Recent turbulence investigations in the TJ-II and W7-X stellarators: experimental characterisation and 3D code-based interpretation

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Experimental results from the first campaigns with divertor plasmas carried out in Wendelstein 7-X [1] (W7-X) have highlighted the importance of turbulence for the confinement of optimized stellarators, both as dominant channel in the ion heat transport, limiting the achievable T_i value at the core [2,3], and as a mechanism responsible for the avoidance of strong impurity accumulation [4]. In this context, an experimental characterization of turbulence and its dependence on plasma parameters becomes a task of great urgency in order to obtain an empirical understanding of enhanced plasma performance and to validate the current theoretical framework for turbulent transport. With those aims, we have carried out a number of experimental studies in the TJ-II heliac and W7-X helias stellarators, in which Doppler reflectometry (DR) is used as the main tool for a systematic characterization of ion-scale core density fluctuations under a broad variety of scenarios.

In this work, we present an overview of the most relevant results of these studies, which have resulted in the creation of large databases of turbulence measurements from both stellarators: In W7-X, a link between density fluctuations and turbulent transport has been experimentally confirmed. The drive of such fluctuations is identified and found to be consistent with ITG turbulence dependencies on local density and Ti gradients [5,6]. One particularly interesting case of this is the pellet-induced high performance scenario, for which similar features in core turbulence have been in W7-X and TJ-II [7,8,9]. Another turbulence-relevant mechanism in which measurements from both devices can be compared is the effect of magnetic islands on fluctuations [10]. As well, the upgraded capabilities of the DR system in operation in TJ-II –which features a steerable mirror-have allowed for a dedicated investigation of the 3D structure of turbulence [11], in which poloidal asymmetries in fluctuation spectra have been characterized. Finally, these results have been compared to fluctuation amplitude and turbulent transport predictions from gyrokinetic codes EUTERPE and stella in order to advance in the interpretation of experimental measurements. Furthermore, the development of synthetic diagnostics and other tools specifically adapted for the comparison of GK simulations to DR measurements in both stellarators can be seen as the groundwork for the kind of systematic comparison required for a general code validation.

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