§2. Effective Formation and Sustainment of the e-ITB with Controlling the Rotational Transform by ECCD

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It was previously reported that the flattening of the electron temperature profile occurs when the magnetic shear near the ι=1/2 rational surface decreases due to 1 MW co electron cyclotron current drive (ECCD) in a plasma in which the line averaged electron density is ~$0.7\times10^{19}m^{-3}$ sustained by balanced tangential neutral beam injection (NBI). The additional power input of the electron cyclotron resonance heating (ECRH) is required to form the electron internal transport barrier (e-ITB) again in such a condition. On the other hand, 1 MW counter ECCD is sufficient to form and sustain the e-ITB in the similar target plasma. It was also derived that the velocity of the heat pulse generated by modulation ECRH (MECH) inside ι=1/2 rational surface is faster in the case of co ECCD than the case of counter ECCD [1]. Stochastization of the magnetic surface near the ι=1/2 rational surface with weak magnetic shear can be caused by co ECCD in the balanced tangential NBI plasma as in the case of switching the direction of the NBI from co to counter directions[2,3]

Here, the experimental results when the 1.4 MW (0.7MW x 2) co ECCD applied to the plasmas sustained by balanced tangential (co and counter) NBI or counter NBI are reported. The target plasmas were sustained for 2.0 seconds from t=3.3 sec. The co ECCD was superimposed for 2.0 seconds from t=3.3 sec. As shown in the left column of Fig.1, the rotational transform ι measured by motional Stark effect (MSE) spectroscopy[4] did not change during the balanced NBI without ECCD. On the other hand, as shown in the right column of Fig.1, ι increases in the plasma central region due to co ECCD. Although in the fast phase of co ECCD, e-ITB is observed (t=3.63 s), the flattening of the electron temperature profile occurred inside r_{eff} < 0.25 m where the magnetic shear is weak near the ι=1/2 rational surface. The e-ITB cannot be sustained with 1.4 MW power input by ECCD.

The flattening of the electron temperature profile is also observed in the case of counter NBI as shown in the left column of Fig.2. The magnetic shear is weak near the ι=1/2 rational surface with increase of ι from the vacuum configuration. The inductive current that compensates the toroidal current driven by counter NBI increases ι. When the co ECCD is superimposed on the similar target plasma, the ι profile in the central region increases more with time as shown in right column in Fig.2. At 0.4 seconds later from the start of co ECCD (t=3.7 s), the magnetic shear is weak near the ι=1/2 rational surface and the flat electron temperature profile is observed between the clear foot of the narrow e-ITB and the outer end of the weak magnetic shear region (r_{eff}=0.3). With time, the magnetic shear in the central region increases and a folding point of the ι profile appears at r_{eff}=0.3. The width of the e-ITB expands with time but remains inside the folding point.

From these and previous experimental results, it is derived that a suitable ECCD application not to decrease the magnetic shear near the rational surface is effective for the formation and sustainment of the e-ITB.

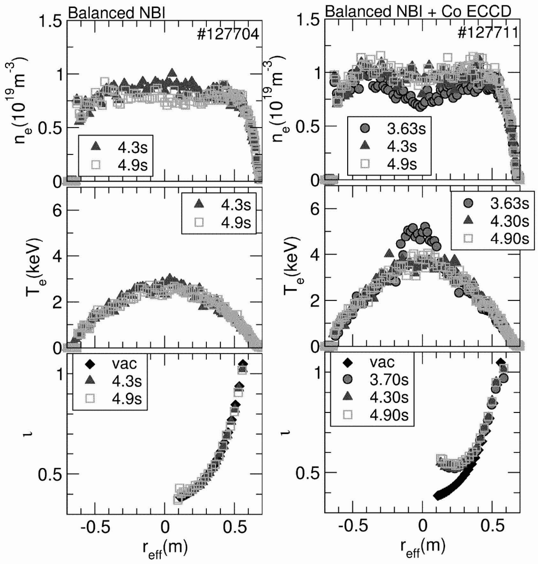

Fig.1: Profiles of the electron density (upper), the electron temperature (middle) and the rotational transform (lower) in plasmas sustained by balanced NBI (left) and sustained by balanced NBI and co ECCD (right)

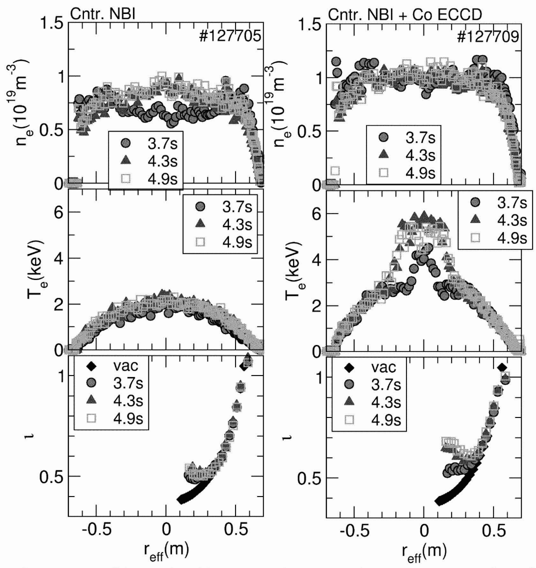

Fig.2 Profiles similar to Fig. 1. Plasmas sustained by counter NBI (left) and sustained by counter NBI and co ECCD (right).

1) Igami, H., et al, EPJ Web of Conferences **32** (2012) 2006.
2) Ida, K. et al.: Phys. Rev. Lett. **100** (2008) 045003
3) Ida, K. et al.: Plasma Phys, Cotrol. Fusion **57** (2015) 014036.
4) Ida, K. et. al., Rev Sci Instrum 76 (2005) 05350