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Dynamics of heat transport and radial electric field during internal transport barrier formation on JT-60U

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Transport processes in plasmas are enrich of nonlinear phenomena, e.g., non-local transport and transport barrier bifurcations. Studies of such phenomena are interesting for fundamental plasma physics and also important for achieving nuclear fusion. In tokamak plasmas, the internal transport barrier (ITB) is attractive scenario for steady-state fusion operation since it can enhance bootstrap plasma current spontaneously [1]. In the steady-state, the ITB is known as reduced transport states associated with turbulence reductions. However, its dynamical process such as structure formation or trigger mechanism are not fully understood.

In JT-60U, large tokamak machine, simultaneous reductions of transport coefficients in wide region are investigated during the ITB formation [2]. In addition, fluctuations with long correlation length are observed during the ITB formations [3]. Motivated by these observations, we investigate the spatio-temporal evolutions of temperature gradients, the heat flux and the effect of radial electric field to the fluctuations. From the point of view of the ion heat flux, there are multi-step evolutions of ITB formations. As shown in Fig. 1(c), spontaneous reductions of the heat flux are observed in twice. First reduction of the heat flux, as shown in dotted line indexed (1) in the figure, happens at $0.4 < \rho < 0.7$, where the ITB foot appears inside the region. Second flux reduction, indexed as (2) in the figure, happens at $0.3 < \rho < 0.9$ simultaneously, and the shoulder and the foot of ITB start to form at this time in terms of gradient bifurcations. It is confirmed that the observed time scale of the flux changes is faster than the diffusion process. As shown in Fig. 1(e), the effect of non-uniformity of radial electric field to the turbulence, including radial electric field shear and curvature suppressions, is introduced as z parameter [4]. The increase of z parameter indicates the enhancement of turbulence suppression. Consistent increase of z parameter and temperature gradient continue until the reduced heat flux states, which is indexed as (3) in the figure. From the critical value of z, the range of correlation length of fluctuations is estimated. It is suggested that the estimated correlation length of fluctuations is as long as previously reported long-range fluctuations [2]. Such long-range fluctuations could connect the local turbulence and gradients, which could possible to induce the global confinement improvements.

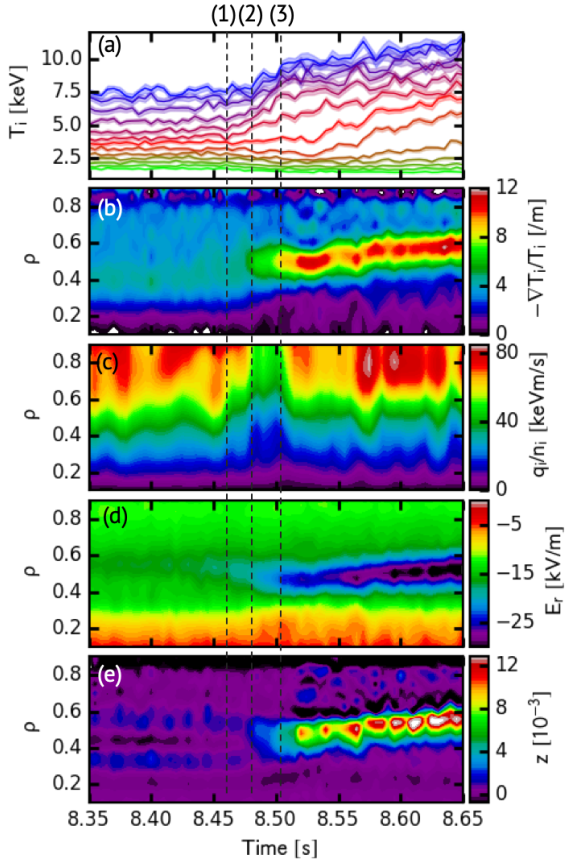

Figure 1. Spatio-temporal evolutions of (a) ion temperature measured by CXRS ($0.25 < \rho < 0.8$), (b) inverse scale length of T_i, (c) ion heat flux, (d) radial electric field and (e) non-uniformity effect of radial electric field represented as z. Spontaneous changes of heat flux (dotted line (1)-(3)) indicate multi-step evolutions of ITB from L-mode plasma.

References

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