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**See appendix of the paper by J.Pamela "Overview of recent JET results", Proceedings of the IAEA conference on Fusion Energy, Sorrento 2000*

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1. INTRODUCTION

Most observations of Neo-classical tearing Modes (NTM) in JET experiments, occur in regimes where the sawteeth are present.

Recent JET experiments showed that it is possible to control the time of onset of the NTM by controlling the frequency of occurrence and the amplitude of sawteeth crashes using ICRH [1].

A clear correlation between the time of sawtooth crashes and the onset of NTMs was obtained from a database of pre 2000 JET experiments [1]. In this paper we study the correlation between sawteeth and other central n=1 MHD modes such as fishbones and the onset of the m=3 n=2 NTMs. In addition we study the amplitude of the n=1 sawtooth precursors around the time the NTM starts.

A larger database including 2000-2001 NTM studies is considered. This includes experiments for the study of shape effects on the NTM trigger [2], NTM studies in ASDEX-Upgrade similarity discharges, ITER like discharges and experiments to control NTMs by sawtooth control [2].

Only discharges, which are dominantly NBI heated, are considered. Studies show that large sawteeth in dominantly ICRH discharges can have a low β limit, β <1 and conclusions for these discharges may differ from these reached here.

2. *M*=1,*N*=1 AMPLITUDE

The amplitude of *m*=1, *n*=1 modes was obtained from observations of magnetic field perturbations induced on magnetic pickup coils using fast Fourier transforms and filter techniques. The acquisition frequency of these coils varies from 250kHz to 1MHz.

We consider the two sawtooth crashes that were nearest to the m=3, n=2 NTM onset. The sawtooth period was obtained from Soft X-ray emission traces.

Figure 1 shows the spectrogram for a discharge in which the (3,2) NTM is triggered just before a sawteeth. The amplitude of the sawtooth precursors for this pulse is showed in Fig. 2. It can be seen from Fig.2 that the largest amplitude of the sawtooth precursor does not necessary trigger the (3,2) NTM.

Figure 3 shows the spectrogram for a discharge in which the (3,2) NTM appears to be triggered by fishbones. The amplitude shown in Fig. 4, is the same order as the sawtooth precursor amplitude seen in Fig. 2.

Figure 4, shows a pulse with similar edge B_p = 0.27T as in the previous two cases, a NTM is not observed. The amplitude of the sawtooth precursor is slightly than in Figs. 2 and 4.

2.1. M=1, N=1AMPLITUDE IN FUNCTION OF NORMALISED β

For this analyses we selected the pulses with values of δ between 0.25 and 0.3 and q_{95} between 3.0 and 3.5.

The mode amplitude of the nearest sawtooth precursor at NTM onset, increases with increasing– β_N, Fig. 6.

The onset of NTM related to fishbones occurs for β_N–> 2.5 while for sawtooth related occurs with lower beta values, β_N > 1.5, in these dominantly NBI heated discharges.

The distribution in Fig. 6 does not change significantly if we take the amplitude of the previous sawtooth precursor.

2.2. M=1, N=1AMPLITUDE IN FUNCTION OF ρ*

The mode amplitude increases with ρ^*, Fig. 7. If the NTM threshold is due to the polarisation current the approximately one would expect the seed island amplitude to scale as ρ^*. So in Fig. 7 a scaling of $br = \frac{1}{B_p}\alpha(\rho^*)^2$ would be expected; it can be seen that such a scaling is not consistent with the data.

2.3. N=1 AMPLITUDE IN FUNCTION OF SAWTOOTH PERIOD

The amplitude of the sawtooth precursor increases with the period for the pulses with δ between 0.25 and 0.3 and q_{95} between 3 and 3.5.

3. NTM TRIGGER RELATION WITH SAWTOOTH CRASH

A key aspect of the underlying theory of the non-linear coupling is the relation between the NTM trigger and *n*=1 instability [3]. Figure 9 shows that the majority NTMs onset occurs before a sawtooth crash. Most are triggered in presence of central n=1 modes. The peak around the sawtooth crash corresponds mostly to pulses with lower β_N, and very long sawtooth periods with short precursor.

CONCLUSIONS.

1. In most JET experiments, with ELMy H-modes plasmas the NTM is found to occur associated with the sawtooth instability and in a minority of cases with fishbones.
2. The required n=1 amplitude for the NTM onset appears to be independent of whether the NTM is triggered by fishbones or sawteeth.
3. The n=1 maximum amplitude of the nearest sawtooth precursor of NTM onset is found to be consistent with the expectation from the polarisation theory model though there is a significant scattering in the data.
4. The mode amplitude of the sawtooth precursor is not the only factor that determines the onset of the NTM. Other factores such as the relative rotation between q=1 and 3/2 need to be examined in future studies.

REFERENCES

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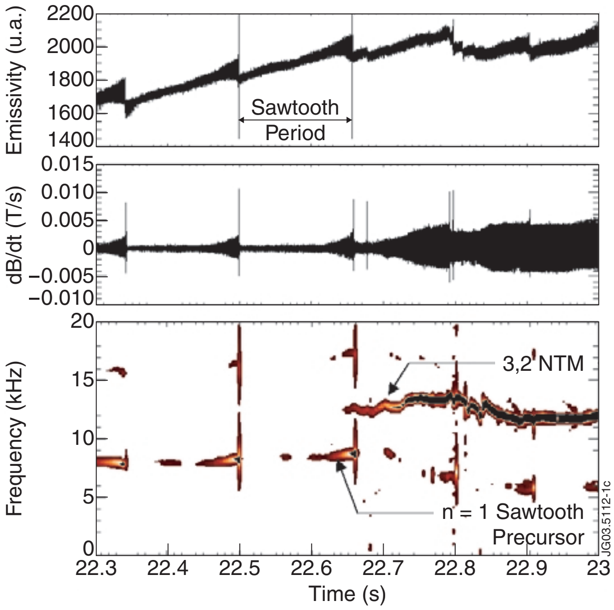

Figure 1: Signal from the Soft X-ray central emission, induced signal in a fast pickup coil from the Pulse No: 51995 and the correspondent spectrogram showing a (3,2) NTM triggered by a sawtooth precursor.

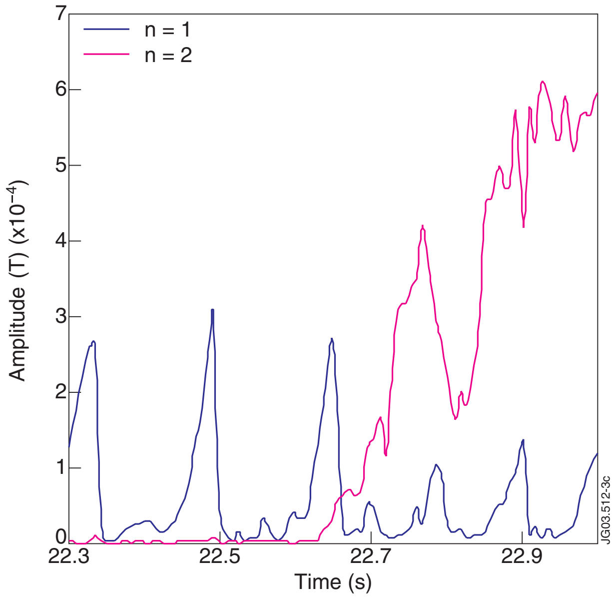

Figure 2: Amplitudes of the n=1 sawtooth precursor and n=2 NTM mode for the Pulse No: 51995.

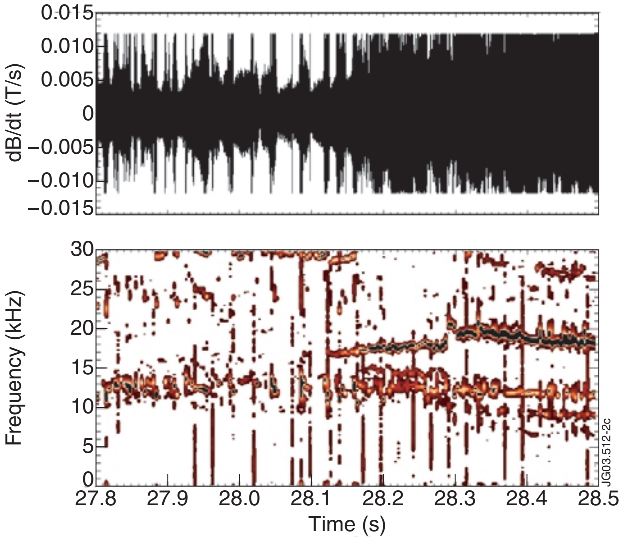

Figure 3: Induced Signal in a fast pickup coil from the Pulse No: 52083 and its correspondent spectrogram showing and NTM triggered in a discharge with frequent fishbones.

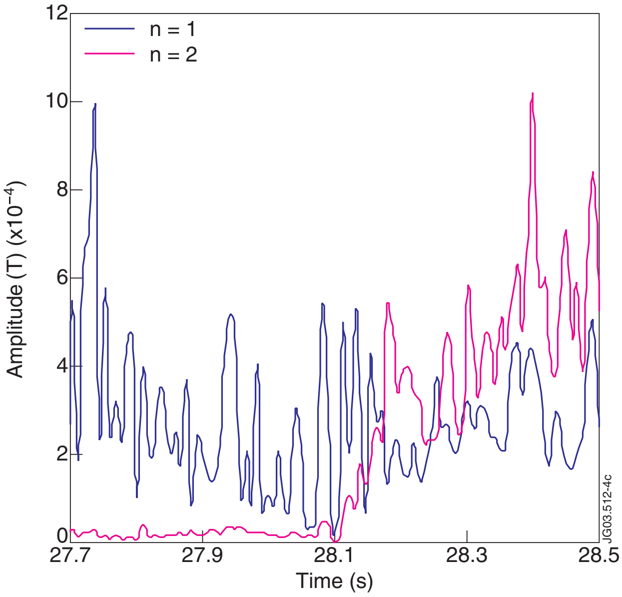

Figure 4: Amplitude of the n=1 fishbone bursts and n=2 NTM modes for the Pulse No: 52083.

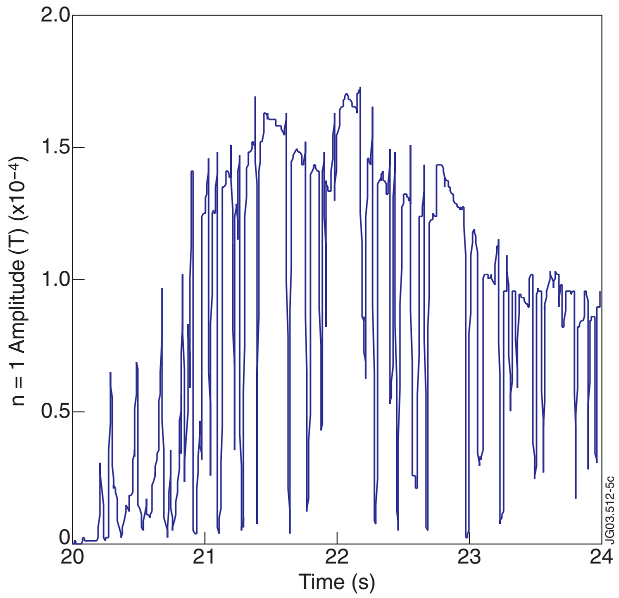

Figure 5: Amplitude of the n=1 sawtooth precursor mode for the Pulse No: 52002 where a NTM was not found.

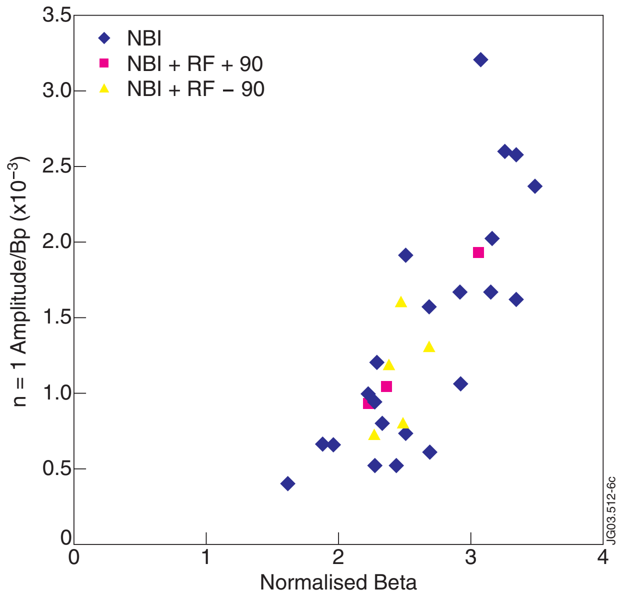

Figure 6: n=1, m=1 amplitude of the sawtooth precursor normalised by B_p at the edge of the plasma versus β_N.

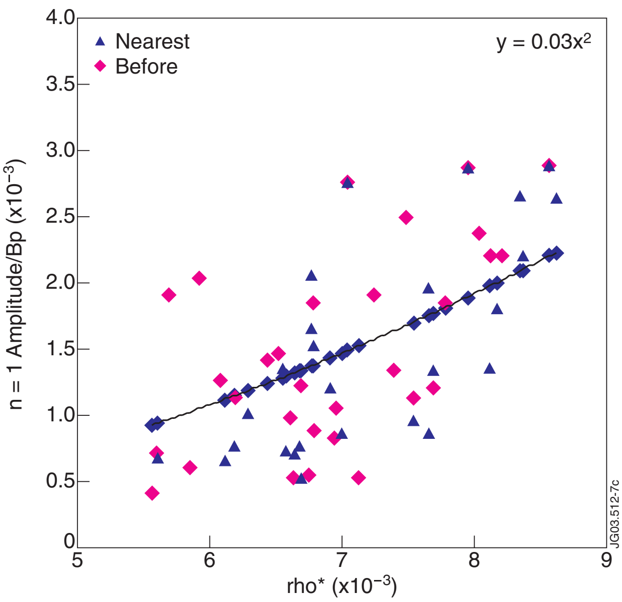

Figure 7: n=1, m=1 amplitude normalised by B_p at the edge of the plasma versus ρ^*.

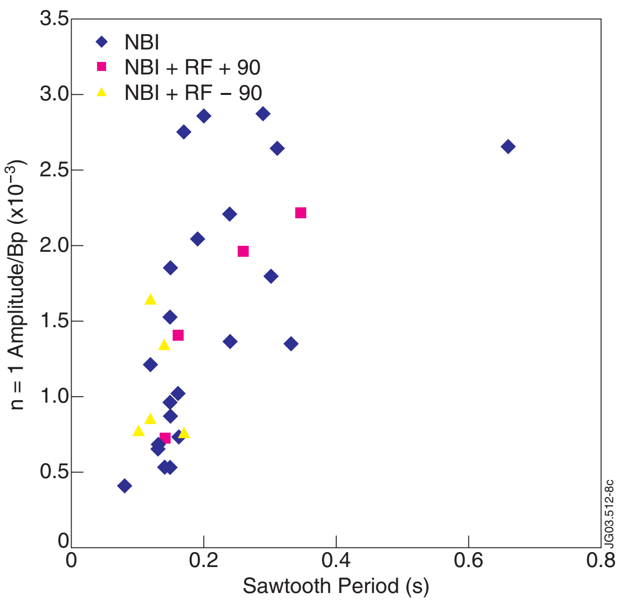

Figure 8: n=1 Amplitude of the sawtooth precursor versus the sawtooth period.

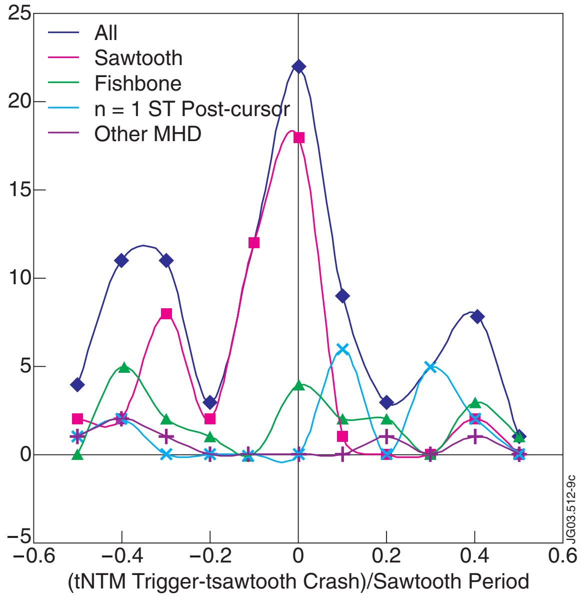

Figure 9: Distribution of NTM occurrence (89 discharges) with respect to the nearest sawtooth crash (dark blue). Distribution of cases occurring when a sawtooth precursor is observed (pink).
Distribution of cases when fishbones are present (green). Distribution of cases with respect to n=1 sawtooth post-cursors.