§15. High Ion Temperature Discharges Using Carbon Pellet Injection

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A carbon pellet injection was carried out to realize high ion temperature plasma in LHD. The peaked ion temperature profile with steep gradient (ion ITB) was formed in the density decay phase after the carbon pellet injection with high power NBI heating. The ion thermal diffusivity was reduced in the core region of ion ITB, where the negative radial electric field is predicted by the neoclassical ambipolarity [1,2]. The significant exhaust of carbon impurity ions was observed after transition to the ion ITB. Therefore the high ion temperature plasma was realized in the condition of low $Z_{\rm eff}$ ($n_{\rm C}/n_{\rm i} \leq 0.01$), even if carbon pellet injection was utilized [3].

The ion temperature obtained with the carbon pellet injection was compared with that obtained with gas puff in the wide range of magnetic configuretion ($R_{\rm ax}$ scan), which is shown in Fig. 1. The ion temperature of carbon pellet discharges is higher than that of gas puff discharges and the dependence on the magnetic configulation ($R_{\rm ax}$) is almost same as that of gas puff discharges. The maximum ion temperature was obtained in the inwardly sifted configuration of $R_{\rm ax}$ = 3.60 m, and the reveresd magnetic field condition corresponding to the co-NBI dominant is prefereble to obtain higher ion temperature.

In order to obtain further higher ion temperature plasma, the sub-cooled operation of super conducting magnetic coils ($B_{\rm t}$ = 2.75 T $\rightarrow$ $B_{\rm t}$ = 2.90 T) was carried out. The procedure of the wall conditioning previously carried out was changed from baking + He glow discharge cleaning + Ti getter to baking + Ti getter. The maximum ion temperature obtained in 12th campaign is $T_{\rm i0}$ = 5.6 keV with the electron density of $n_{\rm e0} = 1.6\times10^{19}$ m^{-3} (line averaged density of $\overline{n_{\rm e}} = 1.3 \times 10^{19}$ m^{-3}), which is shown in Fig. 2. The ion ITB was sustained during the perpendicular NBI injection, indicating much longer than the energy confinement time. However the central ion temperature decreases slowly after reaching maximum value, which seems to be correlated with the hollowing density profile. Further investigatoin is necessary to understand the mechanism of ion ITB formation in helical plasmas.

The superposition of ECH was also carried out utilizing 77 GHz system upgraded at 2008. When the 77 GHz ECH was focused and resonated at the plamsa center, the increase of central ion and electron temperatures was observed in the normal magnetic field direction (ctr-NBI dominant condition), which is the first observation of the clear ion temperature increase due to ECH superposition in high field experiments, while no increase of ion temperature was observed in the reversed magnetic field direction (co- NBI dominant condition). The experimental observation of the electrostatic potential measurement was left for future study.

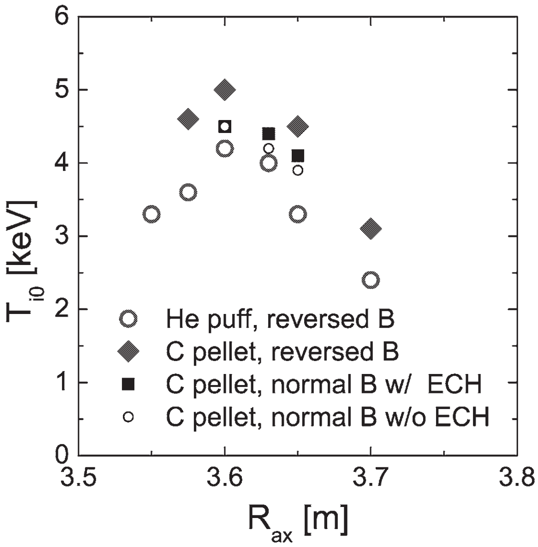

Fig. 1: The central ion temperature as a function of magnetic axis. The carbon pellet discharge, gas puff discharge and ECH superposition discharge are shown.

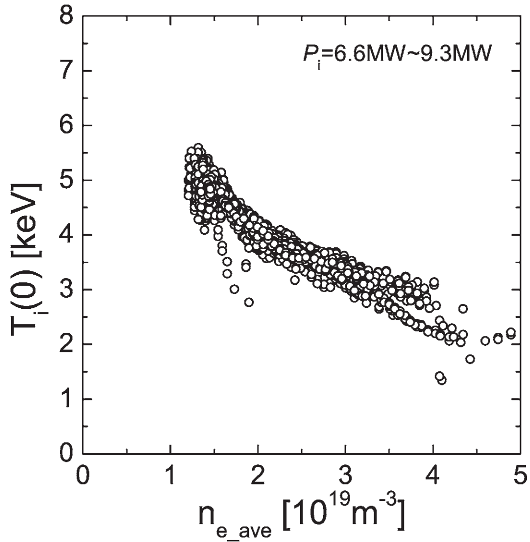

Fig. 2: The central ion temperature obtained with carbon pellet injection as a fuction of line averaged density.

1) K. Nagaoka, et al., Plasma Fusion Res. **3** (2008) S1013.

2) M. Yokoyama, et al., Phys. Plasmas, **15** (2008) 056111.

3) K. Ida, et al., Phys. Plasmas (2009)