

Comprehensive experimental turbulence measurements for scale-resolved multichannel gyrokinetic code validation

K. Höfler^{1,2}, T. Görler², T. Happel², P. Hennequin³, P. A. Molina Cabrera², M. Bergmann², R. Bielajew⁴, G. D. Conway², P. David², R. Fischer², F. Jenko², C. Lechte⁵, R. M. McDermott², P. A. Schneider², A. E. White⁴, U. Stroth^{2,1}, and the ASDEX Upgrade Team*

¹ *Physik Department E28, Technische Universität München, Garching, Germany*

² *Max-Planck-Institut für Plasmaphysik, Garching, Germany*

³ *Laboratoire de Physique des Plasmas, Ecole Polytechnique, Palaiseau, France*

⁴ *MIT Plasma Science and Fusion Center, Cambridge, Massachusetts, USA*

⁵ *Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, Stuttgart, Germany*

* *See author list of U. Stroth et al. 2021 Nucl. Fusion*

Abstract

Turbulence is the main driver of heat and particle transport which deteriorates the performance of fusion plasmas. To design turbulence optimised devices, simulation codes need to be validated by experiments. Validation work has already been done for a single or a small number of turbulence observables. These comparisons showed agreement for some quantities, but also highlighted disagreements, which enabled new physics discoveries [1–4]. In these works individual observables were reproduced by the simulation codes within the error bars of the measured quantities. Increasing the number of observables, however, may reveal "false positives," i.e. situation in which a better match in signal A deteriorates the agreement with signal B. Hence, a comprehensive validation should involve as many observables as possible at the same time - a challenging goal for both experiment and theory which is tackled in this contribution.

A comprehensive set of experimental turbulence data is measured on ASDEX Upgrade for two different plasma scenarios where the electron gradient length is changed by means of ECRH. It includes wavenumber spectra, density and temperature fluctuation amplitudes and radial correlation lengths, the poloidal dependence of the velocity perpendicular to the magnetic field as well as the cross-phase between density and temperature fluctuations. These quantities are measured by Doppler reflectometers in both X-mode and O-mode polarization and an electron cyclotron emission radiometer. They are compared to gyrokinetic turbulence simulations from the GENE code. For this purpose synthetic diagnostic modeling is applied to account for diagnostic effects on measurements.

The work shows the encouraging example of code validation where a remarkable number of measured physics quantities is successfully reproduced by the code. We highlight the simultaneous agreement between experiment and simulation of all investigated turbulence quantities. This study provides a sound scientific justification for using codes such as GENE in the design of future fusion reactors.

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

This work is supported by the US DoE under grants DE-SC0014264, DE-SC0006419, and DE-SC0017381.

References

- [1] T. L. Rhodes et al. *Nucl. Fusion*, 51(6):063022, 2011.
- [2] A. E. White et al. *Phys. Plasmas*, 20(5):056106, 2013.
- [3] T. Happel et al. *Plasma Phys. Control. Fusion*, 59(5):054009, 2017.
- [4] S. J. Freethy et al. *Phys. Plasmas*, 25(5):055903, 2018.