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MODELLING DIVERTOR SOLUTIONS FOR POWER EXHAUST: IN-DEPTH EXPERIMENTAL VALIDATION IN TCV

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Power exhaust remains a key challenge for tokamak-based nuclear fusion, requiring accurate prediction and control of heat loads on divertor targets. Strategies such as increasing divertor closure and exploring alternative divertor configurations (ADCs) are central to mitigating target heat and particle fluxes. The Tokamak à Configuration Variable (TCV) [1] is uniquely equipped to investigate both approaches, allowing for flexible divertor shaping [2] and variable gas-baffling [3] while featuring extensive divertor diagnostics.

This work presents a comprehensive validation of SOLPS-ITER [4,5] simulations against a broad experimental database built from L-mode discharges in TCV, including standard lower single null (LSN) and advanced divertor configurations. The experiments were specifically designed for code validation, relying on high reproducibility and maximised edge and divertor diagnostic coverage. This enables two-dimensional measurements of electron and ion temperatures, density, parallel ion flow, and impurity emissivity, along with wall heat and particle loads and divertor neutral pressure.
Legacy SOLPS-ITER simulations were found to overestimate dissipative effects at the targets, predicting a denser and cooler divertor than observed experimentally [6]. This work introduces key modelling refinements: core-edge coupling is improved using the JINTRAC framework; ion flux limiters are investigated to account for kinetic effects; and carbon source modelling is revised through improved treatment of physical and chemical sputtering. These adjustments lead to significantly improved agreement with experiments, reproducing target conditions and divertor neutral pressure across various density regimes, levels of divertor closure, and magnetic geometries.

Insights from validated scenarios have informed predictive modelling of TCV's forthcoming divertor upgrade, the Tightly Baffled Long-Leg Divertor (TBLLD). Preliminary simulations indicate enhanced detachment and impurity control [7], supporting its development as a promising advanced divertor concept for future fusion devices.

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