DPP15-2015-020102

Abstract for an Invited Paper
for the DPP15 Meeting of
the American Physical Society

Discovery of Stationary Operation of Quiescent H-mode Plasmas with Net-Zero NBI Torque and High Energy Confinement on DIII-D[1]

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Experiments this summer in DIII-D have used edge turbulence control to achieve stationary, high confinement operation without Edge Localized Mode (ELM) instabilities and with no external torque input. Eliminating the ELM-induced heat bursts and controlling plasma stability at low rotation represent two of the great challenges for fusion energy. By exploiting edge turbulence in a novel manner, we achieved outstanding tokamak performance, well above the H98 international tokamak energy confinement scaling (H98=1.25), thus meeting an additional confinement challenge that is usually difficult at low torque. The new regime is triggered in double null plasmas by ramping the injected 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. A 60% increase in pedestal pressure and 40% increase in energy confinement result. 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. The resulting plasmas have burning-plasma-relevant betan=1.6-1.8 and 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. Stationary operation with improved pedestal conditions is highly significant for future burning plasma devices, since operation without ELMs at low rotation and good confinement is key for fusion energy production.

[1]Supported by the US DOE under DE-FC02-04ER54698.