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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

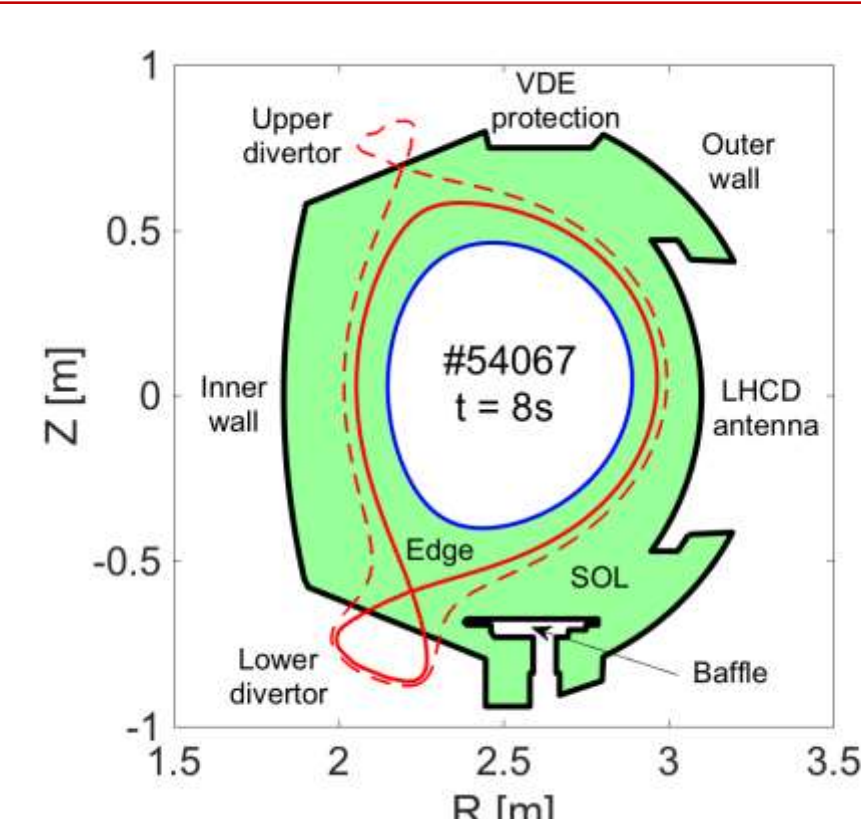
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Modeling of background plasma in a WEST discharge

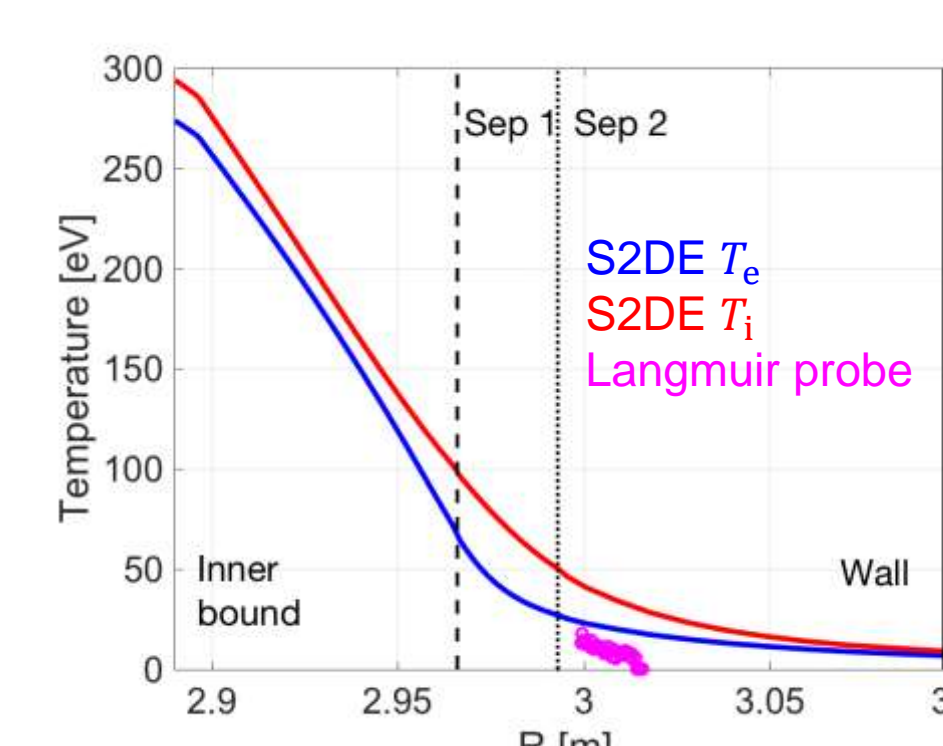
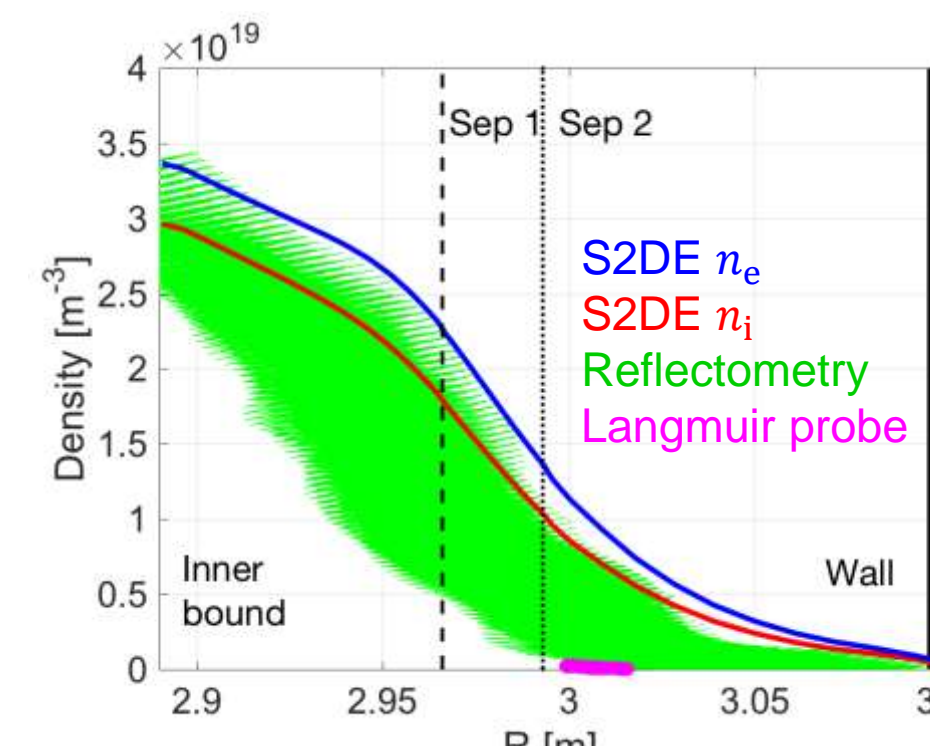
The 2D fluid plasma solver SolEdge2D [2] coupled with the kinetic Monte Carlo code EIRENE for neutrals [3] (S2DE) used to model the background plasma (n_e, T_e, T_i, u) of a recent lower single null, LH heated, L-mode WEST discharge.

Hypotheses

- 1) plasma = deuterium with 2% oxygen at the simulation inner boundary;
- 2) deuterium density at the simulation inner boundary $n_i = 3 \times 10^{19} \text{ m}^{-3}$;
- 3) input power at inner boundary $P_{in} = P_{heat} - P_{rad}^{core} \approx 2.3 \text{ MW}$ (to e^- and D^+);
- 4) Typical L-mode transport coefficients: $D = \nu = 1 \text{ m}^2 \text{ s}^{-1}$, $\chi_e = \chi_i = 2 \text{ m}^2 \text{ s}^{-1}$ spatially constant over simulation domain for both deuterium and oxygen;
- 5) recycling coefficient at full-W wall $R = 99\%$ for both deuterium and oxygen;



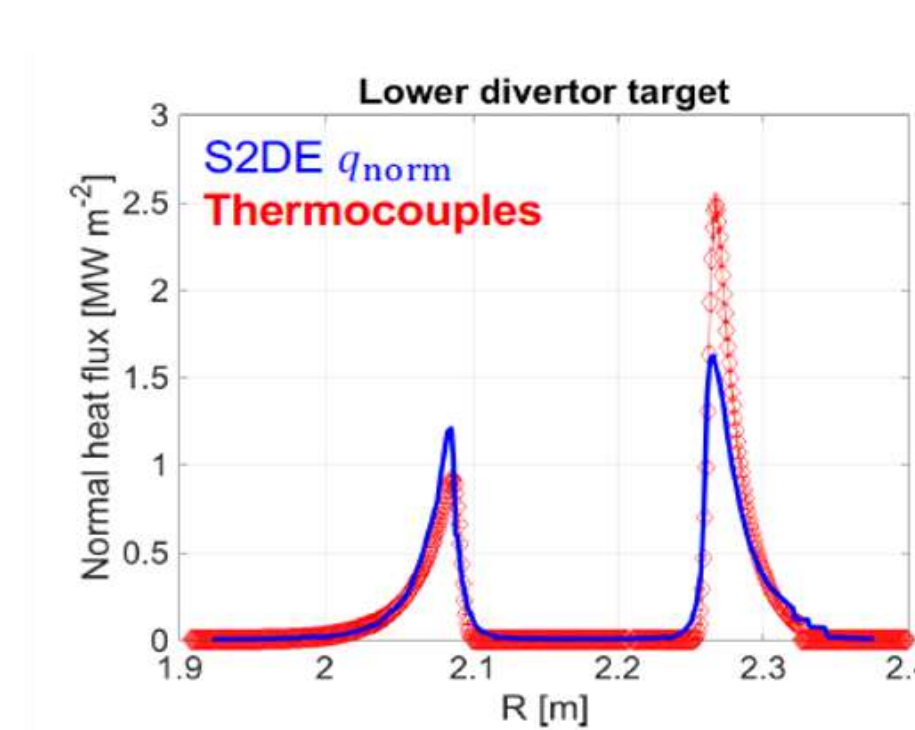
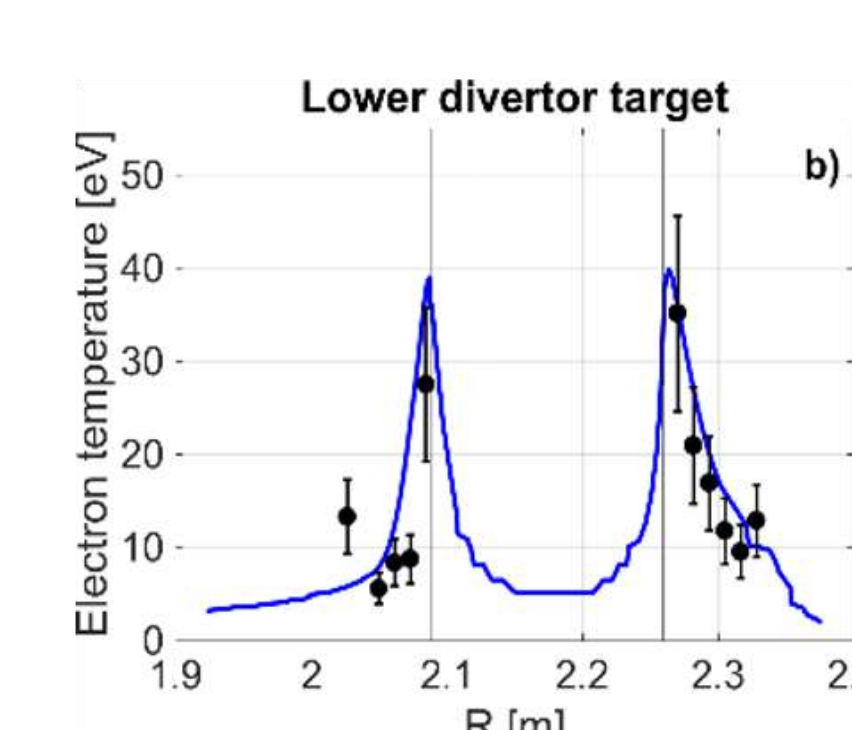
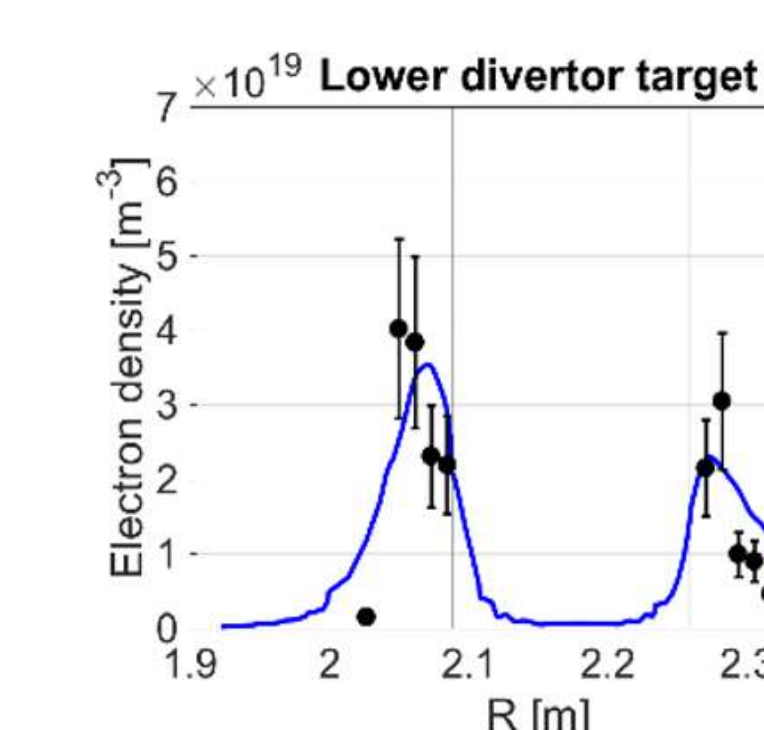
Background plasma along outer midplane



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

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

Background plasma along lower divertor

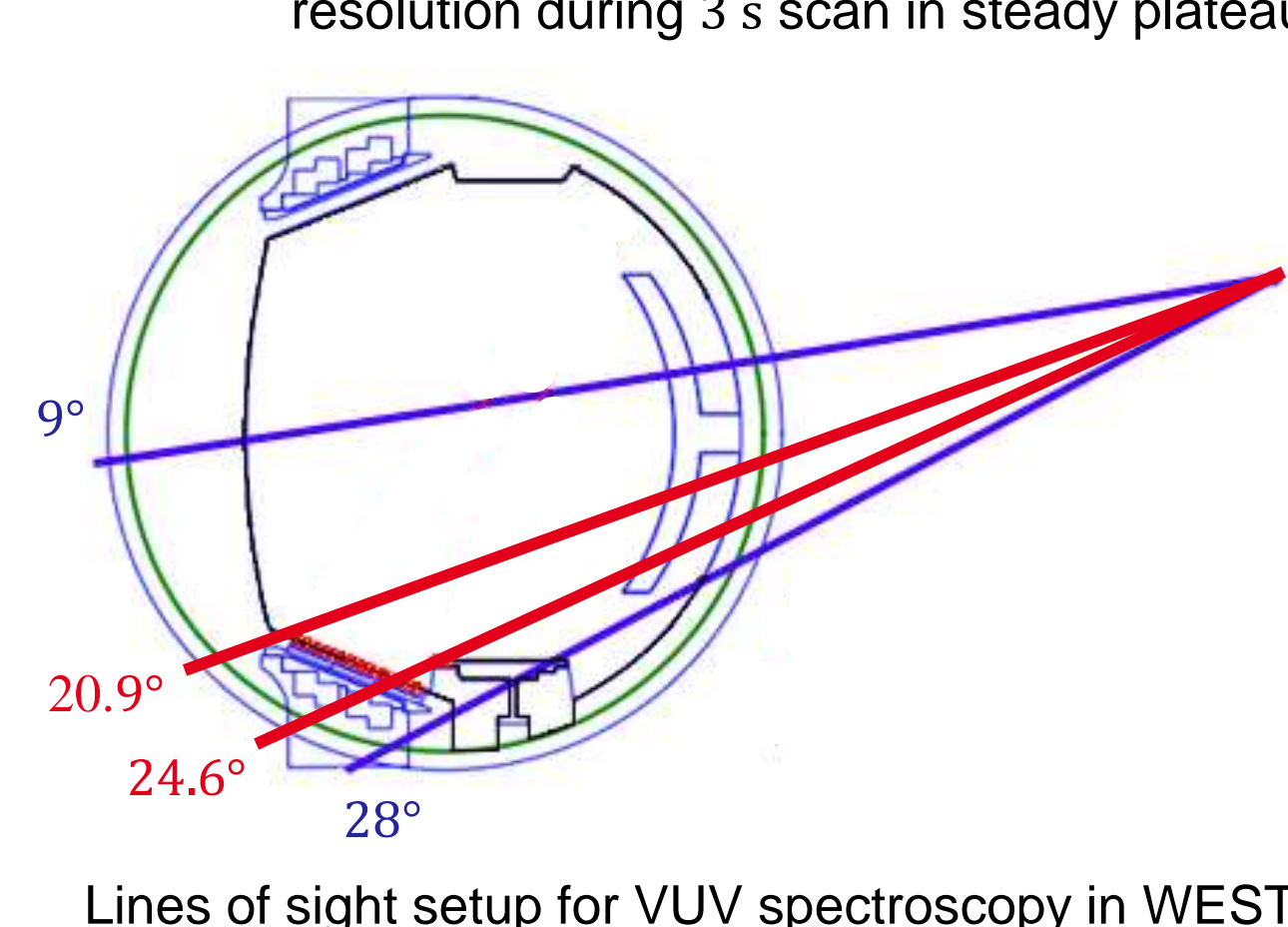


- good agreement with divertor Langmuir probes at outer target, not at inner target (stronger recycling in simulation)
- normal heat flux in qualitative agreement with thermocouples (in/out asymmetry) but $2 \times$ and $2.5 \times$ lower amplitude

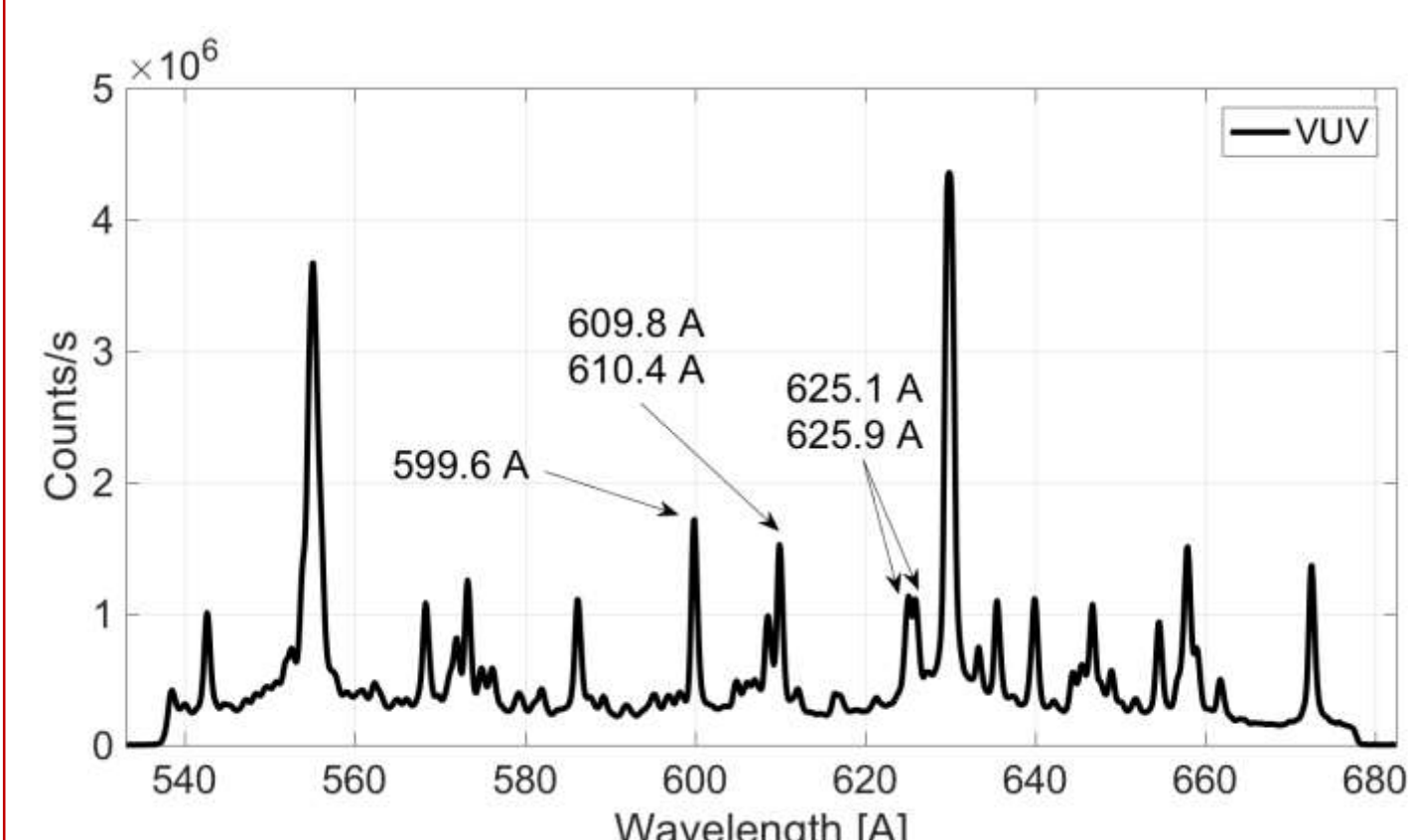
Modeling of impurity transport in WEST and comparison with VUV measurements

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

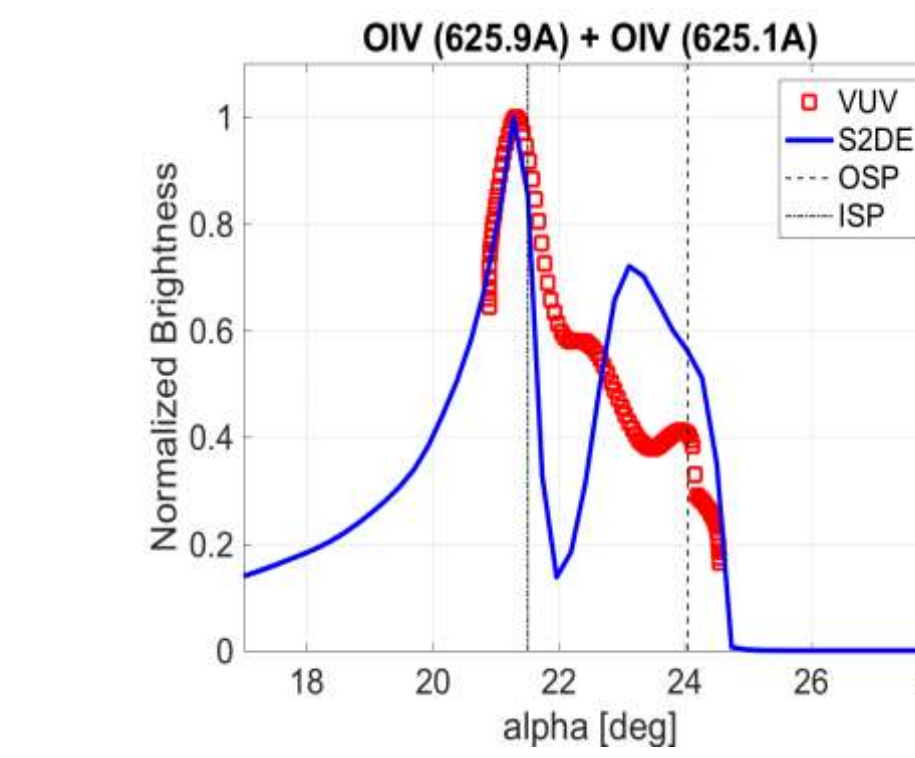
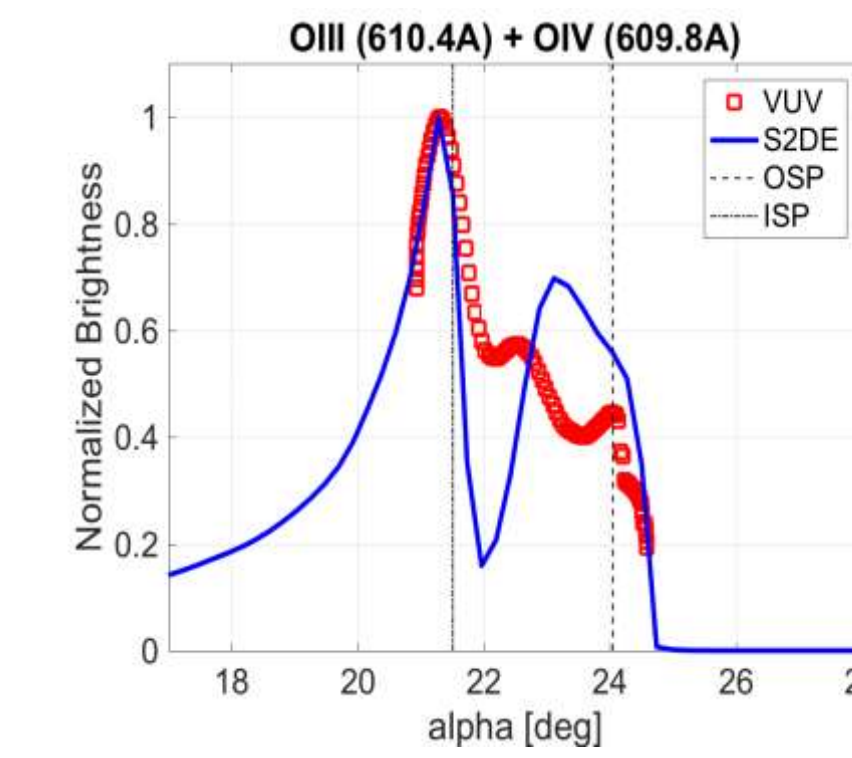
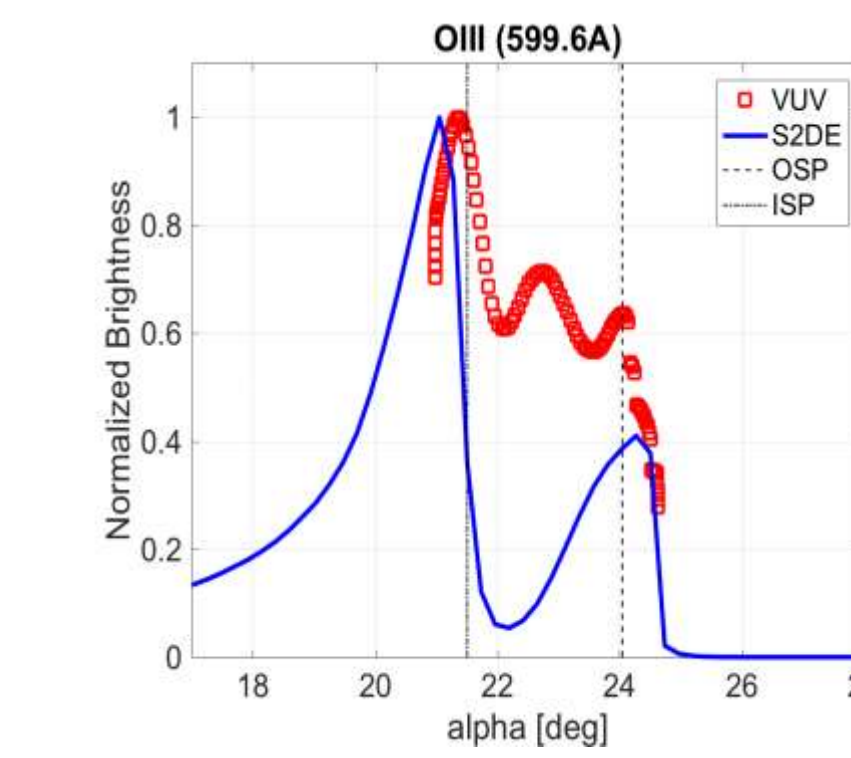


VUV spectrum for WEST #54067 (between 6s and 9s) OIII 599.6A and 610.4A; OIV 609.8A, 625.1A, 625.9A



Normalized brightness poloidal profiles

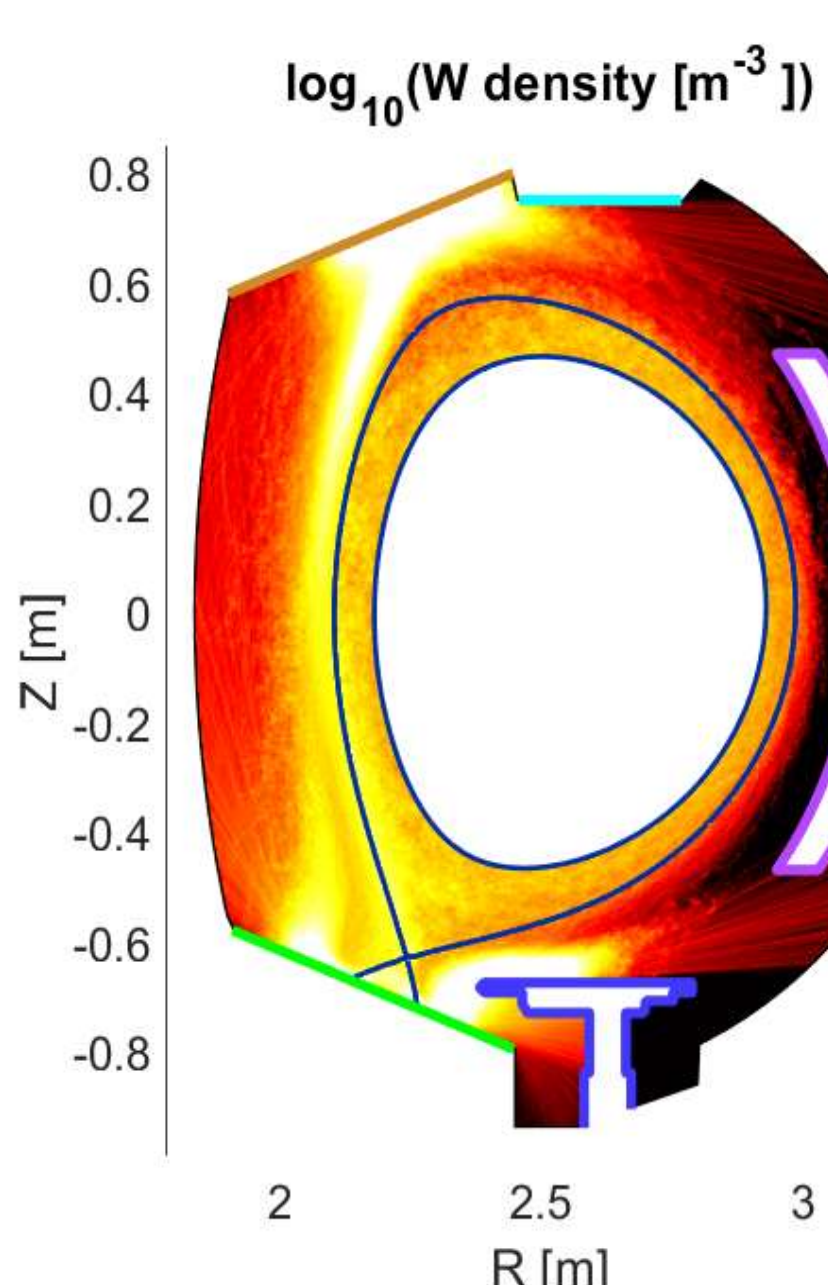
O signal from VUV spectroscopy data peaks at inner strike point and outer strike point (partially shadowed by baffle). Stronger oxygen signal from inner divertor target, consistent with O density/concentration maps in S2DE simulation.



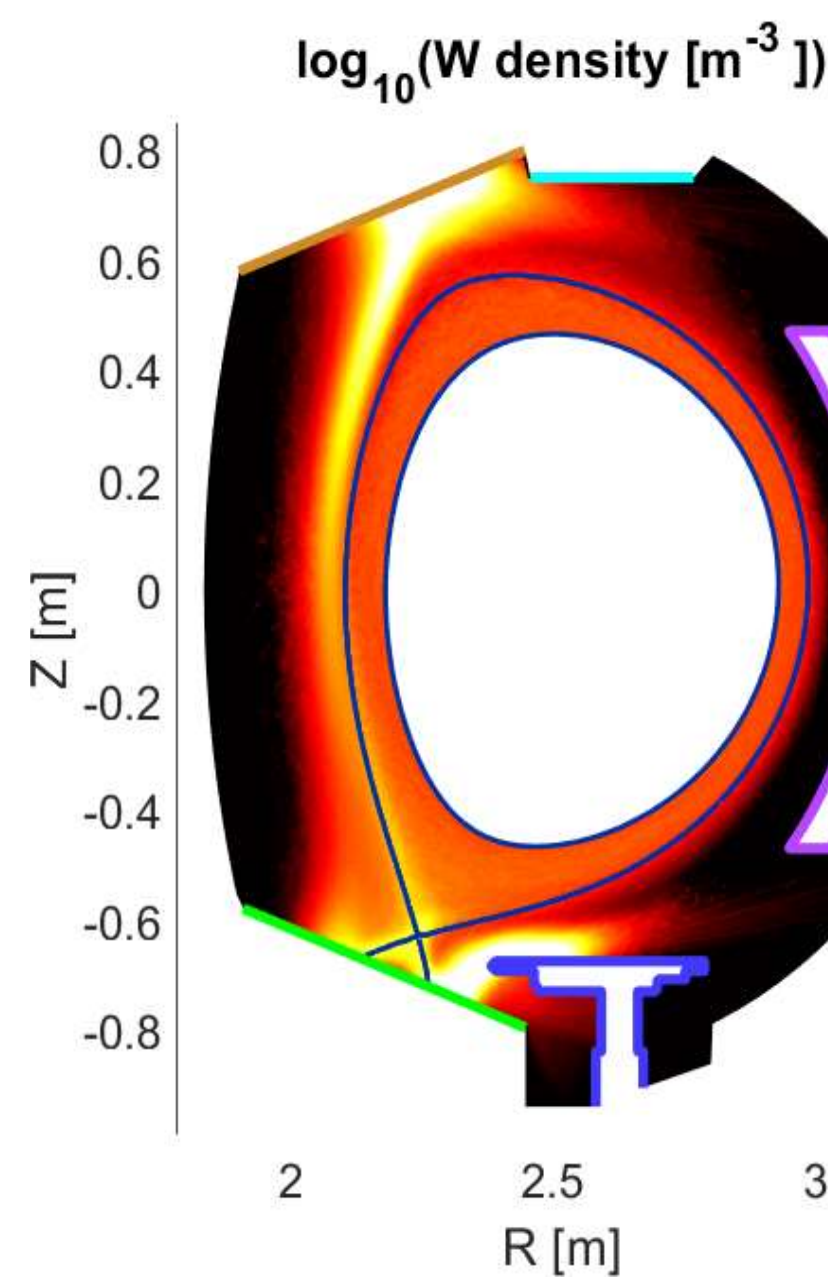
- "Poloidal" profiles of O^{2+} , O^{3+} from VUV compared to synthetic diagnostic in S2DE:
- asymmetry in brightness between inner and outer divertor qualitatively reproduced
 - intermediate peak not observed in simulation: 1) is it oxygen in private flux region? 2) do we miss some physics ($E \times B$ 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 $D=0.3 \text{ m}^2/\text{s}$)

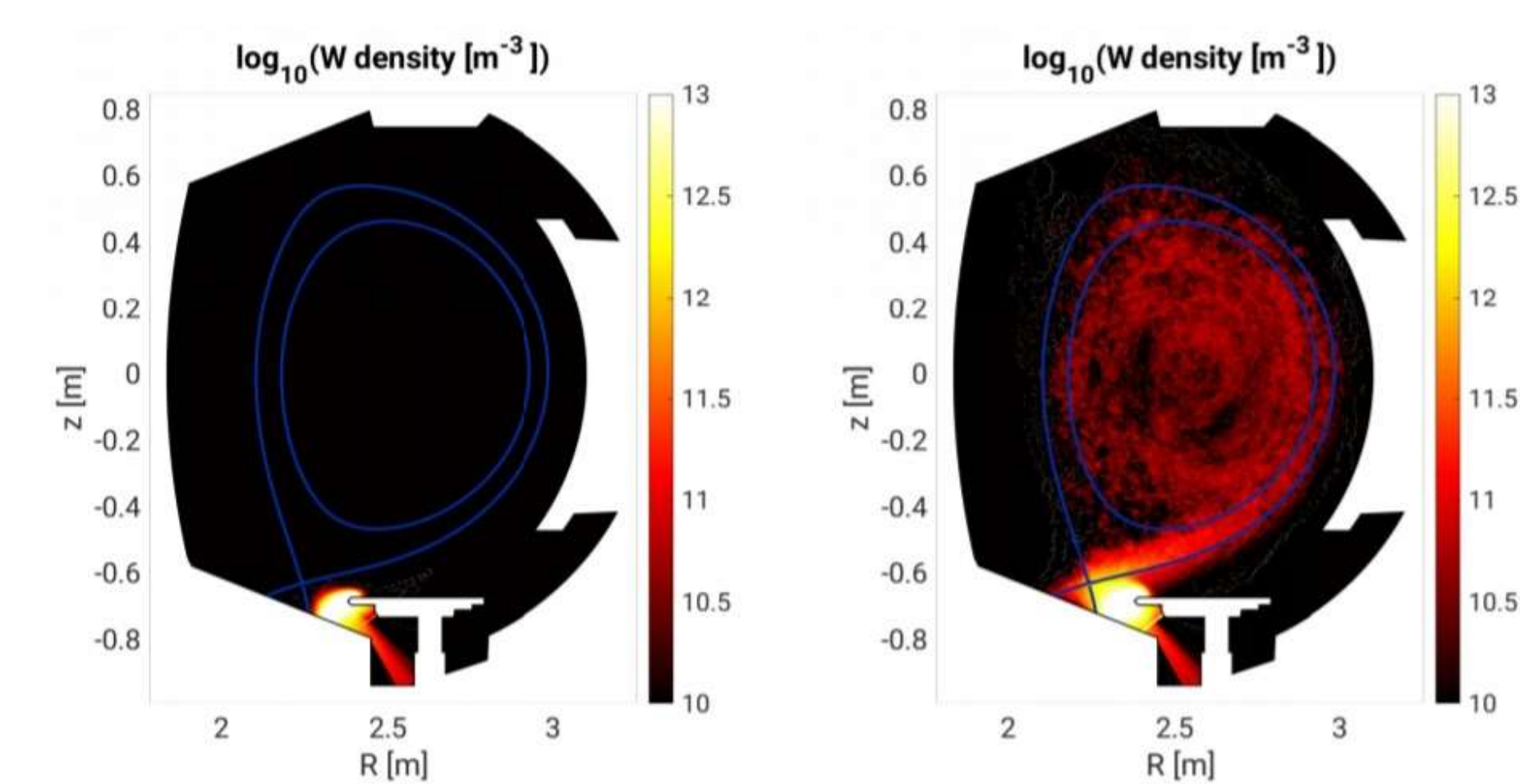


Semi detached plasma background
(coeff $D=0.3 \text{ m}^2/\text{s}$)

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



(a) $D_{\perp}^{an} = 0.3 \text{ m}^2/\text{s}$ (b) $D_{\perp}^{an} = 1 \text{ m}^2/\text{s}$

Using the same plasma background, setting a radial diffusion coefficient $D=0.3 \text{ m}^2/\text{s}$ in ERO2.0 simulations the baffle is not contaminating the core while for $D=1 \text{ m}^2/\text{s}$ the baffle is also responsible for W core contamination