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X-point radiator control and its dynamics in ASDEX Upgrade and JET deuterium–tritium discharges

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Effective heat exhaust control is critical for the successful operation of power-producing fusion reactors. This work presents heat-exhaust feedback control experiments conducted on the JET and AUG tokamaks. At JET, we demonstrate the first successful control of the X-point radiator (XPR) using argon seeding in both deuterium-deuterium (DD) and deuterium-tritium (DT) plasmas. In AUG, we enhance XPR control through nitrogen seeding, achieving, for the first time, a detached L-H and H-L confinement mode transition within a single discharge.

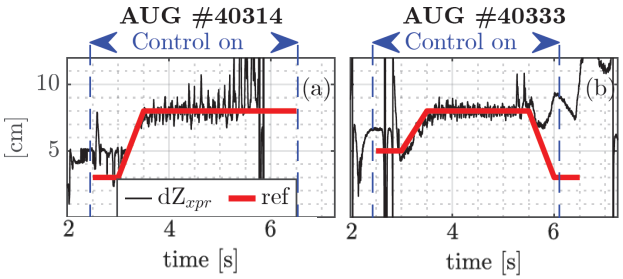

Figure 1: Improved control of the X-point radiator using nitrogen seeding in ASDEX-upgrade [2,3].

The controllers are developed using a model-based design approach, with models derived from perturbative system identification experiments [4]. We investigate the dynamic response of the XPR to different impurity seeding gases and a range of operational conditions. Our results indicate that the XPR's sensitivity (relative gain) depends on the vertical position of the radiator within the confined plasma region, while the relative phase remains consistent across operating points. Additionally, in AUG, we observe reduced XPR sensitivity to impurity seeding at higher heating powers. In JET, we find that XPR dynamics are similar in both DD and DT plasmas, but effective control is achieved only with argon, not neon. These findings

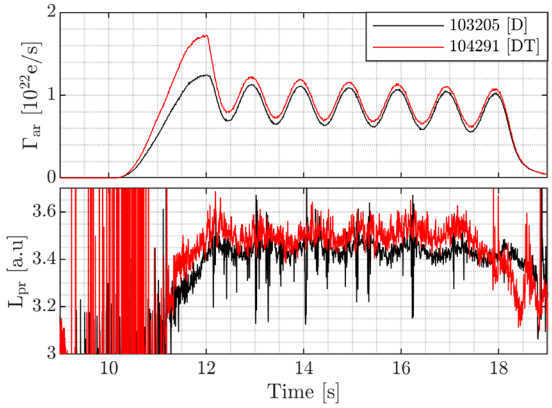

Figure 2: Comparison of the response to a sine perturbation in argon puffing in JET deuterium and deuterium-tritium discharges.

suggest that control strategies developed during early operational phases of future fusion devices can remain applicable and be fine-tuned for full-power scenarios.

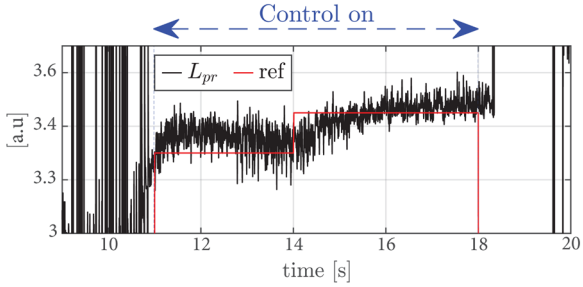

Figure 3: Control of the X-point radiator position in a deuterium-tritium discharge at JET [2].

References
[1] Zohm H. *et al 2013 Nucl. Fusion* 53 073019
[2] T.O.S.J. Bosman *et al* 2025 *Nucl. Fusion* **65** 016057
[3] Bernert M. *et al* 2020 Nucl. Fusion 61 024001
[4] M. van Berkel, *et al, 2025 (submitted)*