THE DIVERTOR TOKAMAK TEST FACILITY RESEARCH PLAN

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This paper summarises the content of the Divertor Tokamak Test facility (DTT) Research Plan [1]. DTT, presently under construction in the Frascati (Italy) ENEA site, will be a device with breakeven class performance, which is designed to address one of the main challenges towards the construction of a fusion power plant, i.e., the development of credible solutions for the heat exhaust.

The Research Plan describes the objectives and research strategy of the DTT experiment [2,3], and proposes a set of programmatic headlines of its scientific programme. The activity for the preparation of the DTT Research Plan (DTT-RP) has been performed during the past three years by an international team comprising approximately 100 European fusion scientists belonging to 20 research institutes from 10 different countries. The RP will be regularly updated and will catalyse and guide the research activities in preparation of the experimental phase.

R (m)	2.19
a (m)	0.7
Volume (m^3)	35
I_p (MA)	5.5
B_T (T)	5.85
$\bar{n}_e$ (10^{20} m^{-3})	1.5
P_{Tot} (MW)	45
P_{ECRH} (MW)	29
P_{ICRH} (MW)	6
P_{NNBI} (MW)	10

Fig. 1: DTT main design parameters

The Research Plan is based on the expected performance of DTT, which will be one of the world most advanced tokamaks in the next decade. The main parameters of DTT are shown in Fig. 1. DTT is equipped with full W actively cooled plasma facing components and has the capability of investigating various divertor configurations. Its compact size and large auxiliary heating power allow to simulate DEMO divertor heat loads and to produce ITER/DEMO relevant plasmas. Moreover, as shown in Fig. 2, DTT has relevant dimensionless parameters as close as possible to those typical of ITER & DEMO-class reactors. For instance, it has a key wall load parameter P_{SOL}/R ~ 15 (ratio of power flowing out the SOL to major radius); simultaneous high edge density and low collisionality; scrape-off layer width of the same order as for ITER and DEMO; ITER/DEMO relevant core confinement properties. In 2024, the EUROfusion Facilities Review report stressed the potential of DTT "for major impact on the design of DEMO", as a device "ideal for testing ITER and DEMO scenarios in relevant conditions". Based on these considerations, DTT was classified by the Facilities Review international panel as one of the few "indispensable" tokamak facilities of the future European fusion programme, without which "the programme goals cannot be realized on the required timescale".

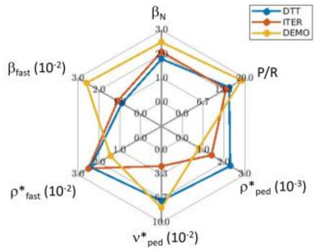

Fig. 2: DTT dimensionless parameters, taken from [4]

The DTT-RP is an extensive document (~200 pages) organized in nine chapters and nine technical appendices, which provide a synthetic description of the device main characteristics. The DTT programme which emerges from the RP will follow the evolution of the machine along three distinct phases, as illustrated in Fig. 3, taken from [4].

The paper will discuss in particular the development of half current/half field scenarios, which will allow a full exploitation of the device since its very beginning, in particular for the exploration of high b_N regimes.

The main top-level headlines of the DTT scientific contribution to the European fusion programme, in support to ITER and in preparation of DEMO are:

(A) Development and assessment of baseline and advanced scenarios for various divertor configurations, at nominal field and current, for performance comparison. The available divertor magnetic configurations, even within the same discharge, are in priority order: Single Null, X divertor and Negative Triangularity. They are all presently analysed based on the Wide Flat Divertor presently selected for DTT.

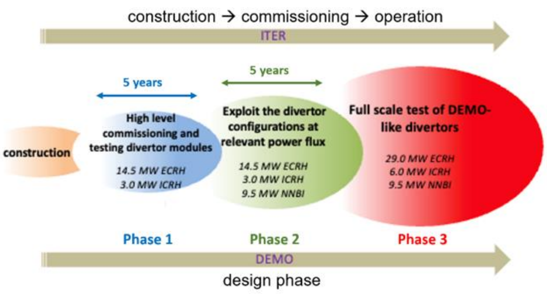

Fig. 3: DTT exploitation phases

(B) Development of scenarios at half field and current, with 2nd harmonic ECRH heating, to study high $\square_N$ regimes. These studies, carried out in a full tungsten device, will complement those performed by JT-60SA with carbon plasma facing components.

(D) Detached regimes optimization and control by impurity seeding in various scenarios. DTT will be equipped with a divertor gas injection system, which is traditionally used in tokamaks. As a risk mitigation strategy, DTT shall investigate alternative actuators and qualify for their requirements during detachment control and during ramp-up. Candidate technologies are supersonic molecular beam injection and micro shattered pellet injection, a novel first-of-a-kind approach.

(E) Evaluation of λ_q at high toroidal field; DTT will be instrumental to pin down the crucial scaling of the power decay length at the plasma edge, λq, as DTT can reach a fully integrated scenario where high core performance with low pedestal collisionality and high density goes together with edge parameters relevant for the next generations of fusion devices.

(F) Development of small/no ELMs scenarios and their control with non-axisymmetric coils and pellets. Like ITER, DTT will be equipped with a set of 27 internal active coils – each independently driven and arranged in three toroidal rows – which together with other actuators allow active control of stability and ELMs. The paper will explain also how DTT will address the development of the science and technology for off-normal events control. In particular, DTT will be equipped with a SPI Disruption Mitigation System similar to the ITER one, which will be discussed together with the simulations result in this field.

(G) Wall erosion, W migration, D retention and removal studies and assessment in view of application to DEMO. The actively cooled tungsten first wall and divertor, associated with the long discharge duration will allow understanding the impact of tungsten impurities and wall erosion/redeposition on plasma performance. Extensive testing with the Divertor Test Modules for new first wall and divertor materials will be done.

(I) Transport, MHD, Energetic Particle physics studies with reactor relevant dimensionless parameters. The simultaneous use of ICRH and High-energy NNBI will generate an energetic particle population with an energy density comparable with that of the core plasma, and characteristic energy more than the critical energy. These are distinctive features of reactor relevant burning plasmas and will be accessible in DTT.

[1] F. CRISANTI, G. GIRUZZI, P. MARTIN et al., Divertor Tokamak Test Facility Research Plan, Version 1.0, May 2024, https://www.dtt-project.it/index.php/about/dtt-research-plan.html

[2] F. ROMANELLI et al., Nucl. Fusion **64** (2024) 112015.

[3] F. ROMANELLI et al, “The Divertor Tokamak Test project: strengths and critical issues”, this conference

[4] F. CRISANTI et al 2024 Nucl. Fusion **64** 106040