The transition properties of the radial electric field \( E_r \) have been theoretically and experimentally examined in the Large Helical Device (LHD) to grasp inter-relationships between magnetic configuration characteristics and \( E_r \) properties \([1,2]\). The \( E_r \) is calculated based on the ambipolar condition with the neoclassical flux estimated by the analytical formulae \([3]\). The effective helicity, \( \epsilon_{\text{ch,eff}} \), used for flux calculations is estimated with the GIOTA code \([4]\), which is based on the bounce-averaging method for evaluating neoclassical ripple transport. The \( E_r \) transition utilizing the non-axisymmetry of magnetic configurations in helical systems is focused, which is possible through the nonlinear dependence of plasma transport on \( E_r \). This study is valuable to utilize \( E_r \) transition for confinement improvement in non-axisymmetric configurations.

One of knobs for controlling \( \epsilon_{\text{ch,eff}} \) in the LHD is the control of the vacuum magnetic axis position \( R_{\text{ax}} \). Fig.1 shows \( E_r \)-diagram on \( (n_e, T_i) \) plane for three cases with different \( R_{\text{ax}} \) : 3.60m, 3.75m, and 3.90m. The calculations are performed at \( \rho=0.8 \) with \( B = 1.5 \) T. The hydrogen plasma is assumed. The assumed \( n_e \) and \( T_{ei} \) profiles are

\[
\begin{align*}
n_e(\rho) &= 1 \times 10^{19} (1-\rho^3) \text{ m}^{-3} \\
T_{ei}(\rho) &= T_{ei}(0)(1-\rho^2) \text{ keV}
\end{align*}
\]

assuming \( T_e=T_i \). The \( E_r \) is positive above the upper boundary and negative below the lower boundary. The region between two boundaries corresponds to the region of multiple \( E_r \) solutions. The \( \epsilon_{\text{ch,eff}} \) is estimated as about 0.05, 0.14, and 0.27 for cases with \( R_{\text{ax}} \) = 3.60m, 3.75m, and 3.90m, respectively. It is recognized that \( \epsilon_{\text{ch,eff}} \) varies largely depending on the control of \( R_{\text{ax}} \). It can be clearly read that the threshold density for entering region of multiple \( E_r \) solutions and/or electron root decreases as \( \epsilon_{\text{ch,eff}} \) decreases for a same temperature.

The experimental results reasonably consistent with this theoretical prediction have been obtained recently in LHD. The threshold density for the transition from ion to electron root has been observed to become lower as \( R_{\text{ax}} \) is decreased (more inwardly shifted) \([5]\), which will also be presented in the workshop. This agreement has given the proof that the \( E_r \) transition properties in LHD are predominantly determined based on the neoclassical transport. Based on this, the dependence of the threshold ECH power on configuration variation for establishing the electron internal transport barrier \([6]\) would also be the interesting subject based on this study.

\[\text{Fig.1}\]

\[\text{[2]}\ M.\text{Yokoyama et al., Nucl. Fusion 42(2002)143.}\]
\[\text{[4]}\ N.\text{Nakajima et al., NIFS LHD Technical Report 1, p.288 (in Japanese).}\]
\[\text{[5]}\ M.\text{Yoshinuma et al., will be presented at the H-mode workshop (2003).}\]
\[\text{[6]}\ T.\text{Shimozuma et al., Plasma Phys. Controlled Fusion (to be published).}\]