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TH/P3-06: Application of Particle-In-Cell Methods for Stellarators

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Particle-in-cell methods are an efficient way of simulating the gyrokinetic equation especially in complicated three-dimensional configurations such as stellarators because they are relatively easy to implement and show a good scaling behaviour on parallel machines. It is however necessary to employ variance reduction techniques in order to decrease the noise inherent to particle methods. Especially if electromagnetic effects are included, it is necessary to use an adaptive control variate technique to overcome the, so called, cancellation problem.
The code EUTERPE is a global (full radius, full flux surface) gyrokinetic particle-in-cell code which, for three-dimensional equilibria provided by the VMEC equilibrium code, is able to simulate up to three kinetic species (ions, electrons, fast/impurities). It solves the field equations for the electrostatic and parallel vector potentials and can be used for linear and nonlinear simulations. We give an overview of recent developments and applications of this code:
- Linear simulations of electromagnetic ITG modes in a sequence of Wendelstein 7-X equilibrium configurations with β increasing from zero to 5%. It was found that electromagnetic effects lead to a significant change in the growth rate and frequency of the modes as compared with the electrostatic case
- For three dimensional systems a new solver for the field equation including the flux surface averaged potential was developed. It allowed to simulate the relaxation towards residual zonal flows in stellarators including an external radial electric field.
- A hybrid model was developed where EUTERPE was coupled with the reduced MHD equilibrium code CKA. This allows the calculation of the energy transfer between fast particles and the MHD mode. This perturbative linear model gives an estimate of the expected growth rate induced by fast particles.
- The implementation of collisions gives the possibility of simulating neoclassical effects using the high flexibility of a Monte-Carlo method.

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