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Analysis of multiscale electron heat transport in JET, AUG and TCV plasmas, confronting experiments with gyrokinetic simulations and reduced models

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Micro-turbulence driven by ion-scale ITG-TEM [1] instabilities is mostly considered the main driver of core transport in present tokamaks. In addition, it has been shown that electron-scale ETGs [2] can impact the electron heat transport, also exchanging energy with ITG-TEM turbulence by multi-scale coupling [3-9]. This could have an impact on devices like ITER, dominated by electron heating. ETG modes have been shown to play a role in plasmas with mixed ion and electron heating, with Te/Ti~1, which lowers the ETG threshold, and high central electron power increasing the T_e gradient, which is the ETG driver.

ETGs can be indirectly experimentally detected through the observation of an increase of the electron stiffness ∂ qegB / ∂ R/L_{Te} (qegB: gyro-Bohm normalized electron heat flux) at large values of the normalised T_e logarithmic gradient R/L_{Te}. Two methods can be used in conjunction to extract information on the threshold $R/L_{Te,crit}$ for the onset of turbulent transport and on the electron stiffness: normalized electron heat flux scans and/or RF power modulation. The experimental results can be compared with the output of gyrokinetic (GK) simulations, which are able to compute both $R/L_{Te,crit}$ (fast linear runs), and the dependence of the saturated heat flux on R/L_{Te} (more costly nonlinear runs). Resolving both ion and electron scales (i.e. performing nonlinear multi-scale simulations) is computationally very demanding and just became possible recently.

In order to explore a broad parameter region, different machines are under investigation, looking for ETG impact on electron heat transport, comparing experimental and numerical results, within the framework of EUROfusion and of the ITPA Transport & Confinement group. In this paper, the analysis of plasmas of three different tokamaks, i.e. the Joint European Torus (JET, at Culham, UK), ASDEX Upgrade (AUG, at Garching, DE) and the Tokamak à Configuration Variable (TCV, at Lausanne, CH), is presented.

Dedicated plasma discharges have been performed, and the experimental results have been compared with GK simulations, including some multi-scale runs, using GENE [11] and GKW [12]. The reduced quasi-linear models TGLF [13] and QuaLiKiz [14] have also been tested. The results of the different tokamaks concour to make a general picture indicating that ETGs could also be important for electron heat transport in fusion relevant conditions, in particular when $T_e \sim T_i$ and in conditions where ion-scale turbulence is near marginality.

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