# §6. Theoretical Study on Transport Properties of High-ion-temperature LHD Plasmas towards Further Increase of Ion Temperature

Yokoyama, M., Ida, K., Yoshinuma, M., Nagaoka, K., Ido, T., Shimizu, A., Takeiri, Y., Kaneko, O.

High-ion temperature plasmas in LHD have been obtained with steepening of ion temperature gradient at the core region. The maximum ion temperature (Ti) reached 5.6 keV in the experimental campaign of FY2008. At the core region, Ti is higher than the electron temperature (Te), and thus, the negative radial electric field (Er) (ion root) has been predicted based on the neoclassical (NC) ambipolarity condition. The measurement of Er at the core region by the charge exchange recombination spectroscopy (CXS) has been difficult since the impurity hole is established in such high-Ti plasmas. The Heavy Ion Beam Probe (HIBP) measurement, having been arranged, could make the potential measurement in such a core region (without using the impurity content), to reveal that Er there is negative [1)]. This experimental finding supports the previous predictions on Er at the core region of high-Ti LHD plasmas based on NC ambipolarity condition. This provides the firm basis of the NC-ambipolarity Er analysis in a wide range of parameter regime in LHD plasmas, in addition to CERC plasmas [2)] where Te is higher than Ti, with the positive Er (electron root).

The impurity-hole establishment is also analyzed from the viewpoint of NC transport. The hydrogen density is estimated from the electron density and carbon density, and NC transport analysis is performed with 2-speices ion content with GSRAKE code [3)]. Such calculations have revealed that the inward velocity is expected for carbon impurities in a circumstance of negative Er, and thus, NC transport cannot explain the establishment of impurity hole. The research to find the cause of its establishment based on particle transport attributed to some turbulent mechanism has been pursued [4)].

Based on the validity of NC-ambipolar Er so far confirmed in LHD experiments, scenario development towards further extension of Ti has been pursued. The utilization of electron root might be a candidate for this direction through the simultaneous increase of Ti and Te, to further decrease of NC heat diffusivity [5)]. The wide range of NC-ambipolar Er calculations have also revealed that the electron root realization becomes easier (eg., threshold Te for entering multiple-root/electron root regime becomes smaller) in deuterium plasmas than hydrogen plasmas through the enhanced reduction of ion particle flux with respect to Er in heavier ion species. In the mean time, electron-root Er also becomes larger for the same temperature conditions in deuterium plasmas, realizing the smaller NC transport.

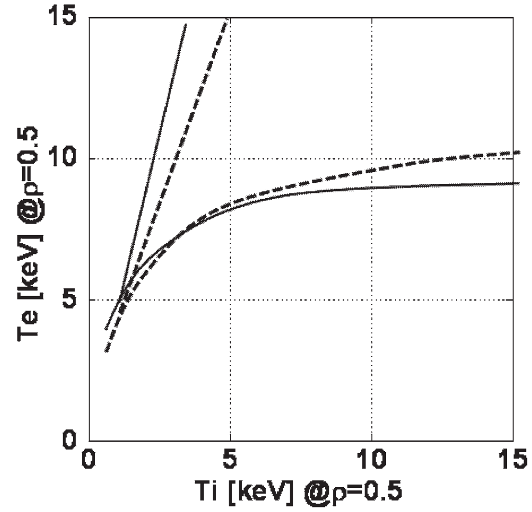


Fig.1. The Er-diagram on (Ti, Te) plane at the mid-radius of a LHD configuration with the vacuum magnetic axis of 3.60 m. The configuration is kept unchanged throughout temperature-scan calculations. The multiple solutions of Er are predicted for the region surrounded by boundaries, and the ion-(electron-) root Er is predicted below (above) the boundary. The solid (dotted) curve is for a case of deuterium (hydrogen). The density at this mid-radius is assumed as $\sim 10^{20}$ m$^{-3}$.


1) A.Shimizu et al.,: presented 18th International Toki Conference (2008).
2) M.Yokoyama et al.,: Nuclear Fusion, **47** (2007) 1213.
3) C.D.Beidler et al.,:Plasma Physics and Controlled Fusion, **37** (1995) 463.
4) K.Ida et al.,: Physics of Plasmas, **16** (2009) 056111 (Invited Talk at the 50th APS-DPP Annual Meeting (2008)).
5) S.Matsuoka et al.,: Plasma Fusion Research, **3** Special Issue (2008) S1056.