Gyrokinetic study of fast ion effects on Alfvenic modes and microturbulence in KSTAR L-mode plasmas

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Understanding and prediction of energetic particle (EP) confinement is a crucial issue for high-performance operation of magnetic fusion devices. The EPs are produced by either auxiliary heating or fusion reaction in present-day and future burning plasmas. It is widely recognized that Alfven eigenmodes (AEs) driven by the EP have crucial influence on the EP confinement [1]. In addition, recent gyrokinetic simulation studies [2-4] have shown that comprehensive understanding of various interactions among EP, AE and microturbulence is needed for a proper prediction of plasma confinement. We aim to achieve a deeper understanding of the EP-AE-microturbulence interactions by controlled gyrokinetic simulations of a target KSTAR L-mode discharge #21695 using global GTC [5] and local GKW [6] codes. In the target discharge [7], control of AE activities has achieved by electron cyclotron current drive (ECCD).

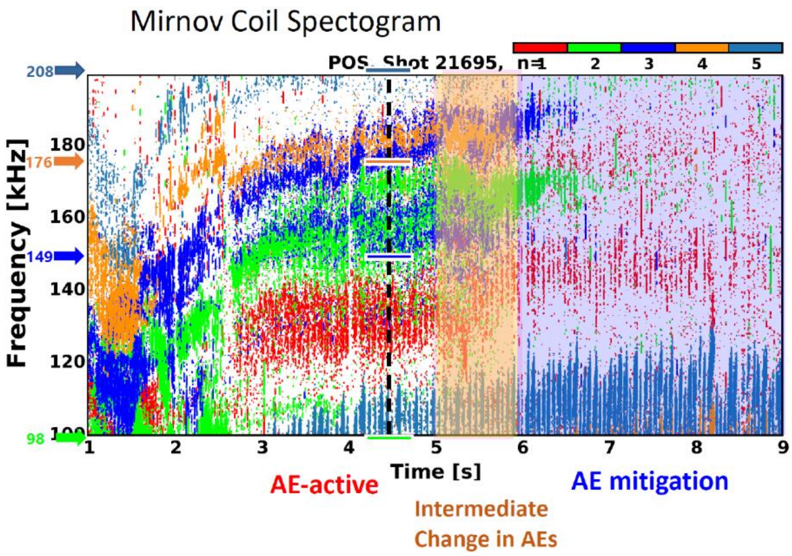

Fig. 1. Linear GTC simulations and KSTAR Mirnov coil measurements of EP-driven AEs show good agreement.

We successfully performed linear global GTC simulations of the EP-driven AEs in KSTAR #21695. Fig. 1 shows a comparison of the linear GTC results to the experimental measurements. Altough linear simulations cannot capture multiple frequency spectra observed in experiment at given toroidal mode number n, we find overall good agreements between the global GTC simulations and the measurements. An interesting point we found is that in the AE-active phase, the linearly most unstable $n = 1$ mode is not a high-frequency AE shown in the Mirnov signal, but a current-driven 3/1 ideal MHD mode peaking at q_{min}. EPs modify this mode to have finite frequency and ballooning feature.

As a next step, for an extensive nonlinear gyrokinetic studies, we have used local GKW code before going to nonlinear GTC. We found that GKW could be successfully used to study AEs in our target plasma, as the linear dispersion relation from GKW simulations at the mode peak position (obtained from GTC) agree well with that from GTC. Fig. 2 is the result of toroidal mode number scan using GKW, which shows fast ion effect on AE and microturbulence in AE-active phase. Clearly, the very low-n modes are fast ion-driven AEs, and the most unstable mode changes to trapped electron mode (TEM) at $n = 15$. The fast ions are found to moderately stabilize ion scale turbulence (TEM), while it destabilizes electron scale turbulence (ETG).

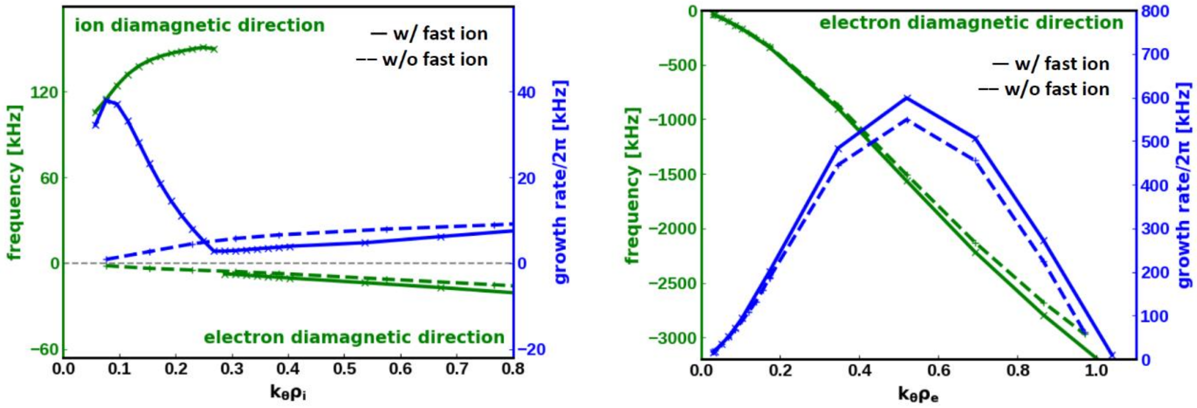

Fig. 2. Toroidal mode number scan of linear dispersion in ion (left) and electron (right) gyroradius scales, with (solid) and without (dashed) EPs.

Controlled nonlinear GKW simulations of the same plasma have shown that while the ETG turbulence is linearly the most unstable, its direct impact on EP and thermal plasma transport is not significant (gyroBohm scale for electron heat and less than that for others) compared to AEs (Bohm scale for heat and EP particle transport, and gyroBohm scale for ion and electron particle transport). It is consistent with a simple estimation using mixing-length argument, where high wavenumber (small unit spatial step) of the ETG mode results in a small amount of transport. An interesting point we found is that overall, AEs induce much larger heat transport compared to the particle transport for all species.

Our ongoing work is to perform nonlinear simulations to study multi-scale interactions among AEs, TEM and ETG to study indirect impact of ETG to EP and thermal plasma transport. The multiscale simulation is also needed for physics understanding of AE-mitigated phase, where the AEs are found to be still linearly unstable in this phase, according to GKW. Either global effect or nonlinear multi-scale interaction is needed to explain the mitigated AEs observed in the experiment. Comparison between nonlinear GKW and GTC will also be presented.

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