§8. Understanding the Impact of Changes in the Magnetic Topology on Transport in LHD

Evans, T.E. (GA), Ida, K., Kamiya, K. (JAEA),
Suzuki, Y., Ohdachi, S., LHD Experiment Group

Large Edge-localized modes (ELMs) are a serious concern for ITER. In DIII-D as well as in LHD and a growing number of tokamaks around the world, resonant magnetic perturbation (RMP) fields have proven to be effective for mitigating (i.e., significantly reducing the size) of ELMs or even eliminating ELMs completely$^{1)}$. Although ITER is proposing to include RMP coils in its baseline design, there are a number of key physics questions that must be understood to assure the best possibility of success for RMP ELM mitigation in ITER H-mode plasmas. The goal of NIFS-GA joint experiment is to combine the resources of LHD and DIII-D in joint experiments on developing an understanding of how the edge magnetic topology affects heat, momentum and particle transport. The direct relationship between the structure of the magnetic island field and the edge radial electric field was investigated in LHD in order to understand the effect of RMP on the radial electric field.

Since both the toroidal and poloidal rotation contributes to the radial electric field, it is import to investigate how the RMP affects the toroidal and poloildal rotations. In order to distinguish the effect of RMP on toroidal and poloidal rotation, beams are switched from co-injection to counter-injection in the LHD experiment. Figure 1a shows the radial profiles of radial electric field without the RMP field and figure 1b with RMP field (near O-point) in the discharges. Here, the direction of NBI is switched from co-direction to counter-direction at t = 4.3s. The radial radial electric field profile becomes strongly positive outside last closed flux surface (LCFS : R = 4.55m) because electrons escape to the wall along the magnetic field in the scrape off layer (SOL)$^{2)}$. The magnetic island is formed by the RMP at $\iota = 1$ rational surface (R = 4.32 - 4.42m) as shown by the dashed lines in figure 1b and in 1a without the island as a reference.

When there is no RMP, the radial electric field is negative following the beam switch from co- to counter. This results from a significant change in toroidal rotation without the island and its contribution to the radial electric field. However, when the RMP is applied with a current of 1920 A and phased to place an island O-point across the measurement region, the radial electric field is approximately zero across the island and there is almost no change after the beam switch. This is because the both poloidal and toroidal rotations are damped due to the formation of the magnetic island created by RMP. This experiment clearly shows the damping of flows due to the magnetic island, which is consistent with the observation of damping of toroidal flow observed in JT-60U when the neoclassical tearing more grows and reaches to the mode locking threshold$^{3)}$.

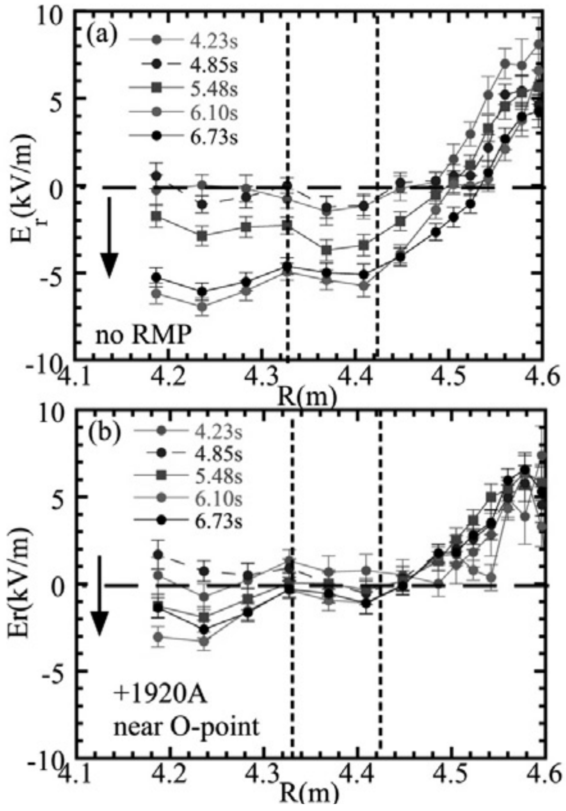

Fig. 1: Radial profiles of radial electric field (a) without RMP field and (b) with RMP filed (near O-point) in the discharges, where the direction of NBI is switched from co-direction to counter-direction.

This experiment suggest two interesting effects of RMP on plasma flow and radial electric field, one is reduction of radial electric field and the other is enhancement to radial electric field when comparing the case with and without and island O-point. In the RMP experiment, the plasma flow and radial electric field are expected to be damped because of the formation of magnetic island. On the other hand, in the region of the open field outside of LCFS, the existence of a significant poloidal flow and positive radial electric field are expected when the stochastic region appears at the plasma boundary by RMP. Therefore the larger radial electric field shear at the LCFS is expected in the plasma with RMP because of the opposite effect of RMP on the plasma flow inside and outside LCFS.

1) Evans, T. E., et. al.,Nucl. Fusion 48 (2008) 024002.

2) Kamiya, K., et. al.,Nucl. Fusion 53 (2013) 013003.

3) Ida, K., et. al., Phys. Rev. Lett. 109 (2012) 065001.