CEA/CADARACHE
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Title : Realistic magnetic equilibrium and field aligned coordinates for high performance computing of gyrokinetic turbulence in tokamaks

Summary :
In magnetic fusion devices, the power gain nonlinearly increases with the energy confinement time. As a matter of fact, the quality of the plasma energy confinement largely determines the size and therefore the cost of a fusion reactor. This confinement time turns out to be mainly governed by the plasma turbulence which develops in such devices (of relative magnitude of a few percent in the hot core) and the associated transport. Understanding its origin and properties in view of its possible control is one of the critical issues in fusion science. Because of the weak collisionality in the hot core of fusion plasmas, a kinetic description of the plasma in phase space is the most justified approach. In such first principle description, the six dimensional evolution equation for the distribution function (Vlasov or Fokker-Planck equations) is solved for each specie, coupled to the self-consistent equations for the electromagnetic fields, namely Maxwell's equations.
As far as turbulent fluctuations are concerned, they develop at much lower typical frequencies than the high frequency cyclotron motion. Therefore, this non-linear 6D problem can be restricted to a 5D one by incorporating part of this small scale temporal behavior into the larger scales temporal dynamics of both the distribution function and the fields. This model is known as the gyrokinetic model. But even with this dimensional reduction, the task of developing 5D gyrokinetic codes reveals extremely challenging and requires state-of-the-art high performance computing (HPC).
Such a code (GYSELA) is developed in our institute since 10 years. It is electrostatic with adiabatic electrons. It computes the full distribution function of up to two ion species in a full torus. The considered magnetic equilibrium, made of concentric circular flux surfaces, is far from the one of ITER or of the WEST project for Tore Supra. Although the physical reason is not yet fully understood, it is observed that turbulence and transport are significantly modified by the magnetric geometry. Therefore, exploring different geometries opens the route towards fusion performance optimization.
The first part of the thesis will be to extend the operational domain of the code to realistic magnetic equilibria. This implies the development of a field solver in generalized coordinates. The idea is to use an innovative technique based on NURBS (Non Uniform Rational Basis Splines) which are very popular in CAD (Computer-aided Design). The GYSELA code will then be coupled to an equilibrium code such as CHEASE, which is already used by other physicists at IRFM.
The second part deals with the coordinate system of the code, which is now $(r,\theta,\varphi,v_{//},\mu)$ with r the radial direction, θ the poloidal angle, φ the toroidal angle, $v_{//}$ the velocity parallel to magnetic field line and μ the magnetic momentum. The drawback of this description is that it couples slow and fast motions, transverse and parallel to the magnetic field, respectively. The proposed work is then to move to field aligned coordinates. Developing this optimized coordinate system is mandatory in view of treating the electrons kinetically.

Skills : Master degree in applied mathematics or in plasma physics. Numerical profile with a strong interest for physics or plasma physicist profile with a strong interest for numerical simulation. In any cases the candidate must be interested in numerical programing activities.