# Tangential magnetic drift, tangential electric field and their impact on stellarator radial neoclassical transport

I. Calvo[1], F. I. Parra[2,3], J. L. Velasco[1], and J. A. Alonso[1]

[1]*Laboratorio Nacional de Fusión, CIEMAT, Madrid, Spain*
[2]*University of Oxford, Oxford, United Kingdom*
[3]*Culham Centre for Fusion Energy, Abingdon, United Kingdom*

In general, the orbit-averaged radial magnetic drift of trapped particles in stellarators is non-zero due to the three-dimensional nature of the magnetic field. Stellarators in which the orbit-averaged radial magnetic drift vanishes are called omnigeneous [1,2], and they exhibit neoclassical transport levels comparable to those of axisymmetric tokamaks.

In the $1/\nu$ regime of non-omnigeneous stellarator neoclassical transport (and in higher collisionality regimes), the piece of the electrostatic potential that is non-constant on the flux surface (equivalently, the component of the electric field that is tangent to the flux surface) is irrelevant for the radial transport of the main ions, and so are the tangential drifts. However, for lower ion collision frequencies (below the values that define the $1/\nu$ regime), the situation is different. Using recently developed techniques [3], we treat such low-collisionality regimes. These techniques rely on an asymptotic expansion in which the small expansion parameter is the size of the deviation of the magnetic configuration from an exactly omnigeneous one.

First, we prove that closeness to omnigeneity allows to rigorously derive a radially local, bounce-averaged drift-kinetic equation for collisionalities below the $1/\nu$ regime, and we give the correct way to incorporate the tangential drifts in this equation, and in particular the tangential magnetic drift. Then, we show that radial neoclassical transport is determined by two small layers at different regions of phase space; one of them corresponds to the $\sqrt{\nu}$ regime and the other one to the superbanana-plateau regime.

We explain why, under these conditions, the tangential component of the electric field has to be correctly calculated in order to compute the radial neoclassical fluxes of the main ions (at least if no large aspect ratio assumption is made), and why resolving the superbanana-plateau layer is fundamental for working out the tangential electric field. The role of the tangential electric field is essential for the emergence of a new subregime of superbanana-plateau transport when the radial electric field is small, and therefore when the tangential magnetic drift is more important. Strikingly, in this subregime a large tangent electric field appears at the bounce points of certain resonant trapped-particle trajectories.

## References

[1] J. R. Cary and S. G. Shasharina, Phys. Plasmas 4, 3323 (1997)

[2] F. I. Parra, I. Calvo, P. Helander et al., Nucl. Fusion 55, 033005 (2015)

[3] I. Calvo, F. I. Parra, J. L Velasco and J. A. Alonso, Plasma Phys. Control. Fusion 59, 055014 (2017)