IFERC Newsletter

IFERC-N-2013-2, 3 April 2013
International Fusion Energy Research Centre, Rokkasho, Aomori 039-3212, Japan

CSC Activity

Lighthouse project: Plasma size scaling of full-f gyrokinetic simulations

The dependency of turbulent transport on the plasma size is one of the critical issues in predicting performances of future fusion devices such as ITER and DEMO, which will be several times larger than the present fusion devices. A primitive picture of turbulent transport in a fusion plasma is given by a local diffusion model or a gyro-Bohm model, in which the ion thermal diffusivity is given as $\chi_{GB}\sim\Delta r^2/\Delta t\sim\rho_i^2 c_s/a$ by assuming random walk processes with characteristic turbulent correlation length, $\Delta r\sim\rho_i$, and time, $\Delta t\sim a/c_s$, where ρ_i is the ion gyro-radius, c_s is the ion sound velocity, and a is the plasma radius. However, the size scaling experiment with L-mode plasmas often shows enhanced transport scaling or Bohm scaling $\chi_B\sim\chi_{GB}a/\rho_i$, where the confinement becomes worse with the normalized plasma radius a/ρ_i. Therefore, it is extremely important to study the transport scaling toward ITER size parameters or $a/\rho_i\sim1000$. To answer this question, the plasma size scaling is studied using the full-f Gyrokinetic Toroidal 5D Eulerian code GT5D. Compared with conventional delta-f simulations, in which steady plasma profiles are assumed and only turbulent fluctuations are solved, full-f simulations compute both turbulent transport and profile formations under fixed power, momentum, and particle inputs as in the experiment. This feature is important for reproducing stiff critical gradient profiles, where the so-called self-organized criticality produces transport properties such as non-local propagation of avalanches, intermittent bursts, and 1/f spectra. Full-f simulations require long time scale simulations to obtain quasi-steady states of turbulent transport and plasma profiles, and therefore, enormous computing power is needed. Thanks to the new computing resources offered by Helios, numerical experiments comparable to and beyond the present fusion devices become feasible. Figure 1 shows a series of numerical experiments, in which the plasma radius a and the heating power P_{in} are scaled as (a) $a/\rho_i=150$, $P_{in}=4MW$, (b) $a/\rho_i=300$, $P_{in}=8MW$, and (c) $a/\rho_i=450$, $P_{in}=12MW$. Here, the case (b) is comparable to the size of JT-60U tokamak. The turbulent electrostatic potential shows the similar eddy size in all cases, and turbulent correlation length and time follow the above characteristic scales $\Delta r\sim\rho_i$ and $\Delta t\sim a/c_s$. Although these scales suggest χ_{GB} if the random walk assumption is correct, the ion thermal diffusivity χ_i is enhanced with increasing the normalized plasma size a/ρ_i, and the transport scaling becomes close to χ_B up to $a/\rho_i=450$. It is found that this transport enhancement is attributed to avalanche like non-local transport processes due to interaction between turbulent fluctuations and temperature profiles.

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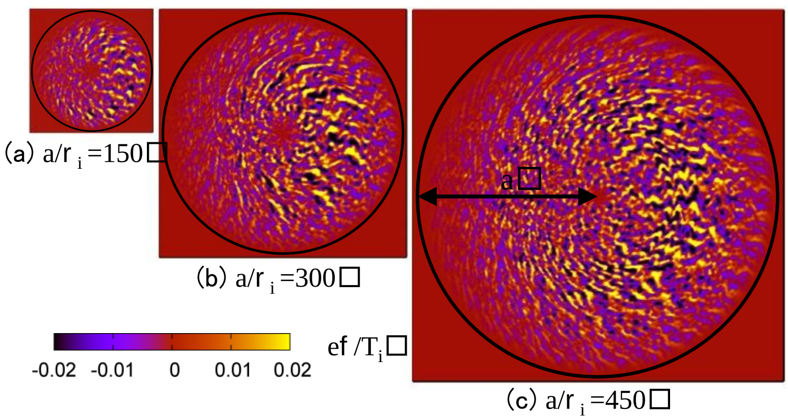

Fig.1: The plasma size scaling of the ion temperature gradient driven turbulence is studied using the GT5D code. The turbulent electrostatic potential is plotted for plasma sizes of (a) $a/\rho_{ti}=150$, $P_{in}=4MW$, (b) $a/\rho_{ti}=300$, $P_{in}=8MW$, and (c) $a/\rho_{ti}=450$, $P_{in}=12MW$. Here, the case (b) is comparable to the size of JT-60U tokamak. A fixed heat source is imposed around the plasma center, and heat transport occurs towards the plasma surface shown by a black circle.

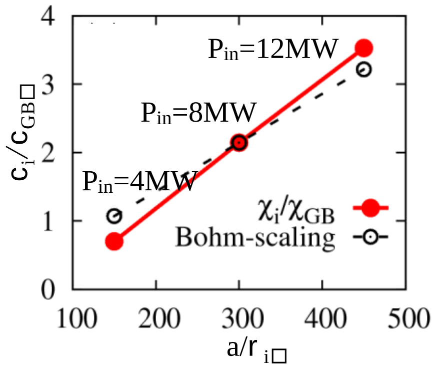

Fig.2: The plasma size scaling of the ion heat diffusivity χ_i in the numerical experiment. The ion heat diffusivity is enhanced from a local diffusion model or a gyro-Bohm model, and the scaling is rather close to a Bohm scaling up to a/ρ_i=450.