Electron Thermal Transport in Tokamak: ETG or TEM Turbulences?

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The renewed interest in electron temperature gradient (ETG) modes comes from numerical simulations of the ETG turbulence using the flux-tube geometry. These simulations find that radially elongated turbulence eddies, or streamers, can drive a transport level much higher than the mixing length estimates. However, the radial scale length of the ETG streamers is comparable to the radial box size of the flux-tube simulation. This contradicts the fundamental assumption of the flux-tube simulation, which uses a radially periodic boundary condition assuming that the radial correlation length of the turbulence eddies is much shorter than the radial box size.

In our studies, a massively parallel, global gyrokinetic toroidal code[1] (GTC) has been utilized to simulate electrostatic ETG turbulences. We use the "cyclone" parameters of a representative DIII-D H-mode plasma. The size of the tokamak is roughly that of the DIII-D with the minor radius $a=8000r_e$. The simulation geometry is an annulus of $r/a=[0.4,0.6]$ with a fixed radial boundary condition and with the whole flux-surface. Other simulation parameters[2] are similar to that in the flux-tube simulation. We find that the electron thermal conductivity is only about three times of that predicted by the mixing length rule, even though the radial scale length of ETG streamers is comparable to our simulation radial box size of up to $1600r_e$. The transport level is well bellow experimental values and is about an order of magnitude smaller than that reported by flux-tube simulations. We perform a machine size scan and find that the transport scaling is gyro-Bohm for $a>2000r_e$ although the radial length of ETG streamers scales with the machine size. Our GTC results are closer to those from a global fluid simulation[3] of ETG modes with a small tokamak size of $a=100r_e$, and from a fluid simulation[4] in the slab geometry. We further find that the ETG transport level is much smaller than that driven by the trapped electron mode (TEM) turbulence for the same plasma parameters. This work is supported by U.S. DOE Cooperative Agreement No. DE-FC02-03ER54695 at UC Irvine, and in part by the DOE SciDAC plasma microturbulence project.

References

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