Turbulence spreading dynamics approaching the density limit

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High plasma density is favorable for fusion reactors as the fusion power is proportional to the square of density. High density operation is considered as the scenario baseline for ITER[1] and DEMO[2]. While the density limit imposes constraints on the attainable maximum density for current-generation tokamak operations[3]. The Greenwald empirical scaling[4] shows that, the maximum line-averaged density is like to scales as current density, n_G=Ip/(π a2). Discharges with deep fuelling demonstrates that the Greenwald density can be considerably exceeded with the centrally elevated density profile[5]. So the underlying physical mechanism of density limit might lie behind the plasma edge. Recent researches indicate that, the collapse of edge shear layer and the enhanced particle transport events can lead to the cooling of edge, and therefore the onset of subsequent radiation losses, current shrinking and MHD instabilities that limit the density in Ohmic and L-mode discharges[6,7]. The increased turbulence spreading is found to associated with the enhanced particle transport events but also shows some different dynamics near the density limit[8], which is worth to be further studied.

In this report, we will present the recent experimental results of turbulence spreading dynamics approaching the density limit in the edge of J-TEXT tokamak. It is found that the divergence of turbulence internal energy flux (i.e. turbulence spreading) increases as the line-averaged density approaches the Greenwald density, which coincides with the collapse of edge shear layer and the enhanced particle transport. As density increases, there exists a certain region in plasma edge, where the turbulence spreading flux $\langle \tilde{v}_r \tilde{n}^2 \rangle /2$ is large, but the turbulence intensity gradient $\partial_r \langle \tilde{n}^2 \rangle$ is near zero, as shown by Figure 1(c)(d). The width of this region is comparable to the radial correlation length of density fluctuations. In this region, the turbulence spreading diffusivity is much larger than the turbulent particle diffusivity. This indicates potentially different mechanisms of particle transport and energy transport.

Studies of correlations show that the increased density fluctuations are quasi-coherent, which exhibit positive skewness. Electron adiabaticity emerges as the critical parameter which signals turbulence spreading event onset. Turbulence spreading rises rapidly as electron adiabaticity transits from the adiabatic regime (α > 1) to hydrodynamic regime (α<<1). This is likely to be a common characteristic of high density discharges with different plasma currents. The higher operational density available for higher current is coincident with the evolution of electron adiabaticity as well as turbulence spreading.

References

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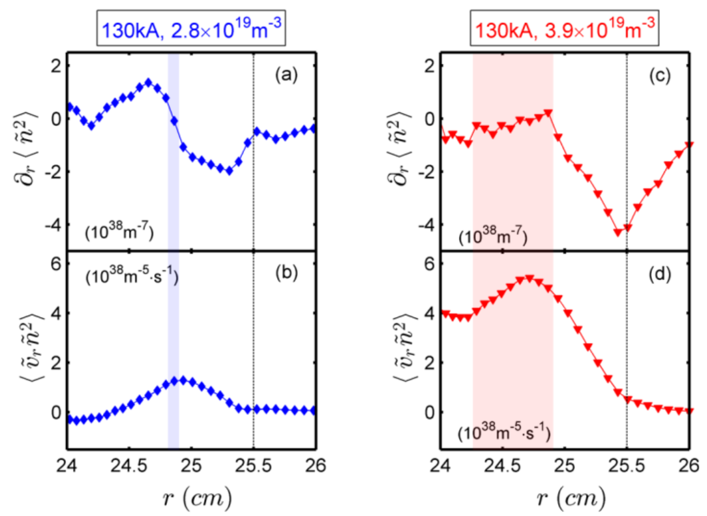

Figure 1. Turbulence intensity gradient and turbulence spreading flux at different densities.