§43. Estimation of Re-entering Fast Ion Effect on Transport Coefficient and Development of Monte Carlo Code Including Re-entering Fast Ions

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Three tangential neutral beam injectors (NBIs) and two perpendicular NBs have been installed on LHD. Using these NBs, the volume averaged beta $<\beta>$ have reached 5% in low field strength (the field strength at magnetic axis $B_{\rm ax} \simeq 0.5$T)[1]. In the low field strength like LHD high beta discharge, a lot of fast ions produced by NBI move outside of last closed flux surface (LCFS). Most of such fast ions become re-entering fast ions[2], which repeatedly pass in and out of the LCFS. Therefore, heat power profiles including the re-entering fast ions require in order to investigate accurately the energy confinement property in the high beta.

On the other hand, in the transport analyses for LHD high beta discharge, heat power profiles have been evaluated by simple heat power evaluation code using equilibrium magnetic fields in boozer coordinates. In the calculation using the boozer coordinates, fast ions cannot be traced on the outside of LCFS. Thus, heat power profiles cannot be evaluated due to the re-entering fast ions and heat power profiles are underevaluated.

In order to evaluate heat power profile including the re-entering fast ions, we have developed a new Monte Carlo code (MORH) using equilibrium magnetic fields in real coordinates, which obtained by the three-dimensional magnetohydrodynamic equilibrium code (HINT). In the code, the velocity distribution function and the Beam pressure can be also calculated.

In order to investigate the effect of re-entering fast ions on the thermal conductivity, we evaluated the heat power profiles in the LHD high beta discharge using the MORH. Then, effective thermal conductivity is calculated using the heat power profiles. Figure 1 shows the effective thermal conductivity in high beta discharge ($\chi_{\rm eff} = (\chi_i + \chi_e)/2$, assuming that $T_{\rm e} = T_{\rm i}$ and $n_{\rm e} = n_{\rm i}$). In fig. 1, the difference of the coefficients between "with re-entering fast ions" and "without re-entering fast ions" is small in the center, whereas it is larger near the LCFS. The local thermal transport coefficient including the re-entering fast ions near the LCFS is 30% larger than that without them.

We also estimated how much the previously identified confinement property changes when the re-entering fast ions are included(fig. 2). In the fig. 2, the thermal transport coefficient with the re-entering fast ions is slightly larger than the previously identified known thermal transport coefficient. However, the difference between the two is almost the same as the dispersion of the previously identified thermal transport coefficient.

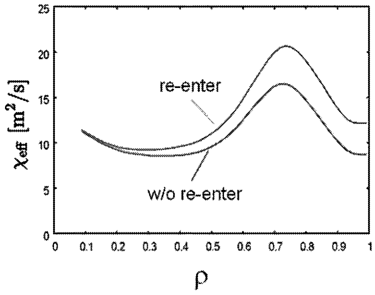

Fig. 1: Effect of re-entering fast ion on the effective thermal transport coefficient.

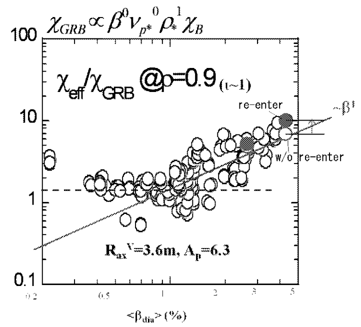

Fig. 2: Local thermal transport coefficient near LCFS in experiments[3].

Therefore, the tendency of the thermal transport coefficient with considering the re-entering fast ions is found to be rarely different from the previously identified tendency.

The re-entering fast ions might be lost because of a charge-exchange reaction with the neutral particles, since the re-entering particles pass through the peripheral region, in which the neutral particle density is higher than that in the core. Thus, it is important to estimate accurately the neutral density in peripheral region. In 14th experimental campaign on LHD, we measured the neutral density in the diverter region in the high beta discharge. We will evaluate the heat power profile using the measured neutral density in the near future. In addition, in order to check the results of MORH, the heat flux of the re-entering fast ions in periphery was measured by the hybrid direction probe. The comparison with the measurement of re-entering fast ions is issue in the near future.

1) K.Y. Watanabe *et al.*, in Proc. of ITC-17 and ISWS-16 Toki (2007) I-13

2) K. Hanatani and F. -P. Penningsfeld, Nucl. Fusion. **32** 1769 (1992).

3) K. Y. Watanabe 52nd Annual Meeting of the APS Division of Plasma Physics, (2010) DI3