Fast ions as a tool for turbulent transport suppression on JET

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Exploiting mechanisms to actively control and reduce turbulence is essential for maximizing the performance of fusion devices. Already in 2010, it became clear that low levels of turbulent transport observed in several JET experiments could not be explained by the usual turbulence reduction mechanisms such as strong plasma rotation and magnetic shear. This talk summarizes main analysis and modeling steps that have been undertaken in the period 2010-2020 to reveal new physical mechanisms responsible for the observed turbulence modification and transport reduction on JET. Initial results clearly indicated that strong pressure gradients, notably from fast ions, can have a beneficial impact on the reduction of heat transport in high-beta JET plasmas [1, 2]. As a next step the stabilization of turbulent transport in low-rotation JET plasmas heated mostly by moderately energetic (~100 keV) ICRF-generated fast ions was demonstrated [3].

This progress has recently led to the important insight that under certain conditions alpha particles can also significantly contribute to stabilize ITG turbulence and reduce heat transport in D-T plasmas of ITER [4]. This result is particularly important for achieving and maintaining high ion temperatures in a fusion reactor, characterized by dominant core electron heating from fusion-born alphas. Furthermore, highly energetic alpha particles can also excite Alfvénic instabilities, commonly considered as detrimental for plasma confinement. In this talk, we will discuss a novel type of turbulence suppression and improved energy confinement in JET plasmas with MeV-range fast ions and strong fast-ion driven Alfvénic eigenmodes (AEs). The detailed gyrokinetic analysis of recent dedicated fast-ion experiments at JET [5] shows that MeV ions trigger nonlinearly large-scale zonal flows both in the electrostatic and electromagnetic potentials, leading to the suppression of the electrostatic transport and leaving electromagnetic fluctuations as the main source of weak electron transport [6]. This mechanism is rather efficient for raising ion temperature in fusion plasmas with a large population of fast ions and collisional electron heating, and hold promises for D-T plasmas with alpha particle heating. The talk is concluded with the discussion of the implication of these results for the upcoming D-T campaign on JET [7] and future ITER operations.

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