4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Interplay between energetic particles and microturbulence: New pathways to high-performance discharges

A. Di Siena[1], T. Görler[2], E. Poli[2], A. Banón Navarro[2], R. Bilato[2], A. Biancalani[2], F. Jenko[2]
[1] The University of Texas at Austin, Austin, USA
[2]Max Planck Institute for Plasma Physics, Garching, Germany
e-mail (speaker): alessandro.disiena@austin.utexas.edu

An increasing effort has been spent in recent years to identify mechanisms able to reduce the outward turbulent driven fluxes via different physical mechanisms. An interesting candidate in this regard is given by supra-thermal ions – generated via external heating schemes. Their presence is often linked to a substantial improvement of the overall plasma confinement in tokamak experiments [1], and the results often confirmed by gyrokinetic simulations [2-5], showing a strong reduction in the ion-temperature-gradient (ITG) anomalous transport. Despite the relevance of the energetic particle effects in suppressing plasma turbulence, a physical explanation has remained elusive for more than a decade.

In this contribution, we present theoretical work able to explain the experimental findings and the numerical results through a coherent physical picture. As it turns out, the interplay between fast ions and microturbulence involves a range of different mechanisms based on wave-particle and wave-wave interactions, some of which may act simultaneously.

This includes a newly discovered wave-fast ion resonance interaction when the energetic particle drift frequency gets close to the linear ITG frequencies [3, 4]. This resonance effect becomes particularly effective in suppressing ITG-driven turbulence in situations when the fast particles' temperature gradient exceeds the respective density gradient, e.g., as in minority ion-cyclotron-heating (ICRH) schemes. If this condition is fulfilled, a significant energy exchange occurs from the ITG micro-turbulence to the energetic particles, depleting the turbulence drive [3]. In particular, as shown in Figure 1, almost a full turbulence suppression can be achieved on an ITER standard scenario during the rump-up-phase, by properly tuning the energetic particle parameters to enhance such resonance effect.

In addition to the previously described wave-particle resonance interaction, we provide first physical insights into fast particle effects in strong electromagnetic regimes [5]. We show that fast ions may drive linearly stable MHD-type modes, to which the bulk ITG turbulence can couple nonlinearly. This is shown in Figure 2, where the electrostatic potential spectra obtained from nonlinear turbulence simulations with energetic particles is displayed for different plasma beta ($\beta = 8\pi p_e^2/B_0^2$). Here, p_e represents the electron pressure and B_0 the on-axis magnetic field. Figure 2 reveals a progressive destabilization of linearly stable high-frequency components with β. When this effect is sufficiently large, an increase in the zonal flow amplitude is usually observed, further decreasing the transport levels. In this contribution, we present scans over several plasma parameters and provide guidelines on how to maximize such nonlinear electromagnetic fast ion effects.

References

[1] J. Garcia et al., Nucl. Fusion **53** 043023 (2013).
[2] J. Citrin et al., Phys. Rev. Lett **111** 155001 (2013).
[3] A. Di Siena et al., Nucl. Fusion **58** 054002 (2018).
[4] A. Di Siena et al., Phys. Plasmas **26** 052504 (2019).
[5] A. Di Siena et al., Nucl. Fusion **59** 124001 (2019).

Figure 1. Nonlinear main ion heat flux in MW units for different injected ICRH power for an ITER standard scenario. Taken from Ref. [3]

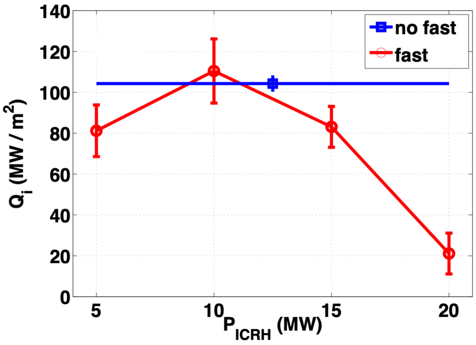

Figure 2. Frequency spectra of the electrostatic potential for different values of the electron plasma beta.