GYROKINETIC ANALYSIS FOR ELECTRON-SCALE TURBULENCE IN KSTAR FIRE MODE DISCHARGE

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1. EXECUTIVE SUMMARY

Gyrokinetic simulations show that fast ions can affect electron-scale turbulence while most previous studies focused on ion-scale turbulence [1-4]. Various physical mechanisms that can affect electron-scale turbulence by fast ion effects were investigated by gyrokinetic analysis for the KSTAR FIRE mode discharge [5], which has a high fast ion fraction. Gyrokinetic simulation results show that increased $\beta_*\left(\equiv -\frac{8\pi}{B^2}\nabla p\right)$ was the dominant turbulence suppression mechanisms for electron-scale turbulence while dilution and changes in shearing rate have negligible effects.

2. MAIN RESULTS

Fast ions can affect the ion scale turbulence by increased β_* [1], dilution [2], changes in shearing rate [3] and fast ion mode [4]. In addition, previous study [6] have shown that fast ions generated ion cyclotron resonance heating can affect electron scale turbulence. However, fast ion effects on electron scale turbulence have not been as extensively investigated compared to ion scale turbulence. In this study, the impacts of fast ion generated from neutral beam injection on electron-scale turbulence were investigated through gyrokinetic simulations. Figure 1 shows that the time series of gyroBohm-normalized electron energy flux predicted by electron scale nonlinear simulations for (red) without and (blue) with fast ions where $Q_{GB} \equiv n_e c_s T_e (\rho_s/a)^2$, $c_s(\equiv \sqrt{T_e/m_i})$, m_i, ρ_s, and a represent gyroBohm energy flux, ion sound speed, ion mass, ion gyro radius, and minor radius respectively. The gyrokinetic simulation results show the significant electron energy flux reduction when fast ions were included.

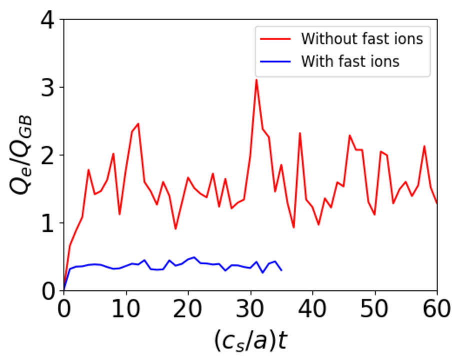

Figure 1. Time series of gyroBohm normalized electron energy flux predicted by electron scale nonlinear simulations for (red) without and (blue) with fast ions

Electron scale turbulence suppression mechanisms by fast ion effects were investigated including increase β_*, dilution, and changes in shearing rate. The time series of electron energy flux considering increased β_* and dilution, respectively, was shown in Figure 2(a). When β_* was increased, electron energy flux decreased to a similar level to the case with fast ions. However, dilution had a negligible impact on the reduction in electron energy flux. In addition, although the shearing rate changes, electron energy flux level does not vary significantly compared to increased β_* effects. Therefore, we can conclude that the impact of increased β_* are the dominant turbulence suppression mechanism for electron-scale turbulence. Since the energy flux level predicted by electron scale simulation was higher than ion scale simulations, multi-scale simulations will be performed. In addition, it was reported that shearing rate can significantly affect electron scale turbulence in multi-scale simulations while the effect was negligible in electron-scale simulation [7]. Therefore, further analysis about effect of change in shearing rate via multi-scale simulations will be performed.

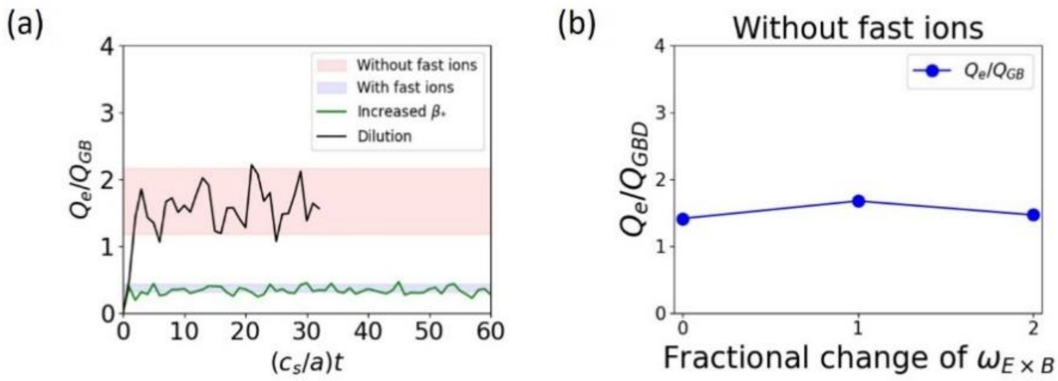

Figure 2. (a) Time series of gyroBohm normalized electron energy flux considering increased β_* effect (green) and dilution effects (black). The shaded regions denote the uncertainty range for without fast ions (red) and with fast ions (blue). (b) electron energy flux with fractional change of $\omega_{E\times B}$, mean $E \times B$ flow shearing rate, for without fast ions

3. CLOSING REMARKS

Gyrokinetic analysis to investigate the turbulence suppression mechanism by fast ion effects on electron-scale turbulence were performed. The gyrokinetic simulation results indicate the increased β_* by the inclusion of fast ions are dominant turbulence suppression mechanism for electron-scale turbulence while dilution and changes in shearing rate have negligible effects.

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