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Neoclassical and turbulent transport in stellarators

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Due to the lack of a symmetry direction in stellarators, it is not necessary to drive current in the plasma to achieve a stable MHD equilibrium. Thus, stellarators do not need costly current-drive systems and do not suffer from current-driven instabilities. These advantages come at a cost: expensive magnets, islands at rational flux surfaces, large energetic particle losses, large neoclassical transport... Of all the aspects of active research in stellarators, this talk will focus on the transport of thermal particles (both neoclassical and turbulent).

First, we will consider the neoclassical transport of particles, energy and momentum in the low collisionality regime relevant in the core of stellarators. In an unoptimized stellarator, there are direct orbit losses and understanding confinement requires a global treatment. However, when stellarators are sufficiently optimized [1], orbit losses are minimized, and neoclassical transport can be treated as a radially local problem [2,3]. We will emphasize that the problem takes a very simple form when expressed in terms of the map of the second adiabatic invariant. Surprisingly, neoclassical fluxes are well above the gyroBohm level and larger than turbulent fluxes. We will describe the processes that lead to this large neoclassical fluxes, making connections with tokamaks with ripple [3].

After discussing neoclassical transport, we will consider the most recent efforts to model turbulent transport in stellarators. We will emphasize the fundamental differences between tokamak and stellarator turbulence: the complicated zonal flow response of stellarators [4] and the problems of the flux tube treatment in systems without symmetry [5,6].

References

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