Modeling of Large Orbit Fast Ion Distribution Evolution with Multiple Frequency Fast Waves Heating*

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The 5-D finite-orbit Monte-Carlo code ORBIT-RF coupled with the 2-D full wave code AORSA is a comprehensive numerical model that can perform a fully self-consistent calculation of simultaneous interactions of large orbit fast ions with multiple fast waves (FWs) frequencies. Even though the corresponding cyclotron resonances are at different spatial locations, the finite orbits of the energetic ions can potentially couple the resonant interations resulting in new synergistic effects.

In recent FWs heating experiments in DIII-D, a synergistic effect was observed when the 6th harmonic 90 MHz FW was applied to the plasma being heated by neutral beams and the 4th harmonic 60 MHz FW. Measured neutron rate and stored plasma energy from the two combined FWs were measureably stronger than the sum of those from separate 4th and 6th harmonic FWs. In this study, we present comparison of ORBIT-RF/AORSA with measured fast ion D_α (FIDA) spectra and spatial profile during two-frequency FW heating. Due to statistical constraint for fast ion signals collected from current FIDA spectroscopy, comparison is limited only in the range of 30 to 60 keV of fast ion energy. Simulations for tangential velocity components of fast ions reproduce fast ion distribution quantitatively consistent with measured FIDA signals, indicating no significant change during the two-frequency heating. However, for vertical components of fast ions, simulations show only minimal increase, while the measured signals indicate a significant increase. Investigation of simulated fast ions in a wide energy range (beyond the FIDA limit) indicates that a significant fraction of fast ions is highly accelerated and lost to the wall, although that was not observed experimentally. The significant fast ion loss in simulation results from large wave field amplitudes. This calls into question the assumption that the injected ICRF power is fully absorbed. By calibrating the power absorption with the measured neutron rate increase we should obtain a more accurate estimate of the rf wave fields. The resulting impact on the fast ion loss and the two-frequency synergistic effect will be reported.

*This work was supported by the US Department of Energy under DE-FG02-95ER54309, DE-FC02-04ER54698, SC-G903402, and DE-AC05-00OR22725.