Modelling Fusion Reactors – Challenges and Opportunities for Distributed Computing

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1. Introduction

Fusion energy is one of the very few renewable energy resources which can provide reliable base load power for the long term. It is an inherently safe process, since the fusion reaction is so difficult to maintain that the slightest disruption will cause it to shut down. Also, as opposed to fission reactors, the amount of fuel present in the reactor at any time is minimal and not only is there no possibilities of a chain reaction but also the dangers associated with nuclear proliferation are also greatly reduced. With the dangers of serious climate change becoming more evident and undoubtedly linked to anthropogenic greenhouse gases emission it is vital we fully explore all viable energy production alternatives. The next step on the way to achieving the goal of clean, almost unlimited fusion energy is the construction of a major experimental facility in Cadarache, France, financed by the European Union, China, India, Japan, Russia, South Korea and the United States, which will test several of the technical features needed for a power plant.

With the advent of the ITER device, currently under construction, research in this area has entered a new major phase and is now more relevant than ever. In this context, an increasing effort is being undertaken on understanding and modelling the main physics involved, with the aim of achieving an improved predictive capacity to help plan, configure and analyse ITER experiments.

2. Predictive capability requires Integrated Modelling

The main focus so far has been on the study of and validation of MHD stability and heat transport on current experiments. Historically, only smaller efforts have been devoted to the modelling of turbulent particle and impurity transport. Understanding the transport properties of impurities and He ash is important, since they are expected to significantly affect the performance of a fusion reactor by their contribution to radiation losses and main ion dilution. For example, high-Z impurity accumulation in the core region, predicted by neoclassical theory, would be devastating for fusion experiments. However, the presence of impurities at the edge of the reactor may be beneficial, and edge seeding of impurities is planned for future devices in order to create an edge-localized radiation belt for continuous heat exhaust. The behaviour of heavy impurities is of particular interest. However, a complete description of the impurity physic require coupling to edge physics codes and hence an Integrated Modelling approach is required that also that accurate account of sources terms for heating and current drive.

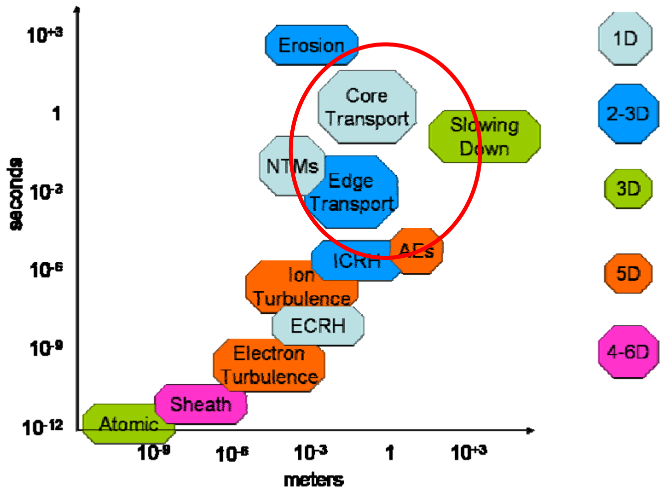

Fig. 1. The challenge of Integrated Modelling of fusion plasmas: Extreme range of temporal and spatial scales and vast range of computational requirements. The core and edge transport coupling is an active area of research and is also the interface where some of the most urgent issues reside.

3. Steps Forwards

There are large scale European and International activities relating to Integrated Modelling activities. In particular, EUFORIA [1] and MAPPER [2] are addressing the opportunities for distributed computing within the integrated modelling frameworks. EUFORIA successfully built on extending the capabilities of the Kepler workflow engine adding actors for transparent access to HTC and HPC resources whereas MAPPER are exploring distributed access through frameworks as MUSCLE and GridSpace with a range of new tools.

4. Conclusions and future work

The activities presented here are largely ongoing efforts and within a few years the remaining technology selections would have been made and a production facility would be made available.

References

1. EUFORIA – EU Fusion For ITER Applications RI-211804, `www.euforia-project.eu`
2. MAPPER – Multiscale applications on European e-infrastructures, `www.mapper-project.eu`
3. Kepler – `www.keplerproject.org`