§7. Evaluation of Positive Electric Field by Electron Cyclotron Heating in CHS

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In CHS, it is reported that the density pump-out or the degradation of the particle confinement is triggered by the production of electrons accelerated perpendicularly to the magnetic field with ECH.\[1\] The transition of electric field from negative to positive value is found when the particle flux is sufficiently enhanced due to the density pump-out with ECH on NB heated plasmas in CHS.\[2\] The transition of the radial electric field was observed with ECH of the high power and at the ripple bottom resonance(low field side resonance). In this report, the relationship between the particle flux and the electric field is discussed.

Figure 1 shows the radial electric field profiles observed and evaluated theoretically for the plasma with ECH, where the following nonlinear diffusion equation for the electric field \( E_r \) \[3\] is used.

\[
\frac{2}{\rho^2 a^2} \frac{d}{d\rho} \left[ \rho^2 \frac{\partial}{\partial \rho} \left( \frac{E_r}{\rho} \right) \right] - \frac{1}{a^2} \frac{\partial}{\partial E_r} \left( E_r - \frac{E_r}{\rho} \right)^2 = e \left[ \Gamma_i^{NC}(E_r) - \Gamma_e^{NC}(E_r) - \Gamma_{ECH} \right],
\]

where \( \rho \) is a normalized radius \( r/a \) and the prime denotes the derivative on \( \rho \). \( \Gamma_i^{NC} \), \( \Gamma_e^{NC} \) and \( \Gamma_{ECH} \) are the ion and electron neoclassical flux, and particle flux enhanced with ECH, respectively. We assume that ECH enhances only electron particle flux, not ion particle flux, and that the anomalous particle fluxes are ambipolar. The dependence of the enhanced particle flux on the electric field is not taken into consideration. Here, \( \hat{\eta} \) is such the factor that \( \hat{\eta} B^2 \) corresponds to the viscosity coefficient. The factor \( \hat{\eta} B^2 \) can be represented by a coefficient of shear viscosity \( \mu_{\text{eff}} \), \( \hat{\eta} B^2 = \eta \rho \mu_{\text{eff}} \). In this analysis, the coefficient \( \mu_{\text{eff}} \) is given as a constant parameter. Disagreement of the electric field profile between the observation and the calculation neglecting the viscosity term (at \( \mu_{\text{eff}} = 0 \) m²s⁻¹) is clear. The calculated electric field is more positive at the plasma edge (\( \rho > 0.8 \)), and is more negative at the core region than the observed electric field. The scattering of the calculation comes from the error in the estimation of the enhanced particle flux \( \Gamma_{ECH} \). Since the calculation neglecting the viscosity term is based on the local flux balance on the each magnetic surface, the discontinuities in the electric field profile are caused. If the change of the radial electric field to positive value occurs in the outer region, the electric field diffuses into the inner region under the influence of the perpendicular viscosity. Therefore, the theoretically evaluated electric field should become more smooth radial profile such as that of the observed electric field by taking the diffusion process of the electric field into consideration. As shown in Fig.1, the observed electric field profile is in good agreement with the theoretical prediction including the viscosity term, where \( \mu_{\text{eff}} = 400 \text{m}^2\text{s}^{-1} \) is used. The value of the coefficient \( \mu_{\text{eff}} \) is about one order larger than the measured ion thermal diffusivity. However, since we does not take into account the dependence of the factor \( \hat{\eta} \) and \( \Gamma_{ECH} \) on the electric field, the further investigation is required for the quantitative comparison.

References
1) Idei, H. \textit{et al.} accept for publication in Fus. Eng. and Design (Proc in 5th Int. Toki. Conf.).

Fig.1 Radial electric field profiles for the plasma with ECH. Closed circles and hatched areas show the observed and calculated electric fields.