

Beam Ion Losses Due to Fast Frequency Chirping Instabilities in DIII-D Plasmas*

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Fast frequency-chirping instabilities in the Alfvén eigenmode frequency range are observed to generate beam ion losses in DIII-D plasmas with little to no other coherent loss flux. The appearance of beam ion losses suggests that the chirping modes warrant improved understanding as a potential energetic ion loss mechanism in ITER. Furthermore, predictive modeling of plasma performance in ITER and future reactors is improved by the inclusion of the fundamental effects leading to nonlinear mode saturation and evolution. Assorted nonlinear instability evolution is observed in rf-heated tokamak plasmas [1], the spherical torus [2], and neutral beam heated conventional tokamaks such as DIII-D. Ongoing studies seek to further develop the understanding of the various underlying physical processes, such as the role of dynamical friction [2,3], by using detailed measurements of the both mode evolution and their impact on the energetic particle profile combined with large-scale nonlinear, non-perturbative gyrokinetic simulations using the GTC code [4].

These fast frequency chirping modes lie within the expected frequency range of both Beta induced (BAE) and toroidicity induced Alfvén eigenmodes (TAE) - highlighted in the density autopower spectrogram of Fig. 1(a). The shots begin with typical DIII-D AE spectral behavior featuring (slow) frequency changes determined by plasma equilibrium, density, and q-profile evolution. This period of considerable AE activity coincides with minimal beam ion losses as indicated in the spectrogram from a fast ion loss detector shown in Fig. 1(b). Nonlinear fast frequency chirping events appear approximately over the interval $800 < t < 1000$ ms with the losses limited to a few modes.

Analysis of a series of discharges shows that the appearance of chirping exhibits strong correlations with injected beam power, normalized beta, and central rotation, but weak correlation with most other plasma parameters including electron temperature and density. The strong correlations may result from a single underlying source (e.g., higher normalized beta and faster central rotation result from increased beam power). The conditions that lead to chirping beam ion losses will be investigated with orbit following codes using measured mode structure and plasma equilibria as inputs. Present experimental results demonstrate that the chirping mode-induced energetic ion losses will be an important consideration for the alpha particle and auxiliary heated ions produced in ITER.

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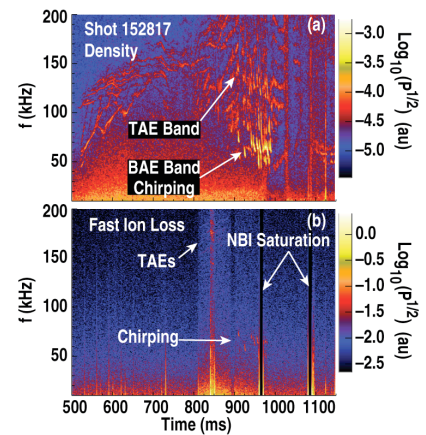


Fig. 1. (a) Spectrogram of density fluctuations in shot 152817 indicating the presence of typical Alfvén eigenmodes ($t < 800$ ms) and chirping modes indicated by rapid frequency evolution. (b) Spectrogram of fast ion losses showing no coherent losses prior to 800 ms and chirping loss signatures from $900 < t < 1000$ ms.

*This work was supported by the US Department of Energy under DE-FC02-04ER54698, SC-G903403, DE-FG03-97ER54415, DE-AC02-09CH11466, DE-FG02-89ER53296, and DE-FG0-08ER54999.