17th Kudowa Summer School "Towards Fusion Energy" Kudowa Zdrój, 3 – 7 June, 2024

Exploring Alternative Divertor Configurations for Efficient Power Exhaust: the MAST Upgrade Super-X Divertor

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Abstract

The management of intense heat and particle fluxes to the plasma-facing components in tokamak divertors, while maintaining acceptable core performance, stands as a critical challenge for fusion energy. Traditional divertor designs may not provide adequate power exhaust, while preserving core performance, in future reactors. As a risk mitigation strategy, altering the magnetic topology of the divertor enables generating Alternative Divertor Configurations (ADCs) that reduce target heat loads and facilitate plasma detachment.

MAST Upgrade leverages extreme divertor shaping within a closed divertor to intensify plasma-neutral interactions to generate the Super-X ADC. The MAST-U Super-X has yielded remarkable results, highlighting drastic reductions in target heat flux (exceeding a tenfold decrease) and detachment onset (over 50% improvement) without compromising core performance. Studying the physics of the Super-X reveals an intricate interplay of plasma-atom/molecular interactions driving power exhaust, which appears to extend to reactor-relevant simulations.

The Super-X divertor is characterised by extending the divertor target to a larger radius, enhancing the ratio between the magnetic field at the target and the X-point. Our MAST-U results indicate that these advantages persist even in scenarios with more modest divertor shaping and a lower target radius. This underscores the potential of divertor shaping and ADCs as powerful tools for optimizing divertor designs, thereby offering viable strategies for enhancing exhaust systems in future fusion reactors.