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SIMULATION OF ICRF INTERACTIONS WITH FAST IONS AND MODIFICATION OF MHD STABILITY

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Simulation of ICRF Interactions with Fast Ions and Modification of MHD Stability

V. S. Chan*

General Atomics, P.O. Box 85608, San Diego, California 92186-5608

Abstract:

ORBIT-RF has been applied to simulate and validate fast Alfvén wave (FW) heating over a range of cyclotron harmonics. ORBIT-RF with TORIC4 qualitatively reproduces the strong FW-beam interaction at 60 MHz (4 Ω_D) and lack of interaction at 116 MHz (8 Ω_D) in DIII-D, consistent with observed neutron reaction rate. The result at 8 Ω_D differs from linear theory using a Maxwellian distribution suggesting the importance of finite orbit and Coulomb collisions in modifying the fast ion distribution. Fast ion energy spectrum calculated from ORBIT-RF is also in agreement with measurement from fundamental ICRF heating experiment on Alcator C-Mod. Agreement between simulated and measured fast ion pressure profiles depends sensitively on the characteristics of the sawtooth oscillations suggesting interactions of fast ions with MHD activities.

Description of Orbit-RF

A Monte Carlo code ORBIT-RF[1] is coupled with a 2D full wave code TORIC4[2] to study the resonant interaction of FW with fast ions at arbitrary ion cyclotron harmonics. ORBIT-RF provides a comprehensive physics package to investigate the interaction between fast ions with finite orbits and FW. It solves the Hamiltonian guiding center drift equations in magnetic coordinates in a 2D axisymmetric numerical magnetic equilibrium. Monte-Carlo operators for pitch-angle scattering of fast ions and drag by electron and background ions calculate changes of test ions in velocity and pitch angle due to Coulomb collisions. A rf-induced random walk model describing fast ion stochastic interactions with FW is used to reproduce quasi-linear (QL) diffusion in velocity space. A generalized arbitrary harmonic rf diffusion coefficient is related to the perpendicular rf-kicks at resonances including Doppler shifts. Steady-state slowing-down distribution of beam ion species is modeled using a re-injection method of thermalized beam ions. TORIC4 provides FW electric fields for the QL diffusion operator in ORBIT-RF.

Summary of Results

In deuterium beam injected plasma in DIII-D tokamak, beam ion absorption of FW has been observed during fast wave current drive experiments in frequency range of 60 MHz to 117 MHz.[3] Strong damping of 60 MHz FW on beam species at 4 Ω_D has been observed in L-mod experiments. However, beam ion absorption of 116 MHz FW at 8 Ω_D appears to be relatively weak in similar L-mode discharges. Figure 1 shows experimental results for discharge #122087 (dotted line for NB

*In collaboration with M. Choi, M.S. Chu, C.C. Petty, R.I. Pinsker (GA); P. Bonoli, M. Porkolab, V. Tang, J. Wright (MIT).

heating only) and #122080(solid for NB+ICRF heating) where P_{NB} = 3.7 MW, E_b = 80 keV, P_{RF}= 1.6 MW at 116 MHz, P_{RF} = 0.8 MW at 60 MHz. Figure 1(b) indicates much stronger beam ion acceleration at 60 MHz (4 Ω_D) than 116 MHz (8 Ω_D) as inferred by the increased neutron reaction rate during ICRF heating.

ORBIT-RF coupled with TORIC4 wave fields reproduces qualitatively experimental observations for both 60 MHz and 116 MHz. In Fig. 2, radial profiles of beam ion pressure calculated from ORBIT-RF are compared. ORBIT-RF calculates energetic tails extending up to a few hundreds keV above beam injection energy (80 keV) during 60 MHz FW heating, which results in a significant increase of fast ion pressure near the magnetic-axis. However, ORBIT-RF shows no significant increase in fast ion pressure during 116 MHz FW heating, which is consistent with minimal increase of neutron rate at 116 MHz in experiment, as shown in Fig. 1(b). It should be noted that the increase in central fast ion pressure by ORBIT-RF is not always corroborated by experimentally deduced fast ion pressure profile in the presence of sawtooth oscillations. Preliminary results suggest a possible correlation between the peaking of the fast ion pressure with lengthening of the sawtooth period during FW heating.

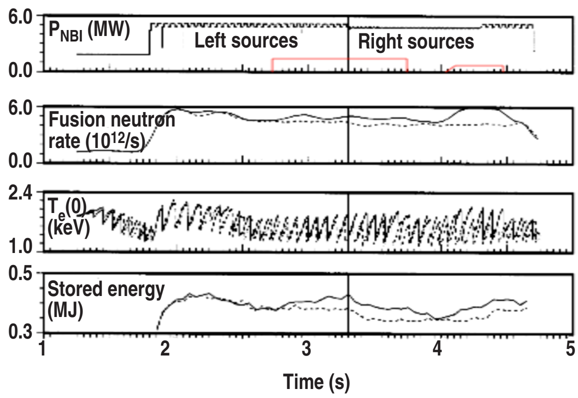

Fig. 1. DIII-D experimental results for #122080 (solid) and #122087 (dotted).

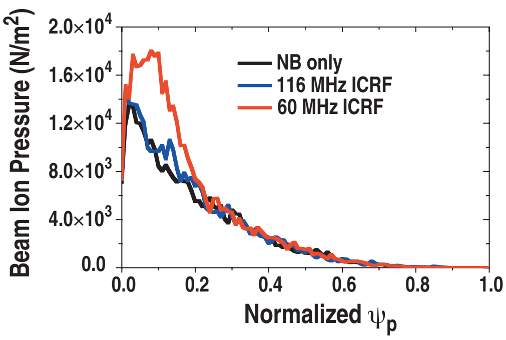

Fig. 2. ORBIT-RF results for radial profile of beam ion pressure for #122080 and #122087.

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References

[1] M. Choi, et al, Phys. Plasmas **12**, 072505 (2005).
[2] M. Brambilla, Plasma Phys. and Control. Fusion **41**, 1 (1999).
[3] R.I. Pinsker, et al., "Absorption of Fast Waves at Moderate to High Ion Cyclotron Harmonics on DIII-D," *Radio Frequency Power in Plasmas* (15th Top. Conf., Park City, 2005) and to be published in Plasma Phys. and Control. Fusion.