Parametric dependence of EPMs in NSTX

E.D. Fredrickson, M. Podesta, S.P. Gerhardt, R.E. Bell, A. Diallo, B. LeBlanc, F. M. Levinton[1], H. Yuh[1]

Princeton Plasma Physics Laboratory, Princeton New Jersey 08543, USA
[1]Nova Photonics, Princeton, New Jersey 08543, USA

eric@pppl.gov

Abstract

The International Tokamak Experimental Reactor (ITER) will have a large population of non-thermal, energetic ions consisting of fusion generated alphas and beam ions injected for current profile control. Potential redistribution and/or loss of those non-thermal ions is thus of concern as it will modify heating profiles, current profiles, and could lead to unacceptable levels of heating of plasma facing components. Redistribution and losses of fast ions have been documented as resulting from multiple Alfvénic modes, Toroidal Alfvén Eigenmodes and energetic particle modes (fishbones) on many smaller plasma devices.

In this paper we present data and analysis of modes driven by neutral beam ions on the National Spherical Torus Experiment (NSTX) [Ono *et al.*, Nucl. Fusion **40** (2000) 557]. Previously, a database was constructed including, among other parameters, the fast ion stored energy, thermal stored energy, Alfvén velocity and full-energy beam-ion velocity. The principal result of that work was that TAE avalanches were present only when $\langle\beta_{fast}\rangle/\langle\beta_{tot}\rangle > 0.3$ and that quiescent plasmas were only present for $\langle\beta_{fast}\rangle/\langle\beta_{tot}\rangle < 0.3$. However, similar constraints on the appearance of the two types of fast-frequency-chirping low frequency modes and non-avalanching TAE were not found. The database has been extended to include data on plasma rotation and q-profile.

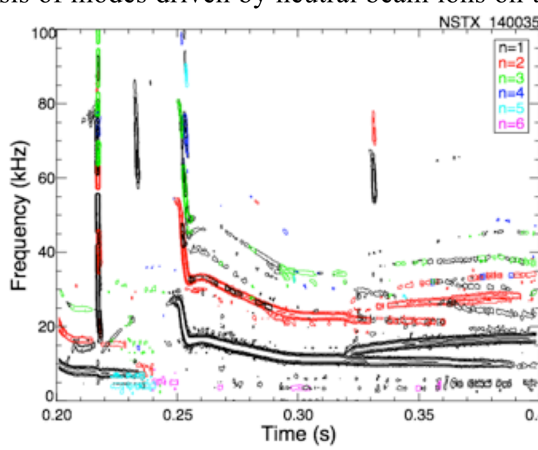

Fig. 1. Mode I.D. spectrogram of Mirnov signal fluctuations during NBI heating on NSTX. An EPM-LLM mode is seen to onset at 0.25s and bifurcate at 0.32s.

Fast downward-frequency-chirping modes, with frequencies of order the toroidal plasma rotation frequency, are common on NSTX. Based on the morphology of their spectrograms, short bursts with fast chirps were classified as fishbone-like energetic particle modes (EPM) and persistent modes originating with a fast downward frequency chirp, as shown in Fig. 1, were classified as EPM-LLM (long-lived-modes). The assumption was that such fast frequency chirps resulted from the interaction of the modes with a large fast-ion population.

The inclusion of CHERs rotation profiles led to the observation that EPM-LLM frequency chirp is a result of the core rotation collapsing. These modes often bifurcate later into two independent modes (0.32s in Figs. 1 &2). The bifurcation is correlated with a re-peaking of the rotation frequency (Fig. 2). The mode frequency is mapped to the radius where it matches the toroidal rotation frequency (green points Fig. 2a). The rotation remains flat across the core region for ≈ 60 ms following the collapse, and then begins to re-peak. The observations suggest that the LLM can have significant impact on momentum transport and that strongly sheared rotation can decouple poloidal harmonics of a kink mode, forming two independent modes.

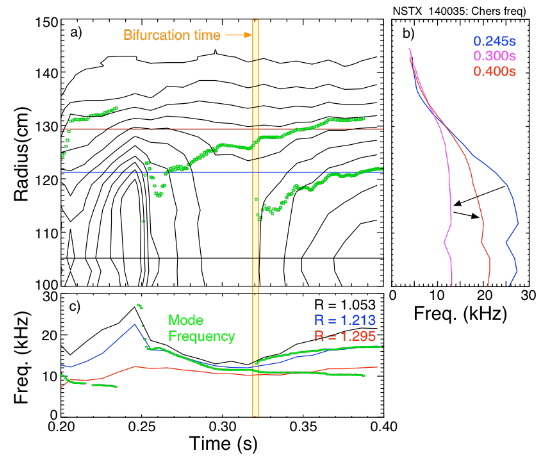

Fig. 2. Contours of plasma rotation with mode locations determined by matching mode frequency to toroidal rotation frequency overlaid.

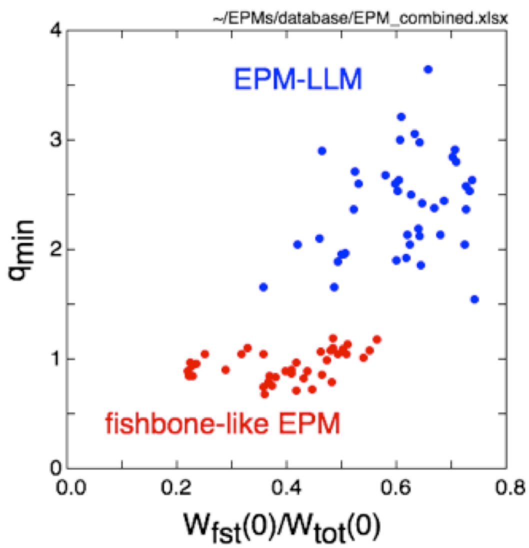

Fig. 3. The minimum in q and the ratio of fast ion to total stored energy at time of fishbone-like EPM and onset of EPM-LLM.

In Fig. 3 are shown some preliminary results from the database where it is found that fishbone-like EPMs are found predominantly in plasmas with $q_{min} \approx 1$. The long-lived chirping modes (EPM-LLM) typically appear for a broad range of q_{min} with $1 < q_{min} < 4$. The threshold for excitation, $\beta_{fast}(0)/\beta_{tot}(0) > 0.2$, is in good agreement with predictions base on simulations with M3D-k. Experiments on NSTX-U will further extend this database towards higher field (lower $V_{fast}/V_{Alfvén}$).

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[1] E.D. Fredrickson, N.N. Gorelenkov, M. Podesta, *et al.*, Nucl. Fusion **54** (2014) 093007.