INTERPRETATIVE MODELING OF IMPURITY TRANSPORT AND TUNGSTEN SOURCES IN WEST BOUNDARY PLASMA

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Motivation

1) Understanding impurity transport in tokamaks is mandatory as impurities usually control both magnitude and spatial distribution of radiative losses.
2) Development of experimental scenarios in WEST relies on better control of light impurities with Oxygen identified as main light impurity species.
3) VUV spectroscopy system in WEST provides measurements of angular distribution of different oxygen ionization states in edge/scrape-off layer.
4) SolEdge2D-EIRENE allows for multi-fluid modeling of boundary plasma for direct comparison with and interpretation of edge experimental data.

Achievements

1) Modeling of recent WEST plasma discharge via SolEdge2D-EIRENE with Zhdanov collisional closure assuming oxygen as main impurity.
2) Good agreement between simulation and diagnostics n_{div} and T_{div} by Langmuir probes, q_{div} by thermocouples, n_{omp} by reflectometry.
3) Force balance between O and background plasma: thermal gradient forces prevail on friction forces, O pushed away from lower divertor.
4) Qualitative agreement between simulation and VUV spectroscopy on brightness poloidal profiles of O^{3+} lines OIV 609.8 A, 625.1A, 625.9A.

Bibliography

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Modeling of background plasma in a WEST discharge

The 2D fluid plasma solver SolEdge2D [2] coupled with the kinetic Monte Carlo code EIRENE for neutrals [3] (S2DE) used to model the background plasma (n, T_e, T_i, u) of a recent lower single null, LH heated, L-mode WEST discharge.

Hypotheses

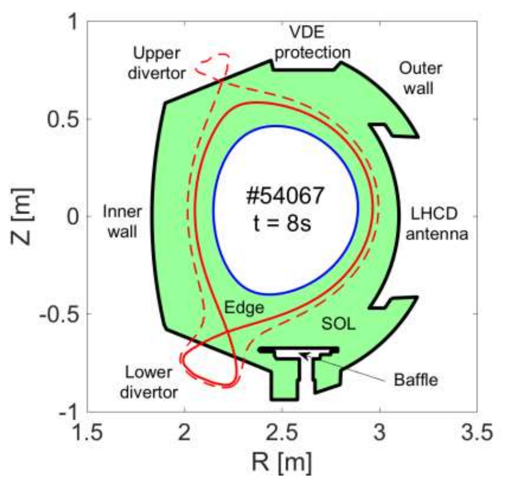
1) plasma = deuterium with 2% oxygen at the simulation inner boundary;

2) deuterium density at the simulation inner boundary $n_i = 3 \times 10^{19}\ m^{-3}$;

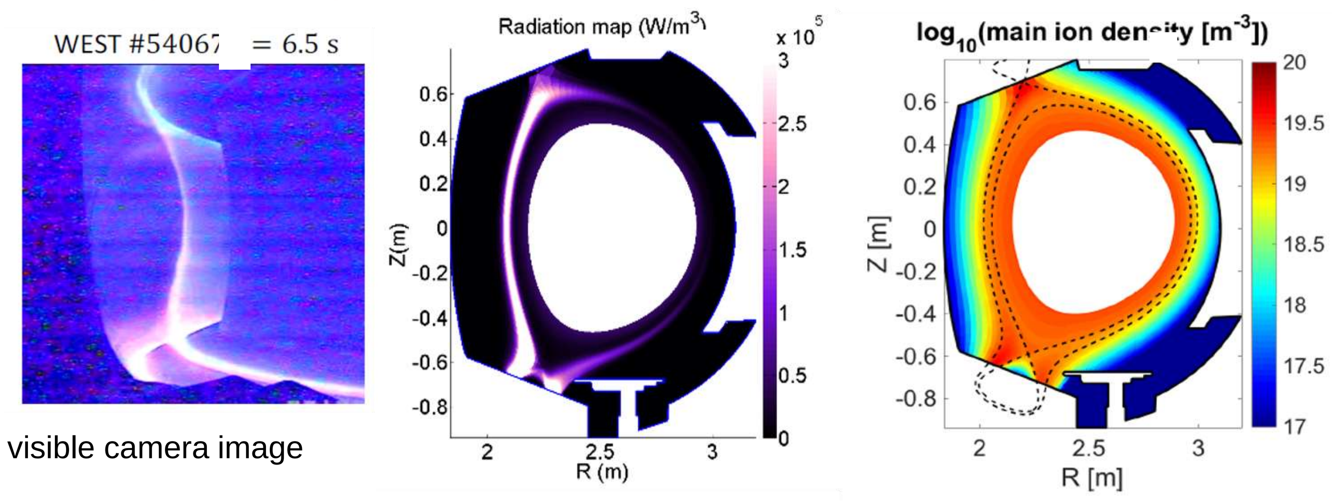
3) input power at inner boundary $P_{in} = P_{heat} - P_{rad}^{core} \simeq 2.3$ MW (to e^- and D^+);

4) Typical L-mode transport coefficients: $D = \nu = 1\ m^2s^{-1}$, $\chi_e = \chi_i = 2\ m^2s^{-1}$ spatially constant over simulation domain for both deuterium and oxygen;

5) recycling coefficient at **full-W wall** $R = 99\%$ for both deuterium and oxygen;

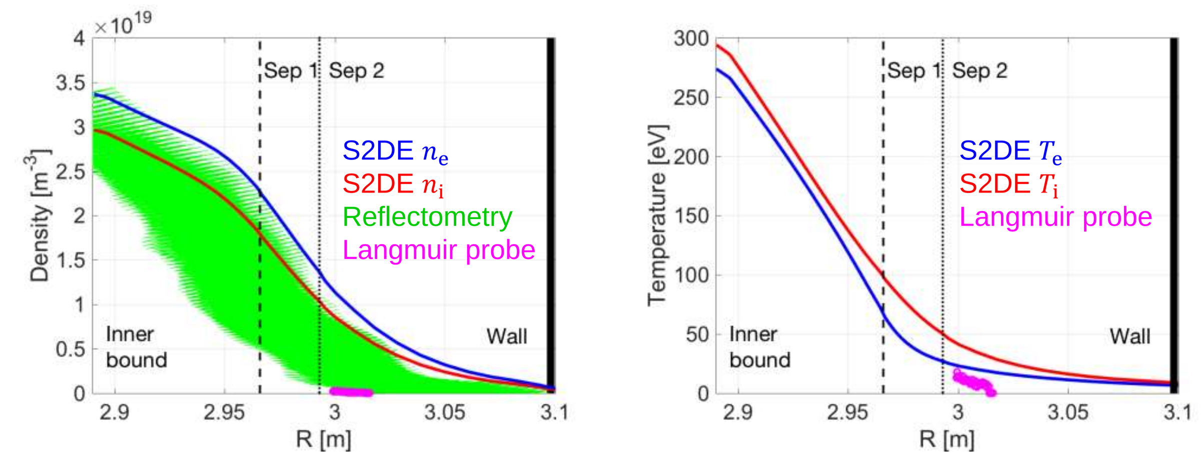


Visible camera image and background plasma poloidal maps



visible camera image

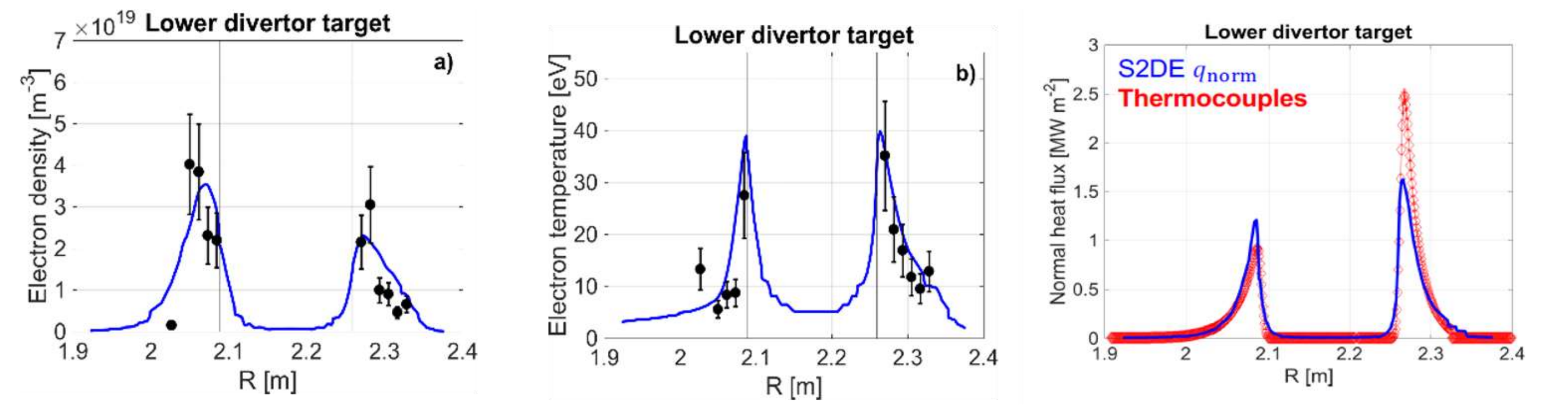
Background plasma along outer midplane



- qualitative agreement with n_e exp. data from reflectometry (measured at outer midplane)

- reciprocating Langmuir probe (plunging from top of vessel) $\simeq 0.01 \times n_e$ and $\simeq 0.5 \times T_e$ BUT remapping to outer midplane affected by big uncertainty on magnetic equilibrium at top

Background plasma along lower divertor

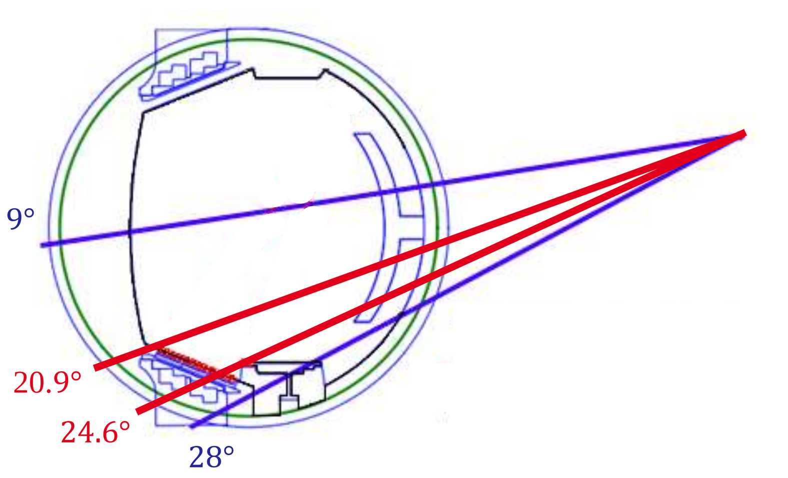


- good agreement with **divertor Langmuir probes** at outer target, not at inner target (stronger recycling in simulation)
- normal heat flux in qualitative agreement with thermocouples (in/out asymmetry) but 2 × and 2.5 × lower amplitude

Modeling of impurity transport in WEST and comparison with VUV measurements

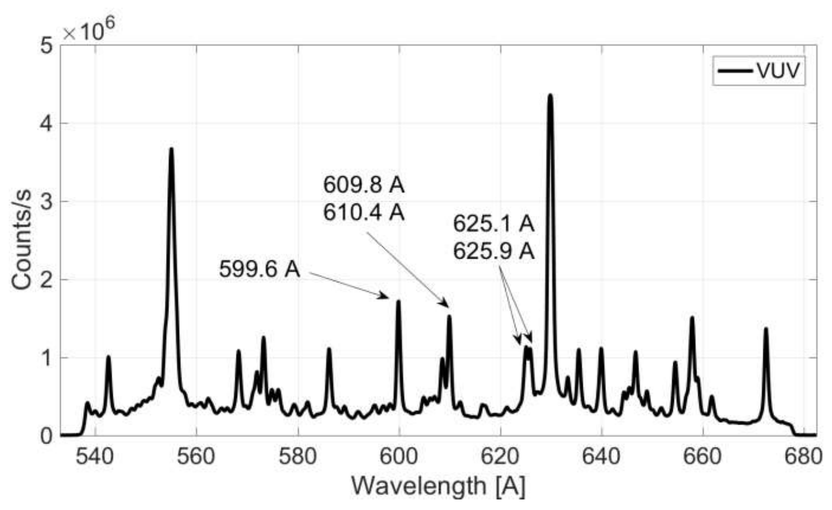
Several O^{2+} and O^{3+} lines identified in spectra from the VUV (Vacuum UltraViolet) spectroscopy system in WEST [8]. A single line of sight in scanning mode maps region between inner midplane and divertor (OSP shadowed by baffle).

#54067: reduced poloidal range to increase angular resolution during 3 s scan in steady plateau



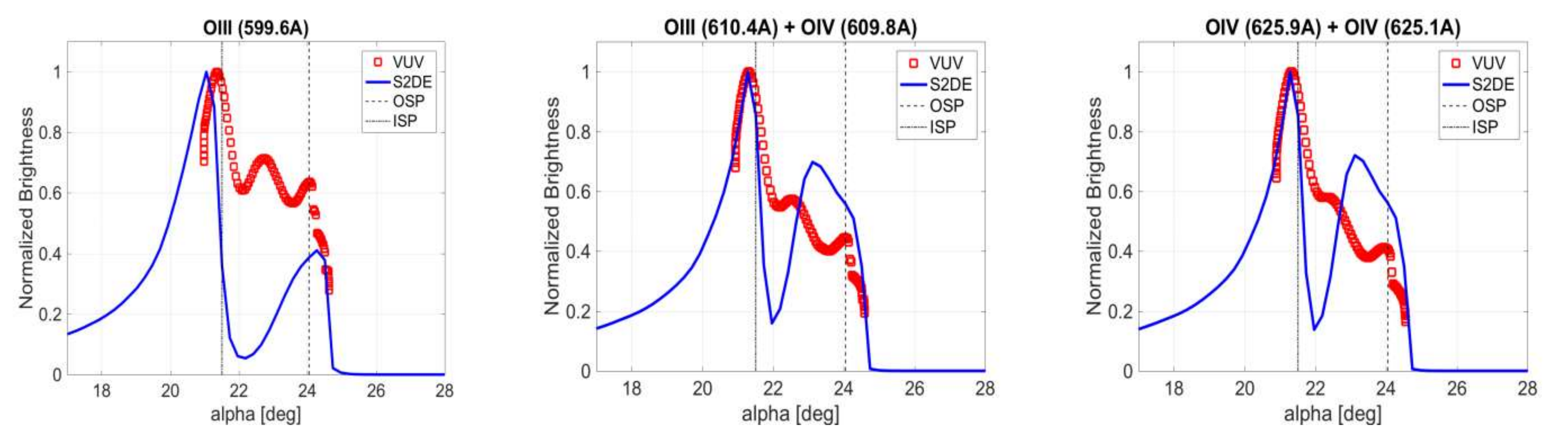
Lines of sight setup for VUV spectroscopy in WEST

VUV spectrum for WEST #54067 (between 6s and 9s)
OIII 599.6A and 610.4A; OIV 609.8A, 625.1A, 625.9A



Normalized brightness poloidal profiles

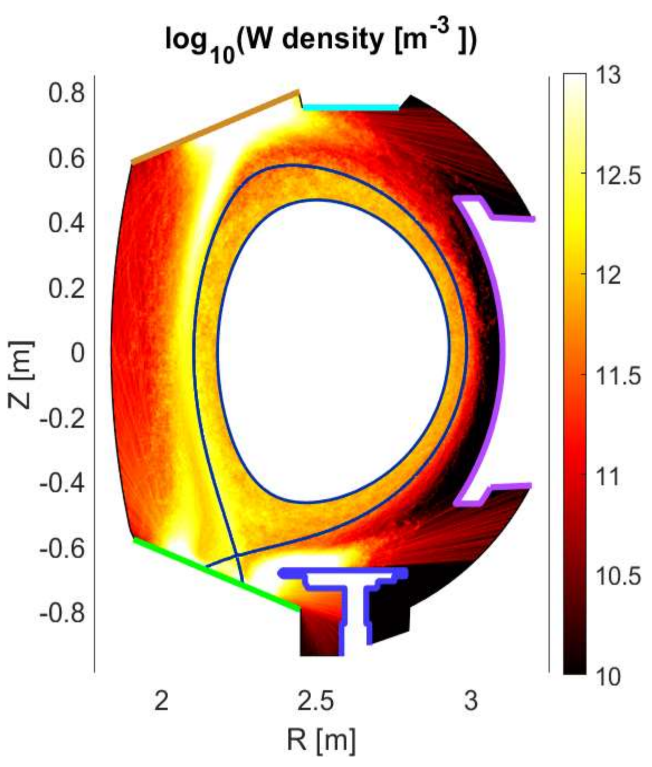
O signal from VUV spectroscopy data peaks at inner strike point and outer strike point (partially shadowed by baffle)
Stronger oxygen signal from inner divertor target, consistent with O density/concentration maps in S2DE simulation.



"Poloidal" profiles of O^{2+}, O^{3+} from VUV compared to synthetic diagnostic in S2DE:
- asymmetry in brightness between inner and outer divertor qualitatively reproduced
- intermediate peak not observed in simulation: 1) is it oxygen in private flux region?
2) do we miss some physics ($E \times B$ drifts)? 3) is the background to be improved?

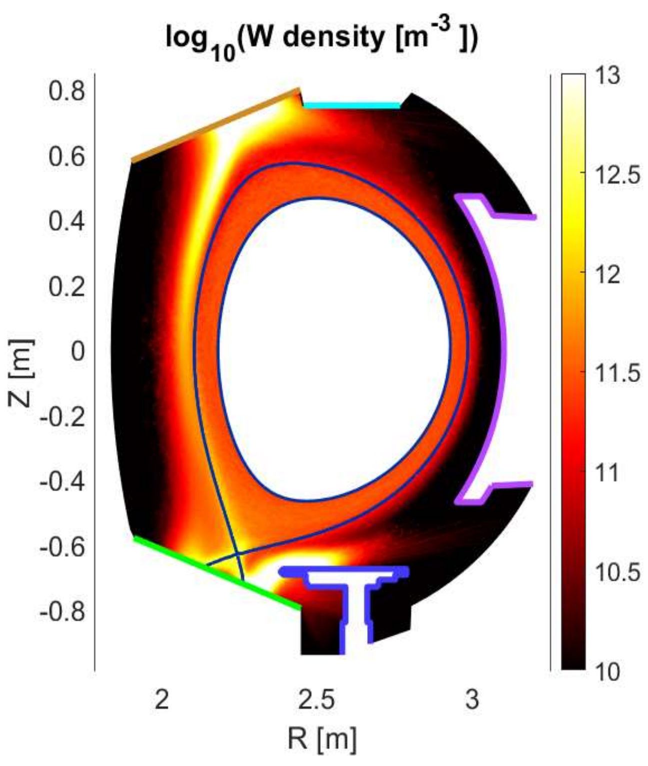
NUMERICAL INVESTIGATION OF THE IMPACT OF SEMIDETACHED PLASMA ON W SOURCES, TRANSPORT AND CORE CONTAMINATION

ERO2.0 simulations for poloidal W density map using SOLEDGE plasma backgrounds



Attached plasma background

(coeff D=0.3m²/s)



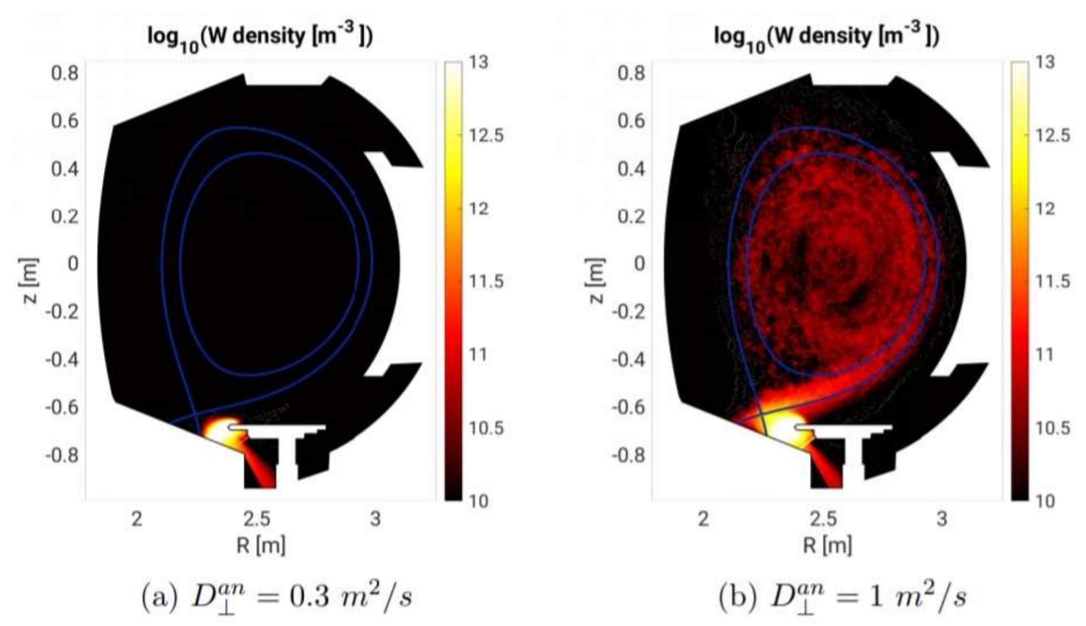
Semi detached plasma background

(coeff D=0.3m²/s)

PFC	*Number of W_{core} [particles] for the attached plasma*	*Number of W_{core} [particles] For the semi-detached plasma*
Inner Target	1.2×10^{11}	2.7×10^{8}
Outer Target	7.5×10^{6}	1.1×10^{8}
Baffle	*negligible*	*negligible*
Antenna	1.1×10^{9}	2.3×10^{7}
Ceiling	1.8×10^{9}	7×10^{7}
Upper divertor	6.4×10^{12}	2.2×10^{12}

Table 1: Number of W particles entering the core region coming from different PFC computed using ERO2.0 and related to an attached and semi-detached plasma background

Sensitivity in ERO2.0 simulations to the value of the radial transport coefficient



Using the same plasma background, setting a radial diffusion coefficient D=0.3m²/s in ERO2.0 simulations the baffle is not contaminating the core while for D= 1 m²/s the baffle is also responsible for W core contamination

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The views and opinions expressed herein do not necessarily reflect those of the European Commission.