MF-I15

1st Asia-Pacific Conference on Plasma Physics, 18-23, 09.2017, Chengdu, China

Exploring the Regime of Validity of Global Gyrokinetic Simulation with Spherical Tokamak Plasmas

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Plasma turbulence is considered one of the main mechanisms for driving anomalous thermal transport in magnetic confinement fusion devices. Based on first-principle model, gradient-driven gyrokinetic simulations have often been used to explain turbulence-driven transport in present fusion devices, and in fact, many present predictive codes are based on the assumption that turbulence is gradient-driven. However, using the electrostatic global particle-in-cell Gyrokinetic Tokamak Simulation (GTS) code [1], we will show that while global gradient-driven gyrokinetic simulations provide decent agreement in ion thermal transport with a set of NBI-heated NSTX H-mode plasmas (see Fig. 1), they are not able to explain observed electron thermal transport variation in a set of RF-heated L-mode plasmas, where a factor of 2 decrease in electron heat flux is observed after the cessation of RF heating [2]. Thus, identifying the regime of validity of the gradient-driven assumption is essential for first-principle gyrokinetic simulation. This understanding will help us more confidently predict the confinement performance of ITER and future magnetic confinement devices.

Acknowledgments

This work was supported by the U.S. Department of Energy under Contracts No. DE- AC02-76CH03073, No. DE-FG03-95ER54295, and No. DE-FG03-99ER54518. The computational resource is provided by NERSC.

References

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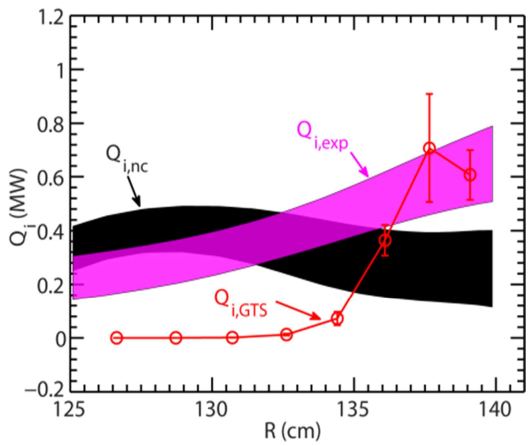

Figure 1 Red circles: ion energy flux, $Q_{i,GTS}$, at t=332 ms as a function of major radius from a nonlinear GTS simulation of an NSTX H-mode plasma, shot 141767; magenta band: radial profile of experimental ion heat flux, $Q_{i,exp}$, at t=332 ms from power balance analysis; black band: radial profile of neoclassical ion heat flux, $Q_{i,nc}$. Note that the vertical widths of the magenta and black bands denote the experimental uncertainties. $Q_{i,GTS}$ is averaged over a quasi-steady saturation period, and the errorbars of $Q_{i,GTS}$ are the standard deviation of $Q_{i,GTS}$ in the averaging time period. Also note that, at larger radius, i.e. $R \gtrsim 136$ cm, taken into account of uncertainties in each term, $Q_{i,GTS}+Q_{i,nc}$ is approximately equal to $Q_{i,exp}$, indicating that the ion-scale turbulence is responsible for observed anomalous ion thermal transport.