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Seville, Spain, 26 September – 1 October 1994

IAEA-CN-60/A-2-IV-2

Control of Radial Electric Field in Torus Plasma

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CONTROL OF RADIAL ELECTRIC FIELD IN TORUS PLASMA

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CONTROL OF RADIAL ELECTRIC FIELD IN TORUS PLASMA

Abstract

The radial electric field is controlled by changing the direction of neutral beam from co to counter to plasma current in tokamak, while it is controlled by the 2nd harmonic ECH and NBI and pellet injection in heliotron/torsatron.

Keywords : Radial electric field, torus plasma

1. INTRODUCTION

Radial electric field E_r is considered to be one of the key parameter to improve plasma confinement. In order to control E_r profiles, the electron cyclotron resonance heating (ECH) and/or neutral beam injection (NBI) are applied in tokamak and heliotron/torsatron plasma. Detailed radial profiles of electric field are obtained from the radial profiles of toroidal and poloidal rotation velocity measured with multi-channel charge exchange spectroscopy (CXS).

2. CONTROL OF RADIAL ELECTRIC FIELD BY NEUTRAL BEAM INJECTION(NBI) IN JIPP TII-U AND CHS

In the tokamak, the toroidal rotation velocity profile can be controlled by switching the direction of momentum input of high energy neutral beam from parallel (co-injection) to anti-parallel (counter-injection) to the direction of plasma current. Figure 1 shows the radial electric field profiles normalized by central ion temperature for parallel injection and near perpendicular injection (9 degree) in JIPP TIIU tokamak. The radial electric field is negative for perpendicular NB injected plasma. It becomes positive near the plasma center for co-injection, while it becomes large negative value for counter-injected NB plasma. This result illustrates the offset part of rotation (spontaneous rotation) and the combination of the external torque. Since the offset toroidal rotation velocity is in the counter-direction (negative electric field), the absolute value of electric field is much larger in counter-injected plasma than that in co-injected plasma[1]. Density peaking associated with this negative electric field indicates the improvement of particle transport in tokamak.

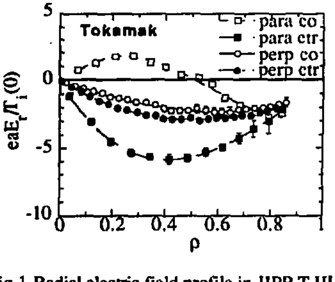

Fig.1 Radial electric field profile in JIPP T-IIU tokamak, where a is plasma minor radius

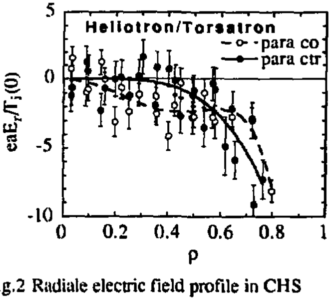

Fig.2 Radiale electric field profile in CHS heliotron/torsatron, where a is plasma minor radius.

On the other hand in CHS heliotron/torsatron, even parallel NBI can not drive toroidal plasma rotation large enough to change radial electric field, since parallel viscosity is dominant in the configuration (R_{ax} = 97.4cm : magnetic field ripple of 2-3% even at the magnetic axis)[2]. The radial electric field in high density plasma is negative regardless of the direction of neutral beam in heliotron/torsatron as shown in Figure 2. The radial electric field depends on other bipolar fluxes such as *ion orbit loss*, charge-exchange loss, neoclassical and anomalous ion/electron fluxes; it does not depend on the NB injection direction dominantly. When the magnetic axis is shifted toward the direction in which more fast ion loss is expected (inward for ctr-NBI and outward for co-NBI), more negative electric field is observed. When the electron density is decreased below $1\times10^{13}\,\mathrm{cm}^{-3}$, the negative radial electric field becomes smaller as expected by neoclassical theory, but no positive radial electric field is observed in NB heated plasma in CHS.

3. CONTROL OF RADIAL ELECTRIC FIELD BY ELECTRON CYCLOTRON RESONANCE HEATING (ECH) IN CHS

The radial electric field is more easily controlled by use of bipolar fluxes due to ECH than the momentum input of NBI in CHS because of magnetic field ripple. The electron cyclotron resonance heating (ECH) has been considered to enhance positive radial electric field, because it heats the electron and enhances electron ripple loss. In order to produce positive electric field, 53GHz ECH is injected to the NBI plasma with the helical field of 0.92 and 1.9T in CHS. The experiment is restricted only for the NB target plasma, because charge-exchange measurement needs NBI. The positive radial electric field is observed only when the off-axis second harmonic ECH is applied to the low density ($n_e < 1\times10^{13}\,\mathrm{cm}^{-3}$) NB heated plasma[3]. As seen in Fig.3 there is a critical ECH power for the radial electric field to jump to positive values (electron root). This jump of radial electric field is more visible near the plasma edge and is considered to be due to the ECH enhanced electron loss. No positive radial electric field is observed even if the plasma with similar electron density and temperature is sustained only by NBI. The perpendicular acceleration of ripple trapped electron is one of the candidate of this electron loss.

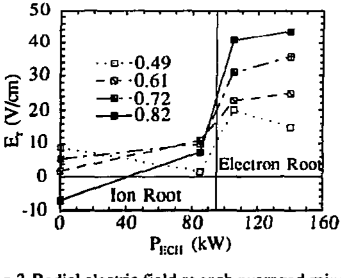

Fig.3 Radial electric field at each averaged minor radius as a function of ECH power in CHS.

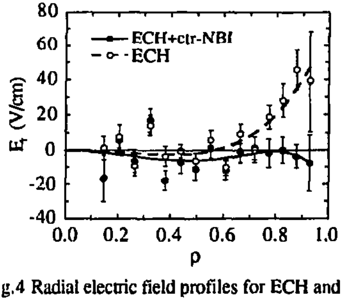

Fig.4 Radial electric field profiles for ECH and for ECH plus ctr-NBI in CHS

The ion dynamics would be also important in determining the total radial electric field. As shown in Figure 4, the positive radial electric field produced by ECH disappears when the neutral beam is injected in counter direction. No improvement of energy transport by the positive electric field is observed at the transition to the electron-root. This is because the radial electric field shear is not large enough to suppress fluctuations. However, if the viscosity for plasma rotation decreases by the reduction of edge neutral density, or the focusing of the ECH power becomes better, the larger radial electric field shear will be produced and the improvement of energy confinement also will be expected.

4. CONTROL OF RADIAL ELECTRIC FIELD BY PELLET INJECTION IN HELIOTRON-E

Radial electric field profiles are measured before and after the pellet injection for NBI heated plasmas in Heliotron-E. The E_r profile before the pellet injection is similar to that for NBI heated plasma in CHS (more negative toward the plasma edge). However, as shown in Fig.5, E_r becomes more negative and has a peak at the half of plasma minor radius after the pellet injection, where the electron density is more peaked at the plasma center. This experiment suggests that the E_r can be controlled through the density profile with pellet injection.

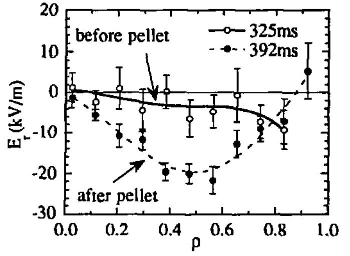

Fig. 5. Radial electric field profiles before and after the pellet injection in heliotron-E.

5. SUMMARY

In conclusion, the radial electric field is controlled by changing the direction of neutral beam from co to counter to plasma current in tokamak, while it is controlled by the injection of 2nd harmonic ECH and NBI (either co or counter direction) and pellet injection in heliotron/torsatron.

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