§39. Relations between the Edge and the Divertor Plasmas

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For a step to detailed understanding of energy and particle transport in the naturally stochastic boundary (ergodic layer) in LHD, the relations between the edge of the core region and the divertor plasmas are investigated by density scan ($\bar{n}_e$ ~1-8 $\times 10^{19} m^{-3}$) under NBI power of 4-5 MW in the two operational magnetic configurations, R_{ax}=3.6m and 3.75m, with different volume of the ergodic layer [1].

The magnetic structure in the ergodic layer depends on the operational magnetic configurations. For example, the width of the region in which long field lines (e.g. L_c>100m) exist is narrower in R_{ax}=3.6m configuration than that in R_{ax}=3.75m configuration (Fig.1). The difference of the magnetic structure causes the difference of the n_e profile in the ergodic layer[2]. The expansion of the n_e profile is larger in R_{ax}=3.75m case than that in R_{ax}=3.6m case. Therefore, both volumes of the ergodic layer and of the plasma in the layer are larger in R_{ax}=3.75m configuration than in R_{ax}=3.6m. In this text hereafter, the configuration with R_{ax}=3.6m and with R_{ax}=3.75m are called the 'thin' and 'thick' ergodic layer configuration, respectively for simplify.

Fig. 2 shows the $\bar{n}_e$ dependence of n_e, T_e at the edge and at the divertor plate for the 'thin' and the 'thick' ergodic layer configurations, respectively. In these figures, the shown divertor plasma parameters were measured by the one of the electrodes of the Langmuir probe arrays embedded in the divertor plates at which T_e is the highest in all electrodes.

In the 'thin' ergodic layer case, both the electron density at the edge of the confinement region ($n_{e,edge}$) and at the divertor plate ($n_{e,div}$) increase with increasing $\bar{n}_e$ up to $\bar{n}_e$ ~ $8\times10^{19}m^{-3}$. The former is almost proportional to $\bar{n}_e$, and the latter is proportional to $(\bar{n}_e)^{1.45}$. T_e at the edge of the confinement region ($T_{e,edge}$) and at the divertor plate ($T_{e,div}$) decrease gradually with $\bar{n}_e$ increase, and $T_{e,div}$ changes almost linearly with $T_{e,edge}$ ($T_{e,\rho=0.97}$, where ρ is the normalized minor radius). These results are consistent with the analysis conducted in ref 2) with lower input power, and there is no sign of the high-recycling or the divertor detachment regime. No clear dependence of both ratios of $T_{e,div}$ and $T_{e,\rho=0.97}$ to $T_{e,\rho=0.97}$ and $T_{e,\rho=0.84}$, respectively, on $\bar{n}_e$ is observed, and it means that the shape of edge T_e profile did not change in this series of discharges.

Three density regimes are recognized in the 'thick' ergodic layer configuration. In the low density range ($\bar{n}_e$< ~ $4\times10^{19}m^{-3}$, regime-I), the properties of n_e and T_e are similar with them in the 'thin' ergodic layer case. With increasing density, T_e at the divertor plate starts to decrease faster (regime-II). Eventually, density at the divertor plate also starts to decrease even the density at LCFS still increases (regime-III). This regime appears to be similar to divertor detachment observed in tokamaks.

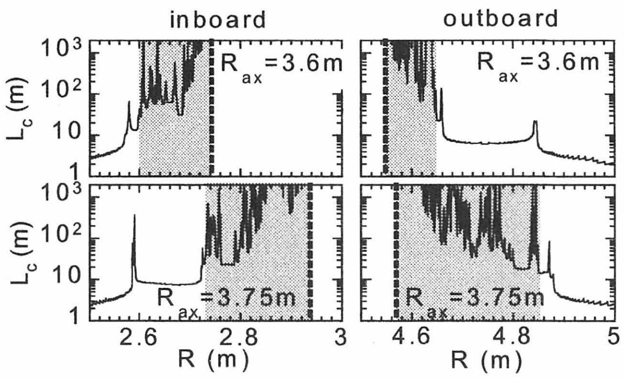

Fig. 1. Connection length (L_c) profiles in the ergodic layer. The start points of field line tracing are distributed from the edge of closed surfaces region to near vacuum vessel along the major radius on the midplane in the horizontally elongated cross-section. Dashed line indicates the position of LCFS. Hatched region indicates the region in which long field lines (L_c>100m) exist.

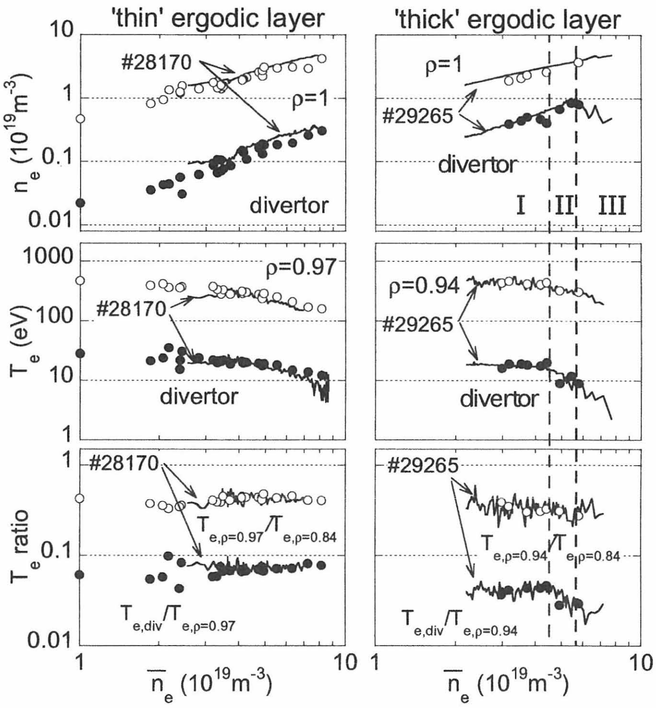

Fig. 2. T_e and n_e in the edge and the divertor plasmas in the configurations with the 'thin' and the 'thick' ergodic layer as functions of operational density (line averaged density in center chord), respectively. NBI power range is 4 – 5 MW. Open and closed circles are data from different discharges at the timing of maximum stored energy. Lines are time evolution of a discharge (#28170 for 'thin' case, #29265 for 'thick' case, respectively). The normalized minor radius is represented by 'ρ'. Top: Electron density, middle: Electron temperature, bottom: Ratios of electron temperature.

References

1) Masuzaki, S. et al. : J. Nucl. Mater., submitted.
2) Masuzaki, S. et al. : Nucl. Fusion 42, (2002) 750.