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Viability of Wide Pedestal QH-Mode for Burning Plasma Operation

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Wide Pedestal QH-mode is a new steady ELM-free regime obtained in DIII-D, exhibiting a transport-limited pedestal regulated by broadband turbulence, with improved confinement relative to QH-Mode under the same conditions, attaining $\beta_N \sim 2.3$ and H98y2∼1.6, which increase with power. Toward compatibility with burning plasma conditions, the need for neutral beam torque to initiate and sustain Wide Pedestal QH-Mode has been completely eliminated. Further, the regime has now been sustained for several confinement times with dominant electron heating, at very low torque, without ELMs or core MHD. Recent experiments show that in Wide Pedestal QH-Mode, both pedestal and core confinement uniquely improve when Electron Cyclotron Heating (ECH) augments or replaces Neutral Beam Injection (NBI). This is promising for burning plasma operation where α-particles heat electrons. Adding 0.8 MW ECH to 3.8 MW NBI power more than doubles pedestal confinement, increasing pedestal pressure by 50%. Wide Pedestal QH-Mode has now been sustained for several confinement times with up to 77% ECH power (3 MW ECH to 0.9 MW NBI), limited by the available ECH power. High electron temperatures exceeding 12 keV are attained suggesting an internal transport barrier (ITB), which is verified using modulated ECH and ECH location scans to measure electron temperature profile stiffness. A deep well forms in the inner core toroidal rotation profile during intense ECH, characteristic of ITBs. The electron transport stiffness has been similarly studied in QH-Mode in the outer core, showing the electron temperature gradient lies close to a critical gradient. Separately, the regime has been maintained with ITER-relevant shape. These and other new developments support Wide Pedestal QH-Mode regime as a viable solution to avoid ELMs and associated divertor damage in a zero-torque, high-confinement, electron heated scenario at ITER collisionality. This work was supported in part by the US Department of Energy under DE-FC02-08ER54966, DE-SC0014264, DE-FC02-04ER54698, FG02-08ER54984, DE-FG02-08ER54999, DE-AC02-09CH11466 and FG03-97ER54415.

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