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Collective fast ion instability-induced losses in NSTX[1]

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A wide variety of fast ion driven instabilities are excited during neutral beam injection (NBI) in the National Spherical Torus Experiment (NSTX) due to the large ratio of fast ion velocity to Alfvén velocity, $V_{fast}/V_{Alfvén}$, and high fast ion beta. The ratio $V_{fast}/V_{Alfvén}$ in ITER and NSTX is comparable. The modes can be divided into three categories; chirping energetic particle modes (EPM) in the frequency range 0 to 120 kHz, the Toroidal Alfvén Eigenmodes (TAE) with a frequency range of 50 kHz to 200 kHz and the Compressional and Global Alfvén Eigenmodes (CAE and GAE, respectively) between 300 kHz and the ion cyclotron frequency. Fast ion driven modes are of particular interest because of their potential to cause substantial fast ion losses. In all regimes of NBI heated operation we see transient neutron rate drops, correlated with bursts of TAE or fishbone-like EPMs. The fast ion loss events are predominantly correlated with the EPMs, although losses are also seen with bursts of multiple, large amplitude TAE. The latter is of particular significance for ITER; the transport of fast ions from the expected resonance overlap in phase space of a "sea" of large amplitude TAE is the kind of physics expected in ITER. The internal structure and amplitude of the TAE and EPMs has been measured with Heterodyne reflectometry and soft x-ray cameras. The TAE bursts have internal amplitudes of $\tilde{n}/n \leq 1\%$ and toroidal mode numbers $2 < n < 6$. The EPMs are core localized, kink-like modes similar to the fishbones in conventional aspect ratio tokamaks. Unlike the fishbones, the EPMs can be present with $q(0) > 1$ and can have a toroidal mode number $n > 1$. The range of the frequency chirp can be quite large and the resonance can be through a fishbone-like precessional drift resonance, or through a bounce resonance.

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