Neoclassical study of the isotope effect with light impurities in density pedestals

S. Buller[1], I. Pusztai[1], S.L. Newton[1,2], J.T. Omotani[1]

[1] *Department of Physics, Chalmers University of Technology, SE-41295, Göteborg, Sweden*

[2] *CCFE, Culham Science Centre, Abingdon, Oxon OX14 3DB, UK*

The energy confinement time in tokamaks is observed to increase for heavier hydrogen isotopes, in contrast to naïve diffusive estimates based on a gyroradius-scale step-size. The relevance of this long-standing *isotope scaling problem* lies in the need to develop an accurate ability to model the behaviour of future experiments, ranging from the non-activated phase of ITER to reactors operating with D-T mixture. Existing experimental results indicate that a favorable isotope effect may originate from the improvement of the pedestal confinement [1], and acquiring an improved dataset is the subject of intense experimental effort [2].

In the pedestal simple diffusive estimates of transport break down, as the plasma profiles can vary significantly over an ion orbit width, introducing an orbit-width scale radial coupling and corresponding non-local behavior. This suggests that the pedestal transport of succesively heavier species could be increasingly correlated with their core transport, which may lead to an improved energy confinement. In this work we numerically explore this hypothesis, in a steep density pedestal using the radially global δf drift-kinetic code PERFECT [3]. We investigate how neoclassical radial fluxes of heat, particles and momentum – and in particular their deviations from local simulations – are affected by various pedestal profile features, such as the pedestal width and pedestal height. Furthermore, we investigate the variations in the experimentally more accessible non-trivial poloidal flow patterns, caused by the divergence-free nature of the radial-poloidal fluxes.

Finally, we also consider the impact of non-trace low-Z impurities, namely helium and lithium. These are significant impurities as the former will be abundant in D-T reactors, whilst the latter will arise in devices featuring Li plasma facing components as a possible solution to plasma-wall interaction problems.

References

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