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Evidence for enhanced cross-field transport mechanisms in the TCV Snowflake divertor[1]

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TCV experiments demonstrate that cross-field plasma transport is enhanced in the Snowflake divertor (SFD) compared to a standard single-null divertor (SND). This enhanced cross-field transport spreads the exhaust power over a larger surface area than can be achieved by magnetic geometry alone and, thereby, reduces the peak heat flux. Comparison of the experiments with modelling identifies steepened radial gradients, ExB drift effects, and β_p-driven instabilities as the responsible transport mechanisms. The uncovered physics is also relevant to the SND and may help improve predictive models for the target profiles in ITER and DEMO. In SFD variants with an X-point in the scrape-off layer (SOL), part of the heat flux profile is split off and redirected to an additional target. The resulting steepened radial gradients enhance cross-field diffusion. This is confirmed by EMC3-Eirene simulations, which show a factor two reduction of the parallel heat flux, even if diffusivities remain constant. Theoretical analysis predicts enhanced ExB drifts in the SFD by increased poloidal gradients of the temperature and density. The predictions are confirmed by target heat and particle flux measurements in dedicated experiments with both toroidal field directions. Cross-field convection by curvature-driven modes at high β_p ("churning modes") explains the large fluxes into the private flux region of the SFD. This activates the extra targets and reduces the peak power to the primary targets up to a factor four. This mechanism is expected to be most effective when the divertor conditions are most severe: near the separatrix of a narrow, high-pressure SOL of a large tokamak. These and other alternative divertor configurations thus provide potential solutions to the power exhaust challenge, as well as laboratories to study SOL transport, one of the most important topics in tokamak research.

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