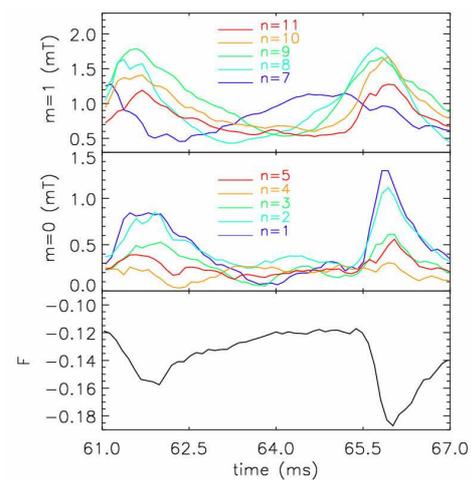


Fig 1: mode dynamic during DRE.

events that was not observed in the past. In this paper we will describe this phenomenology and its link to the magnetic field perturbation through the global deformation of the plasma column produced by the phase and wall locking of tearing modes in RFX-mod discharges. The process of flux generation, involving a rise of magnetic mode amplitudes, produces a deformation of the plasma column: the reconstructions [11] of the LCFS show that the DRE enhances the typical deformation, due to the phase locking of magnetic modes, which is found between the crashes. This can be seen in figure 2, which compares the reconstruction of the  $m=0$  radius deformation  $\delta_0$  and of  $m=1$  shift  $\delta_1$  of the LCFS before and during a DRE, when the reversal parameter  $F$  reaches the minimum, in a discharge at  $I_p=600$  kA with Virtual Shell.

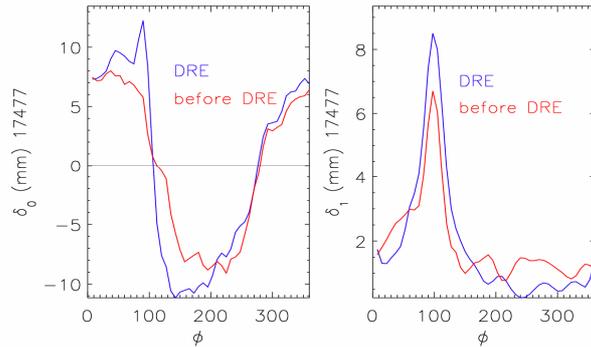


Fig 2: LCFS deformations.

The DRE amplifies the localized helical perturbation of the plasma column and modifies the plasma radius, shrinking the area where the column is already shrunk and further enlarging the area that is bulging: therefore a DRE can be seen as a strengthening of the Locked Mode.

During the DRE there is an enhancement of the plasma-wall interaction with a substantial

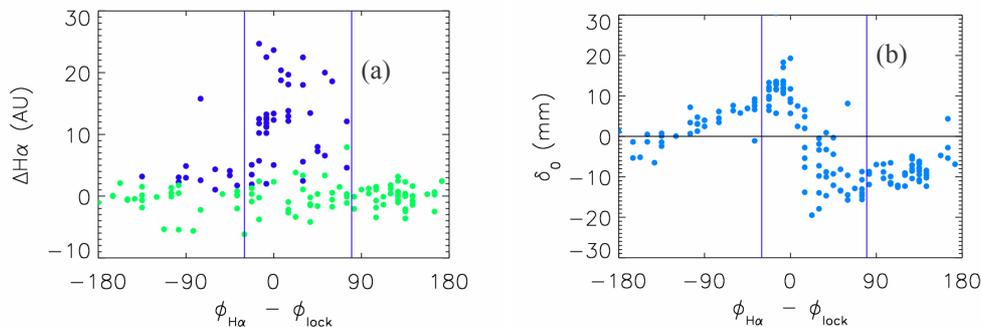


Fig 3: (a) particle influx during DRE, (b) plasma radius deformation versus the toroidal distance from the Locked Mode.

increase of the amount of power lost by the plasma towards the wall: the central electron temperature decreases during the crash by tens of eV. The wall reacts to the load releasing an increased amount of neutral particles. Figure (3a) shows the difference  $\Delta H_\alpha$  between the  $H_\alpha$  signal during and before the DRE, measured by a central chord, versus the distance from the Locked Mode. The plot is obtained selecting 110 VS pulses and choosing a single DRE for each of them. The dots are blue when the  $H_\alpha$  signal is correlated to the reversal

parameter, while they are green if no correlation has been found. The chord measures an increase of the influx during the DRE when the locked mode is less than 90 degrees away from the diagnostic in the toroidal direction. In the rest of the plasma column the interaction with the wall is not significantly modified.

The distribution of highest increases of particle influx is asymmetric with respect to the position of the Locked Mode. High influxes are measured at  $-30 < \phi_{\text{lock}} - \phi_{\text{H}\alpha} < 80$  where the plasma column is strongly deformed, as shown in the figure (3b). Increased influxes, but with lower amplitude, are also observed in the region at  $-90 < \phi_{\text{lock}} - \phi_{\text{H}\alpha} < -30$  where the column is bulging.

During a DRE the plasma density generally increases: figure (4a) shows an example of the density increase,

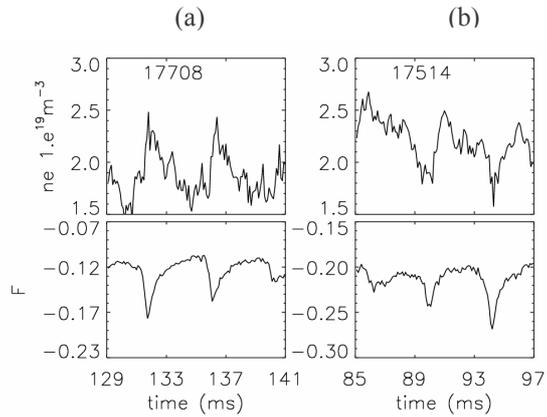


Fig 4: (a) example of a density increase during DRE, (b) example of density crash.

measured by the interferometer, associated to a set of dynamo relaxation events. The data are relative to a chord measuring the outer part of the plasma (normalized impact parameter  $h/a=0.74$ ) where the increase is more evident. However there are also situations where the density is not affected by the DRE, and a few cases where the density even decreases; figure (4b) shows an example of correlation between crashes of the reversal parameter and of the density in the shot 17514. For the same set of DRE used in figure (3) the difference between the density during and before the DRE has been plotted in figure 5 versus the distance of the interferometer from the Locked Mode.

The blue and the red dots indicate that the F crash is correlated respectively to a density increase and a crash, while the green dots indicate that the density is not affected by the DRE. One interesting feature is that the density increase associated to the DRE is toroidally asymmetric: similar

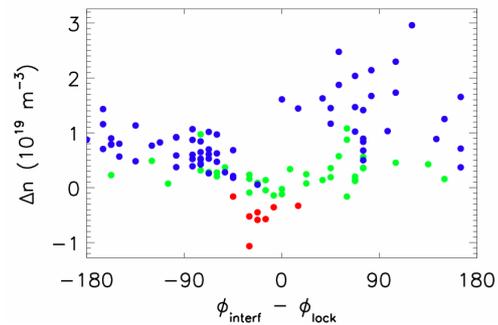


Fig 5: density behaviour during the DRE.

to what happens for the  $H_{\alpha}$  data, highest density peaks are found when the interferometer measures in the region where the plasma column is shrunk. This effect can be related to the asymmetry in the particle influxes, which are more intense in this region. In the rest of the

plasma the density increase is essentially due to the toroidal transport. Figure (6a) shows the modification of the density profile during a DRE when a density peak is observed: the density increases in the outer region of the plasma ( $r/a > 0.75$ ), while the density in the core is not modified. Another feature shown by the plot (5) is that the density crashes are observed in the proximity of the locked mode, and that in the region at  $-30 < \phi_{\text{lock}} - \phi_{\text{interf}} < -30$  it is very rare to observe density peaks, despite the increased influxes. A possible explanation of this evidence could be that this is the region where the transport enhancement due to the DRE is localized. This enhanced loss balances, and sometimes overcomes, the action of the increased particle influxes. The density crashes last for  $\sim 1$  ms, which is longer than the time taken by the toroidal transport to equilibrate the density gradients. This can be explained considering that at the flux surface  $q=0$  is located an island chain due to the effect of  $m=0$  and  $m=1$  modes [12].

The chain is interrupted in a region of about 60 toroidal degrees at  $\phi = \phi_{\text{lock}}$  where there is a strong enhancement of the transport. It is possible to imagine that the islands, which mitigate the radial transport at  $r/a > 0.75$ , act as barrier also in the toroidal direction slowing down the process of gradient equilibration. The reconstruction of density profiles during the density crashes, shown in figure (6b), is consistent with this picture, confirming that the particle loss, which takes place up to  $r/a \sim 0.75$ , happens in the same radial region where the magnetic field is non-axisymmetric.

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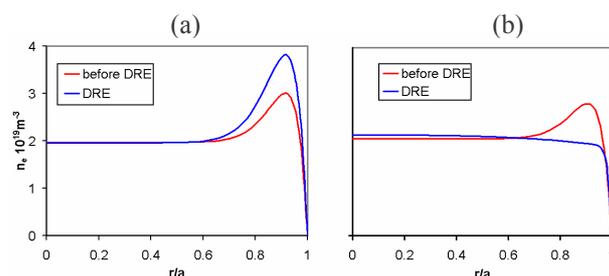


Fig 6: density profiles during DRE, (a) density increase, (b) density crash.