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Validation of the ETG transport models using an ECH-driven TCV discharge

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A high power, multi-phase discharge in the TCV machine has been analyzed in detail for the electron thermal transport from both TEM-ITG turbulence and ETG turbulence [1-2]. A method called the Average Relative Variance is used to score the relative performances and the absolute predictive value from the different models. The discharge selected is a well-documented hot electron plasma with an exceptionally clean electron turbulent thermal flux and highly accurate measurements of the electron temperature profile. The 1.5- second discharge has four phases, all in the H mode, as determined by the Dα signal and other characteristics. The first phase is an Ohmic H mode, the second an ELMy H mode, followed by an ELM-free H mode with the lowest thermal diffusivity, and then the spontaneous bifurcation to an H mode with a 3/2 magnetic island. This multi-regime discharge is a severe test of electron thermal diffusivity models.

We show that the TEM model has difficulty in explaining both the magnitude and radial profile of the electron thermal flux. The non-adiabatic trapped electron response function $h(\omega, k_y, P_j)$ is computed in detail. In contrast, the ETG turbulence is directly driven by the electron temperature gradient, and both the trapped and passing electrons contribute to the instability and turbulent thermal flux. There is a large out-of-phase component of the fluctuating electron distribution function without resonances in its energy spectrum. The nonlinear state of the ETG flux is calculated through turbulent simulations based on three coupled gyrofluid partial differential equations whose linear modes describe the ETG instability. The simulations show that the small-scale fluctuations created at the maximum linear growth rate undergo an inverse cascade to form large-scale vortices and streamers. The correlation length for these large-scale ETG structures reaches $l_c \sim (3\text{-}6)\, q\, \rho_e$. The resulting thermal diffusivity is sufficiently large and has a scaling that is consistent with the power balance data.

For a quantitative measure of the success of the models, we use the Average Relative Variance (ARV). The ETG model has ARV of about 0.37, meaning that the model explains 63% of the variation of the electron diffusivity. For the TEM-ITG model we find that the ARV is above unity, ARV~1.3, which means that the prediction of the model is poor since the value ARV=1 is equivalent to taking the average value of the data as the prediction model.

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[2] E. Asp, J.-H. Kim, W. Horton, L. Porte, S. Alberti, A. Karpushov, Y. Martin, O. Sauter, G. Turri, and the TCV Team, "Electron thermal transport analysis in TCV," Phys. Plasmas **15** (18), 082317 (2008).

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