§12. Effects of Magnetic Configuration on Micro Turbulence in LHD

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An optimization of magnetic configuration is the most important issues to design heliotron type fusion reactor. Especially, the effects of the magnetic ripple are very important parameter both for neoclassical and anomalous transport. In LHD, the magnetic ripples increases with outwardly shifting of magnetic axis. Global scaling study showed better energy confinement at inwardly shifted configuration. Although this agrees with neoclassical prediction, the transport is not governed by neoclassical process but dominated by anomalous process in LHD[1]. There exists a linkage between neoclassical and anomalous transport. Recent gyro-kinetic non linear simulations showed that better ion confinement at inwardly shifted configuration, where magnetic axis position (R_{ax}) was 3.6m, was better than at outwardly shifted configuration, where R_{ax} was 3.75m [2]. The physics mechanism underlined this can be larger zonal flow generated at inwardly shifted configuration with smaller magnetic ripple, then turbulence can be more suppressed at inwardly shifted configuration. This qualitatively agrees with the result of global energy confinement studies.

In Figure 1, measured density (-1), electron and ion temperature profiles (-2), as well as turbulence characteristics including amplitude (-3) and phase velocity (-4) are compared between R_{ax}=3.6m (a,c) and R_{ax}=3.75m (b,d) at low and high heating power; NBI: (a)5MW, (b)4MW which have dominant electron heating and (c,d):15MW which have similar electron and ion heating. In all cases ECRH power is 1.5MW. Between R_{ax}=3.6 and 3.75m (a vs. b, c vs. d), the heating power is almost the same, however, because of the difference of transport, the achieved n_e, T_e, T_i and its profiles were different. Turbulence spatial structures were measured by the two-dimensional phase contrast imaging (2D-PCI). [3] The measured wave number components are poloidally dominated. The propagation direction in the plasma frame can be obtained subtracting poloidal rotation velocity measured by charge exchange spectroscopy (CXS), shown in (-4). At R_{ax}=3.6m, CXS results are unavailable for $\rho<0.8$, however, as poloidal rotation velocity at $\rho=0.8$ is almost zero (as in a-4 and c-4), it is likely that for ρ < 0.8, the phase velocity in the lab frame is close to that in plasma frame.

The peak in the fluctuation level is around ρ=0.5-0.7 in the obtained data set. The fluctuation level is higher at R_{ax}=3.75m (b,d) than at R_{ax}=3.6m (a,c). In both low power heating with dominant electron heating cases (a,b), the fluctuation level was 70% higher at R_{ax}=3.75m. In high power cases with similar electron and ion heating (c,d), it was 40% higher at R_{ax}=3.75m. This qualitatively agrees previous results, which show better confinement at inwardly shifted configuration both experimentally [1] and with Gyro-kinetic simulation [2]. It should be noted that the difference is larger for electron heating case. The propagation direction in the plasma frame is in the electron diamagnetic direction in the strong electron heating case of R_{ax}=3.6m (a-4), while it is in the ion diamagnetic direction for other cases. Ion diamagnetic propagation components can be indication of ion temperature gradient mode (ITG), which is previously investigated in high T_i discharge [4]. One possibility of electron diamagnetic propagation components of electron heating case at R_{ax}=3.6m is the trapped electron mode (TEM). The negative density gradient at ρ = 0.5 - 0.7, where fluctuations are localized may drive TEM mode. This is seen to be move negative in (a) than other cases. More detailed comparison with gyro kinetic simulation is planned for the further understanding of the turbulence mechanism in LHD.

1) Yamada, H., et al, Nucl. Fusion, 45 (2005) 1684–1693
2) Watanabe, T., et al., Nucl. Fusion **47** (2007) 1383–1390
3) Tanaka, K., et al., Rev. Sci. Instrum. 79, 10E702 (2008)
4) Nunami, M., et al., Plasma Fus. Res. 6, 1403001 (2011)

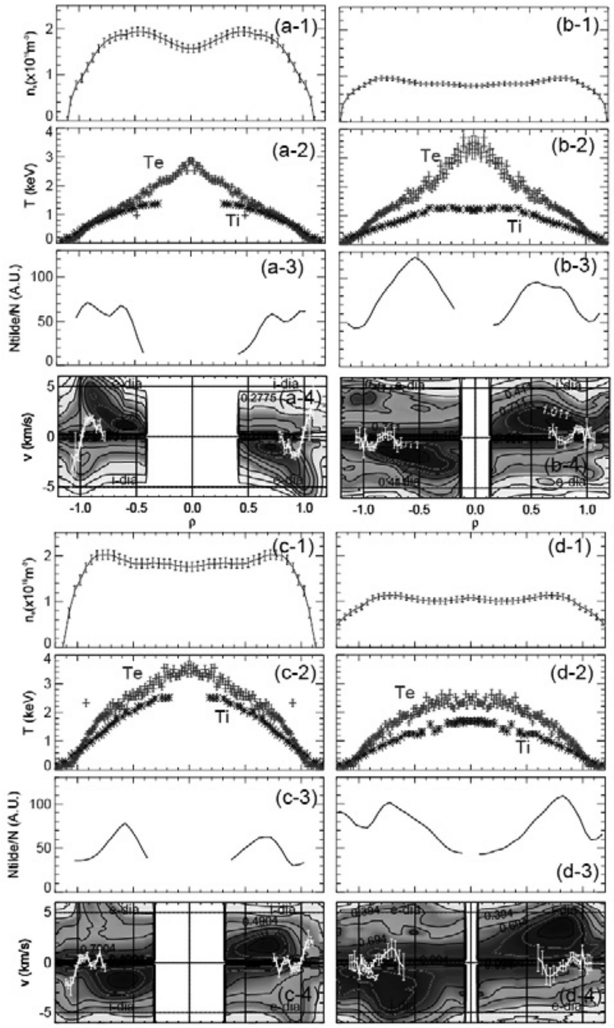

Fig.1 Profiles of (1) n_e, (2) T_e, T_i ,(3) fluctuation level, and (4) phase velocity. Contours of (4) are Log(amplitude). E_rxB_t rotation velocities are plotted by the line in (4). (a) R_{ax}=3.6m, 1.5MW ECH +5MW NBI, (b) R_{ax}=3.75m, 1.5MW ECH +4MW NBI, (c) R_{ax}=3.6m, 1.5MW ECH +15MW NBI and (d) R_{ax}=3.6m, 1.5MW ECH +15MW NBI. Bt is 2.71T at R_{ax}=3.6m, 2.74T at R_{ax}=3.75m.