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Attainment of a stable, fully detached plasma state in innovative divertor configurations.

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The heat load on plasma facing components is a critical engineering constraint for future tokamaks, which has stimulated the community to consider innovative magnetic divertor geometries for future high power devices. Present-day advanced divertor scenarios generally rely on partially detached regimes, also planned for ITER; a fully detached state would usually lead to MARFE and degradation of core confinement [1]. Modeling reveals that novel magnetic geometries can have a major impact on plasma detachment and power handling. Using the UEDGE tokamak edge transport model for configurations with tightly baffled long divertor legs, extended radially [2], or vertically, we find stable, fully detached divertor operation. Including a secondary X-point in the outer leg volume [3] extends the attainment of a stable detached state to the highest power. As the input power is reduced to a threshold value, the outer leg transitions to a fully detached state with the detachment front localized at the secondary X-point or in the leg volume; reducing the power further results in the detachment front steady-state location shifting upstream. As the power is reduced, the detachment front eventually moves to the primary X-point, which sets the lower power limit for the range of stable operation. Still, for a long-legged divertor, a fully detached, stable divertor regime is maintained over an order-of-magnitude variation in exhaust power. In contrast, a standard divertor has a much smaller detachment operational window. These results suggest that stable fully detached divertor operation can be realized in tokamaks with extended divertor legs. [1]Matthews, J. Nucl. Mater. 220-222 (1995) 104. [2]Valanju et al., Phys. Plasmas 16, 056110, 2009. [3] LaBombard et al., Nucl. Fusion 55, 053020, 2015.