§12. Transport Analysis of LHD Discharge for V&V of Neoclassical Transport Codes

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Neoclassical (NC) transport analysis in stellarator / heliotron configurations has more important role than that in tokamaks, because of its large amplitude and the fact that the radial electric field should be determined by the ambipolar NC flux condition. Since it is time-consuming to solve the drift-kinetic equation (DKE) in a helical geometry, local and mono-energy approximation models have been widely adopted in conventional NC transport codes (DKES[1]), GSRAKE[2]), etc.). However, it is now possible to solve 5-dimensional DKE without relying on such approximations by FORTEC-3D code[3]). It is expected that the non-local effect, which is originated from the finite magnetic drift of guiding-center motions both in perpendicular and tangential to the flux surfaces, will change NC flux and the ambipolar condition. In order to benchmark the NC transport codes and to check their predictivity, cross-benchmark the local and non-local codes in helical configurations such as LHD, TJ-II, W7-AS has been carried out recently[4, 5]). Also, by comparing the simulation results with the experimental observations, the impact of the non-local effect on transport analysis has been investigated.

For the purpose of the verification and validation (V&V) of NC transport codes, it is required that several kinds of measurement data should be taken at once in the experiment, such as n_e, T_e, T_i, heating deposition profile by ECH and NBI, and the plasma rotation deduced from CXRS or HIBP measurements. The measured plasma rotation profile is to be compared with the E_r profile estimated from the ambipolar condition for NC particle fluxes. In the previous analysis[4, 5]), the HIBP data was not available. In order to obtain HIBP data and carry out precise comparisons of E_r profile between experiment and simulation, a series of discharges with HIBP measurement were carried out in 2014. The intended plasma collisionality was lower than the previous ones[4, 5]) since the difference between local and non-local codes is expected to be clearer as the collisionality becomes lower.

We obtained similar discharges in the shots #127687 to #127691. These discharges are characterized by (i) ECH+P-NBI heating phase, $T_e > T_i(4.0 < t < 5.0s)$ and (ii) P-NBI phase, $T_e <\simeq T_i(t > 5.0s)$. During each discharge, n_e monotonically increased in time. As intended, the normalized plasma collisionality was low, $\nu_* \simeq 10^{-4} \sim 10^{-3}$ in the phase (i), and $\nu_* \simeq 10^{-3} \sim 10^{-2}$ in the phase (ii), respectively. Fig.1 shows the potential profile measured by HIBP. As $E_r = -d\phi/dr$, E_r is expected to be positive at t =3.6 and 4.6s, and weak negative at t =5.1s. The E_r profile at $\mathrm{r_{eff}} > 0.7$a will be complemented by CXRS measurement. Fig.2 shows the ambipolar-E_r profiles obtained from local GSRAKE code, for four timings. The signs of E_r before and after $t = 5$s agree with the expectation from the HIBP measurement provided that the E_r is in eletron-root at the phase (i).

These shots are being analyzed by FORTEC-3D code now. It will be revealed that whether the non-local effect in solving DKE is significant in evaluating ambipolar-E_r and NC particle and energy fluxes both in the phase (i) and (ii) in near future.

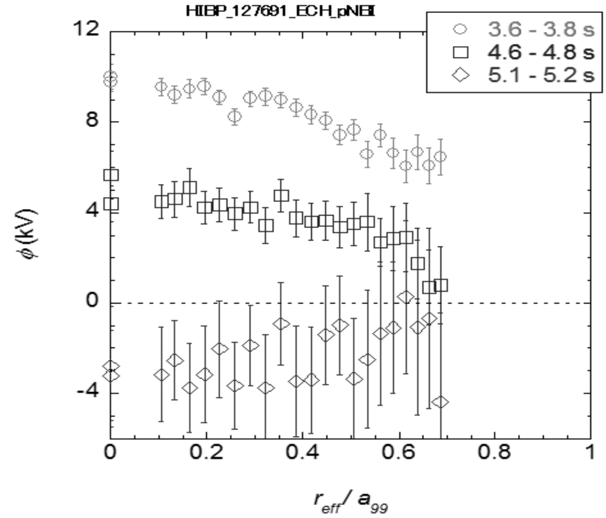

Fig. 1: Potential profile by HIBP #127691.

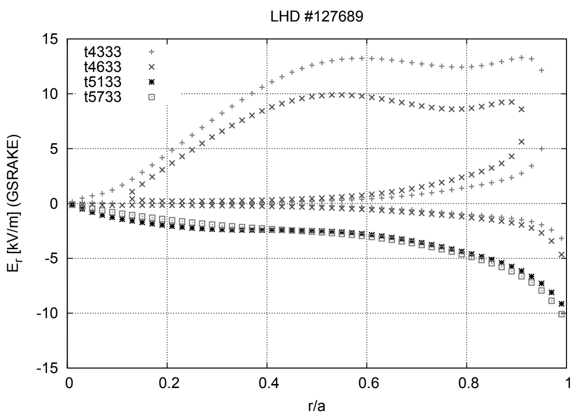

Fig. 2: Ambipolar-E_r profiles for four timings by GSRAKE code.

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