Gyrokinetic particle simulations of reversed shear Alfvén eigenmode in DIII-D tokamak

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Global gyrokinetic particle simulations of reversed shear Alfvén eigenmode (RSAE) [1] have been successfully performed and verified using the gyrokinetic toroidal code (GTC) [2]. The damping rates measured from the antenna excitation and from the initial perturbation simulation agree very well. The RSAE excited by fast ions shows an exponential growth. The finite Larmor radius effects of the fast ions are found to significantly reduce the growth rate. With kinetic thermal ions and electron pressure, the mode frequency increases due to the elevation of the Alfvén continuum by the geodesic compressibility. The non-perturbative contributions from the fast ions and kinetic thermal ions modify the mode structure relative to the ideal magnetohydrodynamic (MHD) theory (Fig. 1) due to the breaking of radial symmetry, in qualitative agreement with XHMGC and TAEFL simulations and recent 2D imaging of RSAE mode structure in DIII-D tokamak [3]. In a simple geometry with concentric-circular flux surfaces and large aspect-ratio, the ideal MHD theory shows that RSAE does not exist when the parallel equilibrium current is taken into account, which is confirmed in our GTC simulations. In a realistic geometry, RSAE can exist even in the presence of equilibrium current due to toroidal coupling and other geometric effects. Our simulations of the DIII-D discharge 142111 near 750ms show that the RSAE exists even without fast ion drive. The mode structure, frequency, and growth rate obtained from GTC simulations are close to those given by GYRO and TAEFL simulations. The frequency dependence on the $q_{\min}$ value is close to the experimental results (Fig. 2). The discrepancy is probably due to the absence of the plasma toroidal rotation in simulation. Study of nonlinear effects of the RSAE is in progress.

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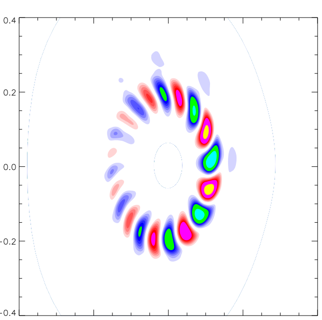

Figure 1: Poloidal contour plots of $\delta\phi$ from GTC for $q_{\min} = 3.18$.

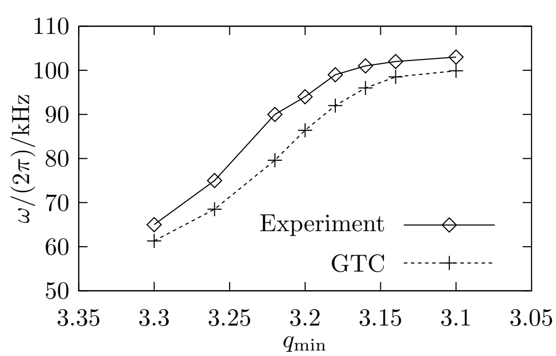

Figure 2: Frequency dependence on $q_{\min}$ comparison between GTC and experiment.

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[2] Z. Lin, T. S. Hahm, W. W. Lee, W. M. Tang, and R. B. White, Science **281**, 1835 (1998).

[3] B. J. Tobias et al., Phys. Rev. Lett. **106**, 075003 (2011).