§16. Common Features of Core Electron-Root Confinement (CERC) in Helical Plasmas

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The improvement of core heat confinement has been realized in a wide range of helical devices with central ECH power deposition (alone or in combination with NBI). Peaked electron temperature (T_e) profiles and strongly positive radial electric fields (E_r) in the core region have been observed commonly in CHS (dubbed neoclassical (NC) internal transport barrier [N-ITB]) [e.g.1], LHD (electron ITB) [e.g.2], TJ-II (Enhanced Heat Confinement (EHC) or electron ITB) [e.g.3] and W7-AS (electron-root feature [e.g.4]). T_e has exceeded 10 keV in LHD and reached 6 keV in W7-AS with this improvement. The formation of strong positive E_r is required within NC theory to satisfy the ambipolarity condition. This "electron-root" feature exists only in low-collisionality helical plasmas in which the electrons make a transition from the $1/\nu$ regime for small E_r to the $\nu^{1/2}$ or ν regime for larger E_r. Density and ECH power thresholds for this improved confinement have been recognized associated with this transition of E_r. Core electron heat diffusivity is reduced significantly compared to its NC level with E_r=0. This improved core confinement, referred collectively as "Core Electron-Root Confinement (CERC)", has signatures quite different than those of tokamak ITBs [e.g.7]. The contribution of additional convective electron flux ($\Gamma_{e,con}$) driven by strong ECH has also been revealed, illustrating the configuration dependence of the ECH power threshold [4].

The collisionality regime and the ECH power threshold for CERC are expected to vary depending on the magnetic configuration as well as the heating scenario [8] since the NC fluxes and ECH-driven $\Gamma_{e,con}$ (by heated trapped electrons) are both influenced by magnetic-field topology. Experiments in a wide range of helical plasmas provide an opportunity for investigating this issue. The accumulation of CERC discharges and related theoretical analyses has led to the initiation of "International Stellarator Profile DataBase (ISPDB)" as an extension of the ongoing research within the International Stellarator Confinement DataBase activity [9]. The collisionality regime for CERC in four devices is compared in Fig. 2, where the electron collisionality, ν_e, in ρ<0.2 is shown. The data at ν_e~10^5 [1/s] in CHS are for non-CERC plasma. The four clusters for W7-AS are due changes in the density. The data points for CHS and LHD are found at smaller ν_e than those of TJ-II and W7-AS. CERC discharges in TJ-II appear in the regime where CHS has not yet achieved CERC. The maximum ν_e, $\nu_{e,max}$, (from Fig. 1) for CERC is plotted in Fig. 2 as a function of the effective ripple (a measure of the ripple-transport level), ε_{eff}, at the core region. The trend that the larger ε_{eff} the higher $\nu_{e,max}$ can be recognized. It is worthwhile summarizing CERC discharges with $\nu_{e,max}$ since the collisionality has been recognized to be the responsible parameter for transition to the electron root [10]. The trend in Fig. 2 can be understood by the change of the ripple-transport level providing the bifurcation nature of E_r. It has been confirmed, so far, that, in W7-AS, larger $\Gamma_{e,con}$ (comparable to the NC electron flux ($\Gamma_{e,NC}$) in ion-root regime, which is contrast to that in LHD where it is at the most 30 % of $\Gamma_{e,NC}$) and higher ECH power density are reasons for higher $\nu_{e,max}$.

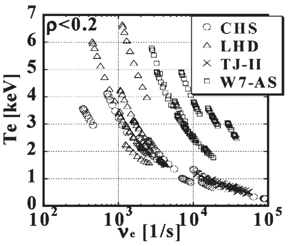

Fig.1. Parameter regime (T_e and ν_e for ρ<0.2) of CERC in the four devices.

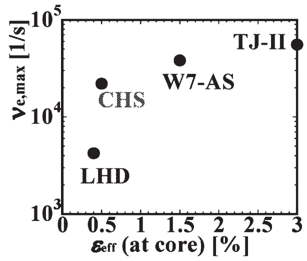

Fig.2. $\nu_{e,max}$ versus ε_{eff} at the core region in the four devices.

The ISPDB activity has allowed us to perform comparative studies of CERC discharges in different devices. It has been recognized that larger ε_{eff} and $\Gamma_{e,con}$ help achieving CERC at higher collisionality.

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