DPP20-2020-000180

Abstract for an Invited Paper
for the DPP20 Meeting of
the American Physical Society

First Observation of A Fully Detached Divertor with Natural Compatibility with A High Confinement Plasma State for Steady-state Operation[1]

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Excellent compatibility of actively controlled full divertor detachment with a high-performance (β_N ~3, β_p >2, H_{98} ~1.5) core plasma has been achieved, for the first time, in DIII-D high-β_p (poloidal beta) plasmas associated with a sustained core internal transport barrier (ITB) and an H-mode edge transport barrier (ETB). Compared to standard H-mode plasmas, the high-β_p plasmas exhibit a much wider window of detachment compatible with a high confinement core. With a newly developed detachment control system, coupled with optimized nitrogen impurity seeding, fully detached divertor plasmas were achieved with low plasma temperature (Te<5eV), low particle flux and low heat flux across the entire divertor target plate. It is found that this high-p high confinement plasma scenario enables full divertor detachment at lower density due to long connection length associated with the high edge safety factor, needed for steady-state, and reduced loss power from core to boundary plasma associated with the high confinement. Furthermore, the divertor detachment facilitates the access to an even stronger ITB at large radius with a weakened ETB through self-organized synergy between ITB and ETB, leading to improved high confinement, in contrast to confinement degradation with divertor detachment in standard H-mode. The presence of a large-radius ITB compensates the degradation of ETB by the divertor detachment, while a weak ETB is more prone to an edge regime with natural small edge localized modes. In particular, with neon injection, a long-period no-ELM H-mode phase has been achieved simultaneously with high-performance core and partially detached divertor plasmas. These results demonstrate the possibility of integrating excellent core plasma performance with an efficient divertor solution, an essential step towards steady-state operation of reactor-grade plasmas.

[1]This work is supported by the U.S. Department of Energy under DE-FC02-04ER54698, DE-AC04-94AL85000, DE-NA0003525, DE-AC52-07NA27344, National Natural Science Foundation of China under 11922513 and National Magnetic Confinement Fusion Science Program of China under 2017YFE0301300.