

EXPERIMENTAL ANALYSIS AND PREDICTIVE SIMULATION OF TRANSPORT BARRIER IN LHD AND CHS PLASMAS

Kozo Yamazaki, Shin Kubo, Kazuto Narihara, Kenji Tanaka, Takashi Minami,

CHS Group and LHD Experimental Group

National Institute for Fusion Science, 322-6 Oroshi-cho, Toki, 509-5292, Japan

Abstract

In the central Electron Cyclotron Heating (ECH) experiments, the internal transport barrier (ITB) has been found in the Compact Helical System (CHS), and recently in the Large Helical Device (LHD). The strong positive radial electric field has been experimentally observed, which reduces neoclassical ripple transport and anomalous losses. The calculated neoclassical transport coefficients without effects of radial electric field roughly agrees with experimentally obtained transport values, but are ten times smaller than the experimental values when the strong neoclassical ambipolar radial electric field is included. The common ITB physics pictures are expected in LHD and CHS high electron temperature plasmas.

1. Introduction

In the helical confinement systems, the strong electric field is supposed to be utilized for improving the plasma confinement. High central electron temperature plasmas with positive electric potential have been obtained in the centrally focused Electron Cyclotron Heating (ECH) experiment of the Compact Helical System (CHS) [1]. The formation of this internal transport barrier (ITB) is correlated with the reduction of density fluctuation and the shear of electric field, and is related to neoclassical positive electric field in the low-density regime [1, 2]. Recently in the Large Helical Device (LHD) we have obtained ten-keV electron temperature plasmas using centrally focused Gaussian beam at the fundamental and second harmonic resonances [3]. Here, transport analysis has been done in both LHD and CHS for their comparisons.

2. Method of Transport Analysis using TOTAL Code

For predictive simulation and experimental analysis of toroidal plasmas, a simulation code TOTAL (Toroidal Transport Analysis Linkage) has been developed [4,5]. This consists of a 3-dimensional equilibrium with ohmic and bootstrap currents and a 1-dimensional transport

with neoclassical loss determined by ambipolar radial electric field as well as anomalous transport (empirical or drift turbulence models). In both core and edge plasma analyses, the plasma equilibrium is iteratively and consistently calculated using experimental data on the virtual expanded edge flux coordinates, and the calculated transport properties are compared with several theoretical models.

3. Transport Barrier formation and Experimental Analysis in CHS

The box-type temperature profile often can be seen in reversed-shear tokamaks and parabola-type ITB is obtained in the normal shear tokamak operations. In helical system bell-type electron temperature profiles are obtained. Figure 1 shows the electron temperature and density profiles with ITB (ECH 200kW) and without ITB (ECH 150kW). The

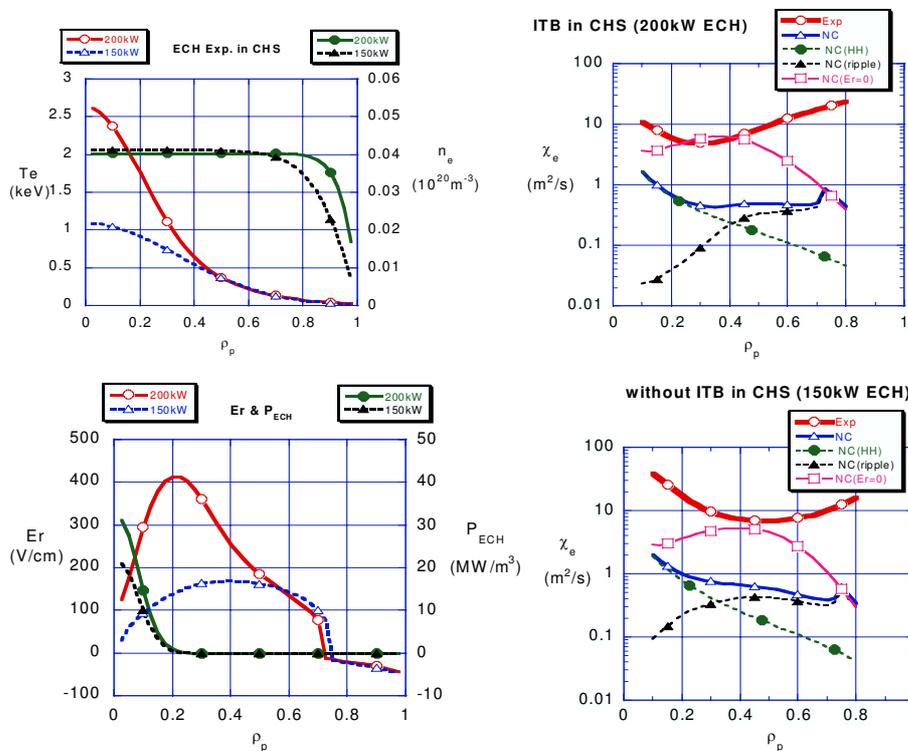


Fig. 1 ITB profiles and transport coefficients of CHS

experimental thermal diffusivities roughly agree with zero radial-electric-field case ($E_r=0$), but are ten times higher than the neoclassical values with self-consistent electric field.

4. Transport Barrier formation and Experimental Analysis in LHD

Hot electron temperature operations have been obtained also in LHD using ~ 1 MW ECH heating power [2]. Figure 2 shows the electron temperature and density profiles measured by 200-channel YAG Thomson scattering system and 11-channel FIR interferometer. The 3-dimensional plasma equilibrium is calculated self-consistently using TOTAL code [5]. Here, we calculated the plasma performance with the assumption of

neoclassical transport with helical field harmonics and self-consistent radial electric field in addition to semi-empirical anomalous transport loss [4]. The calculated electric field in the LHD plasma depends critically on the plasma density and heating power deposition (position and power density).

In order to evaluate transport coefficients, the parabolic ion temperature profile with experimental central value is assumed. We can determine experimental transport coefficients

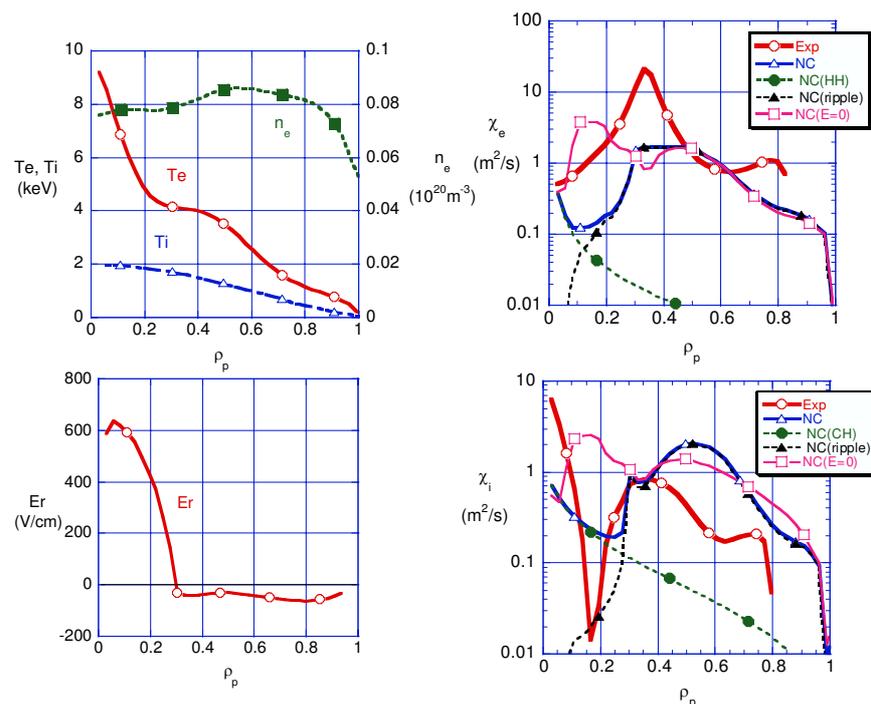


Fig. 2 ITB profiles and transport coefficients of LHD (#26943, 0.5ms)

as shown in Fig. 2.

The experimental electron transport coefficients near the ITB region are ten times higher than the neoclassical values (HH plus ripple transport for electron, CH plus ripple transport for ion). The strong positive radial electric field has been expected.

5. Predictive Transport Simulation in LHD

Related to the ITB shot, the following four predictive simulations have been carried out in addition to the previous section; (1) full simulation, (2) only experimental density profile is used, (2) experimental density and electron temperature profiles are used, and (4) drift wave model simulation.

(1) Full simulation

Without using experimental plasma profiles, we can simulate high T_e plasmas using empirical transport model and neoclassical ripple transport model with self-consistent ambipolar electric field [4]. The experimental line-averaged electron density is used in the simulation. The simulated density profile does not agree with experiments, therefore central temperature is rather low. To simulate slightly hollow electron density profile, anomalous outward particle flow is required in addition to the neoclassical diffusion.

(2) Simulation using experimental density profiles

The anomalous transport coefficients described in Ref.[4] are assumed here. The central electron density and thermal coefficient are both low enough to get higher $T_e(0)$ than 10 keV. The anomalous transport model with fixed profile is not realistic and it should be modified to fit the experimental values.

(3) Simulation with experimental n_e and T_e profiles

The ion temperature has been calculated using experimental n_e and T_e profiles. Several bumps in radial electric field E_r as a function of minor radius have been obtained. The E_r profile critically depends on T_i profile, therefore T_e profile strongly depends on ion temperature.

(4) Drift Wave Model Simulation

Multi-mode transport analysis in addition to neoclassical transport has been carried out for LHD using 5 times smaller drift-wave turbulent transport coefficients of Ref. [4] to fit standard LHD operation. The simulated ion temperature is lower than the experiment. The present model will be modified to include electric shear effect for the confinement improvement in the future.

6. Summary & Discussion

The transport analysis has been carried out for high- T_e ECH discharges in both LHD and CHS focusing on the comparisons between the experimental values and neoclassical values. Experimental transport coefficients near ITB roughly agree with neoclassical values in the case of $E_r=0$, but are about ten times higher than the neoclassical values including the effect of E_r in both LHD and CHS plasmas. The anomalous transport might be dominant near ITB and be reduced by the strong electric field shear. The common physics pictures are expected in LHD and CHS high electron temperature plasmas.

References

- [1] A. Fujisawa et al., *Phy. Rev. Lett.* **82** (1999) 2669-2672.
- [2] T. Minami, A. Fujisawa et al., *Plasma Phys. Control. Fusion* **44** (2002) A197.
- [3] S. Kubo, T.Shimozuma et al, *J.Plasma Fusion Res.*, **78** (2002) 99.
- [4] K.Yamazaki, T.Amano, *Nucl. Fusion* **32** (1992) 633.
- [5] K.Yamazaki et al., 26th EPS Conference on Controlled Fusion and Plasma Physics, 14-18 June 1999, Maastricht (1999) P3.107.