ITER Like Wall impact on MHD instabilities in JET discharges

M. Baruzzo[1], B. Alper[2], Yu.F. Baranov[2], T. Bolzonella[1], A Botrugno[3], C. Bourdelle[4], P. Buratti[3], R Coelho[5], C.D. Challis[2], I.T. Chapman[2], P.C. de Vries[6], D. Dodt[7], C. Giroud[2], M Gelfusa[8], E. Joffrin[4], N. Hawkes[2], T.C. Hender[2], J. Hobirk[7], I. Lupelli[2], J. Mailloux[2], F. Orsitto[3], G. Pucella[3], SE. Sharapov[2], O. Tudisco[3], M. Valisa1 and JET-EFDA Contributors*

JET-EFDA, Culham Science Centre, Abingdon, OX14 3DB, UK

1Consorzio RFX, EURATOM-ENEA Association, Corso Stati Uniti 4, 35127 Padova, Italy
2Euratom/CCFE Fusion Association, Culham Science Centre, Abingdon, OX14 3DB, UK
3Associazione EURATOM-ENEA sulla Fusione, C.R. Frascati, Roma, Italy
4Association EURATOM-CEA, CEA/DSM/IRFM, Cadarache 13108 Saint Paul Lez Durance, France
5Associação EURATOM/IST, Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Av Rovisco Pais, 1049-001 Lisbon, Portugal
6FOM institute DIFFER, EURATOM association, P.O. Box 1207, Nieuwegein, Netherlands
7Max-Planck-Institut für Plasmaphysik, EURATOM-Assoziation, D-85748 Garching, Germany
8Associazione EURATOM-ENEA sulla Fusione, Università di Roma, Italy

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Introduction

JET has been recently refurbished with an ITER-like Be first wall and W divertor (ILW), to study plasma wall interaction processes and integrated scenario development for ITER. With the change of the divertor material, and the related presence of radiating W ions in the plasma, several changes in the pre-existing MHD phenomenology have been observed.
The experimental signature of the new MHD behaviour will be characterized in this work using high bandwidth pick up coils, fast ECE signals and fast Soft X-ray signals (Figure 1).

q=1 activity

An important effect observed in ILW discharges is the change of q=1 MHD activity in hybrid discharges. The q=1 activity with the JET C-wall had usually shown no effect on plasma confinement, except for NTM triggering, its main experimental signature being a rotating kink activity interleaving sawteeth crashes. In the C-Wall hybrid scenario sawteeth had low amplitude and frequency, and the rotating precursor had often fishbone characteristic. The radial profile of the mode fluctuation has been calculated using a coherence technique between one pick up coil and 96 ECE measurements along the red L.o.S in Figure 1. As explained in ref. [1], the coherence phase radial profile shows a π-jump whenever an island is crossed moving along the plasma radius, this effect is due to the radial displacement of magnetic field lines produced by the rotating island, which has opposite directions

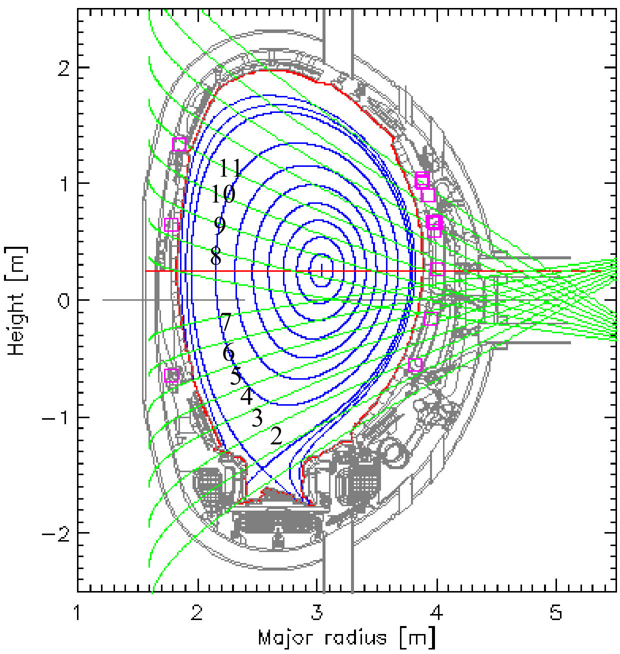


Figure 1: Layout of used diagnostics. In violet pick up coils, in red ECE L.o.S. and in green SXR L.o.S are shown (channel numbers have been changed for plot reasons).

on the outer side of the island x-point than on the inner side of the x-point. In the C-Wall hybrid pulses the ECE fluctuation at the q=1 magnetic frequency did not show any radial phase jump, as can be seen in Figure 2, and therefore had kink characteristic.

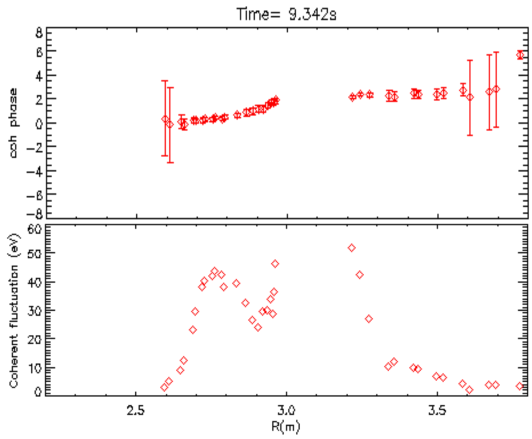


Figure 2: Coherence phase and temperature fluctuation amplitude radial profiles for pulse 74634 (C-Wall).

In the ILW scenario counterpart q=1 activity starts with pure kink parity, but it changes in time from kink to island parity centred on q=1 (Figure 3), as can be observed in the two plots on the right, where vertical lines highlight the island position at 2.65 and 3.1m on the low and high field side. The third inversion at 3.7m is due to ECE non-thermal emission. This change is observed at every sawtooth cycle, since the related crash restores the mode nature from tearing to kink, and the process is repeated. Soft X-Ray line integrated fluctuation also showed a new behaviour in the ILW discharges.

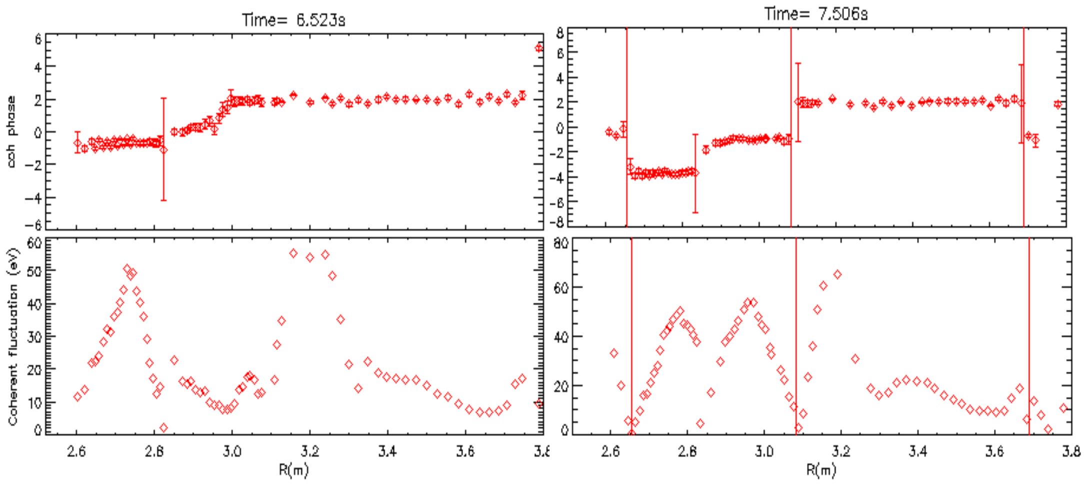
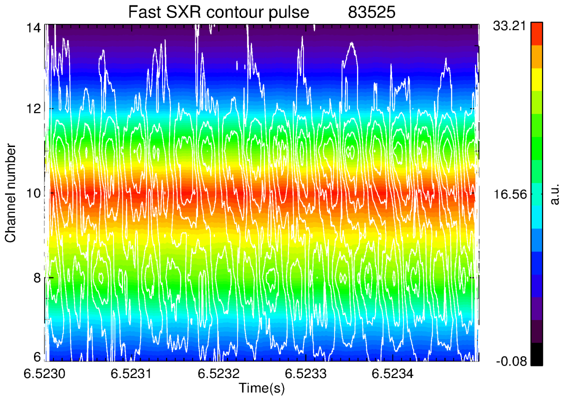


Figure 3: ECE fluctuation phase and amplitude radial profiles for ILW pulse 83525 at 6.52s on the left and at 7.50s on the right.

A coherent fluctuation is observed at the same frequency of the rotating mode in the magnetics, see Figure 4. The SXR emission during the kink phase (left plot) is peaked in the core on channel 10, and a small sinusoidal fluctuation is observed (white contour) that has opposite sign in the channel above and below the magnetic axis, being consistent with a dominant m=1 mode. Later in the pulse, when the mode parity is tearing, a fluctuating emission peak is observed in channel 9 and 10, which are the channels enclosing the magnetic axis. The amplitude is slightly asymmetric top to bottom, but this might be due to channel 10 being closer to the magnetic axis than channel 9. The fluctuation amplitude is several times larger than the back ground plasma emission, and it is more likely to be related to heavy impurity line emission rather than thermal emission linked to a plasma pressure structure. The temperature fluctuation measured by ECE in Figure 3 is of some tens eV, which would not justify the large SXR emission. The measured structure could be attributed to both a kink displacement of the plasma core, as already observed in JET [2] and in metal wall tokamaks [3], which confines impurity given neoclassical transport, or to the presence of a magnetic island which could also confine impurities in its nested flux surfaces. The fluctuation is not perfectly sinusoidal, which might suggest an island



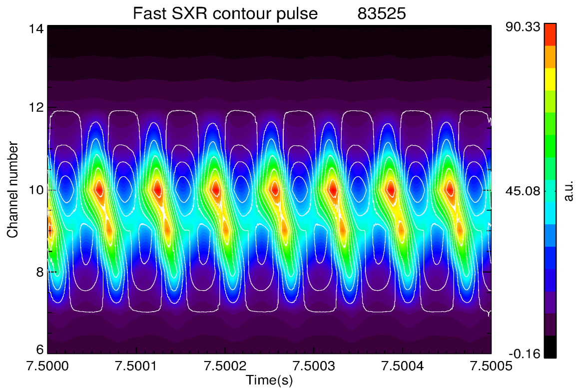


Figure 4: SXR emission contour plot as a function of time and channel number. SXR fluctuations are overplotted in white. The times correspond to Figure 3 frames.

structure. It can be divided in a first part when the island O-point passes in front of the detector, giving a maximum in upper and lower line of sight (L.o.s), and a second part where the amplitude falls both in the upper and lower LoS, this being a time frame when the island X-point crosses the LoS. This transition to a fluctuating SXR peak is often observed towards the end of hybrid discharges, particularly in the discharges where a W accumulation process is taking place, on the other hand at the present stage of the analysis the evaluation of the mode effect on the accumulation process is still premature.

Tearing modes in plasma landing

In several ILW H-mode discharges a slow rise of central bolometry signals happens during the NBI heating. This observation is also accompanied by the presence of a hollow electron temperature profile, a slow frequency rise of the core rotating activity as measured by high frequency pick up coils and the disappearance of sawteeth. In these cases the NBI switch off is always followed by a cascade of continuous modes rising in frequency and going from high n number (4) to low n (2 or 1), the last one always resulting in a mode-lock. This phenomenology is often the cause of a bad plasma termination or a disruption [4].

In Figure 5 the different n mode numbers during the landing phase of a hybrid discharge are shown. These modes do not seem to have an effect on the thermal profiles, being Te profile already extremely hollow at their onset.

The modes have been analysed using a coherence technique between ECE and magnetics, and the results are shown in Figure 6 for the timeframes marked in Figure 5 with vertical black lines. Their coherent thermal fluctuation is always localized radially in a few ECE channels, for this reason is difficult to recognize a fluctuation phase inversion, and therefore a magnetic

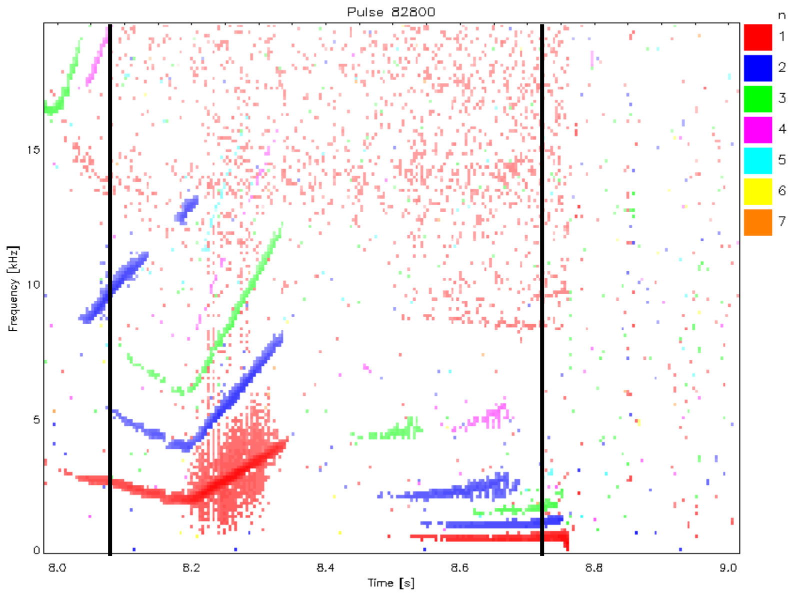


Figure 5: Magnetic spectrogram with mode n number highlighted.

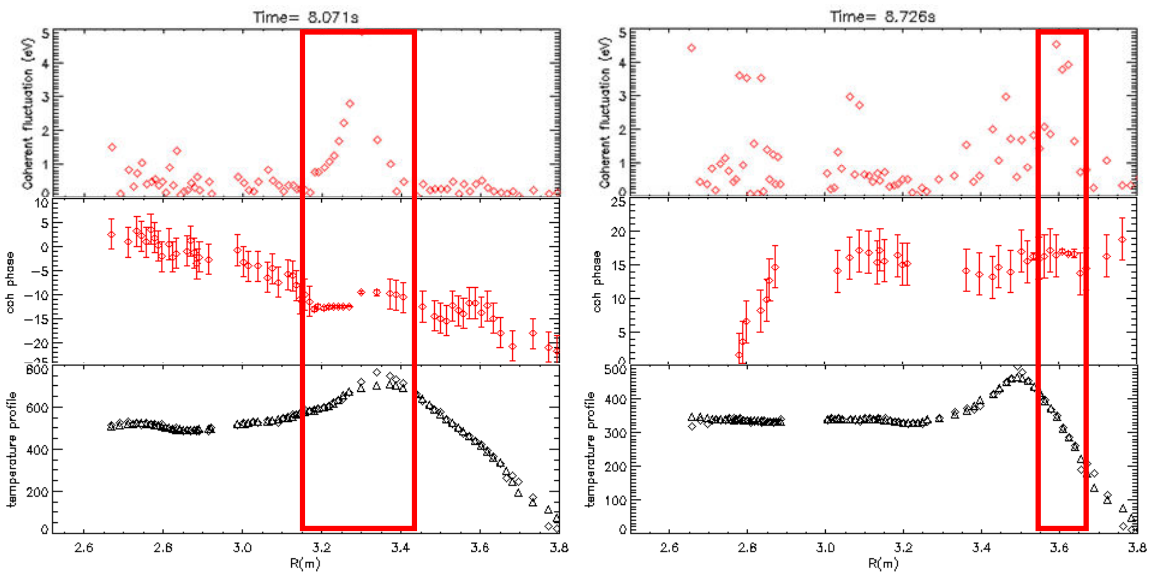


Figure 6: Coherence phase, temperature fluctuation amplitude and temperature radial profiles for pulse 82800 at different times.

island. This can be done in the left column of Figure 6 around 3.3m, while for the left column only a peak at 3.6m can be recognized, but no phase inversion.

The measured radial position has been correlated with the position of the maximum in the hollow electron temperature profile. The modes that chirp up in frequency and generate a cascade of n mode number are usually located inside the maximum of electron temperature, in the zone where the q-profile can be changed by low temperature and high resistivity, and therefore their chirp up reflects a change on q profile as shown in Figure 7, where q profiles and rotation are plotted at the times of the localization measurements in Figure 5. This hypothesis is confirmed by the fact that toroidal rotation around 3.37m did not change during the considered time interval, while the q profile modification is consistent with resonant surfaces moving inwards. On the other hand the mode which usually locks has stationary frequency and sits outside the maximum of the electron temperature profile, and for this reason it is closer to plasma edge and sensitive to error fields.

Future work on both the subjects will be the modelling of the MHD stability of these modes taking into account the reconstructed q-profiles and the effect of radiative cooling on tearing stability.

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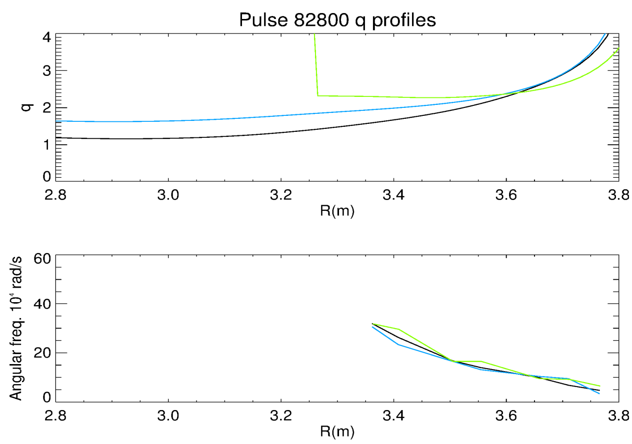

Figure 7: Radial profiles of reconstructed q with pressure and polarimetry data, and plasma rotation at t=8.1s (black) s, t=8.3s (blue), t=8.7s (green)