MHD stability constraints on divertor heat flux width in DIII-D

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The radial width of heat flux flowing into the DIII-D divertor is found to expand at high input power and plasma density, exceeding the existing empirical scaling [1], but consistent with MHD stability limits. This broadening does not inherently lead to degradation of the edge pedestal and core confinement. At low heating power, ~3 MW, the SOL width remains consistent with established empirical scaling [1], dependent only on the midplane poloidal field. The low power midplane separatrix normalized pressure gradient, α_{MHD}, also remains below the stability limit, α_{crit} ~2.5, even for the higher density required for divertor detachment. At high heating power, ~ 13 MW, a higher separatrix density, $n_{e,sep}$, and resulting higher separatrix pressure, are required to achieve divertor detachment. For $n_{e,sep}$ approaching half of the Greenwald density limit the separatrix pressure gradient saturates, consistent with previous studies[2]. Further increases in density or input power result in a broadening of the SOL and divertor temperature and density profiles, maintaining the pressure gradient near the MHD limit. However, any increased turbulence associated with SOL broadening does not excessively propagate inward to degrade the edge pedestal pressure and overall core plasma performance as long as the divertor dissipation is not increased significantly beyond detachment onset. The separate components of the midplane pressure profile are measured with Thomson scattering for the electron pressure and Charge-Exchange Recombination spectroscopy (CER) of the CVI impurity emission for the ion temperature and density contributions. Due to the challenging data analysis and interpretation the CVI ion data will be compared to main ion CER measurements. The separatrix normalized pressure stability limit, α_{crit}, is evaluated with the ideal MHD code BALOO based upon magnetic equilibria reconstructed with measured pressure profiles. The stability limit is found to be relatively constant across the data set at α_{crit} ~2.2 – 2.7. The sensitivity of this analysis to power balance assumptions for location of the separatrix will also be explored. These results imply the potential for divertor heat flux dissipation in future high power tokamaks at lower electron and impurity density than forecasted by existing scaling models [3].

[1] T. Eich, *et al., Nucl. Fusion* **53** (2013) 093031.
[2] T. Eich, *et al., Nucl. Fusion* **58** (2018) 034001.
[3] M.L. Reinke, *et al., Nucl. Fusion* **57** (2017) 034004.

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