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Drift Kinetic Effects on 3D Plasma Response in High-beta Tokamak Resonant Field Amplification Experiments[1]

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Through theory and simulation of drift kinetic effects, modeling with the MARS-K code has for the first time explained the linear plasma response to 3D fields in the vicinity of the "no-wall" ideal beta limit. A longstanding issue in understanding resonant field amplification (RFA) of plasma to 3D fields is that the ideal magnetohydrodynamics (MHD) theory predicts an unlimited amplification near the no-wall stability limit. However, in many experiments such as DIID-D and NSTX, the plasma response increases almost monotonically along with the plasma beta across the ideally predicted no-wall limit. This disagreement is now explained by perturbed drift kinetic theory and associated with distorted particle orbits by 3D fields. The upgraded MARS-K code, which has the capability to solve linearized hybrid MHD equations with drift kinetic effects self-consistently, is applied to study the DIII-D RFA experiments through the quantitative comparison. It reveals the kinetic effect due to thermal particles plays a major role in modifying the response structure throughout plasma and keeps the finite amplification of response, as the experimental measurements, around the no-wall beta limit. The perturbed energy analysis shows the modification of plasma response is mainly contributed by the precession, bounce and transit resonances of thermal ions. The kinetic effect of isotropic energetic particles with slowing down distribution can further slightly change the plasma response without significant contribution. RFA experiments in NSTX plasmas are also analyzed to affirm the role of drift kinetic effect on modifying the plasma response. This study shows good agreements between theoretical results and various RFA experimental measurements, providing the possible physics explanation of RFA phenomena observed in many tokamaks. The results also indicate the validity of self-consistent calculation of hybrid drift kinetic-MHD model with drift kinetic effect in high beta tokamaks.

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