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The effect of transient density profile shaping on transport in large stellarators and heliotrons

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Continuous fueling is a prerequisite for steady-state stellarator and heliotron fusion reactor operation. For 3D magnetic field configurations, outward directed thermodiffusion gives rise to density depletion in the hot plasma core which needs to be compensated by appropriate fuelling schemes. Pellet injection may generate particle sources relevant to the development of discharge scenarios applicable to reactor operation.
LHD and W7-X are sufficiently large to generate plasmas in transport regimes as anticipated for reactors, i.e. to allow studies in the long-mean-free path collisionality regime at high plasma beta. Beyond the capability of allowing to study reactor grade 3D plasmas, the development of quasi steady-state operation scenarios is an objective of experimental strategies.

In 3D fields, transport processes after pellet injection shows characteristics of diffusive and convective contributions. The resulting thermodynamic forces also influence radial electric fields - both as a driving term but also by, e.g., affecting the Er dependence of ion transport.
Experiments have been conducted at different magnetic configurations on LHD. The spatio-temporal evaluation after the injection of a pellet in a LHD discharge showed cases with central density increase on the time scale of transport processes. The temperature gradient length and the density gradient length - and consequently the radial electric fields - change during the density relaxation and have impact on the fuelling efficacy. The time scale of the decay of the stored energy, however, follows the longer decay time of the particle time traces resembling the particle confinement time.

These experimental findings indicate a clear change of the thermodynamic forces, i.e. in particular the inverse density gradient length in the decay phase after pellet injection. The inverse temperature gradient lengths are varying much less, thereby the ratio of both shows a variation even changing its sign. Both measurements and estimates for the radial electric field indicate changes in Er. The paper will discuss transport analyses for extended variations of the magnetic configuration (Rax = 3.6, 3.7, 3.9 m) and the effect of pellet size and sequencing.

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