First-principle based multi-channel integrated modelling in support to the design of the Divertor Tokamak Test Facility

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ABSTRACT
First results of the integrated modelling of DTT scenarios (R=2.14 m / a=0.65 m) using first-principle quasi-linear transport models are presented, in support to the design of the device and to the definition of the DTT scientific work-programme. In the full power scenario, central temperatures of ~20 keV for electrons and ~10 keV for ions with central densities ~2.5 10^20 m^-3 are predicted in fair agreement by the two models used. Gyrokinetic simulations have been used to validate the models in the DTT range of parameters. As a result, the work, the heating mix was defined, the size of device was increased to R=2.19 m/a=0.70 m, and reference profiles for diagnostic design, estimates of neutron yields and fast particle losses have become available.

INTRODUCTION
Performing integrated modelling of the foreseen operational scenarios using first principle based transport models and state-of-art modules for heating, fuelling and magnetic equilibrium is of key importance for the optimisation of the various aspects of the DTT. It is required to:
• support the definition of the heating mix,
• support the design of the neutron shields,
• support the assessment of fast particle losses,
• support the design of diagnostic systems,
• help the elaboration of a DTT scientific work-programme.

INTEGRATED MODELLING SET-UP

SCENARIOS
The integrated modelling of various DTT scenarios with Single Null (SN) configuration in H-mode has been performed. Particularly, the Full Power (FP) scenario steady-state predictions are crucial for the DTT design.

SIMULATIONS
The simulations predict steady-state radial profiles of electron and ion temperature, density, current density, rotation, power deposition, and impurity densities in the region p_D < 0.94. The pedestal was calculated using the EPE1D model. Integrated runs have been primarily done using the JINTRAC[3] suite of codes and in some cases using the ASTRA[4] transport solver with a mixed ASTRA–JINTRAC approach.

TURBULENT TRANSPORT
Inside the top of the pedestal, the turbulent heat and particle transport is calculated by the Trapped-Gyro-Landau-Fluid (TGLF) [5] or QuaLiKiz (QLK) [6] quasi-linear transport models. The two most recent versions of TGLF have been used: TGLF SAT1-geo, released in November 2019, and TGLF SAT2, released in January 2021. In runs with QLK, two versions have also been employed: the new standard QLK release and an "ad hoc" QLK version, specifically developed for DTT to match gyrokinetic predictions in TEM dominant conditions.

Table 1: DTT Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Btor</td>
<td>≤ 6 T</td>
</tr>
<tr>
<td>Ip</td>
<td>≤ 5.5 MA</td>
</tr>
<tr>
<td>tpol</td>
<td>≤ 100 s</td>
</tr>
<tr>
<td>R</td>
<td>= 2.14 m</td>
</tr>
<tr>
<td>a</td>
<td>= 0.65 m</td>
</tr>
<tr>
<td>(E/P)tor a R</td>
<td>= 15 MW/m</td>
</tr>
</tbody>
</table>

HEATING SYSTEMS
Following simulations of several alternatives (some listed in Table 2), the OPTION D has been chosen as reference heating mix for full power scenarios.
• The choice of higher NBNI energy (together with maximum allowed injection angle) was driven by the need of minimizing fast particle losses and allowing resonant excitation of Alfvenic waves.
• The choice of higher ICHR power was driven by the need of central ion heating and fast ions, to alleviate the T_e>T_i tendency due to HICH power.

Table 2: simulated plasma performance for different options of heating mix

<table>
<thead>
<tr>
<th>Heating option</th>
<th>NBI energy/ power</th>
<th>ECH Power (MW)</th>
<th>ICH Power (MW)</th>
<th>re (SAT1-geo)</th>
<th>HWY</th>
<th>H0</th>
<th>r_e/T_e</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>400 keV 15 MW</td>
<td>32</td>
<td>4</td>
<td>0.26 s</td>
<td>0.89</td>
<td>0.57</td>
<td>0.61</td>
</tr>
<tr>
<td>B</td>
<td>600 keV 7.5 MW</td>
<td>40</td>
<td>4</td>
<td>0.26 s</td>
<td>0.91</td>
<td>0.59</td>
<td>0.61</td>
</tr>
<tr>
<td>C</td>
<td>500 keV 10 MW</td>
<td>33.6</td>
<td>8</td>
<td>0.27 s</td>
<td>0.95</td>
<td>0.54</td>
<td>0.57</td>
</tr>
</tbody>
</table>

Figure 1: DTT device. Drawing reproduced from [2].
Figure 2: Plasma shape of the SN DTT scenario.

REFERENCES