Monte-Carlo Simulation of High Harmonic Fast Wave Heating of Neutral Beam Ions and Effects on MHD Stability: Validation With Experiments*

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Abstract. Experimentally, during fast wave radiofrequency (FW RF) heating in DIII-D L-mode discharges, strong acceleration of neutral beam (NB) deuterium beam ions well above the injection energy has been observed. Significant effects on the n/m = 1/1 sawtooth stability are also seen; the sawtooth characteristics depend strongly on a combination of plasma and wave conditions. Simulations using the Monte-Carlo Hamiltonian code ORBIT-RF [1], coupled to the TORIC full wave code, predict beam ion tails up to a few hundred keV, in agreement with the experiment. The ORBIT-RF code solves the Hamiltonian guiding center equations in the background 2D equilibrium field. Resonant kicks are simulated by a quasi-linear (QL) RF diffusion operator, with the fields provided by the TORIC code. Theory also predicts that the fast ions can provide a stabilizing kinetic effect on the ideal magnetohydrodynamic (MHD) internal kink mode involved in sawteeth events. The kinetic contribution to the ideal MHD potential energy of beam ion tails, generated by FW heating, was evaluated for the experimental equilibria. The simplest analysis with the Porcelli model [2] provides a correction, $\delta\hat{W}_{\rm fast}$, to the ideal perturbed energy $\delta\hat{W}_{\rm MHD}$. $\delta\hat{W}_{\rm fast}$ is calculated numerically from the ORBIT-RF code and $\delta\hat{W}_{\rm MHD}$ is evaluated from the common analytic Bussac internal kink model. This yields reasonable consistency with the observations. A more detailed analysis shows a more complicated picture, however. Ideal stability calculations with the GATO code [3] show significant deviations from the Bussac model in some cases, and alternative natural extensions of the Porcelli model to real geometry yield a range of predictions. Other physics effects such as kinetic thermal effects and plasma rotation, probably play a role as well. Detailed comparisons of the Bussac model with the actual numerically calculated modes will be used to identify the reasons for the variations in predictions, and the extensions of the Porcelli model will be compared with NOVA-K calculations with and without additional physics.

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[3] L.C. Bernard, F.J. Helton, and R.W. Moore, Comput. Phys. Commun. **21,** 377 (1981).

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