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A Modified Semi-Lagrangian scheme for non-linear Drift-Kinetic simulations of SLAB-ITG

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Understanding turbulent transport in magnetically confined fusion plasmas remains a key issue for present and future devices. The instabilities driven by ion temperature gradients (ITG) are one of the main instabilities held responsible for anomalous transport. This work focuses on non-linear global simulations of SLAB-ITG in an inhomogeneous collisionless plasma confined by a strong uniform magnetic field. In the drift-kinetic electrostatic model presented, the electrons are assumed adiabatic and the Larmor radius effects are neglected. With these assumptions the ion distribution function depends on the three cylindrical coordinates and on the parallel velocity.

While the linear theory is well established concerning the ITG modes, the non-linear evolution of these modes is a much more difficult problem to analyse. One of the important challenge for the non-linear codes is the energy conservation which is recognized as a key test of validity. The particularity of our massively parallel code is to solve the 4D non-linear Vlasov equation, which describe the evolution of the ion distribution function, by using a semi-lagrangian (SL) method. In the SL approach the particle motions are approximated by second order trajectories and the Vlasov equation is directly treated on a phase space grid which is fixed in time. Compared to PIC codes, one achieves a strong reduction of the numerical noise, especially in the regions of the phase space populated by the fast particles. Furthermore the energy conservation is achieved with reasonable accuracy ($\sim 15\%$).

We present here the new results obtained with a so called "modified semi-lagrangian (MSL) scheme" where the parabolic trajectory approximation has been replaced by an extrapolation of the trajectories with a Bulirsch-Stoer algorithm. The accuracy of this modified scheme is particularly convincing in the non-linear saturation phase. With a relative error on the energy conservation smaller than $2,5\%$, the MSL scheme appears to be an appropriate means to solve non-linear gyrokinetic problems with good control of the energy conservation property. This allows one to analyse the influence of energy conservation on the physical results.