Energy confinement time scaling in GYSELA flux driven simulations:

ρ* and isotope effect

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In the trade-off between cost and performance, the main dimensionless parameter that governs the energy confinement time τ_E is observed to be $\rho^* = \rho_i / a$ where ρ_i is the main ion species Larmor radius and a the minor radius [1]. For the ITER reference scenario (scaling IPB98(y,2)), one finds that $\tau_E = N\, \tau_B M^{\mu} (\rho^*)^{\alpha}$ where $\tau_B = a^2/D_B$, $D_B = T/eB$, N is a numerical factor, M the mass number and $\mu = 0.54$, $\alpha = -0.7$ [1]. Other dependencies are not discussed here. The ρ^*-scaling is thus quite close to the gyroBohm scaling $\alpha = -1$. Consistently, one would then expect a mass dependence scaling as $\mu = -0.5$, while the inverse is observed in the empirical scaling. In the latter, the confinement time varies by two orders of magnitude, yielding typically a 5.5 ratio between the largest and smallest ρ^* value. Given the result of gyrokinetic simulations [2, 3], namely the transition from Bohm to gyroBohm transport when $1/\rho^*$ is increased, one finds that the empirical scaling encompasses a large range of Bohm transport, $\alpha = 0$, and only part of the Bohm to gyroBohm transition -assuming COMPASS at $1/\rho^* \approx 50$ and JET at $1/\rho^* \approx 300$. This is in contradiction with the gyroBohm trend, $\alpha = -0.7$.

We address these issues with the GYSELA code with $1/\rho^* \approx 75$ and $1/\rho^* \approx 150$ flux driven simulations. These are achieved for the three isotopes of hydrogen (H, D, T) with consistent or impeded zonal flows. The standard simulations with consistent zonal flows exhibit complex self-organisation with Micro Transport Barriers (MTB). These govern corrugations of the temperature profiles. Avalanche transport is observed in all simulations. With MTBs, the avalanches can be localized between the latter, or eventually burn across them, leading to reorganisation of the MTB radial pattern. Although the $1/\rho^*$ values belong to the Bohm branch of the gyrokinetic simulations [2, 3], one finds that the isotope effect governs a gyroBohm behaviour. Indeed, the correlation length and correlation time exhibit a mass scaling consistent with the Larmor radius and parallel transit time respectively. Furthermore, the departure from the gyroBohm scaling appears to be more strongly related to the scaling of the correlation time, the complex radial self-organised structure still scaling with Larmor radius. Further analysis of the chosen subset of GYSELA flux driven simulations is under way to clarify these issues.

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