Improvements needed for Predictive Integrated Modeling of Plasma Rotation, Density and Temperature Profiles

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Validated integrated modeling studies are used to predict the performance of devices such as ITER (*e.g.,* fusion power production) and to carry out the scenario modeling for the design of magnetically confined devices. In addition, integrated modeling used to investigate the interaction of physical phenomena within magnetically confined plasmas. It is clear that improvements are needed to the modules that are used within the currently-available integrated modeling codes. Some of the urgently needed modules are described below.

The prediction of toroidal rotation profiles in tokamak plasmas is critically important since plasma rotation affects flow shear stabilization of turbulent transport and plasma rotation affects the stability of resistive wall modes and other large-scale instabilities. Recently, transport models have been developed that predict a strong inward momentum pinch, which results in validated predictions of the intrinsic rotation profile across the outer half of tokamak plasmas given the experimentally measured rotation at the edge of the plasma. The extension of these predictions for future experiments, requires, however, a suitable model for the edge plasma rotation. Detailed kinetic simulations do predict the rotation of the edge plasmas in H-mode tokamak discharges, but reduced models are needed for use in comprehensive integrated modeling.

Currently available transport models are not complete near the magnetic axis. In particular, there is a region in the inner 20 to 40% of the plasma where the ion drift modes (ITG and TEM) are stable and, consequently, turbulence driven by the ITG/TEM mode does not drive transport according to the currently available models. Within that deep core region, neoclassical transport is much too small for the electron thermal and momentum channels of transport. Predictive simulations necessarily include the deep core region of the plasma (the inner 20 to 40%) and a suitable transport model is needed for all of the channels of transport in this region of the plasma.

Integrated modeling simulations include the effects of large scale instabilities such as sawtooth oscillations, ELMs and tearing modes. Models have been developed and are being improved for triggering sawtooth crashes and ELM crashes. In order to predict multiple sawtooth or ELM cycles, however, a model is needed for the redistribution of the plasma current density produced by each sawtooth or ELM crash. There is experimental evidence that the plasma current is only partially redistributed by these instabilities. There is evidence from simulations that sawtooth and ELM cycle periods depend on the fraction of plasma current that is redistributed, which is also called the magnetic reconnection fraction.

There are clearly many more improvements that should be made to the models that are used within integrated simulations. The items described above are examples of some of the more urgently needed improvements.