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Physics Investigations of Wide Pedestal QH-mode Plasmas in DIII-D*

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Recent experiments in DIII-D have led to the discovery of a means of modifying edge turbulence to achieve stationary, high confinement operation without Edge Localized Mode (ELM) instabilities and with no net external torque input [1,2]. Due to novel changes in edge turbulence, we achieved excellent tokamak performance, well above the H_{98y2} international tokamak energy confinement scaling (H_{98y2} up to 1.6). The new regime is triggered in double null plasmas by ramping the injected neutral beam torque to zero and then maintaining it there. This lowers ExB rotation shear in the plasma edge, allowing low-k, broadband, electromagnetic turbulence to increase. In the H-mode edge, a narrow transport barrier usually grows until MHD instability (a peeling ballooning mode) leads to the ELM heat burst. However, the increased turbulence reduces the pressure gradient, allowing the development of a broader and thus higher transport barrier. Strong double-null plasma shaping raises the threshold for the ELM instability, allowing the plasma to reach a transport-limited state near but below the explosive ELM stability boundary. A 60% increase in pedestal pressure and 40% increase in energy confinement result. An increase in the ExB shearing rate inside of the edge pedestal is a key factor in the confinement increase. The dipolar change in the ExB shear (decrease for $\rho \geq 0.9$ and increase around $\rho=0.8$) is surprising, since the actuator used is the variation in the input NBI torque, which has no strong radial variation in this region. Experiments in January 2016 produced the surprising result that normalized confinement increases with increasing neutral beam heating power from $H_{98y2}=1.3$ at 3.8 MW to $H_{98y2}=1.6$ at 5.5 MW. The resulting plasmas have burning-plasma-relevant $\beta_N=1.6\text{-}2.3$ and $\nu^*_e{}^{PED} = 0.16\text{-}1.0$ and, importantly, they run without the need for extra torque from 3D magnetic fields.. To date, stationary conditions have been produced for 2 s or 12 energy confinement times, limited only by external hardware constraints. Further detailed results on ExB shear effects in these plasmas will be presented.

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[1] K.H. Burrell, *et al.*, "Discovery of stationary operation of quiescent H-mode plasmas with Net-Zero NBI torque and high energy confinement on DIII-D", Phys. Plasmas **23** (2016) (in press)
[2] X. Chen, *et al.*, "Stationary QH-mode Plasmas with High and Wide Pedestal at low Rotation on DIII-D", submitted to Nuclear Fusion