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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

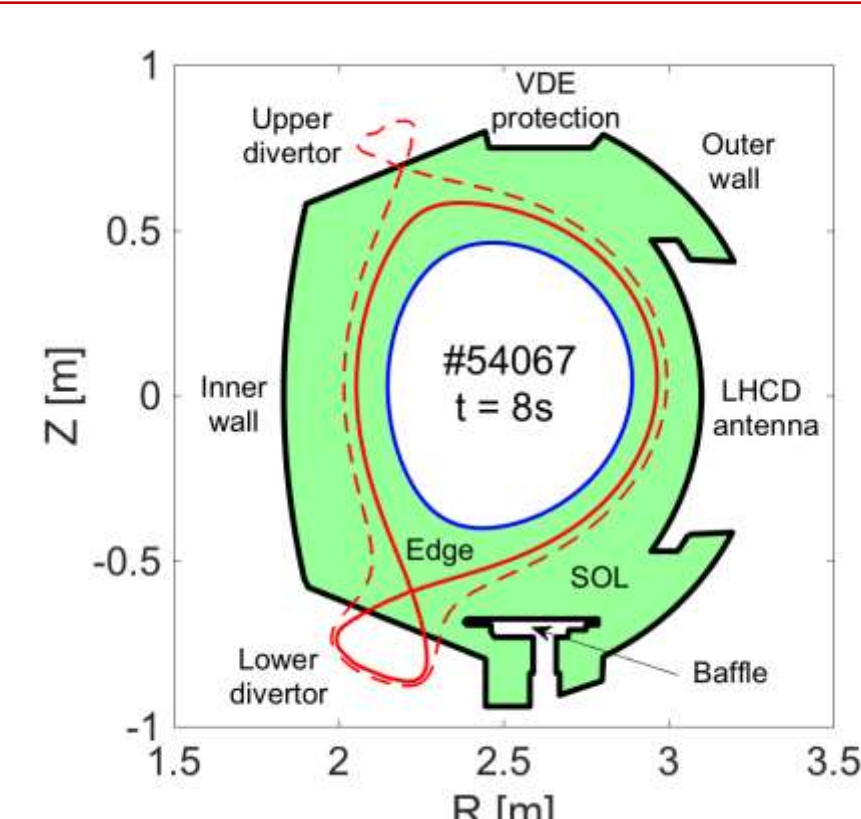
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## Modeling of background plasma in a WEST discharge

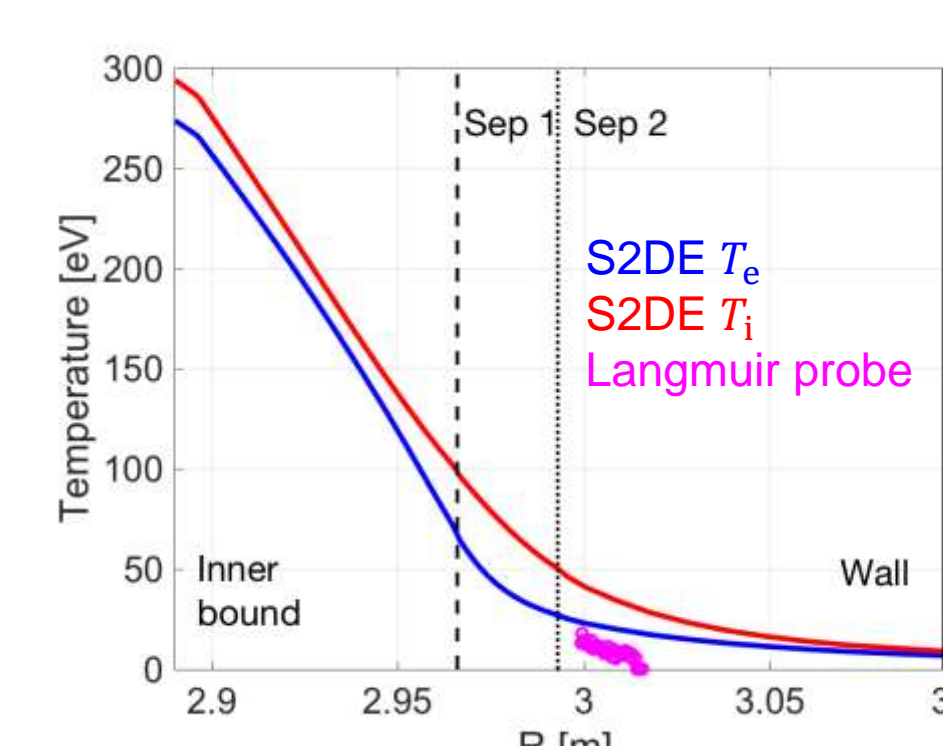
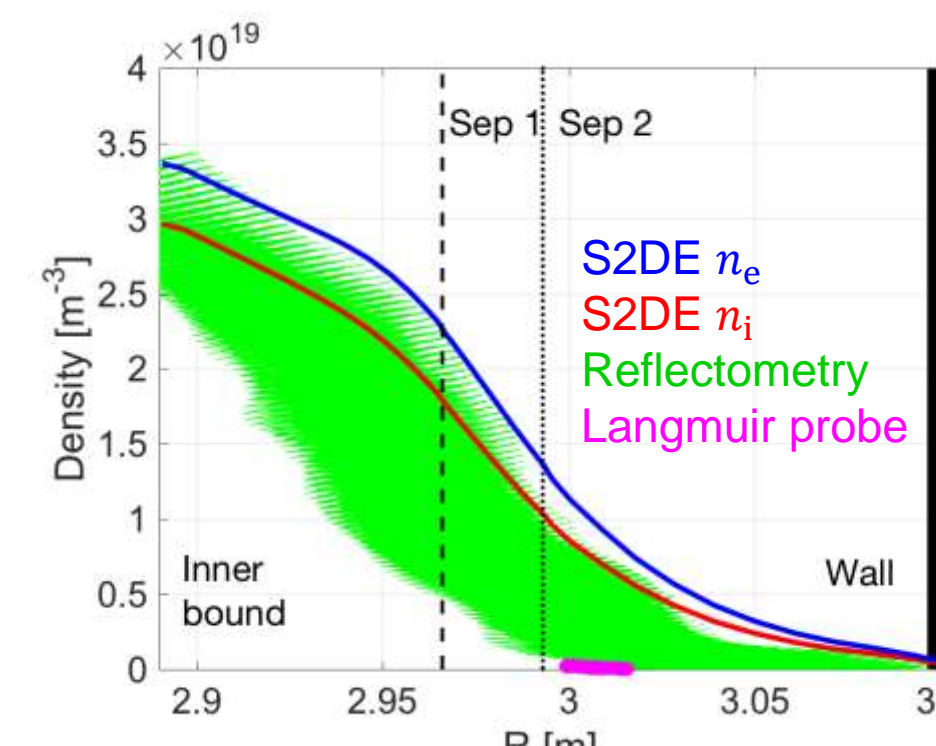
The 2D fluid plasma solver SolEdge2D [2] coupled with the kinetic Monte Carlo code EIRENE for neutrals [3] (S2DE) used to model the background plasma ( $n_e, T_e, T_i, u$ ) of a recent lower single null, LH heated, L-mode WEST discharge.

## 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;



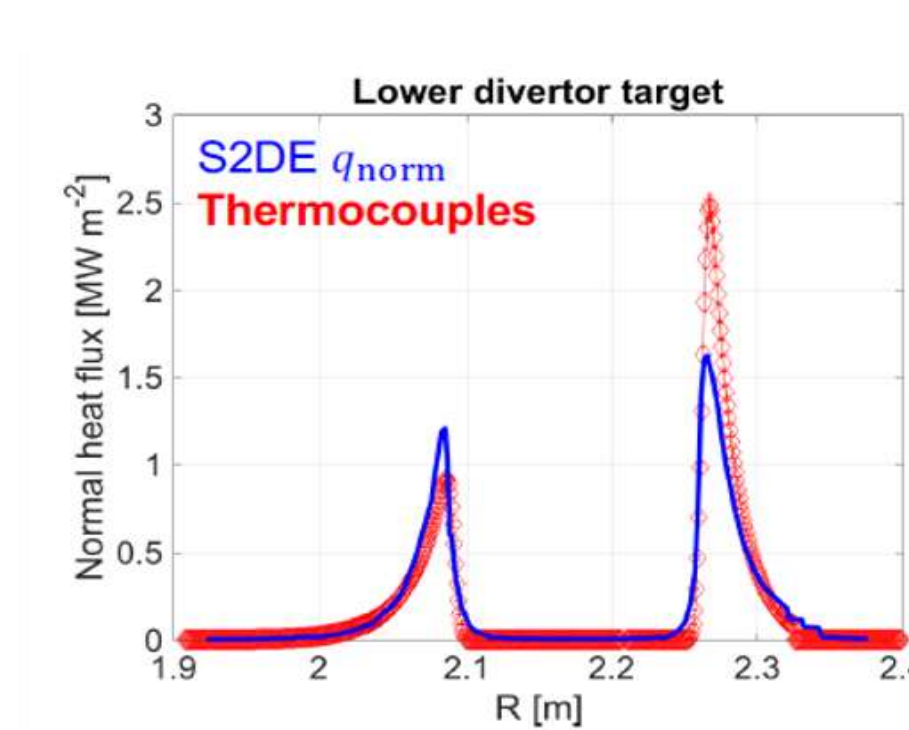
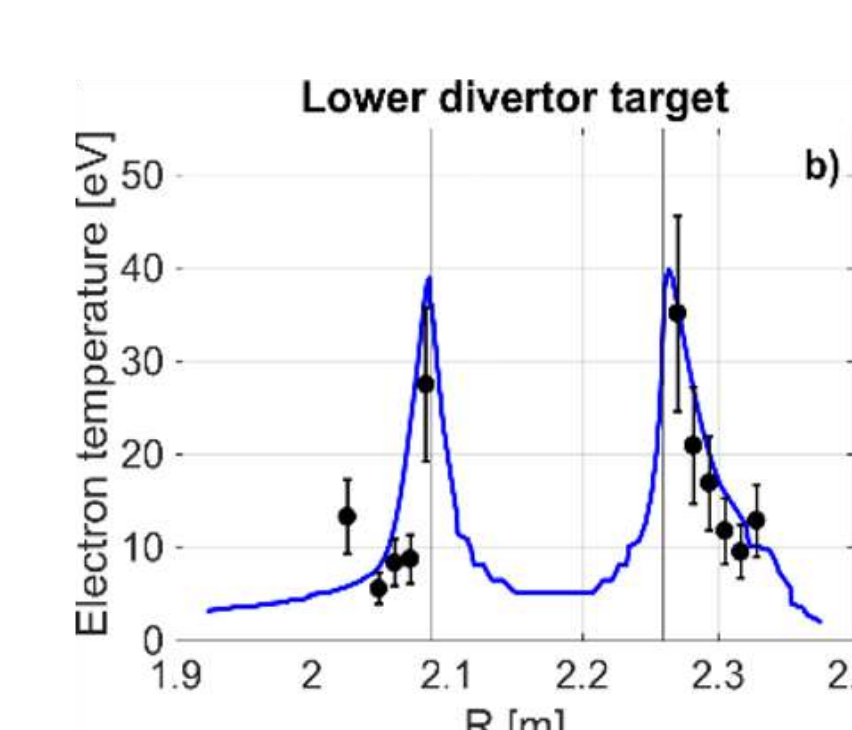
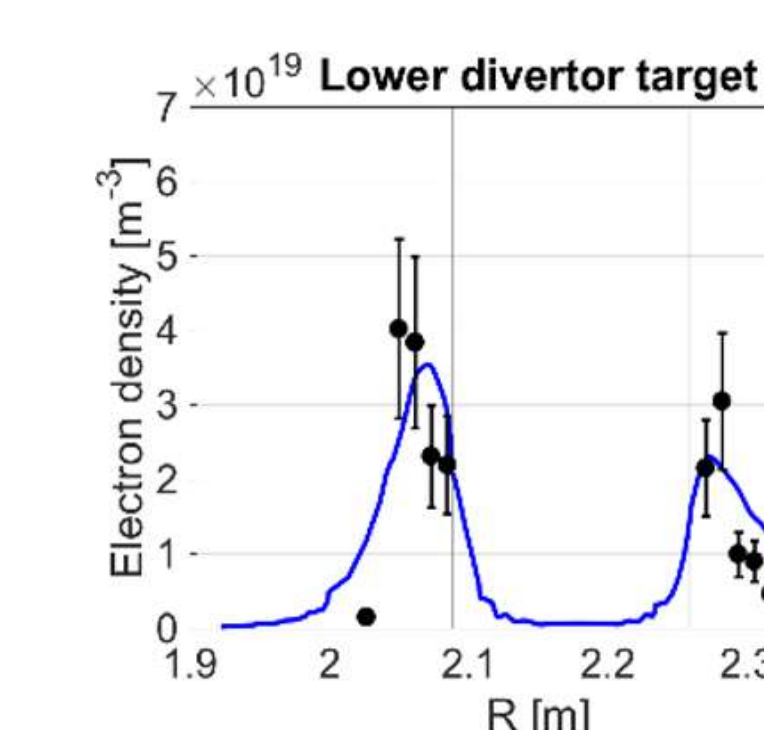
## Background plasma along outer midplane



- 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

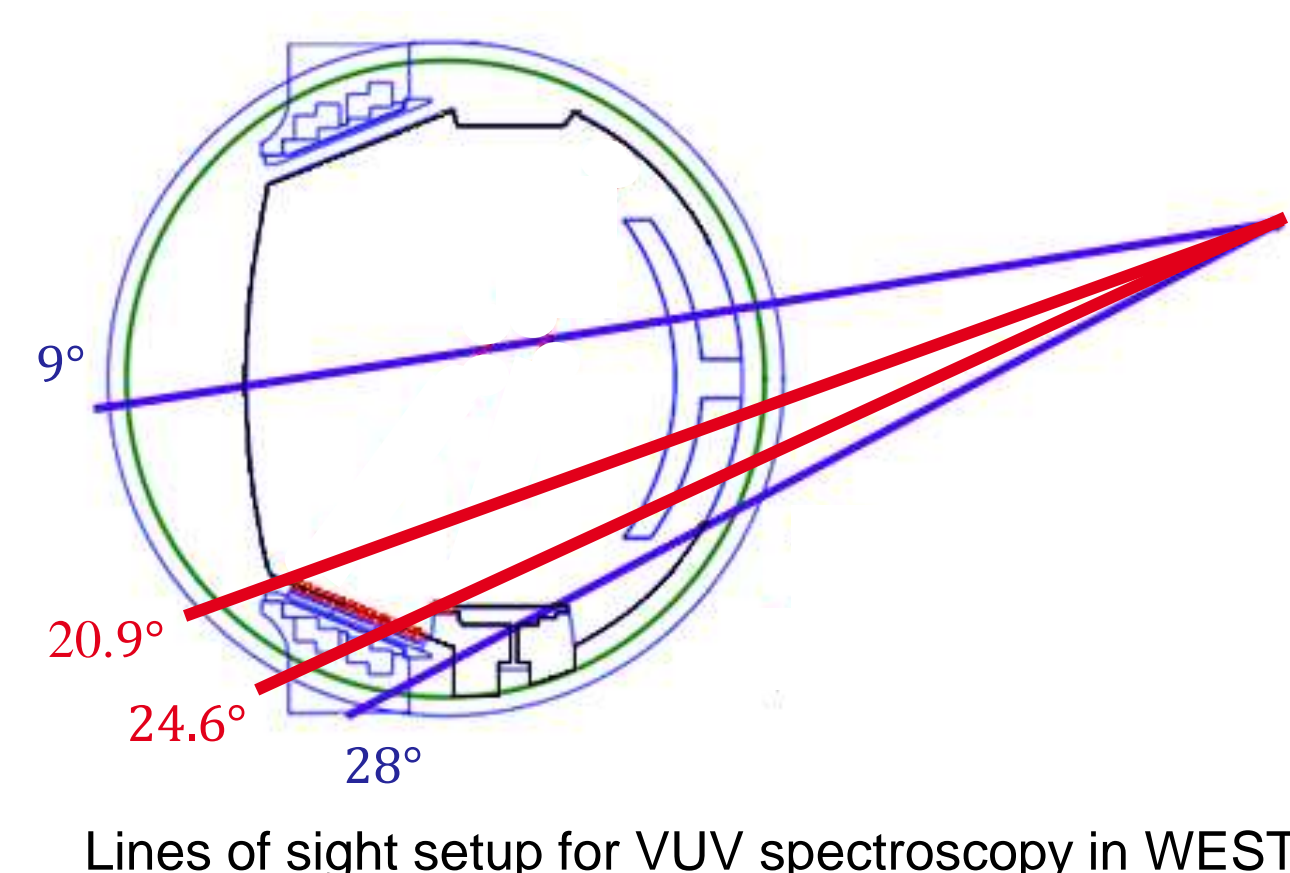


- good agreement with divertor Langmuir probes at outer target, not at inner target (stronger recycling in simulation)
- normal heat flux in qualitative agreement with thermocouples (in/out asymmetry) but  $2 \times$  and  $2.5 \times$  lower amplitude

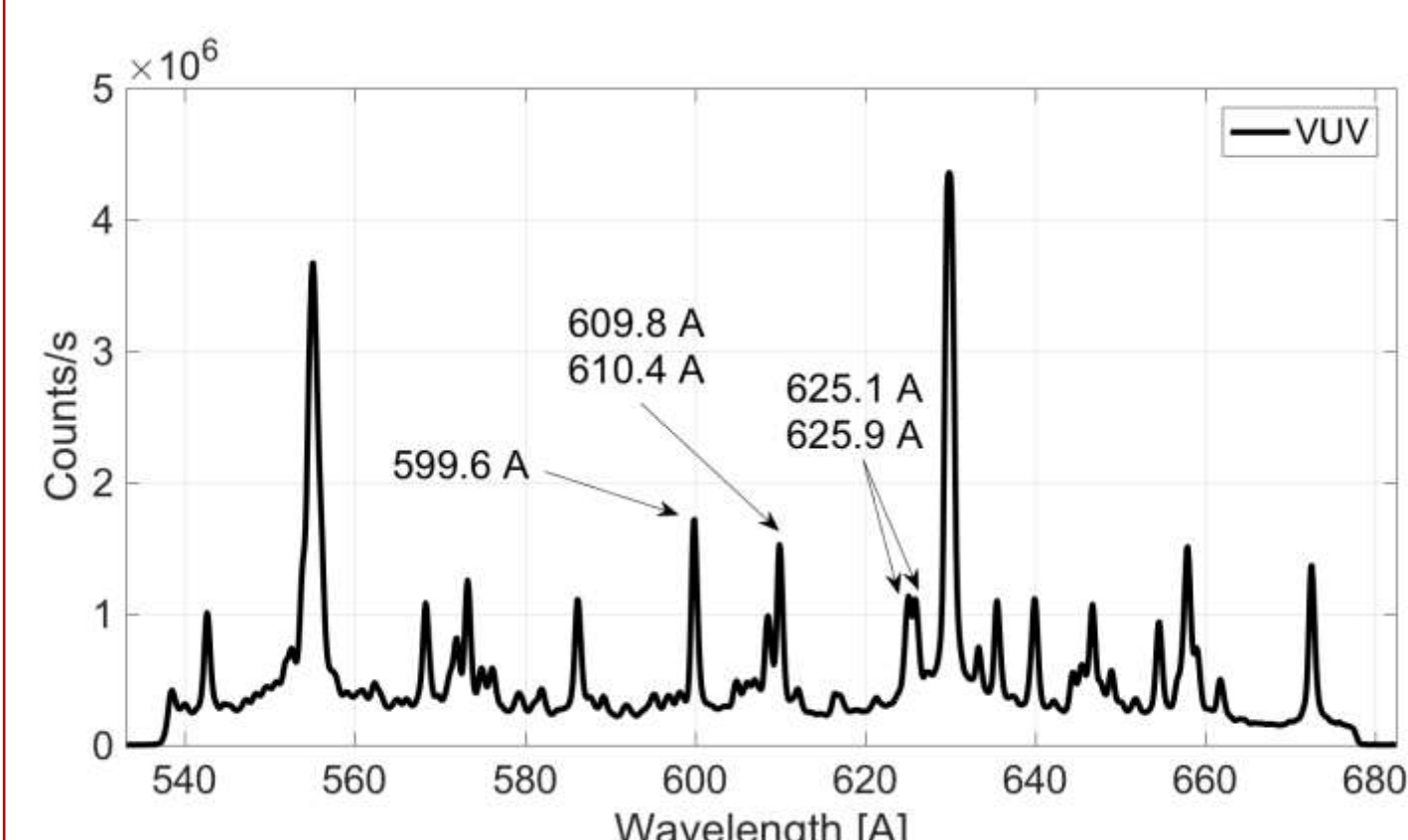
## Modeling of impurity transport in WEST and comparison with VUV measurements

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

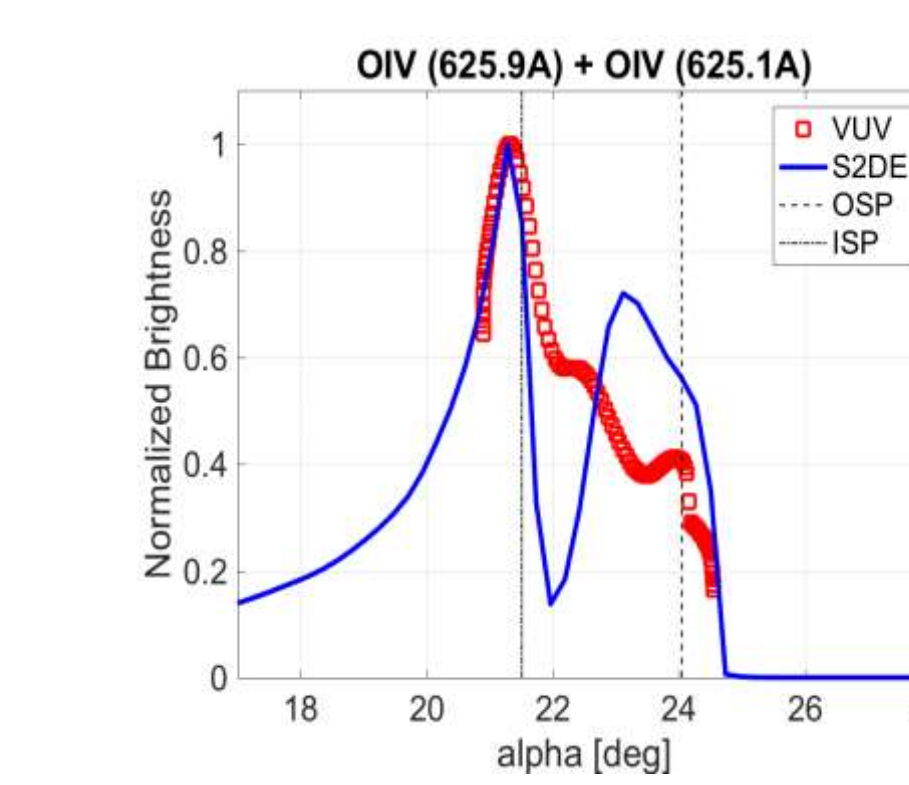
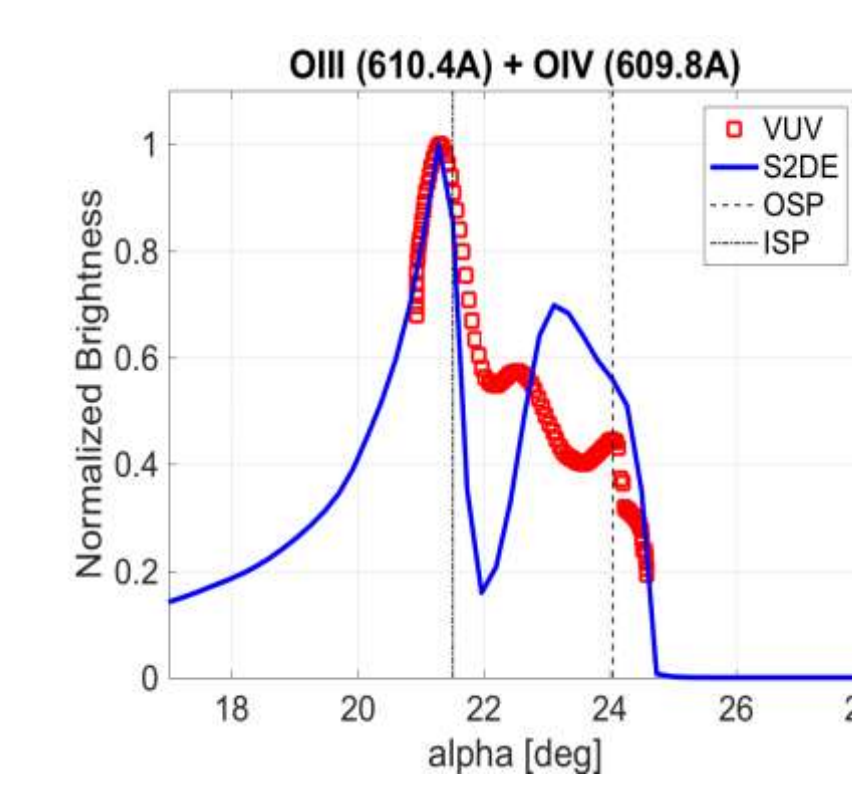
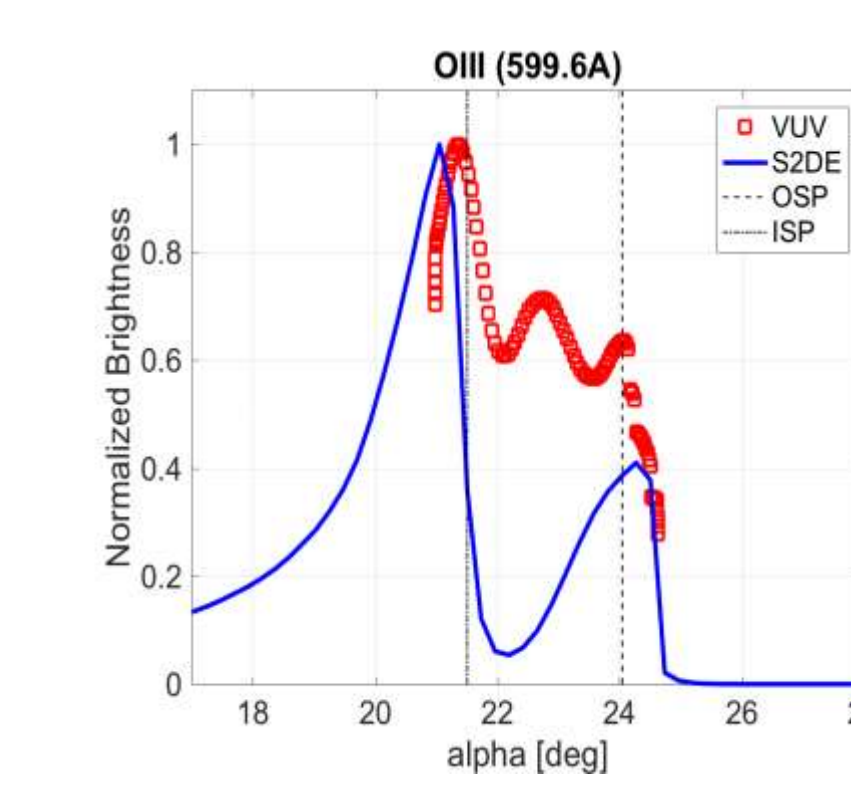


VUV spectrum for WEST #54067 (between 6s and 9s) OIII 599.6A and 610.4A; OIV 609.8A, 625.1A, 625.9A



## Normalized brightness poloidal profiles

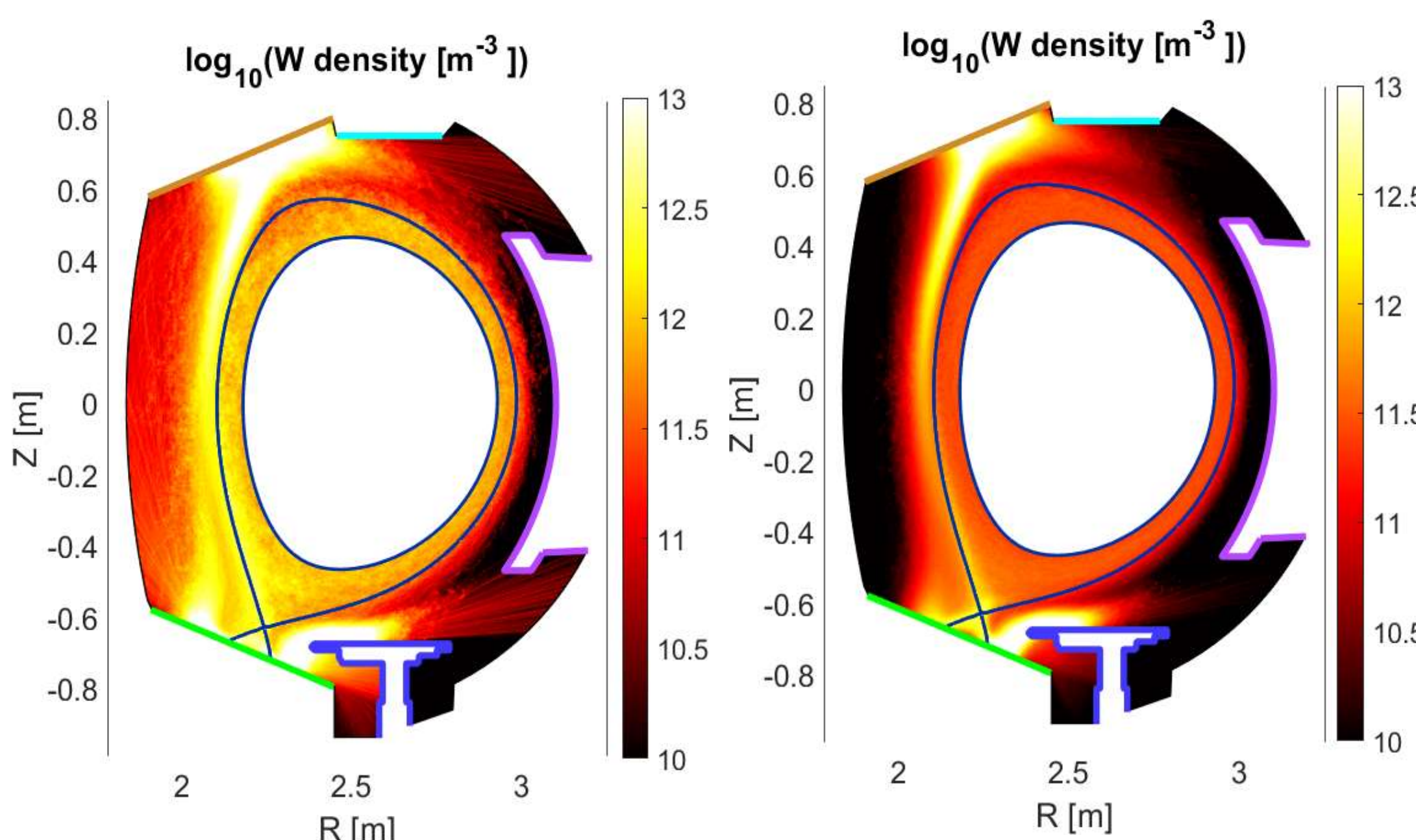
O signal from VUV spectroscopy data peaks at inner strike point and outer strike point (partially shadowed by baffle). Stronger oxygen signal from inner divertor target, consistent with O density/concentration maps in S2DE simulation.



- "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



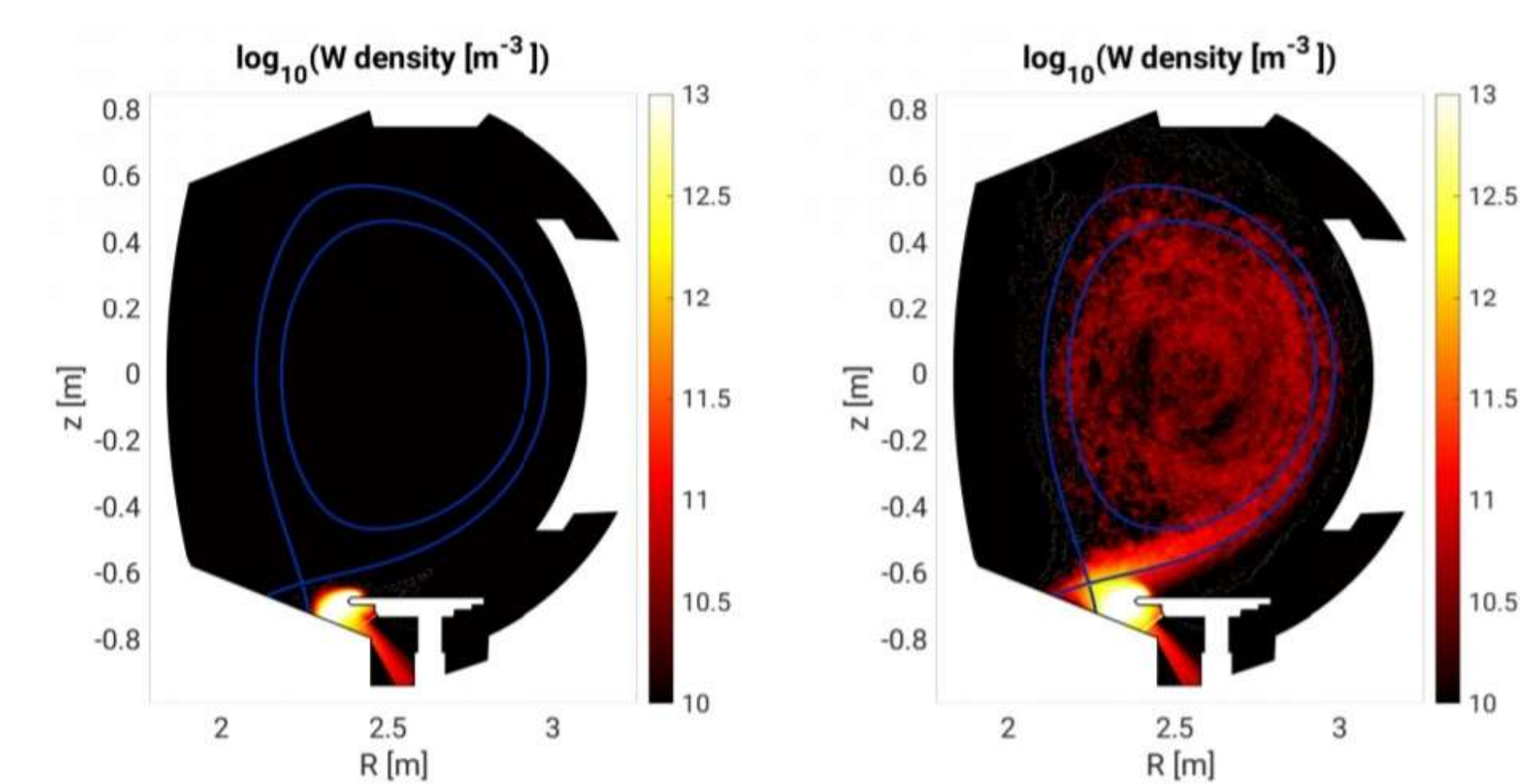
Attached plasma background  
(coeff  $D=0.3 \text{ m}^2/\text{s}$ )

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	$1.2 \times 10^{11}$	$2.7 \times 10^8$
Outer Target	$7.5 \times 10^6$	$1.1 \times 10^8$
Baffle	negligible	negligible
Antenna	$1.1 \times 10^9$	$2.3 \times 10^7$
Ceiling	$1.8 \times 10^9$	$7 \times 10^7$
Upper divertor	$6.4 \times 10^{12}$	$2.2 \times 10^{12}$

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