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First principle scenario modelling of the Divertor Tokamak Test facility

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The construction of the D-shaped superconducting tokamak DTT (Divertor Tokamak Test facility) [1-3] is starting in Frascati, Italy. The main task of DTT is to study the controlled power and particle exhaust from a fusion reactor, which is a main research topic in the European Fusion Roadmap [4]. Alternative divertor configurations and improved plasma facing materials will be developed and tested in DTT, thanks to its high flexibility in magnetic configurations and divertor choice. A large amount of auxiliary heating (~45MW in the full power scenario) is provided by a 170GHz ECRH system, a 60-90 MHz ICRH system, and a system of 400keV negative ion beam injectors. The precise heating mix has still to be defined. The characteristics of DTT (R=2.14m, a=0.65m, BT≤6T, Ip ≤ 5.5MA, pulse length ≤ 100s) make it ITER and DEMO relevant.

In order to support the DTT design and the planning of its scientific work-program, first-principle based multi-channel integrated modelling of plasma profiles in different operational scenarios is required. The simulation results help to optimise the heating mix and provide scenarios for the design of diagnostics and pellet injectors, for calculations of heat and neutron loads, and for the assessment of issues such as ripple losses.

The DTT simulations have mainly been carried out with the JINTRAC [5] suite with the JETTO [6] transport solver. The simulations predict steady-state radial profiles of electron and ion temperature, density, current density, impurity densities and rotation within the separatrix. The impurity (Ar and W) densities and radiation are simulated with SANCO [7]. The ESCO code calculates a self-consistent equilibrium keeping fixed the boundary provided by the free boundary CREATE-NL solver [8]. In some cases, the ASTRA [9] transport solver has also been used to predict temperatures and density with fixed equilibrium, heating, toroidal rotation and impurities, taken from JINTRAC. The Europed code [10] calculates the pedestal using the EPED1 model [11], providing the boundary conditions for the simulations. The turbulent transport is calculated by the QuaLiKiz [12] or TGLF SAT1 [13] models, while the neoclassical transport is calculated by the Romanelli-Ottaviani model [14] for impurities and NCLASS [15] for main particles. The heating is modelled by GRAY [16] for ECRH, by PENCIL [17] for NBI, and PION [18] for ICRH.

Modelling results of 8 full power H-mode scenarios with Single Null (SN) divertor configuration have been compared to assist the forthcoming heating mix choice. The electron density has a moderately peaked profile and at the plasma center it reaches values in the range of $2.2\ 10^{20}\ m^{-3} < ne_0 < 2.7\ 10^{20}\ m^{-3}$. In the central region, the electron temperature T_e is in the range of 17-25keV, while ion temperature T_i is in the range of 8-13keV. This is due to the large and localized ECH power density and the high ion stiffness. The radiated power is around 15MW. In all cases a large amount of thermal power (~15MW) is exchanged from electron to ions. Depending on the sharing between the heating systems, the energy confinement time varies in the range of 0.25-0.5 and the DD neutron rate is in the range of $(0.8\text{-}1.7)10^{17}s^{-1}$ (~30% thermal). In addition, scenarios with reduced power for the initial phase of operations have been modelled, and configurations with negative values of triangularity have been explored.

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