TOPIC: 4. Challenges in modelling transport in ITER and JT-60SA relevant scenarios

# Validation of gyro-kinetic predictions of TEM-driven electron transport against JET experiments

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A main driver for electron heat transport in tokamaks is the Trapped Electron Mode (TEM) instability, for which a threshold in the parameter $R/L_{Te}$ is foreseen by theory and found experimentally in AUG, JET and DIII-D [1]. A stabilizing effect of collisionality ($\nu_{eff}$) on TEM-driven electron transport was found in AUG, in agreement with theory, however the other parametric dependencies foreseen by theory for the TEM threshold have not so far been validated against experiments. These are a stabilizing effect of the magnetic shear s and a destabilizing effect of $R/L_n$ [2]. In addition, not much has been done so far in terms of validation of the theory predictions for electron stiffness against experimental results.
In JET C-wall L-mode plasmas, 3 MW ICRH in Mode Conversion scheme (direct electron heating) provided suitable TEM-dominated targets in which the dependence of TEM threshold and stiffness on the q profile was studied in detail by changing the plasma current in time with different waveforms, resulting in an independent variation of q and s over significant ranges. ON- and OFF-axis ICRH allowed performing heat flux scans from which an estimate of threshold and stiffness were deduced. In addition, power modulation at 20 Hz was performed, in order to derive threshold and stiffness from the heat wave propagation. Good agreement was found between the two methods. Multi-linear regression over the steady-state data clearly show the stabilizing effect of s besides that of $\nu_{eff}$, whilst the dependence on $R/L_n$ appears rather weak and could not be solved due to its limited range of variation and its coupling with s. No significant dependence on q was observed, and also $T_e/T_i$ was found to have weak effects. Stiffness was found at medium level in the core and increasing with radius. The modulation analysis using the ASTRA [3] transport code also indicated the presence of a sizeable inward heat pinch in the turbulent region (outside the ICRH deposition).
Linear gyro-kinetic scans using GKW [4] were performed to find the theoretical value of the threshold and its dependence on $\nu_{eff}$, s, $R/L_n$, $T_e/T_i$. The theory-predicted parametric dependences of the TEM threshold were found in good agreement with the experimental results from the multi-linear regression. For one representative discharge, non-linear GKW simulations at two radii were performed, in order to calculate the theoretically predicted stiffness. This was found comparable to the measured one. Therefore we conclude that gyro-kinetic theory provides a suitable description of the JET experimental data in TEM-dominated regimes, which is a step-forward in model validation.
In order to explore electron heat transport in more ITER relevant, ITG dominated plasmas, NBI heating at the level of 7 MW was also applied. This leads to a reduction of $R/L_{Te}$ with respect to non-NBI plasmas, in spite of increased total power. Various possible mechanisms could contribute to such effect: a larger fraction of electron heat being carried by ITGs; an effect of increased $R/L_{Ti}$ leading to increased TEM stiffness, which found confirmation in linear simulations; a destabilization of ETG modes due to the decrease in $T_e/T_i$, leading to lower ETG threshold in $R/L_{Te}$.

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* *see Appendix of F. Romanelli et al., Fusion Energy 2012: Proc. 24th Intern. Conf., San Diego, 2012 [IAEA, Vienna,2012]*

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