# High Beta, High Confinement, Stationary ELM-free Operation at Low Plasma Rotation*

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A new line of experiments on the DIII-D tokamak has achieved the first-time demonstration of stationary ELM-free plasmas with simultaneous high $\beta$, high confinement, and low rotation conditions [1]. These experiments successfully combine the physics of quiescent H-mode (QH-mode), with the neoclassical physics of 3D magnetic field-driven torque. QH-mode enables constant density operation without edge localized modes (ELMs) at the maximum possible stable pedestal pressure. The magnetic field-driven torque is used for tailoring the rotation profile such that the $E \times B$ shear near the edge is maintained, and indeed enhanced, even with no net injected neutral beam torque and overall low levels of rotation. Plasmas with an ITER-similar lower single-null cross section shape and ITER-equivalent values of the neutral beam injection (NBI) torque, have shown excellent confinement quality $H_{98y2} = 1.3$ at the ITER-relevant values of $\beta_N \sim 2$, $\nu^*_{ped} \sim 0.1$, and $\beta_T^{ped} \sim 1\%$ [2]. The neoclassical torque from nonresonant $n = 3$ fields maintains significant edge counter-$I_p$ rotation even when the net NBI torque is co-$I_p$, and provides a stabilizing effect on locked modes at high $\beta$, zero NBI torque operation. Further, in preliminary experiments using $n = 3$ fields only from a coil outside the toroidal coil, QH-mode plasmas with low $q_{95} = 3.4$ have reached values of the normalized fusion performance $G = \beta_N H_{89}/q_{95}^2 = 0.4$, the desired value for $Q = 10$ operation in ITER.

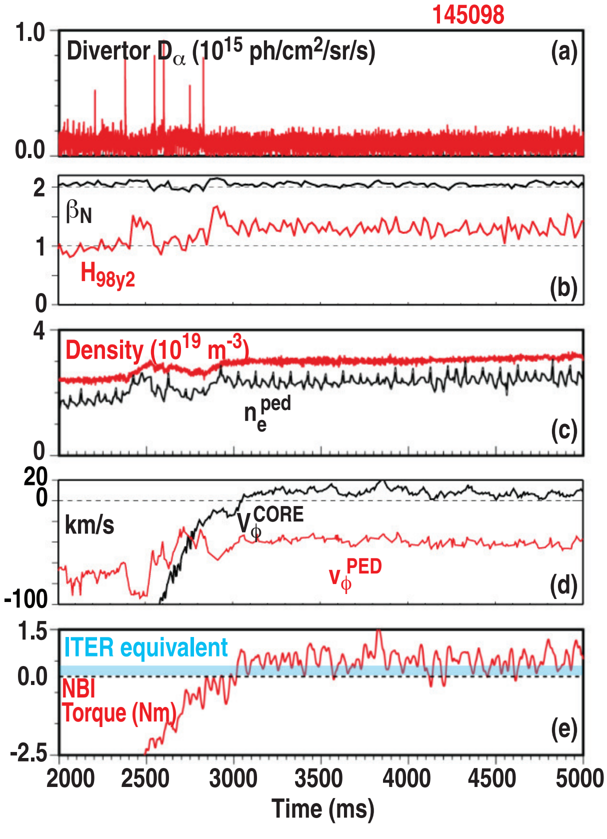


Figure 1: Demonstration of ELM-free QH-mode operation sustained for 2 s at $\beta_N \geq 2$ with constant density, excellent energy confinement and counter-$I_p$ pedestal rotation with co-$I_p$ NBI torque somewhat above the ITER equivalent level.

## References

[1] A.M. Garofalo, *et al.*, Nucl. Fusion **51**, 083018 (2011).
[2] K.H. Burrell, *et al*, Phys. Plasmas **19** (2012) to be published.

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