Topic: Multi-scale Integration

Multi-Scale Fluctuations and Transport Fluxes in the DIII-D ITER Baseline Scenario with Direct Electron Heating and Projection to ITER *

B.A. Grierson[1], G.M. Staebler[2], W.M. Solomon[1], C. Holland[3]

[1]*Princeton Plasma Physics Laboratory, Princeton, New Jersey, USA*
[2]*General Atomics, San Diego, California, USA*
[3]*University of California, San Diego, La Jolla, California, USA*
email: bgriers@pppl.gov

DIII-D ITER baseline scenario exhibits turbulent fluctuations measured in low and high-k ranges, reduced confinement and increased diffusivities when direct electron heating is applied to mid-radius (ρ_{ECH}~0.4). Modeling with TGLF indicates up to 50% of the electron energy flux is in the intermediate and high-k ($k_\theta\rho_S$> 1) range. The high-k electron modes appear to be responsible for the increased electron thermal transport and are predicted to contribute to electron thermal stiffness. During the electron heating the electron density profiles has a shorter scale length in the plasma outer radius $\rho>\rho_{ECH}$ and modeling of the electron particle flux with TGLF displays the existence of an inward particle pinch at intermediate k ($1<k_\theta\rho_S<5$) where Doppler Backscattering indicates strong fluctuations are occurring during ECH. The particle pinch exists in the lower collisionality phase of the discharge, which has ECH+NBI heating early and NBI only heating later. Sensitivity analysis reveals that the particle pinch comes from ∇Te driven electron modes. In addition to increased electron thermal transport and density steepening, we find that the ion thermal and momentum diffusion are both increased during ECH. The impact of ECH on the ion channel comes by increasing T_e/T_i that reduces the ITG critical gradient, which increases the low-k fluxes and causes a flattening of the T_i profile and enhanced angular momentum transport. Low-k fluctuations measured by BES in the outer radius of the plasma confirm that enhanced low-k fluctuations are present, consistent with TGLF modeling. TGYRO modeling with TGLF+NEO is successful at capturing the changes in profiles and confinement. However, due to the observation of multi-scale fluctuations and quasi-linear simulations that indicate transport processes are active up to the electron scale, these conditions may be suitable for validation using multi-scale nonlinear gyrokinetics. When applying TGLF to ITER high current scenario with 47 MW of auxiliary heating, we predict that high-k electron energy flux will also contribute to electron thermal stiffness, as in the DIII-D experiments. Additionally, the same intermediate-k electron particle pinch is predicted to increase a/L_{ne} in the plasma outer half radius. A possible feedback mechanism whereby density peaking stabilizes high-k ETG modes, increasing the fusion gain, will be presented for a range of ExB shear assumptions.

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