EDGE PLASMA MODULATION INDUCED BY PARTICLE AND HEAT PULSES IN SAWTOOTHING PLASMAS OF THE CHS HELIOTRON/TORSATRON

K.Ohkuni[a], K.Toi[b], R.Akiyama[b], M.Goto[b], M.Isobe[b], G.Matsunaga[a], K.Matsuoka[b], T.Minami[b], S.Morita[b], S.Nishimura[b], I. Nomura[b], S.Okamura[b], M.Osakabe[b], A.Shimizu[a], S.Takagi[a], C.Takahashi[b], M.Takechi[c], K.Tanaka[b], Y.Yoshimura[b] and CHS Group[b]

[a] *Department of Energy Engineering and Science, Nagoya university, Nagoya 464-8603, Japan*

[b] *National Institute for Fusion Science, Toki 509-5292, Japan*

[c] *Naka Fusion Research Establishment, Japan Atomic Energy Research Institute, Ibaraki 311-0193, Japan*

Abstract

In neutral beam injection (NBI) heated plasmas of Compact Helical System (CHS), sawtooth oscillations are often excited. Particle and heat pulses produced by the sawtooth oscillations modify electron temperature T_e, electron density n_e, plasma potential V_s profiles near the edge of $r/\langle a\rangle \simeq 0.9 - 1.0$ and enhance the fluctuation levels there. Turbulent particle fluxes induced by electrostatic fluctuations Γ_{turb} at $r/\langle a\rangle \simeq 0.94$ are transiently enhanced inward by the particle and heat pulses. This large inward particle flux correlates with the positive shear of the radial electric field E_r' ($\gtrsim 1\times10^6\mathrm{Vm}^{-2}$). The inward flux is connected to the change in the phase between electron density and poloidal electric field fluctuations.

Introduction

Particle and energy transport near the plasma edge of toroidal plasmas always exceeds the neoclassical transport based on binary Coulomb collisions. There is a broad consensus that this anomalous transport near the edge is caused by various types of plasma fluctuations. The fluctuations are divided into two kinds of fluctuations, that is, one is electrostatic fluctuations and the other electromagnetic ones. In tokamak and stellarator plasmas, electrostatic fluctuations usually dominate the particle and energy transport near the edge. On the other hand, it is well known in several tokamaks that the particle and heat pulses produced by the sawtooth oscillations modulate the edge plasma parameters and often trigger the improved plasma confinement regime called H-mode. In this paper, we focus on discussing the turbulent fluctuations and particle transport near the edge during the sawtooth oscillations.

Using a Langmuir probe array, edge plasma turbulence study are carried out 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, 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 $\tilde{E}_\theta$ are derived from these floating potentials. Here, fluctuations of electron temperature $\tilde{T}_e$ are ignored. This assumption may be plausible since the effect of $\tilde{T}_e$ on particle transport is very small in edge plasmas of tokamaks and stellarators[2]. The turbulent 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 the B_t, γ, α, P and f are toroidal magnetic field, coherence, phase, power spectrum density, and frequency, respectively. Therefore, the flux is reduced by suppression of turbulence, decorrelation of $\tilde{n}_e$ and $\tilde{E}_\theta$ or change of relative phase between them, but inward flux is only realized by the change in the relative phase between both fluctuations.

Change of edge turbulence by sawtooth-induced particle and heat pulses

Sawtooth oscillations are often observed in CHS[3–5]. Time evolution of soft X-ray intensity during the sawtooth oscillations is shown in Fig.1 with toroidal magnetic field $B_t = 1.4$ T, averaged electron density $\bar{n_e} = 1.4 \times 10^{19}$ m^{-3}, absorbed NBI heating power $P_{NBI} \sim 0.5$ MW. Edge plasma parameters T_e, n_e, V_s and their fluctuation levels are

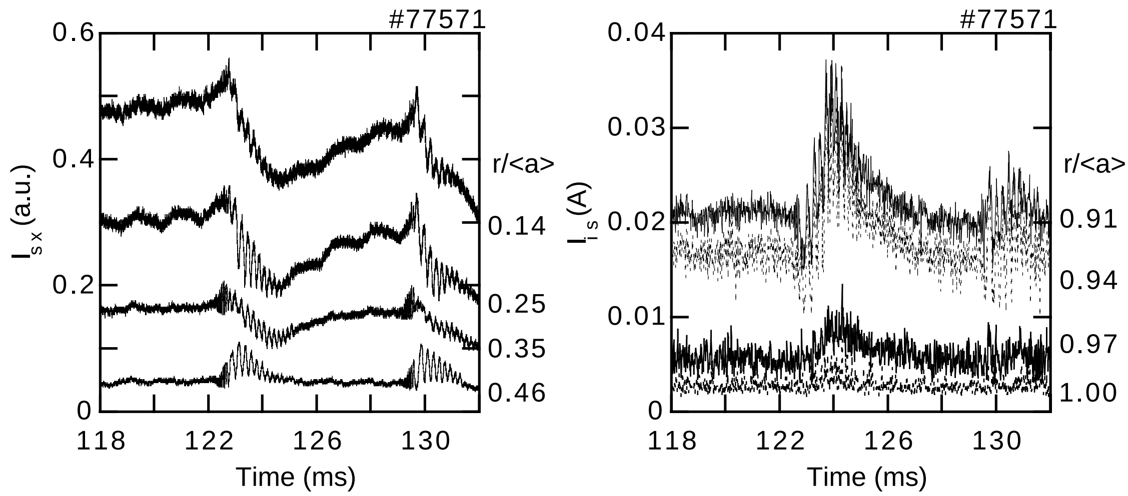

Figure 1: Time evolutions of the soft X-ray intensity I_{sx} at $r/\langle a\rangle = 0.14$, 0.25, 0.35 and 0.46 during the sawtooth oscillations, together with ion saturation current at $r/\langle a\rangle =$ 0.91, 0.94, 0.97 and 1.00

enhanced by the sawtooth crash. The turbulent particle flux Γ_{turb} averaged over 2 ms just before and after a sawtooth crash is shown in Fig.2 together with their frequency

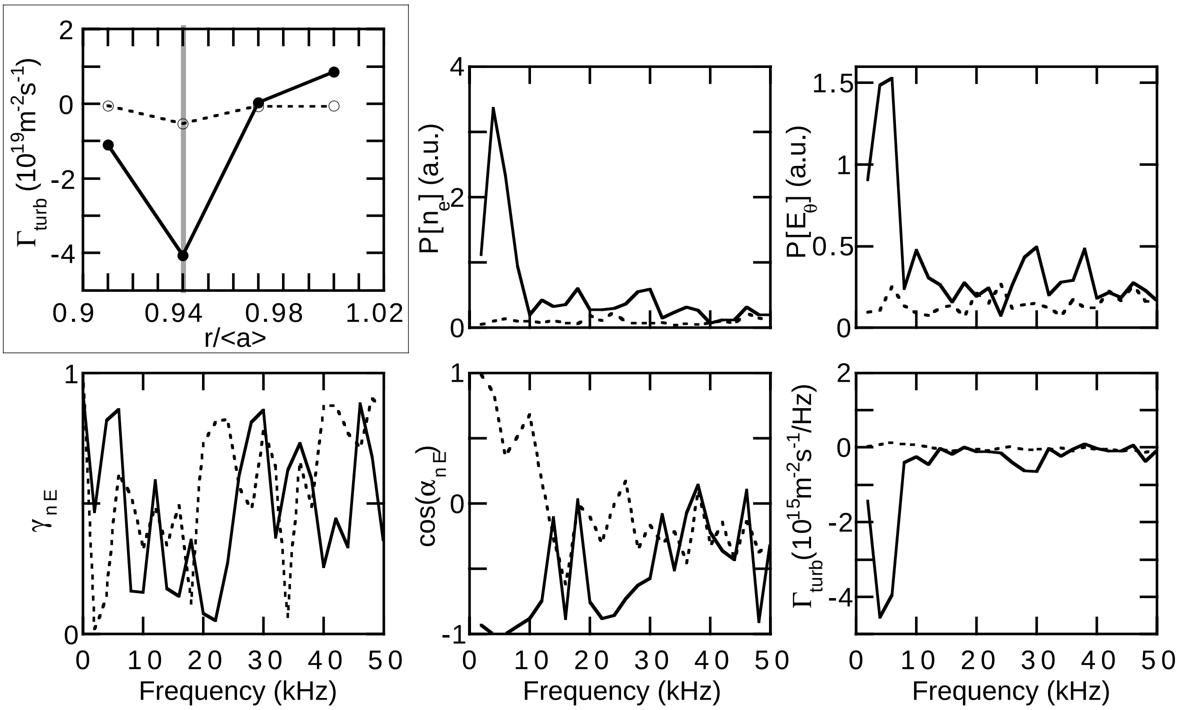

Figure 2: Frequency components of Γ_{turb} at $r/\langle a\rangle = 0.94$ just before (dotted curve) and after (solid curve) sawtooth crash, where these results are obtained in the time windows of 118 - 120 ms and 123 - 125 ms in the shot shown in Fig.1 The change in $\cos(\alpha_{n_eE_\theta})$ leads to the inward particle flux.

components. The change in $\cos(\alpha_{n_eE_\theta})$ leads to the inward particle flux, though $\gamma_{n_eE_\theta}$ is almost unchanged and the spectral powers of n_e and E_θ are enhanced. This effect has a possibility of leading to the improved plasma confinement regime such as H-mode, although the improved regime is not observed in this experimental campaign, so far.

Time evolution of radial electric field shear E_r' and Γ_{turb} during one period of a sawtooth oscillation is shown in Fig.3. This large inward particle flux seems to correlate with the positive shear of the radial electric field E_r' ($\gtrsim 1 \times 10^6\mathrm{Vm}^{-2}$). This relationship between E_r' and inward fluxes are consistent with the previously obtained results in NBI heated plasmas with and without edge electron cyclotron resonance heating on CHS[6,7]. A promising candidate mechanism for the reversal of the particle transport is the decorrelation of fluctuations by $E \times B$ velocity shear or the radial electric field shear. Many experiments and theories are dedicated for clarifying the relationship between transport reduction and $E \times B$ shear effect. However, only Ware's theory discussed the relationship between E_r' and the cross phase of fluctuations[8,9]

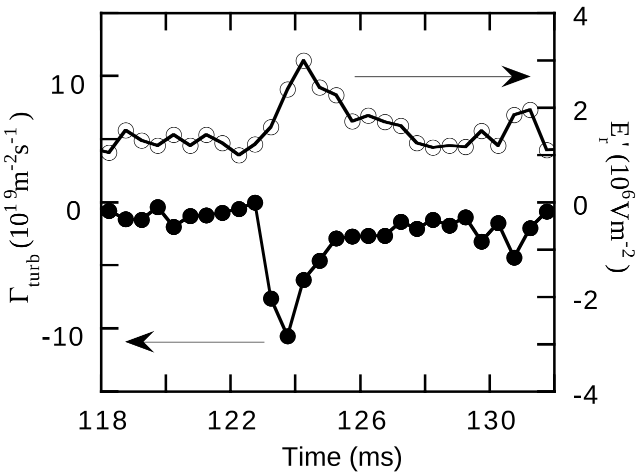

Figure 3: Time evolution of Γ_{turb} and E_r' at $r/\langle a\rangle = 0.94$ during one period of a sawtooth oscillation. Γ_{turb} directs inward in $E_r' \gtrsim 1 \times 10^6$ Vm^{-2}.

Summary

Particle and heat pulses produced by a sawtooth crash modify the radial profiles of electron temperature T_e, electron density n_e and plasma potential V_s near the edge of $r/\langle a\rangle \simeq 0.9 - 1.0$, and enhance the fluctuation levels there. Turbulent particle flux induced by electrostatic fluctuations Γ_{turb} is transiently enhanced inward by the particle and heat pulses at a particular radial location of $r/\langle a\rangle \simeq 0.94$. This large inward particle flux correlates with the positive shear of the radial electric field E_r' ($\gtrsim 1\times 10^6$Vm^{-2}). This relationship between E_r' and the inward flux is consistent with the previously obtained results in NBI heated plasmas with and without edge electron cyclotron resonance heating on CHS. The inward flux is connected to the change in the phase between electron density and poloidal electric field fluctuations. This phenomenon induced by a sawtooth crash might lead to the transport reduction near the plasma edge.

[1] K. Ohkuni, K. Toi and CHS Group, Rev. Sci. Instrum. **72**, 446 (2001).
[2] C. Hidalgo, Plasma Phys. Control. Fusion **37**, A53 (1995).
[3] K. Toi, *et al*, Nucl. Fusion **40**, 1349 (2000).
[4] S. Takagi, K. Toi and CHS Group, Rev. Sci. Instrum. **72**, 721 (2001).
[5] S. Takagi, K. Toi, *et al*, this conference
[6] M. G. Shats, K. Toi, K. Ohkuni, *et al*, Phys. Rev. Lett. **84**, 6042 (2000).
[7] K. Ohkuni, K. Toi, *et al*, to be published in Phys. Plasmas
[8] A. S. Ware, *et al*, Plasma Phys. Control. Fusion **38**, 1343 (1996).
[9] A. S. Ware, *et al*, Phys. Plasmas **5**, 173 (1998).