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Global PIC simulation of RF waves in toroidal geometry

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We report on nonlinear PIC simulations of wave-wave and wave particle phenomena relevant for RF heating and current drive schemes in tokamaks. For this we have developed a new nonlinear kinetic simulation model based on the global toroidal code GTC. In this model, the ions are considered as fully kinetic particles obeying the Vlasov equation and the electrons are treated as guiding centers that are evolved by the drift kinetic equation. We have benchmarked this numerical model to verify the linear physics of normal modes, conversion of slow and fast waves and its propagation in the core region of the tokamak using Boozer coordinates. In the nonlinear simulation of ion Bernstein wave (IBW) in a tokamak, parametric decay instability is observed where a large amplitude pump wave decays into an IBW sideband and an ion cyclotron quasi-mode (ICQM). The ICQM induces an ion perpendicular heating, with a heating rate proportional to the pump wave intensity. Finally, in the electromagnetic lower hybrid wave simulation, nonlinear wave trapping of electrons is verified and plasma current is nonlinearly driven in the core region. However, in many experiments, parametric decay instability is usually observed in the scrape-off layer (SOL). We have upgraded GTC to enable global toroidal simulations that couple the core and SOL across the separatrix by using cylindrical coordinates with field-aligned particle-grid interpolations. Using this new tokamak geometry model, we have implemented the fully kinetic particle pusher to capture the high frequency (ion cyclotron frequency and beyond), and the particle dynamics of guiding center associated with the low frequency waves. To verify the new simulation model, we have carried out simulations to study ion orbit loss at the edge of the tokamak plasma with single null magnetic separatrix for DIII-D tokamak. The ion loss conditions are examined as a function of pitch angle for cases both with and without an electric field.

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