§12. Gyrokinetic Simulation Study on Sensitivity of Turbulent Transport to Temperature Profile in Helical Plasma

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Plasma turbulent transport has been considered to be one of the critical issues in the magnetically confined plasmas researches. To design fusion reactors, it is necessary to predict not only the transport fluxes, but also the plasma temperature and density profiles. The turbulent transport fluxes are quite sensitive to the profiles of the plasma temperature and density. In this work, sensitivities of the transport fluxes to the plasma temperature profiles are discussed within the experimental error ranges of the temperature profiles in helical plasmas.

Radial temperature profiles observed in the LHD experiment have the measurements of the error bars at each radial position. It can be regarded that the error bars mean the width of the standard deviation of the measurement data. Therefore, we can reproduce the temperature data by the normal distributions with the standard deviations which correspond to the experimental error bars. If we obtain the normal distributions for the temperatures at each radial position, we can give the radial function for the temperature profiles by fitting the randomly sampling points from the reproduced data with the function, $T(\rho) = \sum_{k=0}^{n} c_k \psi^k(\rho)$, where the labeling index of the flux surfaces, $\rho \equiv \sqrt{\psi/\psi_{\mathrm{a}}}$. Here ψ represents the toroidal magnetic flux, ψ_{a} is defined at the last closed surface, c_k's are fitting coefficients. If the fitting functions for the ion temperature are obtained, the profile of the radial gradient of the temperature, $R_0/L_{T\mathrm{i}} = -(R_0/a)d(\ln T_{\mathrm{i}})/d\rho$, with a certain allowable ranges according to the experimental errors with the fitting functions as shown in Fig. 1. Here, R_0 is the major radius and a is the minor radius at the last flux surface.

The gyrokinetic analyses for the ITG turbulent transport are performed by using GKV code[1, 2, 3] within the allowable range of the temperature gradients obtained in Fig. 1. In Fig. 2, we show the ion heat diffusivities obtained by the GKV simulations and the LHD experiment. Except for $\rho > 0.8$, the simulations within the experimental errors of the temperature can cover the experimental diffusivities, since the experimental errors enhance the permissible ranges of the simulation results. In the core radial region, the simulation results have larger ambiguity rather than the outer radial region, due to the fact that the experimental errors are larger in the core region. If the ion heat diffusivities are fixed to match the experimental observations of the transport fluxes, the radial profiles of the temperature gradients can be predicted by using the flux-matching method. In fig. 1, we also show the predictions of the ion temperature gradients. Here the predictions agreed with the experimentally allowable ranges of the temperature gradients.

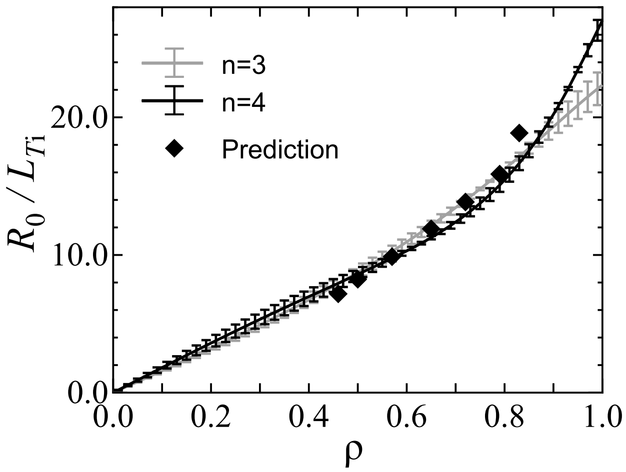

Fig. 1: Profiles of radial gradients of the ion temperature with the allowable ranges according to the experimental errors with the fitting functions $T_{\mathrm{i}}(\rho) = \sum_{k=0}^{n} c_k \psi^k(\rho)$ with $n = 3$ (gray curve) and $n = 4$ (black curve). The symbols represent the predictions of the temperature gradients by the flux-matching method.

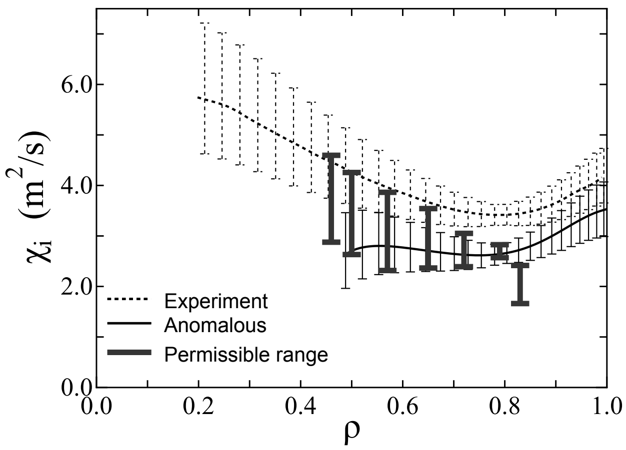

Fig. 2: Anomalous ion heat diffusivities obtained by the experiment (solid curve) and the simulations within the error bars of temperature profile (bold error bars).

1) T.-H. Watanabe and H. Sugama, Nucl. Fusion **46**, 24 (2006).

2) M. Nunami, T.-H. Watanabe, and H. Sugama, Plasma Fusion Res. **5**, 016 (2010).

3) A. Ishizawa, *et al.*, 25th IAEA Fusion Energy Conference, TH/P6-40 (2014).