Validation of low-Z impurity transport theory using boron perturbation experiments in ASDEX Upgrade

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Impurities are unavoidable in fusion plasmas and potentially problematic as they result in fuel dilution and radiative energy losses. Therefore, it is important to have accurate predictions of impurity behavior in future fusion devices, which requires a validated theoretical description of impurity transport. With this goal, an experimental technique was developed at ASDEX Upgrade (AUG) to separately identify the diffusive and convective components of the boron particle flux [1]. Using this technique, a database of B transport coefficients covering a wide range of plasma parameters has been assembled and can now be used to validate theoretical predictions of low-Z impurity transport. This database shows that the normalized ion temperature gradient (R/L_{Ti}) is the strongest ordering parameter for both the B diffusion and convection and strong R/L_{Ti} (>6) is a necessary ingredient to obtain hollow B density profiles in AUG. This database also shows that large changes in the applied neutral beam injection (NBI) have a relatively small impact on impurity transport compared to similar changes in electron cyclotron resonance heating (ECRH). Even low levels of ECRH power dramatically increase both the diffusive and convective fluxes and lead to peaking of the impurity density profile. First comparisons to a combination of neoclassical and quasi-linear, gyrokinetic simulations show good agreement for plasmas heated with a combination of NBI and ECRH. This dataset provides an excellent experimental validation of the complicated, non-monotonic, predicted convective-particle-flux created by the combination of pure-pinch, thermo-diffusion, and roto-diffusion. In addition, this dataset demonstrates a non-monotonic dependence of the experimental particle diffusivity to ion heat conductivity (D_Z/χ_i) in good agreement with theoretical predictions. In comparison, neither the convection nor the diffusion is well reproduced in plasmas heated by NBI only, despite the fact that plasmas dominated by ion temperature gradient (ITG) turbulence modes are traditionally the best understood.

[1] C. Bruhn *et al* 2018 Plasma. Phys. Control. Fusion **60** 085011; Corrigendum Bruhn C. *et al* 2020 Plasma Phys. Control Fusion **62** 049501