§42. Radial Electric Field Effect on Bootstrap Current in LHD

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In helical devices, net toroidal currents are not required to produce magnetic field for plasma confinement, while theoretical prediction suggests that bootstrap (BS) current exists even in the case without any active current drive. Typically, its direct effects on the MHD stabilities are not considered large, however the effects on the MHD equilibrium are quite large especially for the shearless helical plasmas Then the establishment of the accurate estimation method of BS current is a important issue.

According to a theoretical prediction [1], in the helical plasma with different collisionalities between electrons and ions, it is pointed out that the BS current proportional to the radial electric field, E_r because the geometric factors depend on the collisionalities and that, in the positive E_r, the BS current should be negative. In the H-J ECH plasmas, the discharges with the negative net toroidal current were observed, which are inferred as a typical experimental results due the negative bootstrap current in the positive E_r [2]. However, H-J does not have the capability to measure the E_r, the plasma density and the temperature profiles now. Then we made the experiments on the E_r effect of BS current in LHD.

Figure 1 shows the evolution of the beta value (a) and the net toroidal current for 2 discharges with the different collisionalities. The electron and the ion normalized collisionalities ν^{**} at the half of the plasma minor radius, ρ=0.5, of the shot #95439 are ~0.1 and ~1. Here $\nu^{**}<1$ corresponds to the so-called 1/ν-regime. On the contrary, those of the shot #95440 to ~0.02 and ~0.2 as shown in Fig.2. The plasmas are produced and maintained by only ECH, which is injected for more than 3 seconds. The beta value, the plasma density and the temperature are almost constant during the discharges. The beta value of shot #95439 is larger by ~20% than that of #95440. The direction of the observed net toridal current of #95439 are opposite to that of #95540. Here it should be noted that the positive net toroidal current enhances the rotational transform, which is same direction with the bootstrap current in tokamaks and also in the LHD typical configuration. Figure 3 shows the E_r profile measured by HIBP. #95440 (more collisionless discharge) has the much larger the positive E_r than #95439 (more collisional discharge). The result is quite consistent with the theoretical prediction, which the bootstrap current flows in the direction to reduce the rotational transform in the discharges with positive E_r whose electron collisionality is lower than the ion's. However, the simple formula of the bootstrap current model [1] taking the Er effect into account does not predict the existence of the negative bootstrap current when the electron and the ion belongs to the same collisional regimes even if the collisionalities themselves are different. The systematic analysis through the comparison between the theoretical prediction and the experimental observation is a future work.

[1] K.Y. Watanabe et al, Nucl. Fusion 35 (1995) 225.
[2] G. Motojima et al., Fusion Sci. Tech., 51 (2007) 122

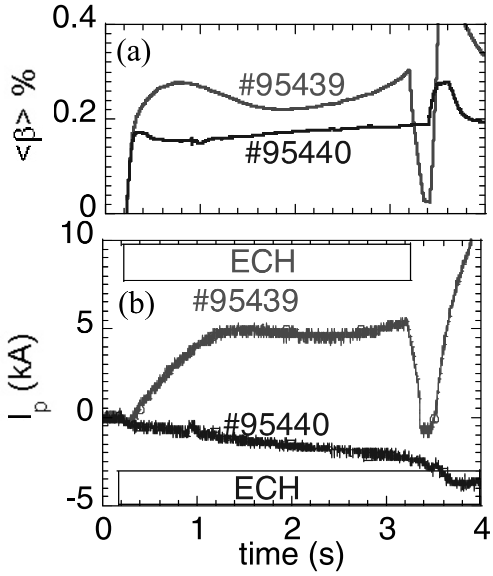

Fig. 1 The time evolution of the beta value and the net toroidal plasma current for the different collisionalities. #95439 corresponds to more collisional discharge, and #95440 corresponds to more collisionless discharge.

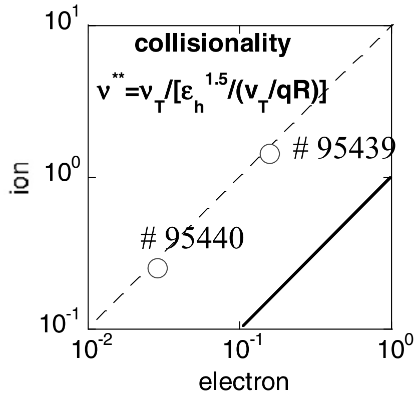

Fig. 2 The ion and the electron collisionalities at the half of the plasma minor radius are shown. $\nu^{**}<1$ corresponds to the so-called 1/ν-regime.

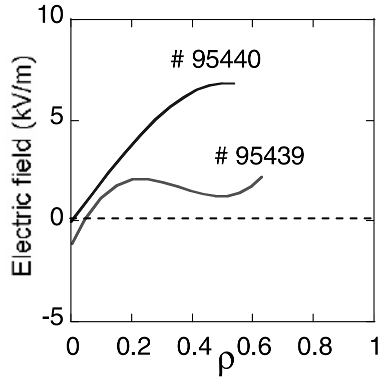

Fig. 3. The radial electric field profile measure by the HIBP systems.