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Transport Barriers in DIII-D High βp plasmas and Development of Candidate Steady State Scenarios for ITER

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Shafranov shift stabilizes turbulence and creates a bifurcation in kinetic ballooning mode(KBM) transport that enables high performance ITB plasmas to be sustained at reactor relevant q_{95}. On DIII-D, the internal transport barrier (ITB), high β_N ~3, and very high normalized confinement $H_{98,y2}$~1.6 of the high β_p scenario has been achieved at q_{95}~6.5. This is projected to meet the ITER steady-state goal of Q=5. The ITB is maintained at lower β_p with a strong reverse shear, confirming predictions that negative central shear can lower the β_p threshold for the ITB. There are two observed confinement states in the high β_p scenario: H-mode confinement state with a high edge pedestal, and an enhanced confinement state with a low pedestal and an ITB. At large radius (ρ=0.8), the enhanced ITB confinement state has a much lower predicted turbulent ion energy transport than the H-mode confinement state. Simulating intermediate states, a large electromagnetic "mountain"of increased transport is found due to a KBM. Transient perturbations such as edge localized modes (ELMs) may trigger the transition between states by temporarily reducing the KBM drive. It has been observed that when there are no large type I ELMs, and there is no transition to enhanced confinement otherwise observed with lower n=3 perturbation. Quasilinear gyro-Landau fluid predictive modeling of ITER suggests that only a modest reverse shear is required to achieve the ITB formation necessary for Q=5 when electromagnetic physics including the KBM is incorporated.

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