First demonstration of real-time exhaust control in long-legged, strongly baffled, alternative divertors configurations

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The challenging power-exhaust issue [1] is compounded in compact reactor designs that promise a more cost-effective path to commercial fusion energy, such as SPARC and STEP. Alternative divertor configurations are posed as a potential solution [2] by leveraging magnetic topology and strong baffling [3]. In presence of core fluctuations and core radiative limits, active control of detachment is a requirement for any future device [4]

This work presents the first demonstration of exhaust control in long-legged, strongly baffled, alternative divertor configurations. We demonstrate feedback detachment control in the MAST-U Super-X and Elongated divertors through deuterium gas puffing. We identify the divertor dynamics through dedicated system identification experiments. Our results indicate: 1) an increased capability for passive transient buffering in the Super-X divertor, a potentially crucial attribute in effectively managing fast disturbances, inline with theoretical expectations [4]; and 2) strong decoupling between upper and lower divertors, as well as between the divertors and core plasma. This illustrates the effectiveness of strong baffling and may imply that independent control of core density and divertor detachment states is possible.

The large detachment window in which various processes contribute at different locations complicate detachment control and necessitate a more precise detachment qualifier. We therefore demonstrate molecular Fulcher band emission as a direct proxy for the ionisation region - a significant milestone for detachment control, departing from indirect methods [5,6]. We show how such detachment sensor strategies can be applied in reactor-relevant conditions.

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