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Transport of collisional impurities with flux-surface density variation in stellarator plasmas

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Highly charged impurities both dilute plasmas and lead to radiation losses, and thus cannot be allowed to accumulate in the core of a magnetic confinement fusion reactor. For stellarators, the outlook has been particularly pessimistic, as early theories predicted that impurities would unavoidably be transported inwards in the core.

However, recent theoretical work has shown that strong temperature gradients can transport impurities outward, in the reactor-relevant scenario of a weakly collisional bulk ion species and a collisional impurity species. In this work, we extend these results to allow for variations of the impurity density on the flux surface in response to an externally applied electrostatic potential, due to –for example –the presence of anisotropic fast particles.

Specifically, we consider the radial transport of a collisional but trace ($Z^2 n_z \ll n_i$) impurity species which varies in response to Φ.
We calculate the neoclassical transport of the impurities, and find that localized impurity densities can have a large effect on the radial flux – even producing sign change – compared to the homogeneous n_z case. Tentative results show that this effect may be highly relevant for understanding the lack of impurities in "impurity hole" shots in LHD, but less relevant for carbon transport in W7-X due to the smaller Φ-variations in the latter. However, the effect becomes more important at higher impurity-charge, and can thus be expected to be relevant for tungsten transport also in W7-X.

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