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Investigation the impact of carbon impurity radiation on density limit in limiter and divertor configurations on J-TEXT

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High-density operation is a crucial aspect of achieving efficient and sustainable fusion reactions in tokamak devices like ITER[1]. However, the operational region of stable tokamak discharges is limited towards high plasma density due to the phenomenon known as the density limit (DL). The DL is a critical issue in tokamak research, and cooling of the plasma edge thought to be a key element, which can lead to current shrinking, strong magnetohydrodynamic (MHD) activity, and ultimately, plasma disruptions[2]. Understanding the density limit is essential for successful and reliable operation of future fusion devices.

This investigation presents the impact of carbon impurity radiation in the density limit in different magnetic field configurations on the J-TEXT tokamak. The study focuses on the edge plasma cooling and its effects on triggering the mode locking of the precursor 2/1 tearing mode (TM) before reaching the density limit. Experiments were conducted in various magnetic field configurations, including the normal limiter, HFS-limiter, and HFS-MSN divertor configurations[3], with different carbon impurity concentrations introduced by methane gas injection from the high-field-side (HFS), as shown on the left of Figure 1. The edge plasma parameters, such as electron temperature and density, were closely monitored as the plasma approached the density limit.

The introduction of carbon impurities resulted in stronger core radiation and enhanced cooling of the boundary region, affecting the temperature profiles near the q=3 surface. The study also revealed that the electron temperature near the q=3 surface exhibited similarities across all magnetic configurations as the density limit approached, as shown in Fig 1(a, b, c). However, significant differences were observed near the Last Closed Flux Surface (LCFS), indicating the importance of q=3 surface temperature as a key factor in the density limit discharge.

In conclusion, the investigation sheds light on the critical role of carbon impurity radiation and edge plasma cooling in influencing the density limit in different magnetic field configurations. The findings contribute to the development of comprehensive models for understanding and mitigating the density limit in future fusion devices, ensuring their stable and efficient operation at high plasma densities.

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References

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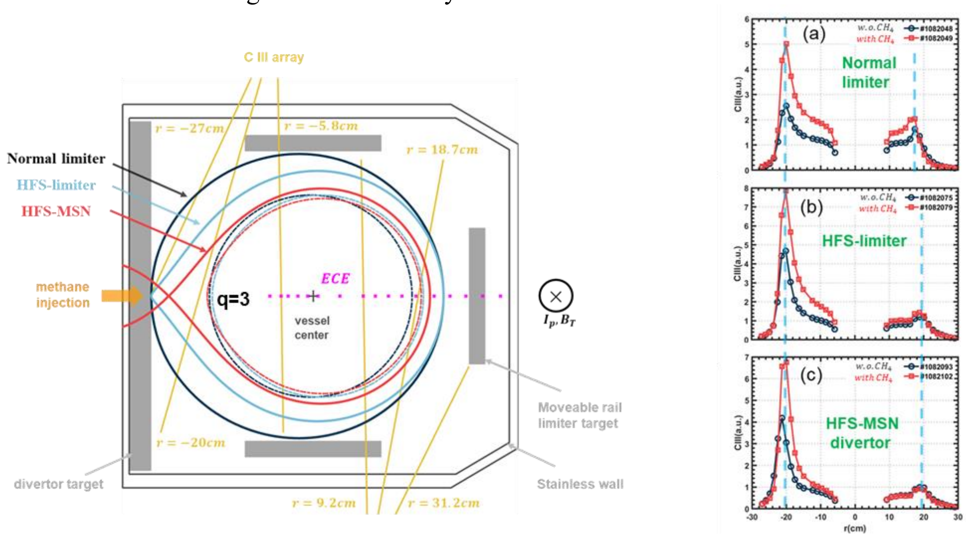

Figure 1. Schematic diagram of three magnetic field configurations (left). C III radiation distribution before approaching the density limit under the normal limiter(a), HFS-limiter(b), and HFS-MSN divertor configurations(c). The blue vertical dashed line represents the position of the q=3 surface.