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Linear and nonlinear dynamics of electron fishbones

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Internal kink instabilities exhibiting fishbone like behaviour have been observed in a variety of experiments where a high energy electron population, generated by strong auxiliary heating and/or current drive systems, was present. Numerical simulations using XHMGC, a hybrid MHD-Gyrokinetic code, has been already applied successfully to analyses of modes driven by energetic electrons. In particular, electron fishbones driven by an energetic particle population with on-axis peaked radial density profile were studied in some detail describing the linear and non-linear mode dynamics using a strongly anisotropic distribution function, mainly constituted by deeply trapped particles. Deeply trapped energetic electrons were recognized to drive the mode, in this case, by precession resonance. In this paper we will further investigate electron fishbones driven by an energetic particle population with on-axis peaked radial density profile showing the relative importance of different driving and damping processes accounted for in the model, i.e., energetic electrons, thermal ion compressibility and diamagnetic effects, thermal electron compressibility. Numerical simulation results have shown that non-linear fishbone dynamics is governed by frequency chirping due to phase-locking: transport of energetic electrons in phase space will be analyzed in detail using test particle Hamiltonian mapping (TPHM) techniques, and the saturation amplitude scaling will be compared with the theoretical predictions. After reviewing the on-axis peaked energetic electron density population, the case of off-axis peaked energetic electron density population will also be analyzed in detail. This case is closely related to the experimental set up of present experiments with off-axis ECRH heating, in particular for the case of high field side deposition, where barely trapped/circulating electrons will be preferentially heated with an inverted radial density profile of the energetic electrons close to the q_min radial surface. It will be shown that, as expected from theory, unstable modes must propagate in the opposite direction w.r.t. the one observed in the case of an energetic electron population with on-axis peaked radial density profile. Both the linear and non-linear dynamics of an energetic electron population with off-axis peaked radial density profile will be presented.

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