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DIVGAS: A Robust and Reliable Workflow for Modelling Divertor Neutral Gas Flow and Optimizing Divertors in Next-Generation Fusion Reactors – Applications to DTT and EU-DEMO Divertors

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The DIVertor GAs Simulator (DIVGAS), developed by the Vacuum group at the Karlsruhe Institute of Technology (KIT), offers a powerful and reliable framework for optimizing and evaluating divertor design –a critical component in advancing fusion technology in next-generation fusion reactors. The DIVGAS framework features two powerful modules –a deterministic one and a stochastic one –allowing users to choose the best fit for their needs. The stochastic module is based on the Direct Simulation Monte Carlo (DSMC) method, while the deterministic module on the Discrete Velocity Method (DVM). Both methods accurately capture neutral gas behaviour across the entire range of collisionality expected in fusion reactor particle exhaust systems, establishing DIVGAS as the leading tool for divertor research. DIVGAS is focused on one of the most critical challenges in fusion reactor operations: creating an approach for particle exhaust in the divertor that aligns with both operational constraints and requirements. DIVGAS represents the main numerical tool for particle exhaust simulations within several EUROfusion work packages (i.e. WP-TFV, WP-PWIE, WP-DIV, etc.).
In the present work two representative divertor analysis examples will be presented, namely the DTT (Divertor Tokamak Test Facility) [1-3] and the EU-DEMO (European Demonstration Power Plant). Both examples include 3D complex modelling of sub-divertor neutral gas dynamics, marking them as the first of their kind, and emphasize the significance of three-dimensional effects. Several key quantities are quantified, including particle fluxes through various surfaces, while the contours of neutral pressure and temperature are also provided to offer a comprehensive overview of the neutral gas dynamics in the sub-divertor region. For both divertors, a significant impact of the leakages on pumping performance was observed, with deuterium flux through the leakages contributing approximately 20-30%. Meanwhile, the flux through the entry gaps towards the plasma vessel consistently accounts for the largest portion of the total incoming flux to the sub-divertor area (~60% for DTT and >60% for EU-DEMO). The present DIVGAS simulations uncover key insights into the particle exhaust of DTT and DEMO, providing a robust framework for developing optimization strategies to improve divertor pumping performance.

References

[1] C. Tantos et al., Nucl. Fusion 62 026038 (2022); [2] C. Tantos et al., Nucl. Fusion 64 016019 (2024); [3] C. Tantos et al., Fusion Eng. Des. 115021 (2025)

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