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The physics basis to integrate an MHD stable, high-power core to a cool divertor for steady-state reactor operation[1]

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Coupling a high-performance core to a low heat flux to the divertor is a crucial step for ITER and any future reactor. DIII-D recently expanded the steady-state hybrid scenario to high density and divertor impurity injection, to study the impact of increased density at high power and the feasibility of a radiating mantle solution. This work presents the physics basis for the trade-offs between density, current drive and stability to tearing modes at high beta. EC power is crucial to tailor the plasma profiles into a passively stable state, and to eject impurities from the core. Off-axis EC depositions decrease the heating efficiency, but calculated electron heat transport coefficients show that this effect is partially mitigated by improved confinement inside the EC deposition. The reduction in pressure is recovered by increasing the density. This favorable scaling of confinement with density was observed in high power plasmas for years, and this work provides a comprehensive explanation. ELITE predictions indicate that a path in peeling-ballooning stability opens up for certain conditions of density, power, q95 and shaping, allowing the edge pressure to continue increasing without encountering a limit. In the core, calculated anomalous fast-ion diffusion coefficients are consistent with density fluctuation measurements in the TAE range, showing that smaller fast-ion losses contribute to the enhanced confinement at high density. The edge integration study shows that divertor heat loads can be reduced with Ne and Ar injection, but this eventually triggers a cascade of n=1,2,3 core tearing modes. We can now show that impurity radiation in the core is small and it is not the cause for the drop in confinement at high Ar and Ne injection. The overlap between the core tearing modes is consistent with the loss of pressure as estimated by the Belt model for the coupled rational surfaces. Optimization of these trade-offs has achieved plasmas with sustained H98y2=1.7, fGW=0.7 and ~85% mantle radiation.

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