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Improving exhaust performance with total flux expansion and the strongly baffled X-point target divertor on MAST-U

N. Lonigro[1,2], K.Verhaegh[3], J. Harrison[1], B. Lipschultz[2], C. Bowman[1], F. Federici[4], J. Flanagan[5], D. Greenhouse[2], Z. Huang[1], D. Moulton[1], P. Ryan[1], R. Scannell[1], S. Silburn[1], the MAST-U Team[5] and the WPTE Team[6]
[1]UKAEA, Culham Campus, Abingdon, Oxfordshire,OX14 3DB, United Kingdom
[2]University of York, Physics dept Plasma Institute, York, United Kingdom
[3]Department of Applied Physics, Eindhoven University of Technology, Eindhoven, Netherlands
[4]Oak Ridge National Laboratory, Oak Ridge, TN, United States of America
[5]University of Liverpool, School of Electrical Engineering, Liverpool, United Kingdom
[5]See the author list of J.R. Harrison et al 2024 Nucl. Fusion 64 112017
[6]See the author list of E. Joffrin et al. 2024 Nucl. Fusion 64 112019
e-mail (speaker): nicola.lonigro@ukaea.uk

Power and particle exhaust is one of the key remaining challenges on the path to a fusion reactor. Alternative divertor configurations (ADCs) are currently being studied on a variety of devices as a risk mitigation strategy for conventional reactors and as a baseline solution of more compact reactor designs.

The Super-X divertor (SXD) configuration on MAST-U combines strong neutral baffling, a large poloidal leg length, and a large strike point major radius to significantly improve the divertor exhaust performance compared to the conventional divertor (CD), without affecting the performance of the core. It has shown reduced peak particle and heat fluxes (>20x) to the target, improved access to the detached divertor regime, and a reduced sensitivity of the detachment front location [1][2]. Further improvements are possible in the X-Point Target (XPT) configuration (figure 1), obtained by adding a secondary poloidal field null near the separatrix.

The first results in NBI-heated XPT H-mode discharges are presented and compared with the SXD, using advanced imaging techniques[3][4] to study the 2D plasma parameters in the divertor (figure 1).

The wider divertor electron density profile and longer connection length lead to more integrated plasma-neutral interactions, evidenced by the larger volume-integrated hydrogenic emission. Coupled with the large local poloidal flux expansion, the XPT further reduces the peak target particle fluxes, heat fluxes and electron temperatures in deeply detached conditions compared to the SXD.

The decreased sensitivity of the detachment front location due to total flux expansion is retained in the XPT, which maintains a slowly moving detachment front position with increasing diverter neutral pressure even once the front moves upstream of the secondary X-point.

Preliminary results for both SXD and XPT configurations show improved ELM buffering with increasing neutral pressure and that both are able to completely buffer small enough ELMs ($\Delta W \lesssim 2$ kJ) with moderate levels of divertor fuelling and no impurity seeding, whereas the CD is attached for comparable conditions[5].

Overall, the XPT augments the benefits of the SXD by further increasing the volume for plasma neutral interactions in the detached region. Future studies will explore how these benefits extend to more attached conditions and in seeded conditions.

References

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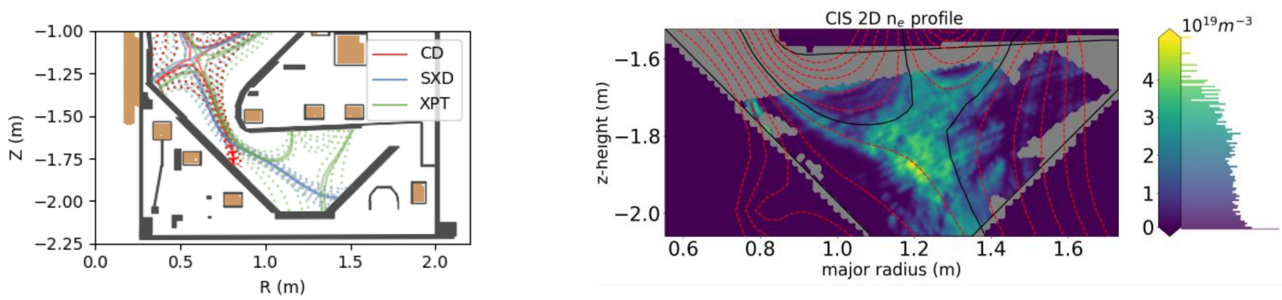

Figure: (Left) EFIT magnetic reconstructions of the CD, SXD and XPT equilibria in H-mode discharges.
(Right) Experimental n_e profile in the XPT configuration inferred via coherence imaging spectroscopy (CIS) [4]