§15. Characteristics of High Power NBI Heated Steady State Discharges without Impurity Accumulation

Nakamura, Y., Tanaka, K., Tamura, N., Yoshinuma, M., Suzuki, C., Peterson, B.J.

Recent experiments with high power NBI heating (P_{nbi} = 13 MW) show a drastic suppression of impurity accumulative behavior. The E_r measurements at the plasma edge indicate almost the same values as those with low power heating (P_{nbi} < 10 MW). The impurity shielding in the ergodic layer is not effective for hydrogen discharges in impurity accumulation window [1]. This remarkable suppression of impurity accumulation requires a new contribution to impurity transport such as turbulent one. Here, we investigate the profile structure of carbon density and also report the parameter dependences of carbon density profile on background ion collisionality and ion temperature gradient.

For this study, a database of carbon density profiles from steady state hydrogen discharges without impurity accumulation is constructed. Figure 1 shows typical carbon density profiles in high temperature plasmas with high power NBI heating. The carbon density profile becomes hollow with decreasing the plasma density, thereby observing a strong hollow profile of carbon, so-called impurity hole in high ion temperature mode. The hollowness of carbon profile becomes stronger with decreasing the background ion collisionality as shown in Fig. 2, where the normalized logarithmic carbon density gradient $R_{ax}/L_{nc} = -(R_{ax}/n_c)dn_c/dr$ is plotted as a function of ion collisionality. The radial electric field also increases with decreasing the ion collisionality and becomes positive so as to drive the impurities outward. However, the neoclassical impurity flux density due to E_r is strongly reduced in the core region (r < 0.5) and the strong outward convection at around mid-radius cannot be explained by only neoclassical impurity transport. A strong correlation is visible between the ion temperature gradient (R_{ax}/L_{Ti}) and the logarithmic gradient of carbon density as shown in Fig. 3. Since temperature gradients are the primary quantity in determining the characteristics of turbulent modes, the correlations between R_{ax}/L_{Ti} and R_{ax}/L_{nc} provide a strong signature that turbulence is important in the impurity transport. One of most probable candidates for anomalous impurity transport is turbulence such as ITG mode, which can be driven in high temperature plasmas (R_{ax}/L_{Ti} > 5) in LHD. A similar strong correlation can also be seen between and the Mach number or the toroidal rotation gradient. The primary correlation is not caused by a single mechanism, but is a non-trivial combination of the correlations between heating powers, temperature gradients and rotation. These quantities together determine the turbulence characteristics in such a way that the overall result produces the strong correlation. Although turbulent impurity transport simulation is under investigation in LHD, there are some results on turbulent impurity transport for tokamak plasmas. These results indicate that ITG turbulence drive the impurities outward in experimental observation and simulation study. Moreover, impurity density gradient strongly depends on plasma rotation (Mach number and rotation gradient). The anomalous impurity transport observed in LHD long pulse discharges has a similarity with the recent results in tokamak plasmas.

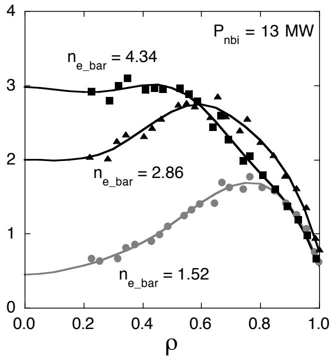

Fig. 1. Carbon density profiles in high temperature plasma with different average density.

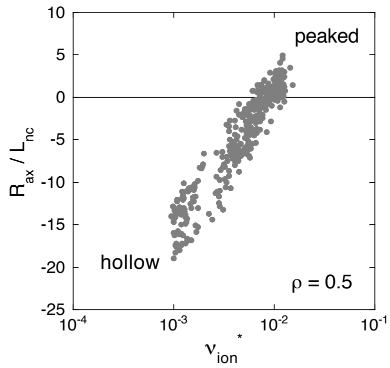

Fig. 2. Correlation between carbon density profile and ion collisionality

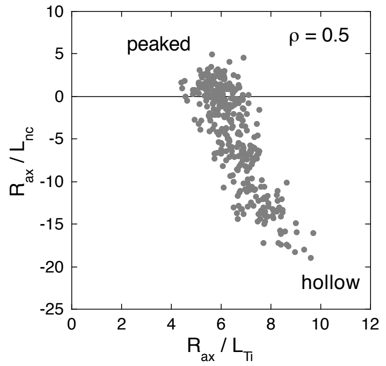

Fig. 3. Correlation between carbon density gradient and ion temperature gradient

1) Nakamura, Y., et al., PPCF **56** (2014) 075014