Simulation of plasma instabilities in two- and three-dimensional fusion devices

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The understanding of plasma instabilities is a crucial issue in fusion physics, as they may lead to losses of particles, energy or both. For a theoretical description, it is desirable to employ numerical tools which address a broad variety of instabilities in the linear and in the nonlinear domain and which are capable to work for tokamaks and stellarators as well. The development of the GYGLES and the EUTERPE code aims particularly at this direction.

The GYGLES code [1] solves the linear electromagnetic gyrokinetic equation for ions, electrons and a third species (which can be fast particles or impurities) in the whole plasma domain (full radius) for a two-dimensional realistic tokamak geometry, calculated by the equilibrium code CHEASE. The code is linear so that a phase factor can be employed to reduce the grid resolution needed to simulate high mode numbers.

The EUTERPE code [2] can solve the nonlinear electromagnetic gyrokinetic equations for all plasma species (ions, electrons and fast particles) in the whole plasma domain (full radius, full flux surface) for a three-dimensional realistic stellarator geometry calculated by the equilibrium code VMEC.

Applications will be shown for linear ion-temperature gradient (ITG) modes, trapped particle modes, ballooning modes and toroidal Alfvén eigenmodes (TAE) in tokamaks with large and small aspect ratio. Furthermore, the transition of TAEs to energetic particle modes (EPM) will be discussed. TAE and EPM are especially important for the prediction of fast particle stability in ITER.

Turbulence simulations will be shown for cylindrical equilibria, which demonstrate the nonlinear behaviour of the method applied while linear calculations of collisional ITG modes will be presented for stellarator equilibria. Also, the influence of an external electric field on the residual zonal flow level will be investigated for different 3D equilibria.

For Alfvénic modes, an MHD-kinetic hybrid code CKA/EUTERPE is used to calculate growth rates in tokamak and stellarator geometries. It will be shown to what extend results of the fully kinetic approach can be recovered with conventional kinetic MHD using CAS3D-K [3]