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Integrated modeling and experimental validation of H-mode divertor detachment and core confinement compatibility on HL-2A tokamak

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Abstract: The divertor detachment and heat flux control under high-confinement H-mode conditions in tokamaks represent critical physical challenges in current magnetic confinement fusion research. Understanding the impact of detachment on H-mode boundary transport physics, particularly its compatibility with core confinement, is central to resolving divertor detachment physics. In this study, experimental results on divertor detachment and core confinement compatibility in H-mode plasmas from the HL-2A tokamak are presented. On the OMFIT (Objective MHD Framework for Integrated Tasks) integrated modeling platform, a novel neural network-based fast integrated modeling method for the divertor target region has been developed, by integrating a new edge neural network module (Kun-Lun Neural Networks, KLNN) to enhance divertor, scrape-off-layer and edge pedestal fast prediction capability. For the first time, this method is applied to conduct integrated simulations of divertor detachment and core confinement compatibility in HL-2A discharge #39007 in high-confinement mode. The simulation results are validated against experimental measurements, which are consistent well with each other. Further analysis reveals that in HL-2A H-mode detachment scenarios: turbulent transport in the core region () with high poloidal wave numbers () is dominated by ion temperature gradient (ITG) modes, while electron-driven turbulence prevails in the region . In the boundary region, electron turbulence dominates at low normalized poloidal wave numbers (), whereas ITG modes become predominant at higher wave numbers (), accompanied by minor electron turbulence contributions. The research results of this paper provide a certain foundation for integrated simulation and experimental verification in the study of core-edge coupling physics in tokamak devices and some insights for understanding of detachment-compatible H-mode scenarios in next-step fusion devices.

Keywords: tokamak, detachment, H mode, integrated simulation

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