§6. Shear-flow Drive and Production of Nonneutral Plasma by Electron Injection to Helical System

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There has been considerable interest in toroidal non-neutral plasmas, which are relevant to heavy ion accelerators, sources of highly stripped heavy ions, thermonuclear fusion reactors, and recently particle traps in helical magnetic field[1]. Most of these concepts are based totally on the electrostatic confinement of ions in a deep potential cavity. For this purpose, a background cloud of magnetized electrons has been considered to be a candidate to form the negative well. Another significant feature of the background electrons is that a strong electric field intrinsically forms due to their space charge. This field can produce strong shear flows if we apply an appropriate magnetic field. This property may be applied to produce two-fluid high-β plasmas which possess diamagnetic structures formed by the hydrodynamic pressure of the significant shear flows.

In order to test experimentally the production of non-neutral plasmas and driving flow by the self-electric field of the plasmas, we have conducted an experiment of particle trapping in the CHS helical magnetic field. An Initial result from the experiment can be found in a companion report[2]. The data shows broad profiles of space potential formed inside the separatrix surface of the CHS helical field. This suggests strongly a deep penetration of the injected electrons into the helical magnetic field, although they are launched outside the separatrix. In the following, we will present the time history of electron flux Γ measured by a single probe.

Data in Fig. 1 are obtained at different radial coordinates between r = 1 and -18 cm, where the separatrix surface is at r = 0 cm. Here, one notes that the electrons are fired at t = 0.5 ms from the electron gun which is located at r = 2 cm, outside the separatrix. However, substantial values of Γ can be recognized even inside the separatrix. As seen from the data taken at r = 1 cm, the value of Γ ($\sim 8\times10^{16}$ $/m^2s$) is not so large as compared with the values of Γ measured inside the separatrix that are in the range between 10^{17} and 10^{18} $/m^2s$. This is probably attributed that the field lines are opened outside the separatrix: no magnetic surface at r > 0 cm. Thus, only a part of electrons just launched from the gun should be detected at r = 1 cm.

In contrast to the above result, the measured Γ enlarges inside the separatrix (r < 0 cm). Around r ~ -(1-3) cm, the value of Γ significantly increases up to ~ 5×10^{19} $/m^2s$, which is 50 times as large as the data at r = 1 cm, probably due to the confinement of electrons closed magnetic surfaces. As recognized from the data, this value of Γ gradually decreases at r ~ -5 cm, which is about 6×10^{18} $/m^2s$. It, however, slightly increases again at r ~ -7 cm up to 1.5×10^{18} $/m^2s$ and then, decreases down to ~ 1×10^{17} $/m^2s$ around the magnetic axis of the CHS helical field. One notes that Γ is not zero but still finite which is almost comparable with the value measured outside the separatrix. Since $\rho_e \sim 0.5$ cm around the separatrix, this result cannot be explained by a finite Larmor radius effect. Regarding with the classical collisional transport of electrons against background neutrals, the process should partly work to penetrate into the separatrix. This is because the rise-up time of signals in Fig. 1 is about several hundred μs, which is comparable with the electron-neutral collision times, as described in Ref. 2. However, the classical process is insufficient to explain such a deep length of penetration of electrons too long to be accomplished in such a single collision time. Thus, some collision-free effect should occur to bring about the result. The second series of experiments focused on the detailed mechanism will be performed in this academic year.

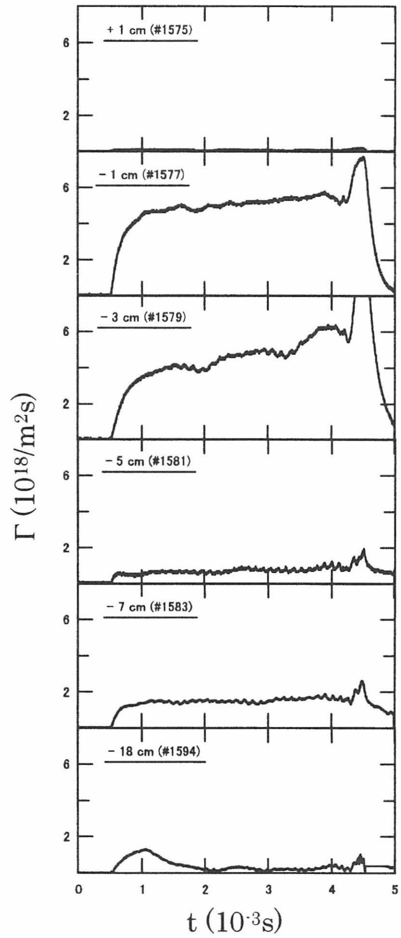

Fig. 1. Time histories of electron flux Γ measured by a single probe without the bias voltage (= 0 V). Data are measured at several different coordinate. These data shows that the electrons launched from the outside of the separatrix traverse across there and furthermore, penetrate deeply inside the separatrix.

1) Pedersen, T. and Boozer, A., Phys. Rev. Lett. **88**, 205002 (2002)
2) Yoshida, Z., Himura, H. et al., 'Production of Shear Flow by Electron Beam on LHD and Confinement of Non-neutral Plasmas', NIFS Report Apr. 2001 – Mar. 2002.