23P043

Potential profile measurement with heavy ion beam probe on the Large Helical Device
大型ヘリカル装置における重イオンビームプローブによる電位分布計測

Akihiro Shimizu, Takeshi Ido, Masaki Nishiura, Mitsuki Nakamura[1], Ryohei Makino[1], Masayuki Yokoyama, Hiromi Takahashi, Yasuo Yoshimura, Takashi Shimozuma, Hiroe Igami, Shin Kubo, Haruhisa Nakano, Katsumi Ida, Mikiro Yoshinuma, LHD Group
清水昭博，井戸毅，西浦正樹，中村充希[1]，牧野良平[1]，横山雅之，高橋裕己，吉村泰夫，下妻隆，伊神弘恵，久保伸，中野治久，居田克巳，吉沼幹朗，LHD実験グループ

The National Institute for Fusion Science, 322-6, Oroshi-cho, Toki, Gifu 509-5292, Japan
[1]Dept. of Energy Science and Engineering, Nagoya University, Furo-cho, Chikusa, Nagoya 464-8601, Japan
核融合科学研究所　〒509-5292　土岐市下石町322－6
[1]名古屋大学工学研究科エネ理工

The radial profile of potential in the core region of the Large Helical Device (LHD) plasma was measured with a Heavy Ion Beam Probe (HIBP). The radial profiles of E_r were estimated from differentiation of the experimental data of HIBP. In relatively low temperature (~0.8keV) and medium density plasmas (~0.5 × 10^{19} m^{-3}), which is heated by neutral beam injection, the small negative radial electric field was observed. In high electron temperature (~2 keV) and low density plasmas (~0.2 × 10^{19} m^{-3}), which is heated by NBI and electron cyclotron heating, the positive radial electric field was observed. These E_r profiles were compared with the calculation result from neoclassical theory, and the theoretical prediction almost coincided with the experimental data of E_r in the core region of LHD plasmas.

1. Introduction

The radial electric field E_r is a very important parameter to study plasma confinement in magnetized toroidal plasmas. For example, in improved confinement discharge in tokamaks, the shear flow suppresses the turbulence in plasma and high performance of plasma is realized. In helical configuration, of which magnetic configuration is not axisymmetric, trapped particles in helical ripples enhance diffusion loss in low collision regime, so called in 1/ν regime (diffusion coefficient is proportional to 1/ν). This helical ripple induced loss is intrinsically non-ambipolar, therefore E_r is formed to satisfy ambipolar condition. This E_r reduces the helical ripple diffusion loss, so the formation of E_r in helical device is important.

In order to study physics of the formation of E_r in LHD, heavy ion beam probe (HIBP) was installed and has been developed [1-3]. We measured the profile of potential in wide plasma parameter space such as high ion temperature plasmas and high electron temperature plasmas.

2. Experimental setup

LHD is a helical device, magnetic configuration of which is characterized by the major radius of magnetic axis R_{ax}, the pitch parameter γ, and the quadrupole field component B_q. On experimental results shown here, γ and B_q are fixed to standard ones, namely 1.254 and 100%, respectively. By changing the major radius magnetic axis, R_{ax}, the amount of helical ripple can be changed.

HIBP system has been developed in many yeas. By using tandem accelerator, the gold ion (Au^+), maximum energy of which is 6MeV, is generated and is injected to plasma as primary beam. The secondary beam (Au^{2+}) is produced by the collision with plasma, of which energy is analyzed by the tandem energy analyzer. The three dimensional orbit of probe beam is controlled by two 8-pole electrostatic deflectors. The radial profile of potential is obtained by sweeping the beam in 10 Hz. The spatial resolution (the scale of sample volume) is about a few cm [2]. The primary and secondary beam current intensity is about a few μA and a few nA respectively. In order to detect this level of secondary beam current, the very sensitive current detector, micro channel plate (MCP), is used.

3. Experimental result

Density evolution of a typical shot is shown in Fig.1, when the radial profile of plasma potential with HIBP was measured. The magnetic field strength, B_t was 1.5 T, and the major radius of

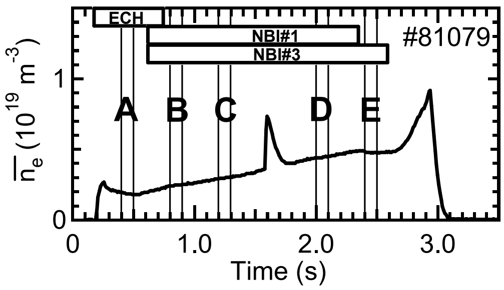

Fig.1 Temporal evolution of line averaged density and heating methods

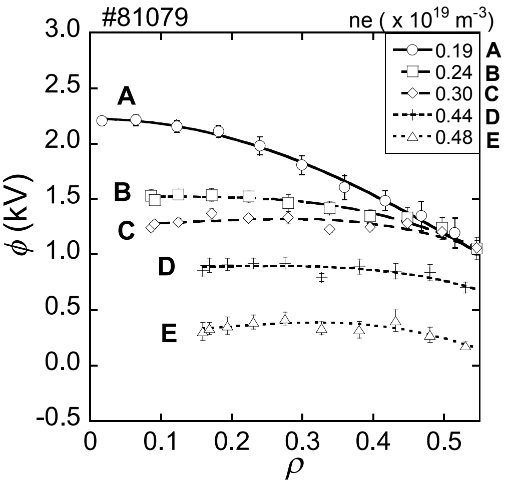

Fig.2 Potential profile measured with HIBP

magnetic axis, R_{ax} was 3.75 m. The line averaged density gradually increased from 0.2×10^{19} m^{-3} to 0.5×10^{19} m^{-3} by gas puff control. The central electron temperature was about 2.5 keV at the line averaged density of 0.19×10^{19} m^{-3} and ~1.0 keV at the line averaged density > 0.30×10^{19} m^{-3}. In each period marked by alphabets A~E, the potential profile was measured with HIBP as shown in Fig.2. As the density increased, the potential decreased in the core region. In low density and high electron temperature case, the potential at the center tends to be positive. In high density and low electron temperature case, the potential at the center tends to be negative or nearly zero.

By using a polynomial function of ρ as a fitting function, radial electric field profile was obtained from the experimental data. Obtained radial electric field profiles are compared with those estimated by GSRAKE code [4-5]. In Fig.3 (a) and (b), the comparison in period A and C are shown respectively. In the period A ($\overline{n}_e$ = 0.19×10^{19} m^{-3}), from the theory the positive radial electric field, so called electron root, is predicted. And this prediction roughly coincides with the

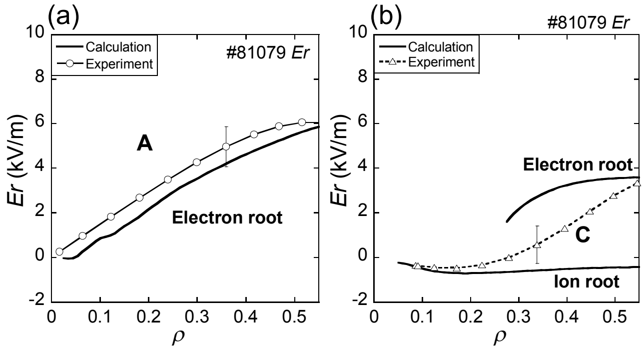

Fig.3 Comparison of measured Er with theoretical prediction in case A (a) and in case C (b)

experimental results. In the period C ($\overline{n}_e$ = 0.30×10^{19} m^{-3}), the negative radial electric field, so called ion root, in the core region is predicted. And in this case, in the region $\rho > 0.26$, both roots of electron and ion roots are expected. In the core region, the ion root calculated by the neoclassical theory coincides with the experimental result. In the outer region where $\rho \sim 0.6$, the electron root of theoretical prediction coincides with the experimental result.

4. Summary

The radial potential profile was measured with HIBP in LHD. The radial electric field, E_r, was obtained from measured radial potential profile. Based on the condition of neoclassical ambiporarity, E_r is estimated theoretically and compared with experimental results. Theoretical predictions roughly coincide with the experimental results. Thus, we clarified that physics of neoclassical context is almost dominant in E_r formation. The results will provide a physical basis to consider further improved confinement scenarios utilizing E_r in helical plasmas.

Acknowledgement

This work was supported by MEXT Japan under Grants-in-Aid for Young Scientists (Nos. 18760640, 20686062), NIFS/NINS under the project of Formation of International Network for Scientific Collaborations, and NIFS09ULBB505, NIFS09ULBB515.

References

[1] A. Shimizu, T. Ido, M. Nishiura *et al.*, J. Plasma Fusion Res. **2** (2007) S1098-1.

[2] T. Ido *et al.*, J. Plasma Fusion Res. **2** (2007) S1100.

[3] A. Shimizu, T. Ido, M. Nishiura *et al.*, J. Plasma Fusion Res. **5** (2010) S1015.

[4] C. D Beidler., W. D. Dhaeseller, Plasma Phys. Control. Fusion **37** (1995) 463.

[5] M. Yokoyama *et al.*, Nucl. Fusion **42** (2002) 143.