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Advances in physics basis of L-mode edge negative triangularity tokamak reactor

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Negative-triangularity Tokamak Reactor [1, 2, 3] is an innovative reactor concept based on “power-handling-first” philosophy based on TCV’s pioneering work [4]. Quite recently, DIII-D [5] achieved reactor relevant performance ($\beta_p = 2.7$, $H = 1.2$) in negative triangularity (NT) shape. Importantly, DIII-D high performance NT plasma exhibits L-mode edge while positive triangularity (PT) plasma undergoes limiter H-mode transition [5]. Values of $P_{L}/P_{H}$ in DIII-D NT and PT shaped plasmas are both ~6.7 and NT stays in L-mode edge and PT made $L-H$ transition. There seems a resilience to stay in L-mode edge in NT shape (see Figure 1).

The ratio of transport power to L-H threshold $P_{L}/P_{H}$ is 2.6-3.5 in our recent designs of L-mode edge NT Tokamak reactor [3]. Thus, there might be a possibility of NT Tokamak reactor stay in L-mode edge.

As we discussed in 2013 in US-TTF [6], current problems on power and particle exhausts is originated from the H-mode operation. L-mode edge, if it is feasible, is robust and has higher particle exhaust capability and hence heat exhaust/particle is expected to be lower than in H-mode.

Edge turbulence is expected to be lower in NT than in PT shape if it is driven by the resistive ballooning mode [7], which implies turbulent drive for the Zonal flow. Due to geometrical structure, NT may have less toroidal coupling to produce GAM. Since flow shear and GAM/zonal flow plays an important role in L-H transition [8], experimental and theoretical investigation of GAM/zonal flow in NT is crucially important.

Figure 1 1 D-shaped and NTT experimental configurations in TCV (PT:S = 9.9 m, NT:10.3 m) and DIII-D (PT:S = 42 m, NT: S = 45 m). Here $\delta$ is plasma surface area.

Recent design of L-mode edge NT Tokamak reactor [3] (see Figure 2) showed that length along the divertor plate to receive heat from the reactor can be as much as 20 mm if the SOL width of L-mode edge is twice as large as H-mode.

Figure 2 Divertor geometries for NTT ($L = 15$ MA, $R = 7$ m, $I_e = 2.5$ MA). For a 1 mm SOL width at outboard mid-plane, inboard mid-plane thickness is 3.7 mm. Use of FTE coils expanded the flux tube and 4-5 mm along the divertor plate for the original semi-open divertor target geometry (black lines). With more inclined divertor targets, 1 mm SOL at outboard mid-plane will be projected to 10 mm along the divertor plates (green lines).

References