

Preparing WEST tungsten divertor operation: Nitrogen seeded H-mode plasma simulation with SOLEDGE2D-EIRENE

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Introduction

In the perspective of operating WEST (W Environment Steady State) tokamak at Cadarache [1, 2], a dedicated effort has been made to develop the transport code SOLEDGE2D-EIRENE [3]. This code is used in a prospective way to investigate the operational domain of WEST, focusing on target heat loads and plasma conditions in the SOL. During the operation, the code will be used to analyze experiments, help interpreting edge plasma behavior (using synthetic diagnostics for instance [4]), and link WEST results to ITER. Using edge transport codes in a predictive way is a challenge since turbulent transport is not modeled self-consistently. Prescribed radial diffusion coefficients are usually adjusted to match experimental density and temperature profile in the outer mid-plane. Therefore, to investigate WEST plasma properties, we first simulate an H-mode plasma on ASDEX Upgrade which is a comparable medium size tokamak. The simulation relies on the transport coefficients determined in Ref. [5]. The same transport coefficients are then used to simulate edge plasma conditions for a WEST H-mode discharge.

AUG H-mode simulation

In [5], a thorough study is carried out to match AUG H-mode discharge #17151 with SOLPS. The influence of the different transport code parameters on the solution is carefully studied. In this contribution, we propose to reproduce this work with SOLEDGE2D-EIRENE. The magnetic equilibrium for AUG shot #17151 at t=4.13s has been used to generate a SOLEDGE2D-EIRENE grid (resolution: 110 points in the radial direction, 180 points in the

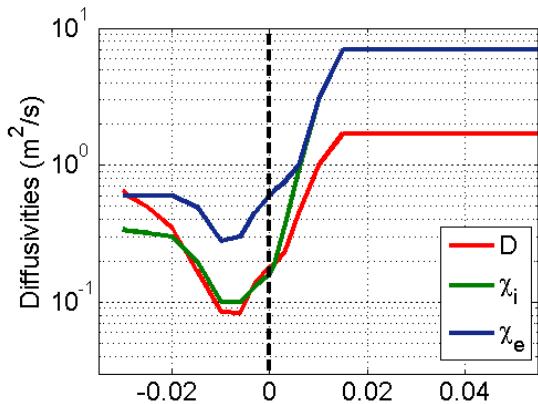


Figure 1 : Radial profiles of flux surface averaged transport coefficients used in SOLEDGE2D-EIRENE simulations inspired for [5]

interface, the input power is set to $P_{SOL} = 5.4MW$ with an equal repartition between ions and electrons and the density is set to $n_e = 4.2 \cdot 10^{19} m^{-3}$. Transport coefficients are identical to those given by Chankin in [5]. They follow a $1/B$ dependence. The flux surface average values are reported on Figure 1, the H-mode transport barrier being created by a drop in diffusivities at the vicinity of the separatrix. Drifts are not taken into account.

Typical simulation results for electron density, temperature and Carbon density are reported on Figure 2. Radial profiles in the outboard mid-plane are reported on Figure 3. A rather good agreement is found between

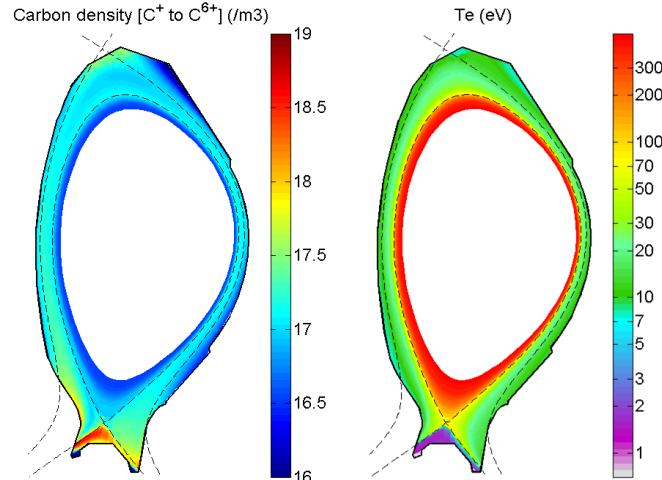


Figure 2 : SOLEDGE2D-EIRENE simulation results for AUG #17151 H-mode plasma. Left: Carbon density (log scale), right: electron temperature.

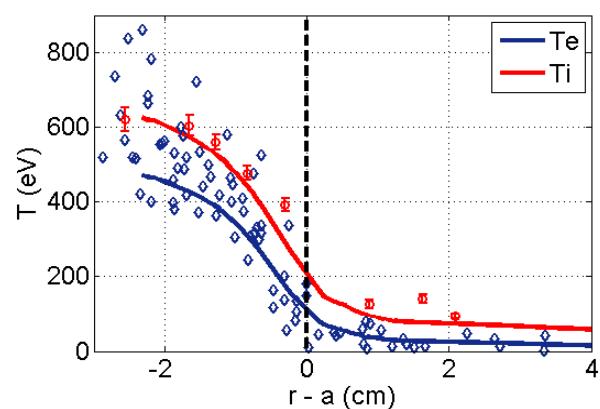
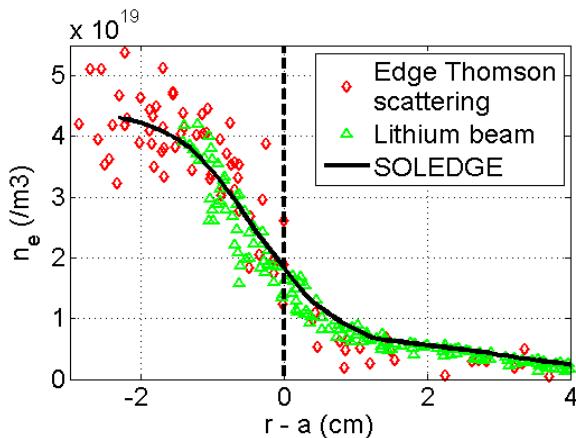


Figure 3 : Radial profiles for plasma density (left) and ion and electron temperature (right). Comparison between measurements (symbols from [5]) and SOLEDGE2D-EIRENE simulation (lines).

poloidal direction). The simulation domain is extended up to the first wall which is considered to be made of Carbon. The plasma simulated by the code is made of Deuterium with a small amount of Carbon. The Carbon is generated by wall sputtering. The sputtering yield used in the simulation is constant and set to $Y_C = 2.3\%$ including both physical and chemical sputtering and has been adjusted to match $P_{rad} = 1.15MW$ as measured in the experiment. At the core edge

simulated and measured results for density and temperature, as expected. Indeed, the transport coefficients, which are the main free parameters of the code, have been adjusted in Ref. [5] so as to match experimental mid-plane profiles.

Figure 4 shows target profiles for density, temperature and heat flux on the outer target. The simulation results are in rather good agreement with Langmuir probes measurements and IR camera data.

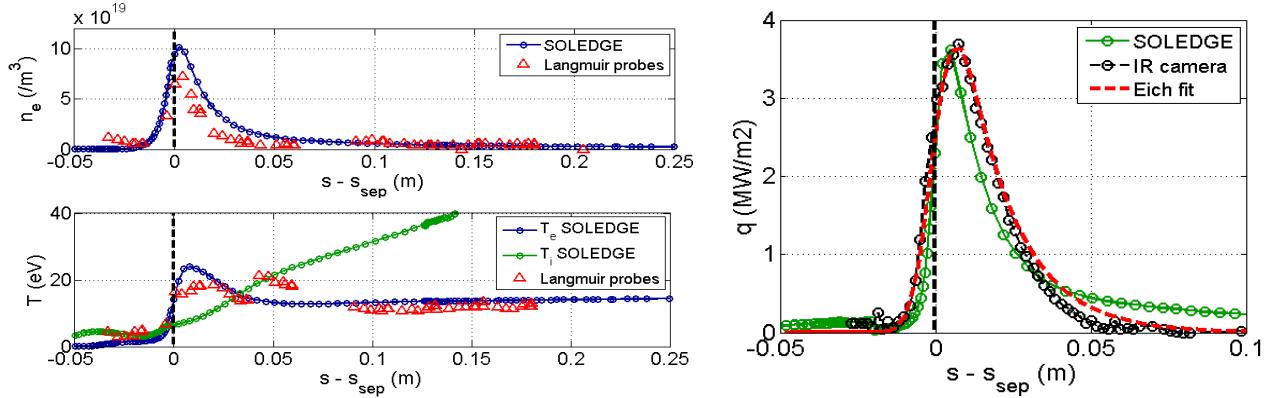


Figure 4 : Comparison between measurements (symbols from [5]) and SOLEDGE2D-EIRENE simulation results for outer target profiles on AUG..

On Figure 4 is also displayed a fit with Eich's function [6]. The fitting parameter found for this AUG case ($f_x = 4.65$) are: heat flux radial decay $\lambda_q = 3.5\text{mm}$, divertor spreading $S = 1.7\text{mm}$. The value found for λ_q is compatible with the scaling law given by [7]. We consider that this case provides a reference set of transport coefficients for an H-mode plasma in a medium-size tokamak, and thus rely on this set for WEST simulations.

WEST H-mode simulation

The wall material for WEST is Tungsten and Tungsten sputtering is not taken into account in the simulation. The Carbon radiator sputtered from the wall in the AUG case is replaced by Nitrogen seeding in the lower divertor private flux region. Nitrogen is supposed to entirely recycle on the wall ($R_N^* = 1$). The input power entering the SOL is set to $P_{SOL} = 8\text{MW}$ (equal repartition between ions and electrons), the electron density at the separatrix is set to $n_{sep} = 3.4 \cdot 10^{19}\text{m}^{-3}$ by adjusting core fueling and the Nitrogen puff rate is set to $\phi_N = 5.6 \cdot 10^{21}\text{el/s}$. Simulation results are summarized on Figure 5. The following values are found for heat flux width using Eich fit: $\lambda_q = 3\text{mm}$ and $S = 1.2\text{mm}$.

This simulation is part of an ongoing effort to map the WEST tokamak operation domain, which is aimed at providing guidance to prepare for WEST operation.

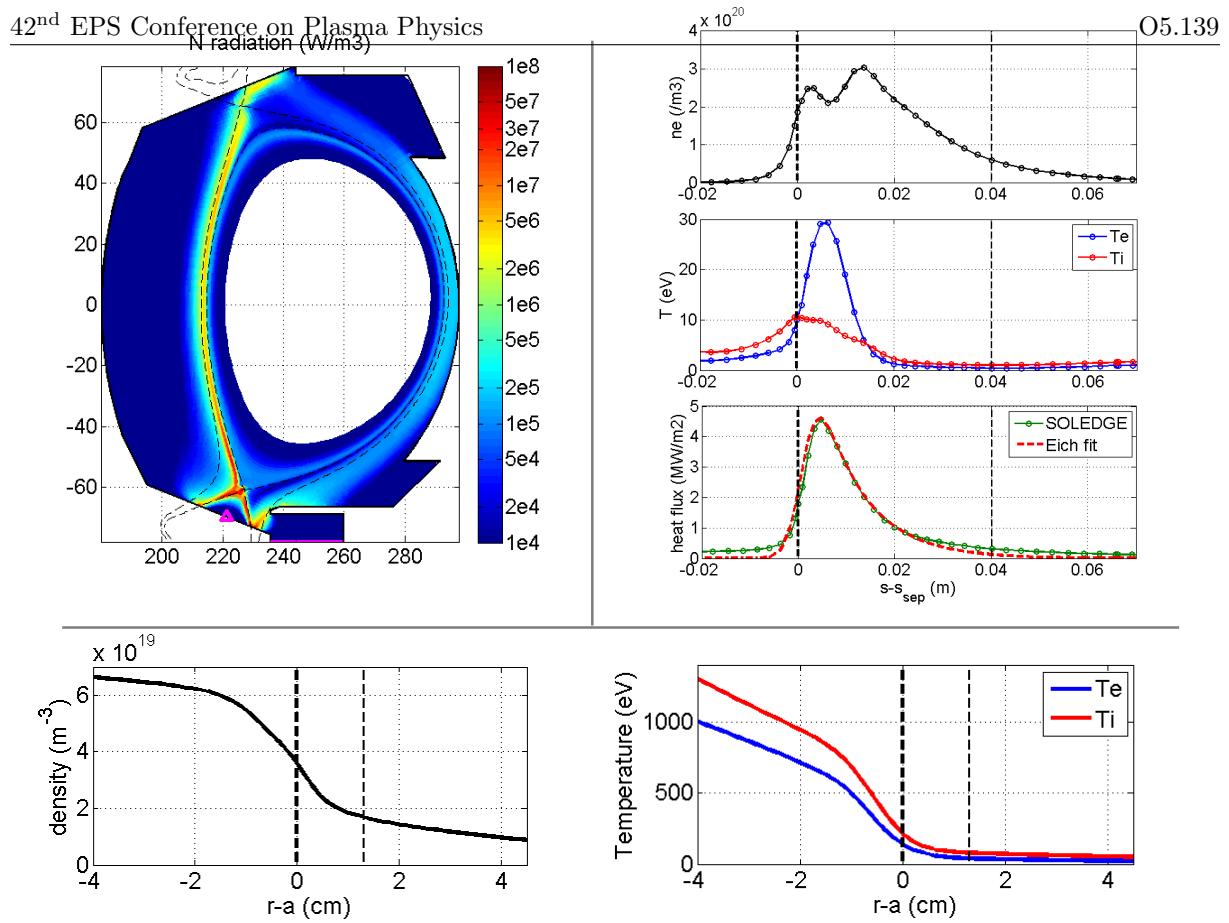


Figure 5 : SOLEDGE2D-EIRENE simulation results for WEST H-mode discharge. Top Left-hand quarter: Nitrogen radiation (purple triangle show location of Nitrogen puff). Top Right-hand corner: Outer target profiles. Bottom: outer mid plane profiles.

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