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LHD と W７-X におけるイオンスケール乱流
Ion turbulence studies in LHD and W7-X

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In stellarators and heliotrons, ion scale turbulence plays an essential role in limiting energy confinement and fusion performance. Future stellarator optimization therefore needs to focus on (ion) turbulence minimization. Comparing W7-X and LHD can teach us which optimization criteria to consider. For example, thanks to the so-called stability valley in W7-X [1], a reduction of ion scale turbulence was achieved by enhancing a/Ln after pellet injection, after which ion temperature gradient mode (ITG) as well as trapped electron mode (TEM) turbulence were simultaneously suppressed, resulting in the condition of elevated $a/L_n \sim a/L_T$. However in low-density gas fueled ECRH plasmas with $\bar{n}_e \sim 2 \times 10^{19} m^{-3}$, ion scaled turbulence in W7-X appears stronger than in LHD [2,3]. In contrast in LHD, we think that minimized turbulence level are obtained at the transition of ITG to resistive interchange (RI) turbulence. Figure 1 (a) for LHD shows the density dependence of energy confinement time (τ_E) at constant ECRH power (1.8MW) at magnetic axis position (R_{ax}) 3.6m. The stellarator confinement scaling ISS04 shows a positive density dependence as $\tau_{E,ISS04} \sim n^{0.51}$. At $\bar{n}_e < 1.6 \times 10^{19} m^{-3}$, this scales as $\tau_E \sim n^{0.84}$, whereas at $\bar{n}_e \geq 1.6 \times 10^{19} m^{-3}$, this reduces to $\tau_E \sim n^{0.43}$, suggesting transition of confinement characteristics. Figure 1 (b) show that density fluctuation measurements by 2D-PCI feature a minimum in $\tilde{n}/n$ around this transition density. The gyrokinetic linear calculation by GKV code including kinetic electron and collisionality effects shows that ITG growth rate (γ_{ITG}) decrease monotonically with increase of density as shown in Fig.1 (c). This density dependence does not account for the increasing turbulence level in the experiment at higher density of transition. The growth rate of RI turbulence (γ_{RI}) in the bad average curvature of the R_{ax}=3.6m configuration was evaluated from two-fluid-MHD equations as the turbulence code GKV does not cover resistive interchange (RI) modes. Indeed the RI growth rate becomes positive above the transition density. Configurations with different magnetic curvature (R_{ax}=3.53, 3.6 and 3.8m) are compared for the further investigations of RI turbulence. Lessons learned from W7-X and LHD experiments will be used to define turbulence optimization criteria.

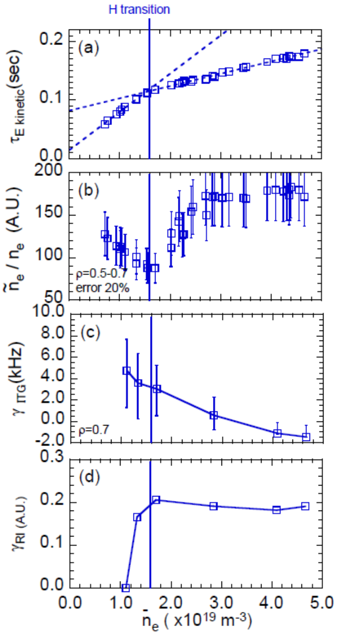

Fig.1 LHD: Density dependence of (a) τ_E, (b) turbulence level, (c) γ_{ITG} and γ_{RI}

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