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Study of passively stable, fully detached divertor plasma regimes attained in innovative long-legged divertor configurations

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Passively-stable fully detached divertor regimes have been found in numerical modeling of divertor configurations with radially or vertically extended, tightly baffled, outer divertor legs, with or without a secondary X-point in the leg volume [1]. Simulations carried out with the tokamak edge transport code UEDGE [2] using the base parameters of the ADX tokamak design [3] show that long-legged divertors provide up to an order-of-magnitude increase in the peak power-handling capability compared to conventional divertors, and a fully detached plasma state can be passively maintained over a wide range of parameters. In the simulations, the radial transport in the scrape-off layer is set to reproduce profiles observed in the experiment, which includes 'shoulders' indicative of main-chamber recycling phenomena [4]. In the UEDGE model used here, strong radial transport is assumed to occur in the outer divertor leg as well, leading to plasma predominantly recycling on the divertor leg outer sidewall. Analysis of simulations shows that the detachment front location is set by the balance between the power entering the divertor leg and the losses to the walls of the divertor channel. Therefore, for a fixed level of power exhaust, the location of the detachment front is insensitive to the divertor leg length - as long as the leg length exceeds the front location. The key physics for attaining the passively stable, fully detached regime involves an interplay of strong convective plasma transport to the divertor leg outer sidewall, confinement of neutral gas in the divertor volume, geometric effects possibly including a secondary X-point, and atomic radiation. In response to variation of model assumptions (magnitude of anomalous radial transport, impurity radiation, neutral transport model, geometry of plasma-facing components), the overall divertor plasma behavior remains qualitatively similar: a stable fully detached regime is maintained, lending confidence in the modeling results. [1] M.V. Umansky et al., Phys. Plasmas 24, 056112 (2017); [2] B. LaBombard et al., Nucl. Fusion 55, 053020 (2015); [3] T. D. Rognlien et al., J. Nuc. Mat. 196, 347-123 (1992); [4] B. LaBombard et al., Nucl. Fusion 40, 2041 (2000); *Work supported by US DoE contract DE-AC52-07NA27344 and cooperative agreement DE-SC0014264.

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