6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Development of a plasma scenario for the EU DEMO tokamak reactor

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The plasma scenario for EU DEMO [1] has to fulfill the basic performance requirements (at present, 2 GW fusion power and pulse length in excess of 2 hours, derived from the EU stakeholder requirements for a DEMO machine) while at the same time respecting the boundary conditions of exhaust and controllability in order to minimize the risk of machine damage. We have addressed this problem by separating the plasma into three areas: core, edge and Scrape-Off-Layer (SOL)/divertor, which are described by different physics, but are nonlinearly linked in the scenario.

Candidate solutions for all three areas have been identified as follows:

- The plasma core is envisaged to be in the ‘hybrid’ scenario [2], characterized by a flat q-profile just above 1 and edge q_{95} in the range 3.5-4.0, which avoids sawteeth and leads to good energy confinement and a high no-wall β-limit without the need for active current profile control. This scenario has been chosen for its experimentally demonstrated good performance and robustness. It also has the prospect of allowing long pulses since central current drive is expected to be compatible and very efficient.
- The plasma edge is envisaged to exhibit an H-mode edge transport barrier, but without ELMs. We explore candidate no-ELM scenarios such as QCE [3] or EDA [4], with RMP suppression of ELMs [5] as a back-up solution to be validated in ITER. As a consequence, 3-D perturbation coils have been added to the design [6] that should also allow to correct error fields, manipulate locked tearing modes and tailor kinetic profiles through NTV.
- The presently envisaged SOL/divertor solution is based on a conventional single null divertor operated in detached mode [7]. This choice requires a relatively high core radiation fraction, limited by the need to stay in H-mode. Since the remaining power crossing the separatrix still presents a large challenge to the exhaust scheme, as a back-up solution, alternative divertor geometries and materials are studied within the EUROfusion programme [8].

A research programme has been set up within the EUROfusion science department that addresses these items in both experiment and theory, with the aim to obtain fully predictive capability for these elements in areas where we still rely mainly on experimental results and empirical scalings derived from them. The talk will highlight these areas and show how we address them in the EUROfusion programme in a combined experimental and theoretical effort. Examples treated will be electromagnetic and fast particle effects on transport [9], q-profile clamping by flux pumping [10] and pedestal tailoring by additional transport channels [11].

Together with the engineering choices such as magnet or coolant technology, this plasma scenario determines the basic features of the machine, including the geometric size. We will show the resulting present EU DEMO baseline design, which is built on conservative technology assumptions, and discuss the viability of different options to improve it, e.g. by reducing the aspect ratio or going to higher toroidal field.

For these optimization studies, it is important to develop tools that can be used to map out the available design space. One of them is a time independent systems code that integrates the physics and technology restrictions [12]. In our strategy, this is complemented by a newly developed ‘flight simulator’ [13] that allows to simulate the dynamics of controlling the scenario with unprecedented realism. Our developments in these two areas will also be reported.

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This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion).