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Prediction and realization of ITER-like pedestal pressure in the high-B tokamak Alcator C-Mod[1]

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Fusion power in a burning plasma will scale as the square of the plasma pressure, which is increased in a straightforward way by increasing magnetic field: $P_{fus} \sim p^2 \sim B^4$. Experiments on Alcator C-Mod, a compact high-B tokamak, have tested predictive capability for pedestal pressure, at toroidal field B_T up to 8T, and poloidal field B_P up to 1T. These reactor-like fields enable C-Mod to approach an ITER predicted value of 90kPa. This is expected if, as in the EPED model, the pedestal is constrained by onset of kinetic ballooning modes (KBMs) and peeling-ballooning modes (PMB), yielding a pressure pedestal approximately as $p_{ped} \sim B_T \times B_P$. One successful path to high confinement on C-Mod is the high-density ($\bar{n}_e > 3 \times 10^{20}\mathrm{m}^{-3}$) approach, pursued using enhanced D-alpha (EDAs) H-mode. In EDA H-mode, transport regulates both the pedestal profiles and the core impurity content, holding the pedestal stationary, at just below the PBM stability boundary. We have extended this stationary ELM-suppressed regime to the highest magnetic fields achievable on C-Mod, and used it to approach the maximum pedestal predicted by EPED at high density: $p_{ped} \approx 60$kPa. Another approach to high pressure utilizes a pedestal limited by PBMs at low collisionality, where pressure increases with density and EPED predicts access to a higher "Super H" solution for p_{ped}. Experiments at reduced density ($\bar{n}_e < 2 \times 10^{20}\mathrm{m}^{-3}$) and strong plasma shaping ($\delta > 0.5$) accessed these regimes on C-Mod, producing pedestals with world record $p_{ped} \approx 80$kPa, at $T_{ped} \approx 2$keV. In both the high and low density approaches, the impact of the pedestal on core performance is substantial. Our exploration of high pedestal regimes yielded a volume-averaged pressure $\langle p \rangle > 2$atm, a world record value for a magnetic fusion device. The results hold promise for the projection of pedestal pressure and overall performance of high field burning plasma devices.

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