*36th EPS Conference on Plasma Phys. Sofia, June 29 - July 3, 2009 ECA Vol.**33E**, P-5.190 (2009)*

Characterization of Scrape-Off Layer profiles and transport processes in MAST in the presence of Resonant Magnetic Perturbations

P. Tamain[1], A. Kirk[1], E. Nardon[1], B. Hnat[2], M. Price[1]
[1] *Euratom-UKAEA Fusion Association, Culham Science Centre, Abingdon, OX14 3DB, UK.*
[2] *Centre for Fusion, Space and Astrophysics, Department of Physics, Warwick University, Coventry CV4 7AL, UK*

1. Introduction

The MAST spherical tokamak has recently been equipped with a set of Resonant Magnetic Perturbations (RMP) coils (or ELM Control Coils, ECC) [1] with the aim of studying this method as a possible solution for the control of ELMs on ITER. The idea is to generate a stochastic magnetic field in the pedestal region in order to increase the radial transport and keep the pedestal pressure gradient below the threshold of the peeling-ballooning modes that are thought to be the dominant mechanism in the development of ELMs [2][3]. However, recent experimental and theoretical results [4][5] seem to indicate that such a picture is probably too simple. In that perspective, experiments in L-mode plasmas constitute a useful input to shed more light on the subject and help to isolate the fundamental mechanisms at play in the plasma response.

2. Impact on plasma fluctuations

We present here results obtained with the MAST fast Reciprocating Probe (RP) during 400kA Ohmic L-mode plasma discharges. As already reported in ref. [5][6], an important effect of the ECC has been found, with a drop of the line-integrated density of the plasma reminiscent of the density pump-out observed in DIII-D in H-mode [7]. Those discharges have been repeated to measure Scrape-Off Layer (SOL) profiles and fluctuations using a Gundestrup (GDS) probe head [8]: 8 pins distributed around the probe measured the ion saturation current I_{sat} while 3 pins located at the front of the probe were configured to measure the floating potential V_f. Fig. 1 shows an extract of the temporal traces of the ion saturation current as measured by one of the 8 I_{sat} pins when the probe is located 3cm inside the Last Closed Flux Surface (LCFS). Three discharges run with 3 different values of the current in the ECC are shown. Several observations can be made from these data. First of all, the ECC at their maximum current (1.4kA) trigger a drop of the average level of the I_{sat} signal for some of the pins of the GDS probe. In the case of pin 2 shown in Fig. 1, the relative amplitude of the decrease is found to be comparable to the amplitude of the density pump-out (of the order of 15%). Interestingly, some pins do not exhibit a major change of $\langle I_{sat} \rangle$ while others do show a drop of up to 60%. Such an asymmetry in the evolution of the signals of the various pins of the GDS probe suggests a change in the edge plasma flows. We come back on that point in the following section.

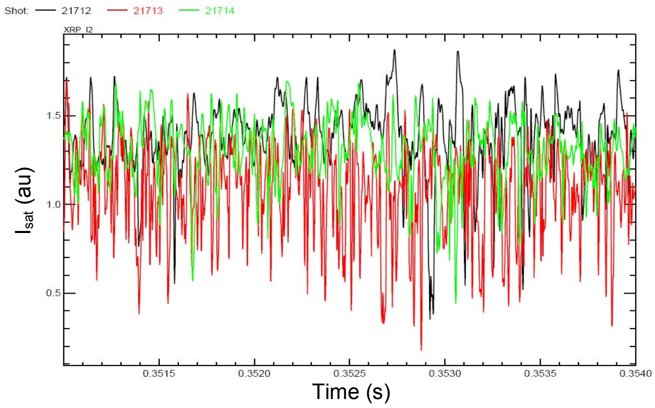

Fig. 1: Temporal traces of the ion saturation current measured by pin 2 of the GDS probe at r - r_{LCFS} = -3cm for 3 different currents in the ECCs: 0kA (#21712, black), 1kA (#21714, green) and 1.4kA (#21713, red).

An important change in the characteristics of the plasma fluctuations is also observed. As an example, Fig. 2 (a) shows the power spectra of the I_{sat} signals, normalized to $<I_{sat}>$, as measured by pin 2, 3cm inside the LCFS. ECC at full current (1.4kA) are responsible for a broadening of the spectrum similar to what was observed on TEXTOR with the ergodic divertor in 3/1 mode [9]. As could already be inferred from Fig. 1, driving the ECC at 1kA shows on the contrary very little effect on the spectrum. This observation confirms the existence of a threshold on the current under which the RMP do not have any influence on the plasma [5]. The Probability Distribution Function (PDF) of the I_{sat} signal for the same pin is plotted in Fig. 2 (b) at two different spatial locations corresponding to two different times during the reciprocation of the probe. When no current is applied in the ECC, a rather symmetric "Gaussian-like" distribution is found 3cm inside the LCFS while the PDF 1cm out in the SOL exhibits a strongly asymmetric shape with a dominant positive tail. Such results are usual for fluctuation measurements in the edge plasma in L-mode. When the ECC are driven at 1.4kA, the PDF of the signal 3cm inside the LCFS gets broader and develops a dominant negative tail, but no significant modification is found in the SOL. Note that once again, all the I_{sat} pins of the GDS probe head do not measure the same alteration of the PDF in the presence of the RMP: a broadening is systematically

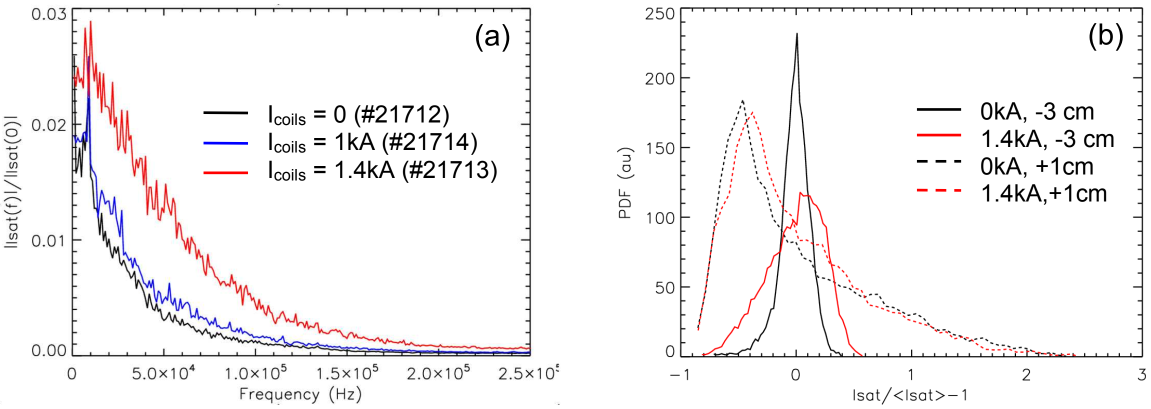

Fig. 2: (a) Power spectra of the I_{sat} signal for pin 2 for 3 different values of the current in the ECC at r - r_{LCFS} = -3cm ; (b) Probability Distribution Functions of the ion saturation current for I_{coils}=0 (black) and I_{cois}=1.4kA (red) at r-r_{LCFS}=-3cm (solid) and r-r_{LCFS}=+1cm (dashed).

observed but, according to which pin is considered, it is the positive or the negative side that becomes dominant. However, they do all show an influence of the ECC inside the LCFS whereas no influence is noticeable in the SOL. Hence, our data demonstrates a strong impact of the ECC on the turbulence in the edge plasma, only localized inside the LCFS.

3. Impact on the radial electric field and plasma flows

The floating potential (V_f) measurements at the front of the GDS probe head give an insight on the evolution of the plasma potential V_p during RMP following the classical relation $V_p = V_f + 2.5T_e$. Thomson scattering data were used for the electron temperature (T_e) profiles.

Fig. 3 shows the radial electric field (E_r) profiles obtained by this method for the three studied values of the current in the ECC. The 0kA and 1kA cases are very similar, demonstrating the existence of a threshold. At 1.4kA however, E_r appears to be modified in a 2cm wide layer located just inside the LCFS, with an increase of the order of up to 2kV/m at r-r_{LCFS} = 1cm. This increase is expected theoretically in the presence of a stochastic field in the edge to preserve the ambipolarity of the plasma [9][10]. It is in qualitative agreement with the measurement of E_r by Doppler spectroscopy in these discharges [11]. It is also interesting to note that the 2cm thick layer inside the LCFS corresponds to the stochastic region predicted by the vacuum modelling of the RMP. Furthermore, a slight shift of the radial electric field towards less positive values is visible inside the SOL, but it is difficult to conclude about its significance.

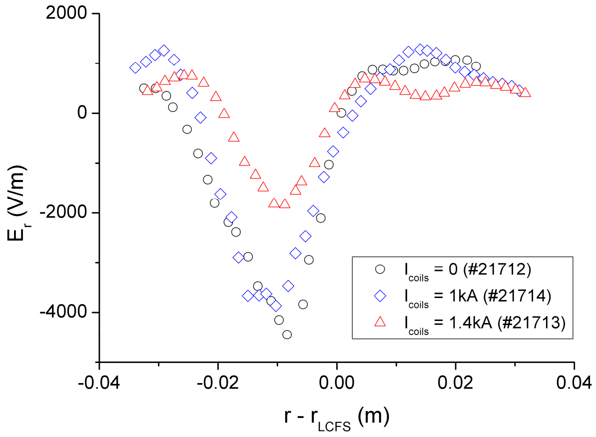

Fig. 3: Radial electric field profiles derived from reciprocating probe floating potential measurements for three different currents in the ELM control coils in 400kA L-mode plasmas.

We finally come back to the analysis of the asymmetries of the I_{sat} signal levels around the GDS probe head. A direct application of the Van Goubergen model [12], leads to the flow velocities shown in Fig. 4. The ECC appear to trigger an acceleration of the plasma in both parallel and perpendicular directions inside the LCFS while both velocities seem to decrease in the SOL. Once again, a clear threshold is visible, the 1kA case showing almost no effect compared with the 1.4kA one. One can however notice that the error bars of the fit are large in the SOL as well as all across the profile in the 1.4kA case. This is linked to the limited applicability of the Van Goubergen approach for strongly fluctuating plasmas. Nevertheless, the impact of the ECC on the perpendicular flow is in agreement with the observed modifications of the radial electric field shown in Fig. 4, both in direction and order of magnitude. The parallel flow is more difficult to interpret since it is both linked to the turbulent radial flux distribution and the poloidal drifts.

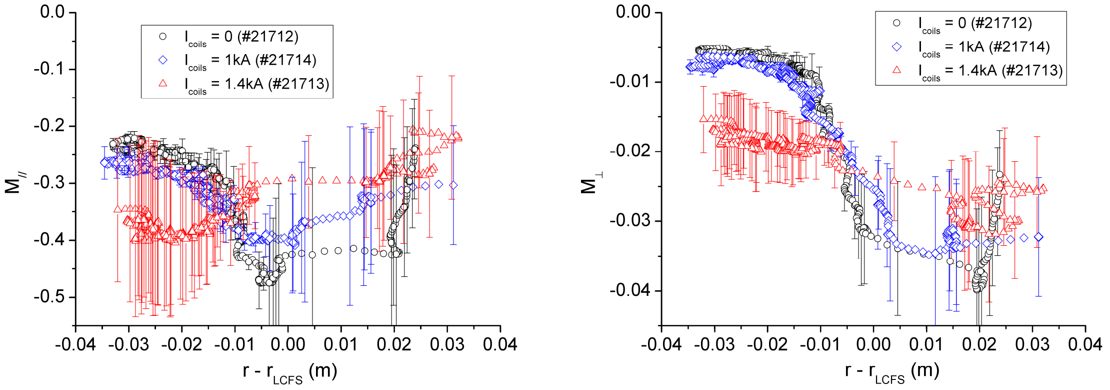

Fig. 4: Plasma flow velocities inferred from the GDS probe data for 3 values of the current in the ECCs (0kA – black, 1kA – blue, 1.4kA – red). Left: parallel Mach number ($M_{//}<0$ => towards upper divertor) ; right: perpendicular Mach number ($M_\perp<0$ => towards lower divertor).

Summary

Probe measurements performed in the edge plasma of MAST in the presence of resonant magnetic perturbations in L-mode demonstrate a strong impact on turbulent fluctuations as well as on the radial electric field and flow velocities. The existence of a threshold coil current as well as a radial localization of the perturbation has also been observed.

Acknowledgements

This work was funded jointly by the United Kingdom Engineering and Physical Sciences Research Council and by the European Communities under the contract of Association between EURATOM and UKAEA. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

References

[1] E. Nardon et al., J. Nucl. Mater. 390-391, 773 (2009).
[2] J.W. Connor, Plasma Phys. Control. Fus. 40, 531-542 (1998).
[3] G.T.A. Huysmans, Plasma Phys. Control. Fus. 47, B165-B178 (2005).
[4] E. Nardon et al., submitted to Nucl. Fusion (2009).
[5] E. Nardon, 36th EPS Conference on Plasma Physics, submitted to Plasma Phys. Control. Fus. (2009).
[6] A. Kirk et al., submitted to Nucl. Fusion (2009).
[7] T.E. Evans et al., Nucl. Fusion 48, 024002 (2008).
[8] C.S. MacLatchy et al., Rev. Sci. Instrum. 63, 3923 (1992).
[9] Y. Xu et al., Nucl. Fusion 47, 1696-1709 (2007).
[10] M.F.M. De Bock et al., Nucl. Fusion 48, 015007 (2008).
[11] D. Temple et al., 36th EPS Conference on Plasma Physics, Sofia (2009).
[12] J.P. Gunn et al., Phys. Plasmas 8, 1995 (2001).
[13] P. Tamain et al., J. Nucl. Mater. 390-391, 347 (2009).