Resonant Field Amplification as a Measure for Plasma Stability

J Pearson[1]¥, M Gryaznevich[2], Y Liang[1], Y Yang[1,3], M Rack[1], L Zeng[1,3], P Denner[1] and JET EFDA Contributors*

[1] Institut für Energie- und Klimaforschung - Plasmaphysik, Forschungszentrum Jülich GmbH, Association EURATOM-FZJ, D-52428 Jülich, Germany.
[2] EURATOM/CCFE Fusion Association, Culham Science Centre, Abingdon, Oxon, OX14 3DB, United Kingdom.
[3] Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China.
¥E-mail: J.Pearson@fz-juelich.de
*See the Appendix of F. Romanelli et al., Proceedings of the 23rd IAEA Fusion Energy Conference 2010, Daejeon, Korea

Introduction and Motivation

Resonant field amplification (RFA) [1] is the phenomenon whereby meta stable modes in the plasma amplify externally applied or error magnetic fields through a resonant response. This can cause a rapid damping of the toroidal rotation through a transfer of angular momentum from the plasma to the surrounding coils. RFA is defined as

$$RFA = (B_r - B_r^{VAC})/B_r^{VAC}$$

"That a plasma can have a large amplification to a small perturbation is synonymous to a lightbulb with a small resistance dissipating more energy than one with larger resistance."

An increase in RFA has been observed just before a fast rotating 5kHz tearing or internal kink mode has been destabalised. Thus RFA is a useful tool when looking at the plasma stability. It can

- Predict the appearance of limiting modes.
- indicate the no-wall beta limit seen as a significant enhancement of RFA when the plasma exceeds the no-wall stability limit [2,3].

RFA is most commonly induced by external fields with low-*n* and low-frequency. Thus the resonant mode must also have these characteristics.

The Resistive Wall Modes (RWMs) fits these parameters and has been identified as the dominant driving mode behind the increase of RFA at the no-wall beta limit .

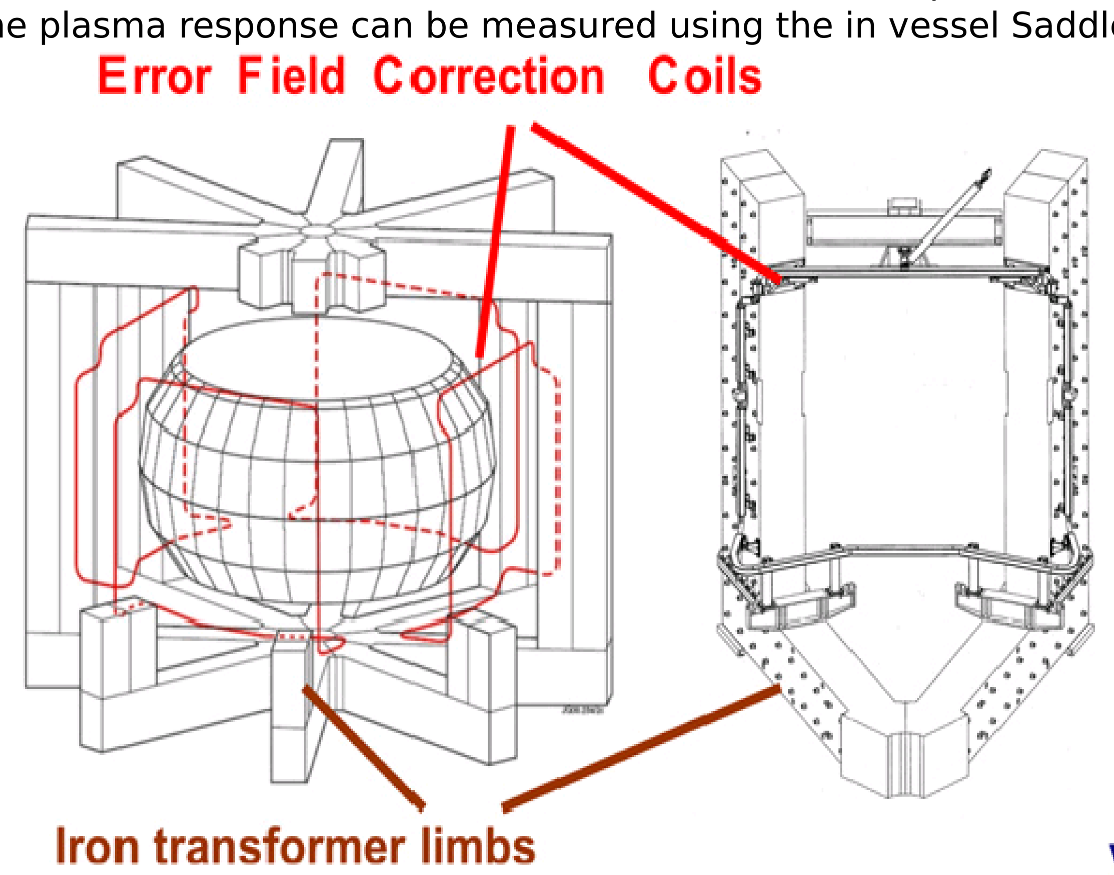
This work looks at an alternative to the RWMs, the *n*=1 Peeling mode.

Specifically, its effect on the RFA at the first Edge Localized Mode (ELM) and in the steady state ELMy phase.

Measurement Setup

JET

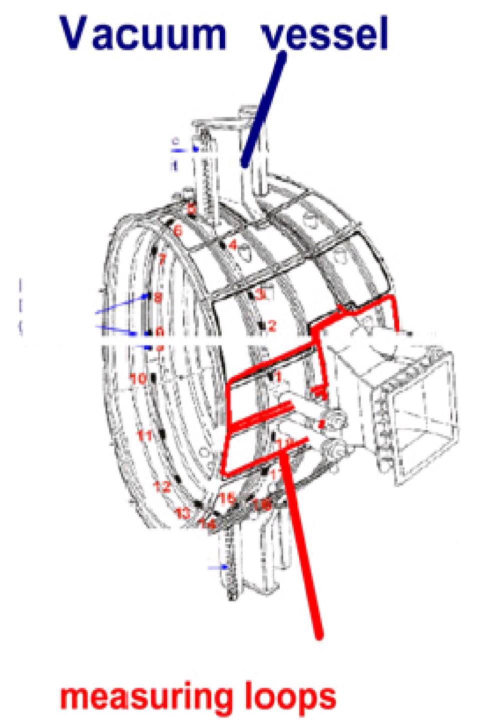
Using the Error Field Correction Coils (EFCC) external low-**n** perturbations are applied to the plasma. The plasma response can be measured using the in vessel Saddle coils.



Each signal needs a single value decomposition and a fourier analysis performed to extract the signal from the background.

The ratio of amplitudes from the tangential pairs (octants 1 and 5 verses 3 and 7), gives the value of RFA.

Note: Thus far only an oscillating field has been applied to JET; not an AC field. This means that phase must be taken into account when looking at the plasma response.



Puffing at first ELM

Recently, a peak in RFA has been observed at the first ELM.

The *n*=1 increase is seen at β_N below the RFA threshold associated with the ideal no-wall limit.

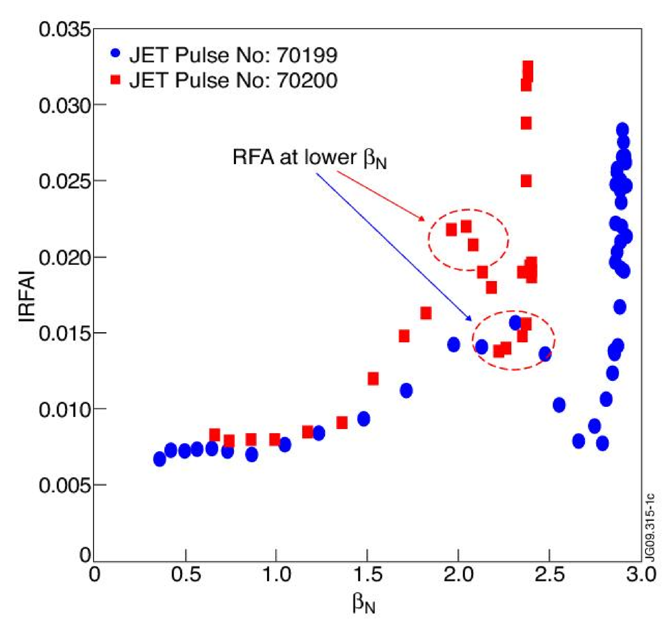


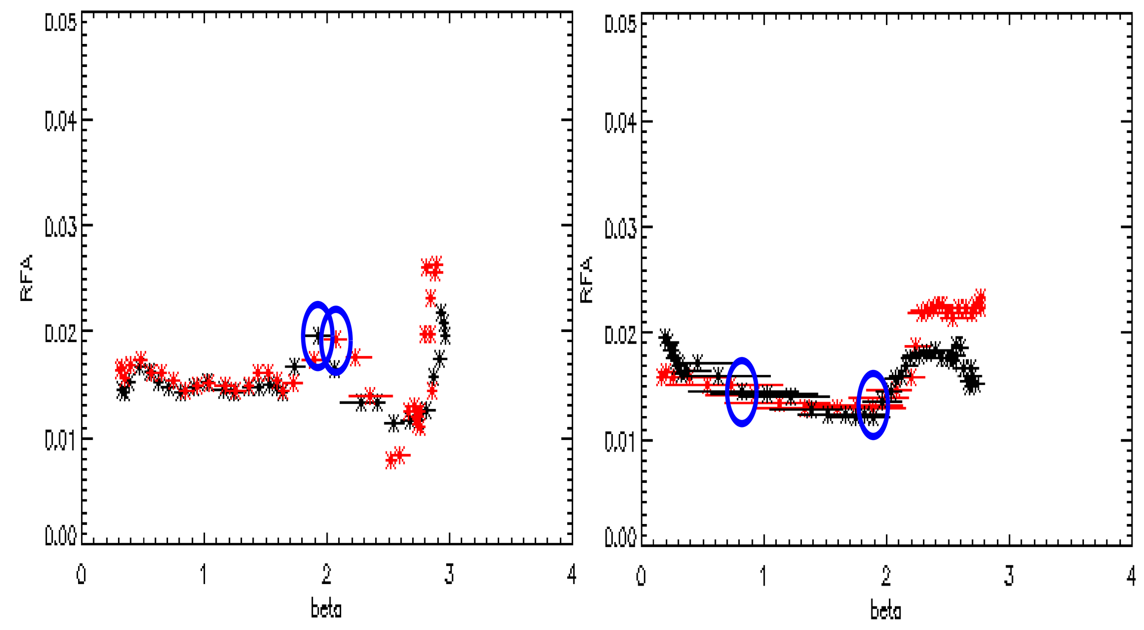
Figure 3: Two adjacent shots modelled using MARS-F showing a peak occurring before the βN threshold is reached. This corresponds to the time of the first ELM.

Behaviour not dominated by the RWMs as this is highly stabalised at low β_N.

- Alternatively an *n*=1 peeling mode suggested as the dominant mode at 1st ELM peak [4].
- Then the peeling mode becomes stable after the first ELM and thus the RFA drops back down, leaving the peak only at the first ELM.
- β_N will continue to rise to the no-wall limit and thus the RWMs take over as the dominant contributor increasing RFA.

A method of adding extra puffing to control the first ELM was often used on JET. A correlation between the extra puffing at the 1st ELM and the disappearance of the RFA peak at lower β_N can be seen.

Figure 4: Four adjacent JET shots taken over a short time interval including the first ELM which is circled. (left) two shots with a normal level of puffing showing the low β_N RFA peak corresponding with the first ELM. (right) two shots with extra puffing at the first ELM showing no peak in RFA at the first ELM.



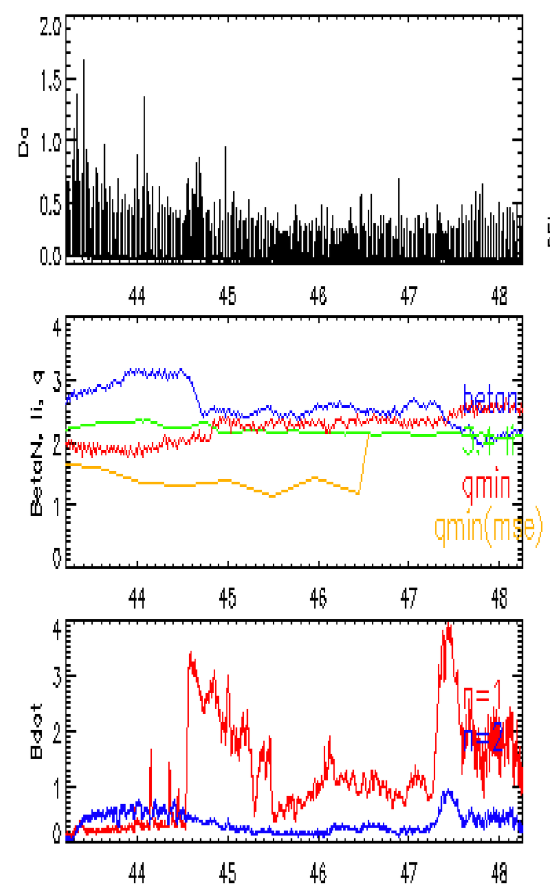
This suggests that the **extra puffing at the first ELM is probing the low n mode stability.**

puffing increases
↓
convective losses increases
↓
decreases the pedestal
(mostly through the temperature gradient)
↓
increases edge collisionality
↓
increases resistance
↓
decreases edge current density

thus according to peeling relaxation model [5] higher *n* dominant.

Steady State Behaviour

In the steady state ELMy flat-top region the presence of a low *n* mode is thought to alter the stability conditions resulting in the RFA threshold occurring at an earlier β_N.



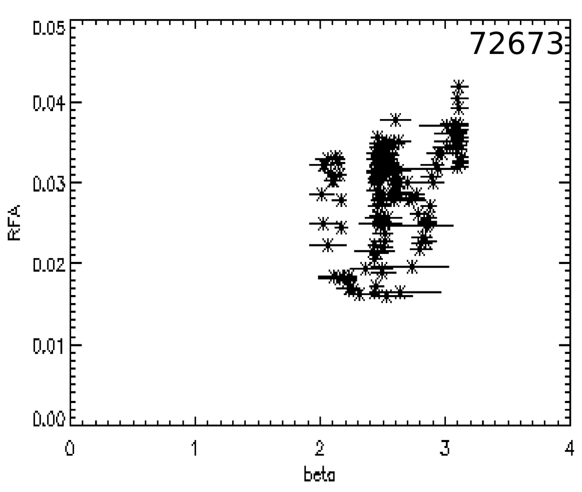


Figure 5: RFA in a steady state ELM phase. The red marker corresponds with the time when the n=1 mode activity increases showing the transition of the beta threshold from 3 to 2.5. The second burst of n=1 mode at 47.3s correlates with the second transition to the lowest level of βN.

When *n*=1 activity appears, the value of beta decreases. Interestingly this does not change back to the higher beta value when the *n*=1 activity decreases.

This result shows clearly that the plasma stability is affected by an *n*=1 mode and is to be compared with ELM control experiments being undertaken in 2012 on JET.

These experiments will modify the edge stability using induced *n*=1 and *n*=2 modes through Resonant Magnetic Perturbation (RMP) fields. This will develop the understanding of how the application of external fields effects the plasma stability and thus how these fields can be used to control the tokamak plasma.

Summary and Outlook

RFA is a useful tool for measuring the stability of a plasma and indicates the ideal no-wall stability limit.

An *n*=1 Peeling mode has been suggested to be the cause of the peak in RFA at the first ELM observed. Puffing at the first ELM has suppressed this early peak in RFA through probing the n=1 peeling mode stability.

On the EAST tokamak the small perturbation coils are due to be tested and a dedicated experiment has been proposed for the RFA measurements. These coils are situated near the lower divertor and consist of 10 small coils at two opposite toroidal positions which will be able to produce a highly localised *n*=1 perturbation. The plasma response can be measured through Mirnov coils.

Acknowledgments

This work was supported by EURATOM and carried out within the framework of the European Fusion Development Agreement. The views and opinions expressed herein do not necessarily reflect those of the European Commission. Support from the Helmholtz Association in frame of the Helmholtz-University Young Investigators Group VH-NG-410 is gratefully acknowledged.

References

[1] A. H. Boozer, Phys. Rev. Letts. 86 (2001) 5059 [2] M. P. Gryaznevich, Plasma Phys. Control. Fusion 50 (2008) 124030 [3] M Gryaznevich et al. Submitted to Nuclear Fusion, 2012 [4] Y. Liu, Plasma Phys. Control. Fusion 52 (2010) 045011 [5] J. Pearson et al. Nucl. Fusion, 50 (2012) To appear in

JÜLICH FORSCHUNGSZENTRUM CCFE CULHAM CENTRE FOR FUSION ENERGY TEC TRILATERAL EUREGIO CLUSTER