Turbulent transport in magnetically confined fusion plasmas

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Among the numerous challenges that await fusion on its way to being an economically viable energy source, they are still several open issues related to controlling plasma confinement and in particular plasma turbulent transport [1]. In order to simplify the presentation, the problem can be framed in terms of thermal resistivity within the reactor. At present, the best performance is obtained in tokamaks [1] where a strong magnetic field generated by a set of large coil defining a torus are used to confine the plasma. To define a stable confining system several additional components of the magnetic field are generated. The geometry of the magnetic field plays a key role in confinement and plasma transport. An outstanding feature is the large anisotropy of transport along the magnetic field lines and that transverse to the field lines. The latter is strongly restricted by the Larmor gyration of the particles while the former appears to be free. We address here two facets of this asymmetry and its consequences on the confinement properties of fusion plasmas.

In the plasma core, one aims at sustaining plasmas with thermal energy up to 20 keV corresponding to temperatures in the range of $10^8 K$, while solid state condition of the vessel components facing the plasma must remain at temperatures in the 1000 K. The required thermal resistance transverse to the magnetic field of the turbulent plasma $R_\perp$ is therefore $R_\perp \approx 10^3\ K\ m^2\ /\ W$. The heat transport in these plasmas is investigated with very large kinetic simulations [2]. The kinetic approach is required because these plasmas are characterized by a very weak collisionality. In these global simulations where the drive of transport is a prescribed flux, one finds that the plasma is prompt to self organization with the generation of avalanche like transport events and large scale flows. Self regulation of plasma transport is also observed in regimes with temperature corrugation or transport barriers [3].

At the plasma edge, where plasma facing components intersect the magnetic field lines, a thin boundary layer is generated due to the very small parallel thermal resistance of the plasma, typically $R_\parallel \approx 10^{-3}\ K\ m^2\ /\ W$. Controlling the physics of this boundary layer is achieved by modifying the geometry of the magnetic field by so-called divertors. Results of the ergodic divertor of Tore Supra [4] will be recalled and relevance of the theoretical and experimental achievements for ITER operation will be presented. The complex interplay between non-linear ionization processes and transport along chaotic field lines will be addressed.

Références

1. Doyle I. J., Chapter 2 : Plasma confinement and transport, *Nuclear Fusion*, S18-S127, 2007.
2. Grandgirard V., A drift-kinetic Semi-Lagrangian 4D code for ion turbulence simulation, *Journal of Computational Physics*, 395-423, 2006.
3. Dif-Pradalier G., On the validity of the local diffusive paradigm in turbulent plasma transport, *Physical Review E*, 025401 (R), 2010.
4. Ghendrih Ph., Theoretical and experimental investigations of stochastic boundaries in tokamaks, *Plasma Physics and Controlled Fusion*, 1653-1724, 1996.