§1. Application of a Transit Time Distribution Analysis to the Nonlocal Transport Phenomenon in LHD

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On a nonlocal transport phenomenon in LHD, there exists a hysteresis loop in the relationship between a core electron temperature gradient ∇T_e and a core electron heat flux normalized by an electron density q_e/n_e [1]. This indicates that there are several possibilities of changing in core heat transport, such as bifurcation and/or transition, by the nonlocal transport phenomenon. Thus it is important to assess dynamic characteristics of the transport state in the core region during the nonlocal transport phenomenon. In the turbuent heat transport of magnetically-confined toroidal plasmas, it is expected that there is a consistent relationship among the heat flux normalized by the density q_e/n_e, the temperature T_e and the temperature gradient ∇T_e, since the state of turbulence, which is mainly specified by the temperatures and those gradients, determines the heat flux for the given temperature gradients and the temperature gradients are tuned by the externally-input heat flux. When there is a unique solution in the relationship, the T_e and ∇T_e are set uniquely with the given q_e/n_e. According to Fick's law, the proportionality coefficient between the q_e/n_e and the ∇T_e is defined as a thermal diffusivity. Consequently, in order to investigate the dynamic response characteristics of the transport state, a deviation probability of the ∇T_e against the perturbation is evaluated with a transit time distribution (TTD) for a certain window of $-\nabla \delta T_e$ [2].

Figure 1 (c, d) shows the temporal evolution of the $-\nabla T_e$ in the core region and the TTD of the $-\nabla \delta T_e$ for the whole nonlocal transport phenomenon. As a reference, the results for the formation phase of the electron internal transport barrier (ITB) are also shown in Fig. 1 (a, b). At the formation phase of the electron ITB (see Fig. 1(b)), two peaks is clearly identified in the TTD of the $-\nabla \delta T_e$: One peak at $-\nabla \delta T_e = 0$ represents the original transport state and the other at $-\nabla \delta T_e \sim 8$ keV/m represents the electron ITB state. Therefore the TTD of the $-\nabla \delta T_e$ clearly demonstrates the formation of the electron ITB is the transition to the another transport branch. On the other hand, in the case of the nonlocal transport phenomenon (see Fig. 1(d)), the profile of the TTD of the $-\nabla \delta T_e$ shows a bit wider trapezoid structure on which a sharp peak at the zero displacemet is superimposed, which is qualitatively different from that of the electron ITB (see around the zero displacement in Fig. 1(b)). Thus this profile shape suggests the following points. The nonlocal transport phenomenon is not categorized as the transition to the another transport branch (not even on its way to that). The plasma exhibiting the nonlocal transport phenomenon can easily modify the $\nabla \delta T_e$ over a bit wider range stochastically. And the nonlocal transport phenomenon may not necessarily require the well-known turbulent transport reduction process, the breaking of turbulent eddies (i.e. the disappearance of the nonlocality). In LHD, the nonlocal transport phenomenon has been observed even in the electron ITB plasma, where the the turbulent eddies are expected to be already sheared. This experimental fact may support that the breaking of the turbulent eddies is not a major cause of the core T_e rise during the nonlocal transport phenomenon.

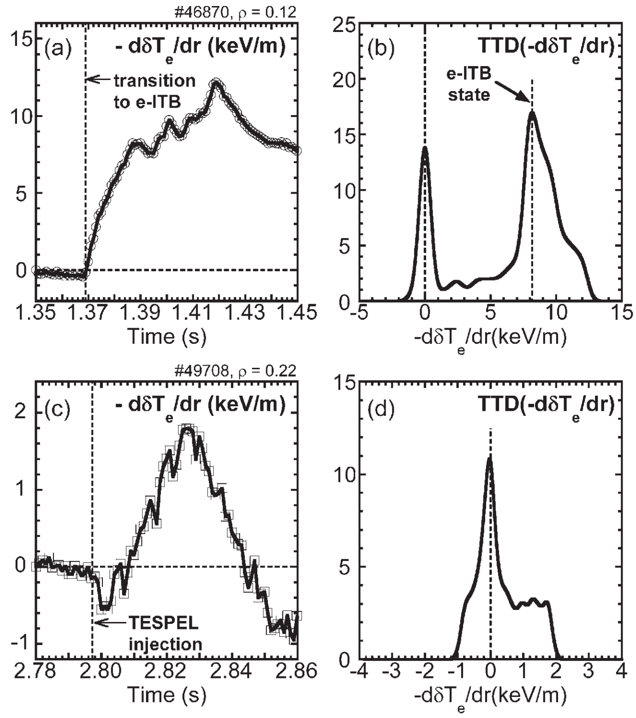

Fig. 1: Comparison of the transit time distribution (TTD) of the -dδT$_e$/dr between the spontaneous electron internal transport barrier formation and the nonlocal transport phenomenon. (a, c) Temporal evolutions of the electron temperature gradient and (b, d) transit time distributions of the -dδT$_e$/dr.

1) N. Tamura et al.: Nucl. Fusion **47** (2007) 449.

2) K. Ida et al.: J. Phys. Soc. Jpn. **77** (2008) 124501.