# On the effects of kinetic minority ions on transport in Wendelstein 7-X

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Three-dimensional transport modeling in the plasma edge region and in divertors is challenged, amongst others, by the typical hybrid kinetic–fluid character of multi-phase flows. In most of the current edge plasma codes all ion components are typically described in a fluid approximation. However, particularly for minority components, the life span of some of these ions compared to local collisional relaxation times can be too short to meet the fluid constraint.

The three-dimensional edge transport code package EMC3-EIRENE [1,2] provides a unique hybrid fluid–kinetic solution approach within a single, largely monolithic Monte-Carlo description. Hence, it is particularly well suited for an integrated hybrid treatment of the various neutral and minority ion components in a (fluid) bath of electrons and main ions.

Recent results [3] have already highlighted significant ballistic effects when treating $He^{+}$ ions kinetically, in He–$He^{+}$–$He^{2+}$ edge plasma conditions typical for early limiter Wendelstein 7-X helium discharges. For the investigated conditions it turned out that the primary source of singly charged helium is ionization of He, rather than recombination of $He^{2+}$. This is distinct from approximations made in earlier 2D edge plasma simulations in which all He ion charge states were treated with continuum approximations and strong mutual coupling assumptions (e.g. a common temperature for all ion components).

We extend the rudimentary kinetic ion treatment within EIRENE with important features, e.g. drift effects and pitch-angle scattering. With this enhancement, we revisit previous investigations on helium operation in Wendelstein 7-X, as well as expand the impurity species study with hydrogenic and carbon ions. Although we presently focus on stellarator physics, the expanded kinetic ion transport strongly coupled to the neutral gas component can analogously be applied to tokamak studies. We draw conclusions on transport features, and plasma profiles and give an outlook on how the full three-dimensional EMC3-EIRENE code package is being further developed into a useful and predictive tool for impurity studies for ITER.

## References

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