Nonlinear electromagnetic stabilization of ITG microturbulence by ICRF-driven fast ions in ASDEX Upgrade

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INTRODUCTION

Tokamaks are devices used to confine a fusion fuel mixture heated to high temperatures in the range of hundreds of millions of degrees, arriving in a state of matter called plasma. Several auxiliary systems are used for this purpose. They include Neutral Beam Injection (NBI) and electromagnetic waves. The largest tokamak up-to-date, aiming to achieve self-sustained nuclear fusion, is the International Thermonuclear Experimental Reactor (ITER) [1] shown in figure 1. It is presently under construction in Cadarache, France.

Figure 1 Cross section of the ITER tokamak [1]. Its reactor core consists of a vessel used to contain the gas and several magnetic coils used to generate the magnetic field that confines the plasma.

ION CYCLOTRON RESONANCE HEATING (ICRH)

One of the main auxiliary heating systems foreseen for ITER is the Ion Cyclotron Resonance Heating (ICRH). In this system, c. f. figure 2 and 3, powerful electromagnetic wave antennas are used to transfer energy to the plasma.

Figure 2 ICRF antenna systems that will deliver 10 MW of heating power each into the ITER machine [1].

Figure 3 Close up look in the antennas used to heat the tokamak plasma using ICRF [1].

We find that addition of fast ions generates a reduction in the linear instability growth rate and considerably shifts the KBM threshold value. At $k_\perp = 0.33$ the effect is still notable, albeit weaker than at $k_\perp = 0.1$ due to different proximity to the KBM threshold.

Since fast ions reduce ITG growth rates, as well as stabilize KBM modes, they appear to play a key role in the formation of the extreme ion temperature peaking observed in the experiment.

GENE MODELLING OF MICROTURBULENCE

We show a scan in plasma thermal beta for two $k_\perp$ values around which kinetic ballooning mode (KBM) instability has the smallest critical beta and ion temperature gradient (ITG) modes are most likely to appear.

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METHOD

We make use of the codes PION [3], FIDO [4] and GENE [5]. The Finite Ion Drift Orbit (FIDO) code and the PION code are used to compute Ion Cyclotron Resonance Heating in tokamaks. The output of these codes is used as input in GENE, c. f. figure 4, enabling us to quantify the impact of the presence of fast ions in the stabilization of microturbulence, which is the objective of the present work.

Figure 4 Artistic reconstruction of GENE’s global simulator [8] in the left hand side of the torus, one can see a single flux surface isolated from the full torus.

RESULTS

Two AUG discharges are considered, 31563 and 31562, as seen in figure 5. Their pressure profile is reconstructed using the code FIDO, figure 6, and it is used as input parameter for the code GENE.

Figure 5 Experimental value of ion temperature for different heating scheme [6].

Figure 6 FIDO reconstruction of the pressure profile, used as input in the GENE code.

Figure 7 Linear instability growth rate as calculated by GENE with and without ICRF-driven fast ions. The KBM threshold is characterized by the sharp upturn in the growth rate as a function of beta. The vertical lines represent the experimental thermal beta.

Further work involves performing nonlinear simulations and comparing the simulated values of particle and heat fluxes with the ones found in reference [6].

REFERENCES