Synchronisation of ELMs within magnetic perturbation bursts in TCV

K.Schombourg, J.B.Lister, Y.R.Martin

CRPP - EPFL, Association Euratom-Confédération Suisse, 1015 Lausanne, Switzerland

Introduction

The ELM frequency of H-modes has been successfully controlled with a magnetic perturbation inducing vertical excursions of the plasmas in TCV and ASDEX Upgrade [1,2]. This paper presents the results of new experiments on TCV which were performed in order to address precise questions in relation to the underlying mechanisms of magnetic triggering of ELMs. The major point deals with the question whether one single perturbation can trigger an ELM or if a succession of perturbations is necessary to regularly trigger ELMs.

Experimental set-up

In TCV, the perturbations were injected into the plasma vertical position feedback loop. The actuator consists of a pair of coils (G-coil) located inside the vaccuum vessel. Top hat perturbations with variable amplitude but fixed duration were used in theses experiments. The delay betwen the perturbation pulses can be varied, either regularly or randomly. The induced vertical movement reached about 2cm.

The triggering of ELMs is due to the modification of edge parameters, essentially the current profile and in a less important way the pressure profile, when the plasma rapidly moves in the vertical direction [3]. The vertical velocity of the plasma induced by the perturbation is the important term to characterise the perturbation strength. This strength depends on the perturbation amplitude as well as on the vertical feedback loop gains since the current flowing into the G-coil is controlled by these gains.

Measurement of the synchronisation

Two methods were used to measure the synchronisation of ELMs on the perturbation. The first one consists of the delay between the perturbation and the following ELM. In an experiment, ELMs are said to be triggered by the perturbation if the distribution of delays peaks around a certain value. Individual ELMs can then be considered as triggered if they occur around that value. The second method is also based on the delay between perturbation and ELM occurence. However the synchronisation is established if **n** successive perturbations induce **n** ELMs and that the standard deviation of the delays remains below a given value.

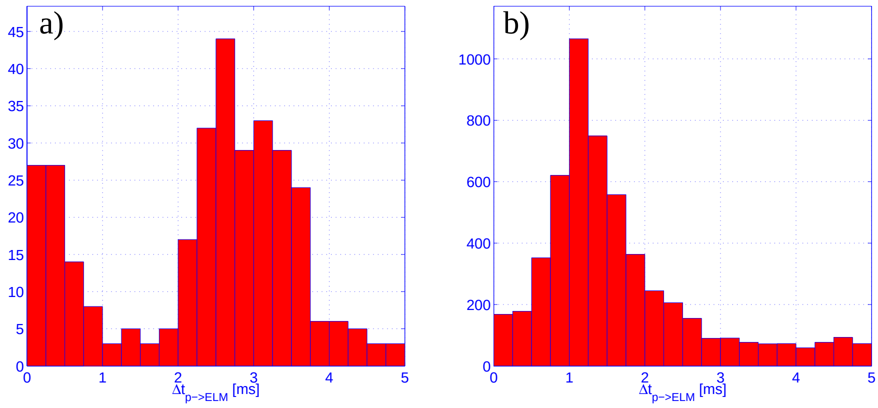

Figure 1: Delay between perturbation and ELM for a) positive and b) negative top hat perturbations

Effect of perturbation sign

Positive and negative top hat perturbations have been applied to stationnary ELMy H-modes. Although the frequency of the perturbation was smoothly or randomly varied within several plasma discharges, a good level of synchronisation was found in both cases. On the contrary, the perturbation-ELM delay changed significantly between the two cases, as shown in Fig.1. When compared with the evolution of the G-coil current and the plasma vertical excursion, the histograms show that the ELMs are triggered when the plasma moves down, in both cases. In a) the plasma moves down as soon as the perturbation starts and this movement can trigger ELMs. Then the plasma goes up and this inhibits the ELMs. After 1.5-2s the plasma recovers its initial position and the ELMs might occur again. In b) the plasma moves up first and at about 0.75ms goes back down and triggers ELMs. Because of their less inhibitive effect, the negative perturbations were preferentially used and all the following results were obtained with negative top hat perturbations.

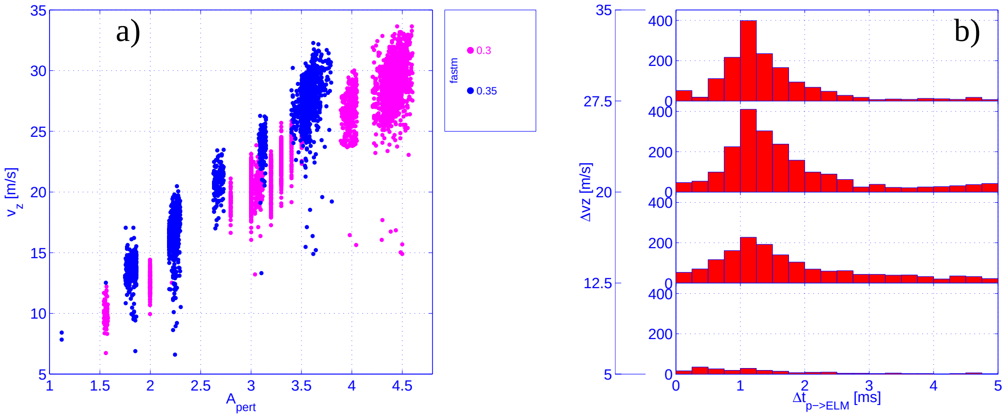

Figure 2: a) Plasma vertical velocity as a function of the perturbation amplitude. b) ELM synchronisation with different plasma velocities

Effect of plasma vertical velocity

The amplitude of the perturbation ranged over a factor of 3 and two values of vertical feedback gain were used. In Fig.2.a, the vertical plasma velocity increases with both the perturbation amplitude and the strength of the vertical position feedback. The perturbation-ELM delays, grouped for different velocity classes, show more peaked distributions for higher velocities in Fig.2.b. In other words, the ELM triggering is more efficient at higher velocities. This is certainly due to a correspondingly larger influence on edge parameters.

ELM triggering mechanism

The mechanism which leads to the ELM synchronisation can either be of 'prompt' or 'cyclic' nature. 'Prompt' nature means that a single perturbation could provoke the triggering of an ELM, while the cyclic nature refers to the requirement of a periodic perturbation, which resonates with the ELM cycle, to synchronise the ELMs. For instance, the perturbation could influence the ELM limit cycle and, in consequence, the ELM frequency would be modified.

In a series of discharges, perturbations were grouped in short 5-7 impulses bursts, separated by long random delays to prevent memory effects. The delay between perturbations within a burst are kept constant. The synchronisation of the ELMs onto the $\mathbf{n}^{th}$ perturbation was measured. Fig.3. shows the distribution of the delay for the 1^{st} and 4^{th} perturbations.

In these figures, perturbations occuring soon (<1ms) after an ELM are removed because the chance of triggering an ELM so close to the preceding one is negligeable, since this interval corresponds to the ELM relaxation time. This happens since the perturbations are turned on at a random phase of the ELM cycle. The natural delay between ELMs being ~5ms in these discharges, this restriction does not influence the results.

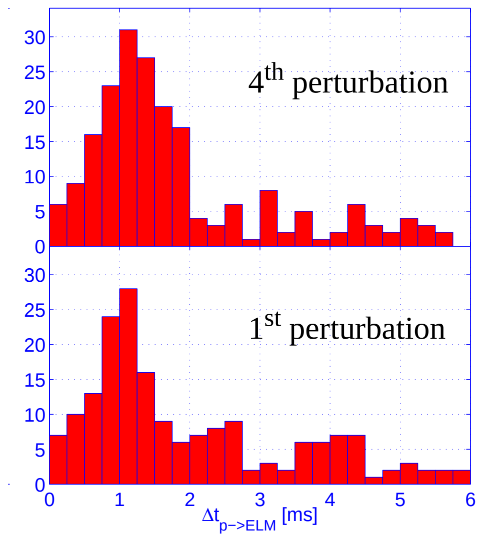

Figure 3: Histogram of delays between perturbation and ELM for the 1^{st} and 4^{th} perturbation in several perturbation bursts from several plasma discharges

At the first perturbation, the delay distribution is already significantly peaked, indicating a quite strong prompt nature. However, the distribution is slightly more peaked for the 4th. It could be attributed to a cyclic nature, but could also be due to an improvement of the prompt nature through

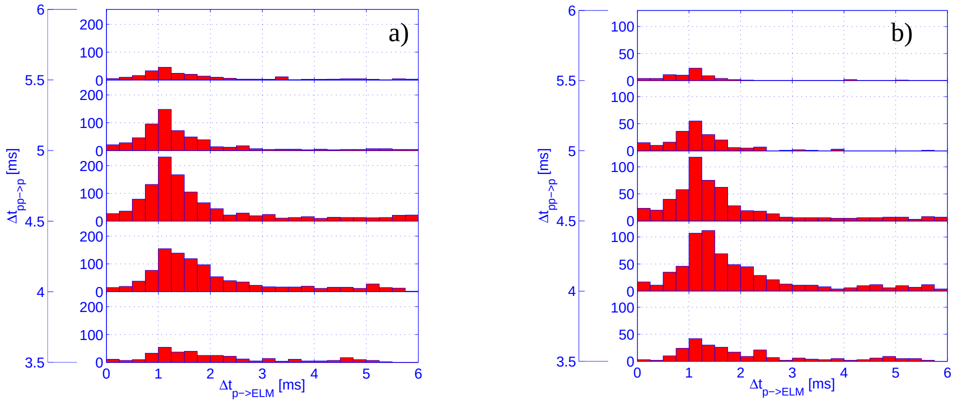

Figure 4: a) Delay between perturbation and ELM for a) slowly varying perturbation frequency and b) randomly varying frequency

the increased collection of synchronised ELMs.

Effect of perturbation train types

Other experiments were dedicated to this question. In a series of long perturbation bursts (up to 180 perturbations in one burst) the delay between perturbations was either varied slowly between two values, typically 4 and 7 ms, or varied randomly within the same range. The distribution of the delays between perturbation and ELM is similar for the different experiments as presented in Fig.4. The same level of synchronisation for monotonic, almost equal delays or random delays also indicates that ELMs respond to prompt perturbations.

Conclusions

Various experiments were performed in TCV to study the nature of the ELM trigerring mechanism by magnetic perturbations. The sign of the perturbation has a strong influence on the delay between perturbation and ELM since, in these experiments, the ELMs are provoked by a vertical downwards movement and inhibited by a vertical upwards movement. The largest induced displacement of the plasma (~2cm) led to the best ELM synchronisation. Experiments dedicated to the study of the prompt or cyclic nature of the ELM control indicated that a prompt mechanism is most likely dominating.

Acknowledgement

This work was partly supported by the Fonds National Suisse de la Recherche Scientifique.

References

[1] A.W.Degeling et al. Plasma Physics and Controlled Fusion (2003), 1837.

[2] P.Lang et al. Plasma Physics and Controlled Fusion (2004) L31

[3] S.H.Kim et al, this conference