# Parametric dependence of fast-ion transport events on the National Spherical Tokamak Experiment

E. D. Fredrickson, N. N. Gorelenkov, M. Podesta,
S. P. Gerhardt, R. E. Bell, A. Diallo, B. LeBlanc,
*PPPL, Princeton NJ*
A. Bortolon,
*Univ. of Tennessee., Knoxville, Tennessee*

Email contact of main author: efredrickson@pppl.gov

Neutral-beam heated tokamak plasmas commonly have more than one third of the plasma kinetic energy in the non-thermal energetic beam ion population. This population of fast ions heats the plasma, provides some of the current drive, and can affect the stability (positively or negatively) of magneto-hydrodynamic instabilities. This population of energetic ions is not in thermodynamic equilibrium, thus there is free-energy available to drive instabilities, which, of course, leads to redistribution of the fast ion population. Understanding under what conditions beam-driven instabilities arise, and the extent of the resulting perturbation to the fast ion population, is important for predicting and eventually demonstrating non-inductive current ramp-up and sustainment in NSTX-U, as well as the performance of future fusion plasma experiments such as ITER. This paper presents an empirical approach towards characterizing the stability boundaries for some common energetic-ion-driven instabilities seen on NSTX.

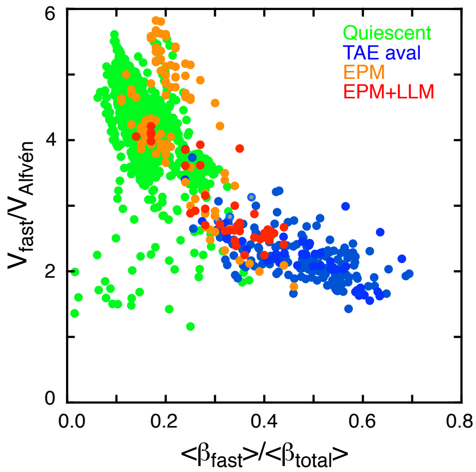


Fig. 1. Existence plot for a variety of types of energetic particle driven MHD activity, as well as quiescent plasmas with weak or no MHD activity (green).

A database was constructed by dividing each of ≈360 NSTX TRANSP runs into 50ms intervals, starting at 150ms. Typically by 150ms NSTX plasmas have reached a plasma current of ≈ 0.6MA to 0.7MA, and fast ion confinement is reasonably good. The 50ms time interval is several fast-ion slowing down times, and is comparable to the timescale for evolution of MHD phenomena. The MHD activity in each 50ms interval was subjectively classified as having TAE avalanches, Abrupt Large Events (ALEs), bursting TAE, constant-amplitude TAE, energetic particle modes (EPMs), global Alfvén eigenmode avalanches or plasmas quiescent in the TAE and lower frequency range.

Figure 1 is constructed from this database and the where the color of the point indicates the type of instability dominant in that interval. The horizontal axis is the ratio of the energy in the fast ion beta, $\beta_{fast}$, to the total plasma beta, $\beta_{total}$. The vertical axis is the ratio of the birth velocity of the full-energy beam ions normalized to an average Alfvén speed. Generally, NSTX shots evolve, starting from the lower right of Fig. 1 and moving upwards and to the left as the plasma density increases. Thus, there can be hidden correlations in these figures as, for example, points in the lower right would tend to have elevated $q_{min}$. The quiescent discharge periods (green), and periods with TAE avalanches and ALEs (both blue in Fig. 1) are well localized in this parameter space. Quiescent plasmas mostly have a ratio of fast-ion stored energy to total stored energy of less than ≈ 30%. Conversely, the TAE avalanches and ALE events occur where that ratio, $\beta_{fast}/\beta_{total} > 0.3$. Within this dataset, there does not seem to be a significant dependence on the $V_{fast}/V_{Alfvén}$.

The empirical scaling of neutron rate drops versus a single parameter, the peak mode amplitude as measured by a Mirnov coil, is shown in Fig. 2 for TAE avalanches (green) and EPMs (red and blue). The neutron rate drops follow an offset-linear scaling with mode amplitude, suggesting an amplitude threshold for the onset of the avalanche. The peak EPM edge magnetic fluctuation level tends to be larger that that for TAE avalanches for a similar drop in the normalized neutron rate. The scaling of the neutron rate drop with edge magnetic fluctuation amplitude is similar for the two types of fishbone-like EPMs, although there is considerably more scatter for the EPM coupled to the long-lived mode.

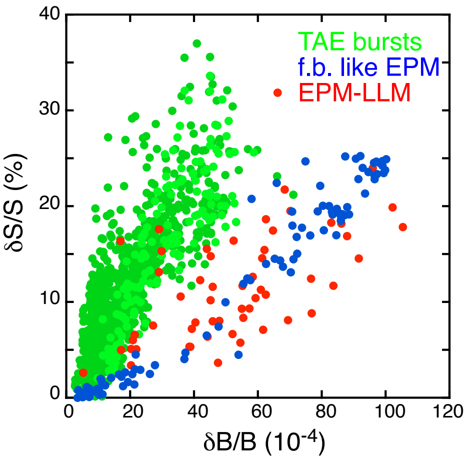

Fig. 2. Scaling of neutron rate drops with edge magnetic fluctuation amplitude for TAE (green), fishbone-like EPM (blue) and EPM coupled to long-lived modes (red).

On NSTX the TAE avalanches and fishbone-like Energetic Particle Modes are predominantly responsible for fast ion redistribution events. The dependence of these events on plasma global parameters has been studied. It has been shown that for this NSTX data set, TAE avalanching is only seen when the calculated $\beta_{fast}/\beta_{total} > 0.3$, and conversely, that quiescent plasmas are only seen for $\beta_{fast}/\beta_{total} < 0.3$.

*Work supported by U.S. DOE Contracts DE-AC02-09CH11466.