§23. Hollow Density Profile in LHD

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In the LHD, observed density profiles are often hollow in various configurations, for example R=3.75m configuration, which seems to be different from tokamaks whose the density profile is flat or peaked. On the other hand, it is discussed recently that the density profile tends to be flat near the R=3.53m configuration, which is neoclassically optimized configuration[1].

In this report, we will investigate the neoclassical(NC) and anomalous quasi-linear(QL) particle fluxes across a magnetic surface, in order to discuss the tendency of the density profiles observed in two LHD configurations whose magnetic axis in vacuum are R=3.75m and R=3.53m. For the QL anomalous flux, GOBLIN code[2] based on the linear gyrokinetics is used. For the NC ambipolar flux, GSRAKE code[3] based on the bounce-averaged drift kinetics is used.

Three density profiles are assumed as in Fig.1; peaked (circles), intermediate (triangles) and squares (hollow). The temperature is assumed as $T=T_0(1-\rho^2)$ with T_0=1[keV]. Also B_0=1[T] is assumed.

The neoclassical particle fluxes for these density profiles are shown in Fig.2, in R=3.75m and R=3.53m configurations. It can be seen that the NC particle flux is almost independent of density profiles, and shows strong configuration dependence. The latter is explained by the strong change of ε_{eff}[1]. The weak dependence on the density profiles, or $1/L_n$ on the NC particle flux in the $1/\nu$ regime can be also explained[2]; it is dominated by $1/L_T$.

Next the QL particle flux are plotted as a function of $1/L_n$ in Fig.3. Here a surface ρ=0.8 and $k_\perp \rho_{thi}$=0.5 are chosen. Since the parameters above give β_{ax}~0.8% so that the mode can be considered electrostatic. The ITG and TEM are candidates in this case, and we can confirm that the modes here are basically ITG modes with weaker TEM-drive. We can also confirm that the results are insensitive to the magnetic configurations. On the other hand, as is contrast with the neoclassical case, it strongly depends on $1/L_n$; the sign is changed as $1/L_n$ becomes negative.

Here we consider the particle balance equation, $\partial n/\partial t + \nabla\cdot\Gamma = S$, where S is particle source. In the gas puff plasmas, the NBI is not main particle source, so the source is deposited only near the edge. Thus in the steady state, in the core, $(1/r)\partial/\partial r[r(\Gamma^{NC}+\Gamma^{QL})]=0$ should be satisfied, yielding (by integrating with rdr) $\Gamma^{NC}+\Gamma^{QL}=0$. When Γ^{NC} is large, since the positive tendency of Γ^{NC} is robust, the negative Γ^{QL} is needed. This will impose the density profile to be hollow, from Fig.3. This discussion will be applicable to other devices if $1/\nu$ NC flux can become large.

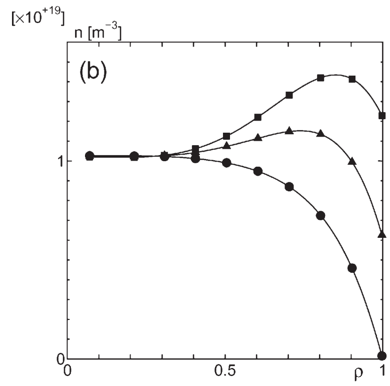

Figure 1: Assumed density profiles.

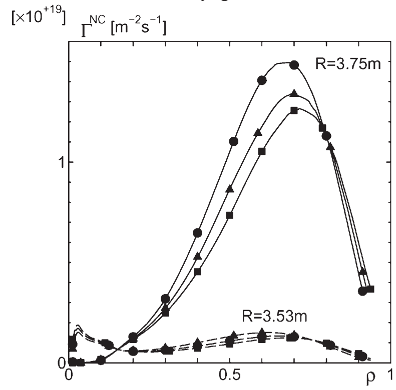

Figure 2: Neoclassical particle flux in R=3.75m(solid) and R=3.53m(dashed) LHD configurations.

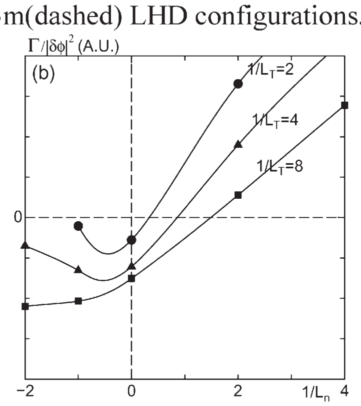

Figure 3: Quasi-linear particle flux in R=3.75m configuration at ρ=0.8, which is mainly by the ITG .

1) S.Murakami et al., Nucl. Fusion **42** L19 (2002)
2) O.Yamagishi et. al., to be submitted to Phys. Plasmas
3) C.D.Beidler et. al., Plasma Phys. Control. Fusion **37**, 463 (1995)