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Interaction among magnetic island, flow and turbulence and its impact in plasma confinement

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Magnetic island has dual role in fusion plasmas. On one hand, it degrades the plasma confinement due to the "short-cut" of pressure profiles inside the island. On the other hand, strong flow shear layer can be formed at the island boundary, which could improve the confinement. Therefore, improved understanding of multi-scale interaction among the magnetic island, plasma flow and turbulence is important, and has potential implications for future fusion devices such as ITER. In this work, experimental studies on the interactions among the magnetic island, plasma flow and turbulence, as well as its impact in the plasma confinement in HL-2A and HL-3 plasmas will be reported, respectively.

The perpendicular flow profiles are measured dedicatedly across the island region in the HL-2A ohmic plasmas with rotating m/n=2/1 island. It is found that the flow profile is quite flat near the island center, while it increases dramatically toward the island boundary, leading to an enhanced rotation shear at the O-point boundary [1]. However, the flow shear rate is still smaller than the decorrelation rate of the ambient turbulence at the O-point boundary, which is driven by the steep pressure gradient there. Therefore, no obvious confinement improvement by magnetic island is observed in the ohmic discharges. In addition, it is evidenced by electron cyclotron emission imaging (ECEI) diagnostic that turbulence enhancement and turbulence spreading at the island reconnection region results in the stochasticity of the magnetic field lines and decline of the flow shear, and thus facilitates the plasma thermal quench [2], as shown in Figure 1.

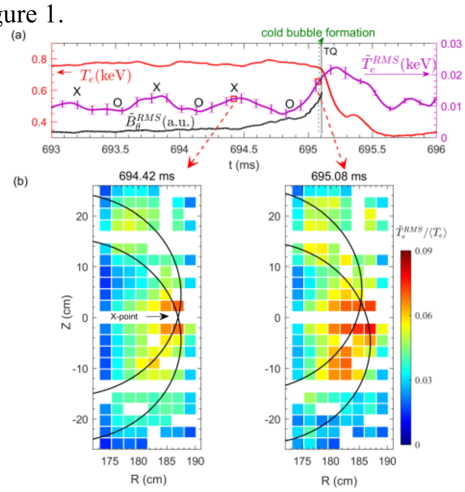

Figure 1. (a) Time evolutions of core electron temperature, turbulent temperature fluctuations and magnetic fluctuations. (b) Spatial distributions of the temperature fluctuations at the reconnection region before and close to the plasma thermal quench.

In the recent HL-3 experimental campaign, it is found that the ion energy confinement is improved significantly, namely the formation of the ion internal transport barrier, induced by a large static magnetic island in the neutral beam heated plasmas. The mode locking occurs at 610 ms. As shown in figure 2(a), the ion temperature in the inner region increases immediately after the mode locking. The ITB foot is located at the q=2 island region, farther outward than that of ITB induced by fishbone. The core ion temperature is proportional to the toroidal rotation shear at the island inner boundary which is regulated by the island width, as shown in figures 2(b) and (c). Both the temperature fluctuations and density fluctuations are reduced dramatically inside the ITB foot. More details will be shown in the presentation.

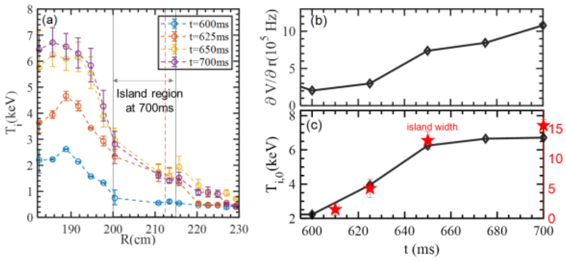

Figure 2. (a) Time evolutions of the ion temperature profiles. (b) and (c) Time evolutions of the toroidal rotation, core ion temperature and island width.

References

[1] M. Jiang et al., Nucl. Fusion 58 026002 (2018).
[2] Y. C. Li et al., Sci. Rep. 13 4785 (2023).