§9. Inward Turbulent Particle Transport in NBI-Heated Plasmas

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Edge plasma turbulence study are carried out using a Langmuir probe array in the CHS heliotron/torsatron. The Langmuir probe array consists of 4 sets of a triple probe, which are separated radially[1]. Each triple probe set has 4 molybdenum electrodes. Radial profiles of time-averaged plasma parameters such as electron temperature T_e, electron density n_e and plasma potential V_s are measured by 4 set probes for one discharge. Floating potentials are measured by two electrodes in each probe set, which are separated by 4.5 mm in the poloidal direction. Fluctuations of poloidal electric field E_θ are derived from these floating potentials. Here, fluctuations of electron temperature T_e are ignored. The turbulent particle flux is expressed as

$$\Gamma_{turb} = (2/B_t)\int_0^\infty \gamma_{n_e E_\theta}\cos\alpha_{n_e E_\theta}[P_{n_e}P_{E_\theta}]^{1/2}df,$$

where B_t, γ, α, P and f are the toroidal magnetic field, coherence, phase, power spectrum density, and frequency, respectively. Therefore, the flux is reduced by reduction of fluctuation amplitude, decorrelation of n_e and E_θ or change of relative phase between them, but inward flux is only realized by the change in the relative phase between both fluctuations.

In some shots, the averaged inward flux is seen around r/<a> ~ 0.94 during the NBI heating phase. We investigated the parameter space where the inward flux is realized, changing fuel gas, B_t, NBI heating power P_{NBI} and n_e near the edge, in the inward-shifted configuration of R_{ax} ~ 0.92 m. As seen from Fig.1, the inward flux is observed in the space of T_e > 15 eV and $n_e < 3\times10^{18}$ m^{-3} at r/<a> ~ 0.94. The inward particle flux appeared in several fuel gases (H and He) and at B_t = 0.9 - 1.4 T. This parameter space approximately corresponds to the low collisionality regime (the effective collision frequency normalized by the transit frequency of a circulating particle $\upsilon^* < 1$) less than lower bound of Pfirsch-Schlüter regime, as seen from Fig.1.

The radial electric field E_r, its shear E_r' and curvature E_r'' are thought to be the possible candidates for the reversal of fluctuation-induced particle flow. The inward flux obviously correlates with E_r', that is, the large positive E_r' is generated near the relevant region where the inward flux takes place. Moreover, T_e profile in the low density discharge clearly has a plateau or slightly hollow structure, of which location approximately corresponds to that of the 1/q = 1 rational surface $r/\langle a\rangle|_{1/q=1}$ = 0.94 - 0.97. The sign of the phase $\cos(\alpha_{neE\theta})$ between n_e and E_θ in an inward flow discharge is in $\cos(\alpha_{neE\theta})$ ~ -1 up to 50 kHz, in contrast to that in an outward flow discharge ($\cos(\alpha_{neE\theta}) > 0$), while the coherence $\gamma_{neE\theta}$ remains unchanged in both discharges. The correlation between the flow reversal and E_r, E_r' and E_r'' is further investigated for many shots in CHS. The dependence of the turbulent particle flux Γ_{turb} on E_r' is shown in Fig.2, where Γ_{turb} and E_r' are evaluated at r/<a> ~ 0.94. From Fig.2, the critical value that induces the large inward turbulent flux ($>1\times10^{20}$ m^{-2}s^{-1}) seems to be E_{rc}' ~ 1×10^6 Vm^{-2}, although the inward flux is observed even in the range of $0 < E_r' < E_{rc}'$. This threshold in E_r' is about twice of that in the edge ECH experiment[2].

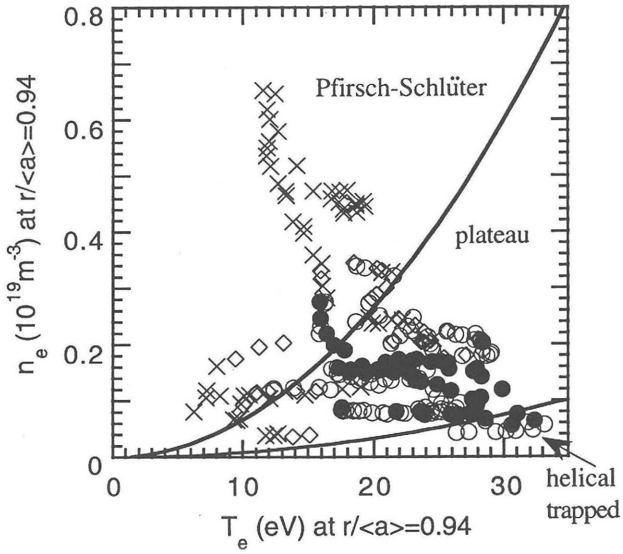

Fig. 1 Data points of Γ_{turb} at r/<a> ~ 0.94 on the parameter space defined by T_e and n_e at r/<a> ~ 0.94. The solid circles, open circles, open squares and crosses respectively indicate the data with $\Gamma_{turb} < -3\times10^{19}$, $-1\times10^{19} > \Gamma_{turb} > -3\times10^{19}$, $0 > \Gamma_{turb} > -1\times10^{19}$ and $\Gamma_{turb} > 0$ m^{-2}s^{-1}. Inward particle fluxes are clearly observed in the range of T_e > 15 eV and $n_e < 3\times10^{18}$ m^{-3}.

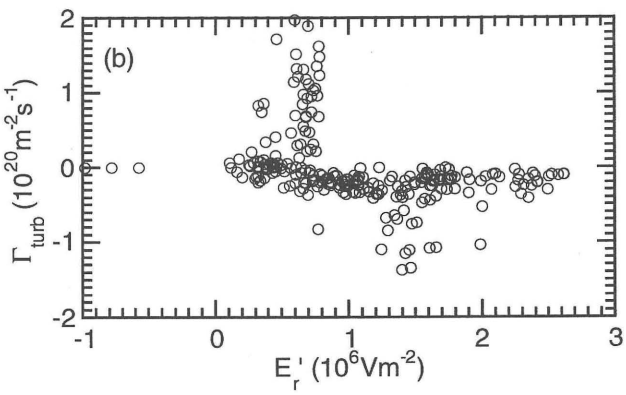

Fig. 2 Dependence of Γ_{turb} at r/<a> ~ 0.94 on the radial electric field shear E_r' at r/<a> ~ 0.94. When E_r' is more than 1×10^6 Vm^{-2}, large inward Γ_{turb} is observed.

Reference

[1] K. Ohkuni, *et al.*, Rev. Sci. Instrum. **72**, 446 (2001)
[2] M.G.Shats, K.Toi, K. Ohkuni, et al., Phys. Rev. Lett. 84, 6042 (2000)