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Effect of magnetic field structure on electron internal transport barrier formation in Heliotron J

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An electron internal transport barrier (eITB) that is formed in helical plasma, has been observed widely in helical devices such as Heliotron J, CHS, LHD, TJ-II, and W7-AS. The eITB generated by electron cyclotron resonance (ECR) heating has been observed in Heliotron J with a steep electron temperature gradient in the core region. When injected ECR heating power is reduced under constant density, the electron temperature of the core region decreases considerably. However, the decrease in temperature in the peripheral region is small. Further, while the effective thermal diffusivity (χ_e^{eff}) in the peripheral region of the eITB plasma is larger than that in the non-eITB plasma, a clear reduction in χ_e^{eff} was observed in the inside region of the eITB plasma. An outstanding characteristic of the eITB in Heliotron J is that the threshold power required to form the eITB is smaller than that required in other helical devices.

A comparative study of eITB formation was carried out between Heliotron J and CHS to investigate the effect of the magnetic field configuration on barrier formation. The threshold electron transition density in Heliotron J ($1.2\text{x}10^{19}\text{m}^{-3}$@$P_{inj}$~330kW) was two times larger than that in CHS ($0.5\text{x}10^{19}\text{m}^{-3}$ @P_{inj}~130kW)[1].

The physical mechanism of the barrier formation is associated with the magnetic field configuration. Thus, it is necessary to clarify the role of the magnetic field and magnetic field configuration in the formation of the eITB.

It is essential to clarify the role of helical ripples in the formation of the eITB. The eITB formation hypothesizes that it is easily formed in a larger effective helical ripple (ε_{eff}) magnetic configuration in the core region. Since the helical ripple dominates neoclassical transport in helical plasma, a larger helical ripple causes a larger neoclassical electron transport with significant power absorption to the ripple-trapped electrons. The comparison of the threshold electron density and the achieved $T_e(0)$ of the eITB formation agree with the hypothesis that the barrier is predicted to be easy to form eITB in the larger ε_{eff} configuration. Effective helical ripple control by bumpy components in Heliotron J indicated that eITB formation is related to neoclassical transport through the ε_{eff}. However, this cannot be explained only by the ε_{eff}[2].

In addition, the Heliotron J experimental result indicated that the barrier formation was affected by the magnetic field structure besides the helical ripple such as the rational surface or magnetic island production. The experimental results of Heliotron J show that the foot point of eITB moves as the plasma current increase as shown in figure 1. When the plasma current is below 0.7kA, the foot point is kept at almost same position. When the current increases above 0.7 kA, the foot position jumped from 0.13 to 0.24, and the improved confinement region expand. After that the foot point moves towards the outside of plasma. The foot point movement has a good agreement with the magnetic island movement [3]. The confinement improvement region can be further expanded by the electron cyclotron current drive (ECCD). As shown in figure 2, the area of the eITB is extended by ECCD which drives the plasma current so that the rational surface moves outward of the plasma, and the foot point moves from 0.35 to 0.45. In order to clarify the effect of the magnetic field structure on the formation of eITBs, we investigate not only the neoclassical transport, but we clarify the effect of the magnetic islands presence on the barrier formation.

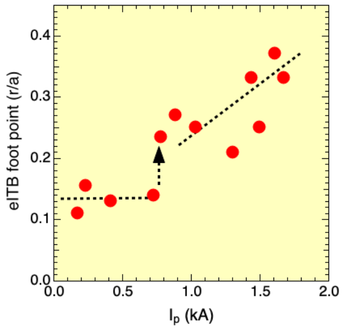

Figure 1 eITB foot point location vs. plasma current in N//=0.0

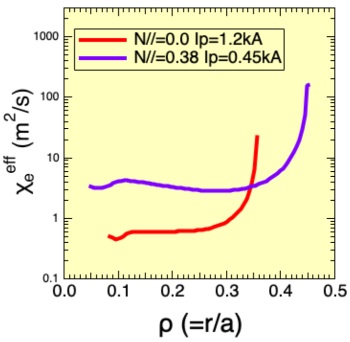

Figure 2 Effective thermal diffusion coefficient on with ECCD (N//=0.0) and without ECCD (N//=0.38) (spatial resolution $\delta\rho$ ~0.1)

References

[1] Kenmochi N, et al., Plasma Phys. Control. Fusion **59** (2017) 055013

[2] Minami T, et al., to be submitted to Nucl. Fusion

[3] Kenmochi N, et al., Scientific Reports **10**, Article number: 5 (2020)