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A Low Plasma Current (~ 8 MA) Approach for ITER's Q=10 Goal

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Experiments on DIII-D support a new approach, confirmed by transport modeling, to achieve Q=10 in ITER using a scenario with low plasma current (~ 8 MA), high β_p, and line-averaged Greenwald fraction (f_{Gw}) above 1. At 8 MA, the disruption risks, the ELM and the radiative divertor challenges are greatly reduced, with the possibility that uncontrolled ELMs may be acceptable [1]. Due to the need of sufficient fusion power and low plasma current, this approach requires high density with $f_{Gw}>1.0$ simultaneous with high confinement quality ($H_{98y2}>1$). Using impurity injection, the recent DIII-D experiments achieve and maintain these simultaneous conditions. Previously, high β_p plasmas with f_{Gw} up to 1.0 and $H_{98y2}>1$ were obtained in JT-60U, albeit transiently and usually operated at low absolute density [2, 3], which is not favorable to reactor plasma. For the first time in a tokamak, experiments demonstrate that a stationary ITB at large radius ($\rho\sim0.7$) is compatible with $H_{98y2}>1$, at reactor-level absolute density ($n_{e0}>1.0\times10^{20}\ m^{-3}$), $f_{Gw}>1$, and reactor-relevant q_{95} as well (fig. 1). Such ITB is a key feature of the ITER 8 MA Q=10 modeling. Comparison between the experimental DIII-D profiles and the predicted ITER profiles shows also a good match of ITB location and profile shape (fig. 2). The DIII-D experiments confirm that the high density ITB in ITER modeling is achievable at similar q_{95} using the high β_p scenario.

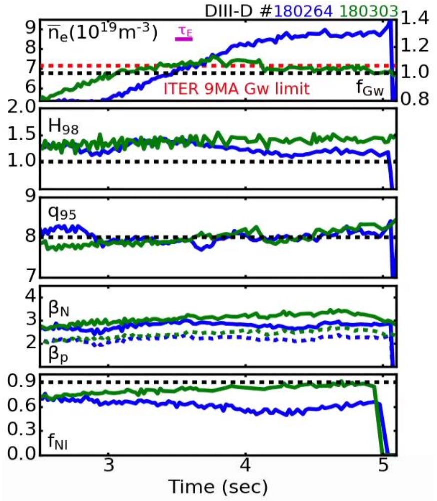

Fig. 1. Time histories of DIII-D high β_p discharges showing line-averaged n_e at ITER Greenwald limit level with stationary ($8\text{-}21\times\tau_E$) $f_{Gw}>1.0$, $1.2\leq H_{98}\leq1.4$, $q_{95}\sim8.0$, $\beta_N\leq3.5$, $\beta_p\leq2.7$ and $f_{NI}\leq0.9$.

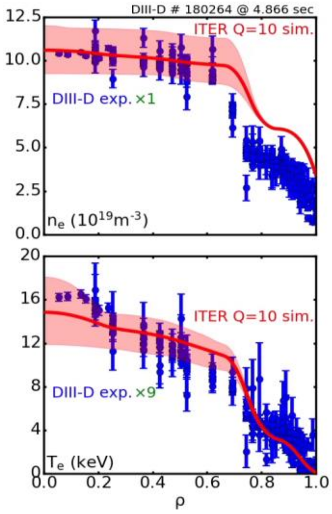

Fig. 2. Electron Temperature and density profiles predicted by 1D ITER simulations (solid lines with bands) overlaid with scaled DIII-D high β_p plasma experimental profiles (dots with error bars). Multipliers for DIII-D n_e and T_e data are 1 and 9, respectively.

The DIII-D high β_p experiments also demonstrate the excellent compatibility of actively controlled full detachment with high-performance ($\beta_N\sim3$, $H_{98y2}\sim1.5$) core plasma for the first time. It is confirmed that impurity injection, low plasma current and feedback controlled low heating power at high confinement are beneficial to the achievement of divertor detachment, which is consistent with the prediction of radiation-driven detachment modeling. The existence of large radius ITB, which breaks the stiffness of the core profiles, compensates for the loss of stored energy due to the lower pedestal pressure induced by divertor detachment. The DIII-D high β_p experiments show a path to the integration of excellent core plasma performance and efficient divertor solution towards the ITER and future reactor plasmas.

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References

[1] R. A. Pitts, *et al.*, *Nucl. Mater. Energy*, **20** (2019) 100696

[2] R. C. Wolf, *Plasma Phys. Control. Fusion*, **45** (2003) R1

[3] N. Oyama and the JT-60 Team, *Nucl. Fusion*, **49** (2009) 104007