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Geometry effects on gyrokinetic instabilities and turbulence in W7-X

The stellarator Wendelstein 7-X (W7-X) demonstrated the effectiveness of reducing neoclassical transport through magnetic field optimization [1]. Its confinement is primarily governed by turbulence arising from instabilities at scales comparable to the gyroradius [2,3]. For small plasma beta (the ratio of kinetic to magnetic pressure), these instabilities are predominantly electrostatic and often driven by ion temperature gradients (ITG). ITG-driven turbulence is sensitive to magnetic field properties—a dependence that needs to be considered in the design of the next-generation optimized stellarators. However, the experimental characterization and theoretical modeling of turbulence in W7-X remain incomplete, particularly regarding its geometrical properties.

In this contribution, we numerically investigate gyrokinetic plasma turbulence in W7-X, with a focus on potential performance improvements through the modification of geometrical properties. Specifically, we compare density fluctuation measurements from the Phase Contrast Imaging (PCI) diagnostic [4,5] with both linear and nonlinear simulations performed using the gyrokinetic code stella [6]. As part of this comparison, we examine the impact of the mirror ratio and the global value of the rotational transform on plasma performance [7]. Our simulations show good agreement with analytical expectations, although some experimental observations still remain puzzling. Finally, we propose a method for locally modifying ITG turbulence through tailored adjustments of the rotational transform profile [8]. This approach builds on the influence of electron cyclotron current drive in plasmas heated via electron cyclotron resonance [9].

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