



# First wall fluxes in ITER from full vessel edge-plasma simulations

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## ► To cite this version:

Nicolas Rivals, Patrick Tamain, Y Marandet, X. Bonnin, Hugo Bufferand, et al.. First wall fluxes in ITER from full vessel edge-plasma simulations. PSI25 - 25th International Conference on Plasma Surface Interaction in Controlled Fusion Devices, Jun 2022, E-conference, France. cea-03784828

HAL Id: cea-03784828

<https://cea.hal.science/cea-03784828>

Submitted on 23 Sep 2022

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# First wall fluxes in ITER from full vessel edge-plasma simulations

*25<sup>th</sup> International Conference on Plasma Surface Interaction in Controlled Fusion Devices, June 12-17, 2022*

DE LA RECHERCHE À L'INDUSTRIE

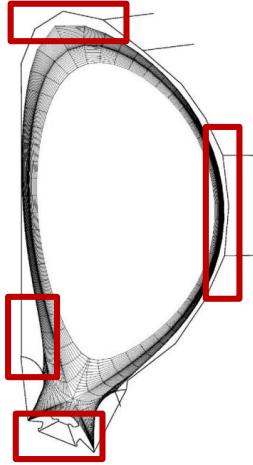
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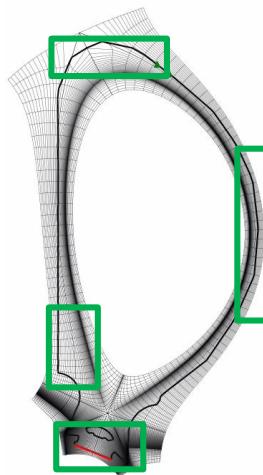


# Simulating ITER plasmas with SOLEDGE3X aims at providing self-consistent up-to-the wall plasmas and fluxes

SOLPS-ITER  
domain



SOLEDGE3X  
domain



- Divertor design mainly based on **SOLPS-ITER simulations**, domain restricted to common SOL  
[R.A. Pitts et al. 2019 NME 20 100696]
- New **self-consistent plasma simulations** with numerical grid extended to all plasma-facing components

## Motivation:

- Provide **self-consistent extended grid simulations for ITER**, providing, e.g.:
  - **far-SOL plasma backgrounds** for erosion migration studies (e.g. WALLDYN, ERO2)
  - Estimation of **first wall heat load**

**See R.A. Pitts talk, T105**  
« Physics considerations for the ITER First Wall lifetime »

## The SOLEDGE3X code and setup:

- **SOLEDGE3X:** Mean-field multispecies (Zhdanov closure), 3D-turbulent or 2D-transport fluid-plasma solver coupled to kinetic neutrals from EIRENE or fluid neutrals  
[H. Bufferand et al. 2021 Nucl. Fusion 61 116052]
- **Simulation setup:**
  - Based on SOLPS-ITER cases (#103027-#103030)  
[J.S. Park et al. 2021 Nucl. Fusion 61 016021]
  - 2D-transport mode, constant diff. coeffs.
  - **Most recent magnetic eq.** from DINA scenarios & wall contour
  - Pure-H
  - 20MW (PFPO-1)
  - No fluid drifts
  - **Advanced options in EIRENE** (elastic ion col., MAR, neutral-neutral col.)

# Improvements had to be made in SOLEDGE3X to enable simulation of the right physics of cold detached divertors

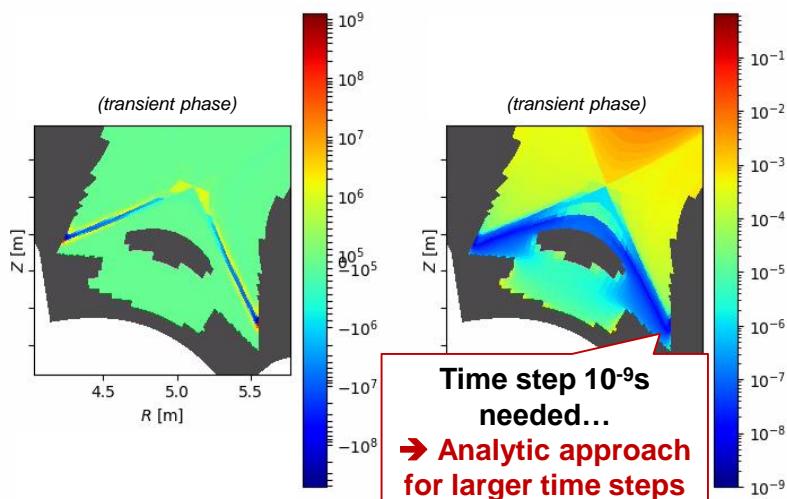
## Collisional electron-ion energy exchange:

$$Q_{e \rightarrow i} = \frac{m_e Z^2 e^4 \Delta}{m_i (2\pi)^2 \epsilon_0^2 \sqrt{m_e}} n_e n_i \frac{1}{T_e^2} (T_i - T_e)$$

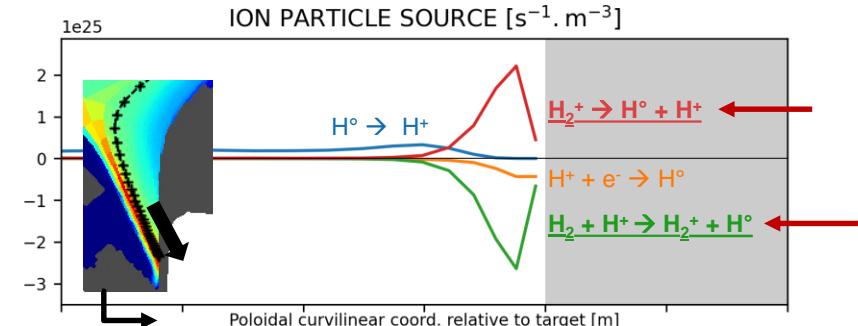
**Quantum effects required for asymptotics OK at low  $T$**

[Raghunathan et al, 2021, Hahn et al., 1971]

**Strong term at low  $T$**



## Major contributions from molecular ion $H_2^+$ near the target:



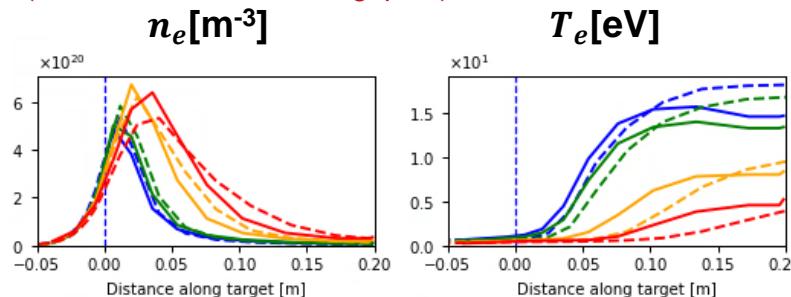
**Reactions varying strongly at low  $T$ ...  
→ More stable source extrapolation schemes  
(better stable vs computation time trade-off)**

# Good quality benchmark is obtained between SOLEDGE3X and SOLPS-ITER

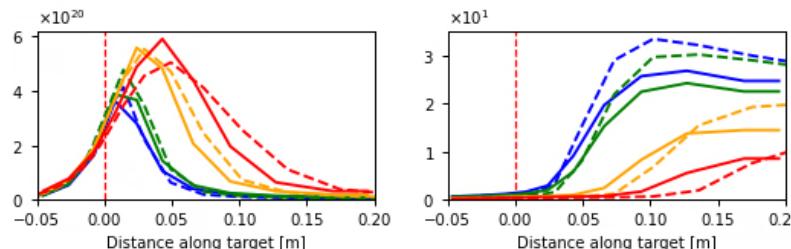
## Throughput scan, from attached to partially detached

(colors are different throughputs)

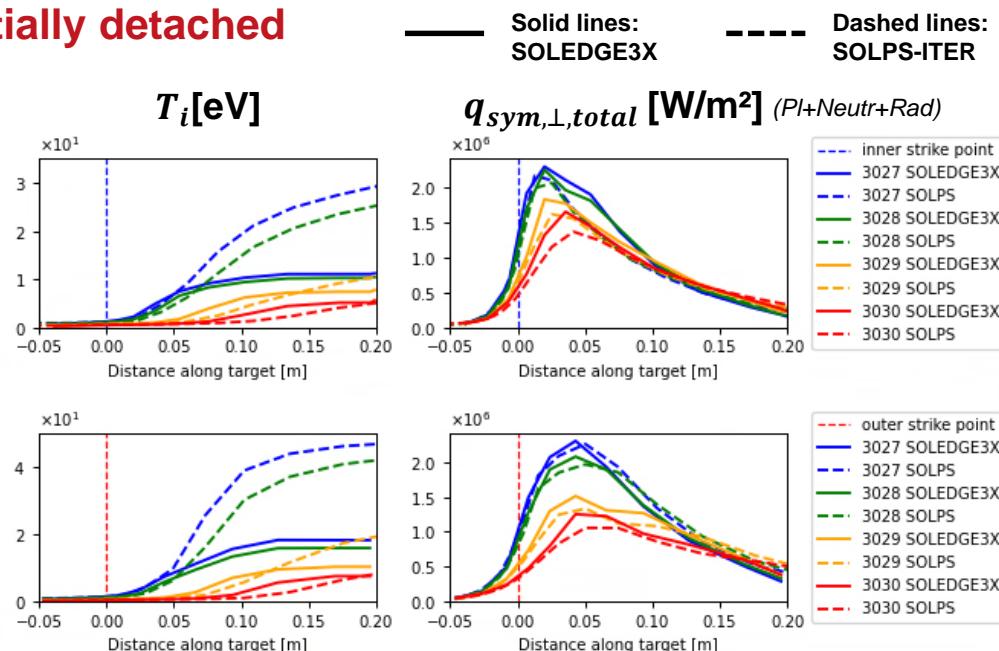
INNER Target



OUTER Target

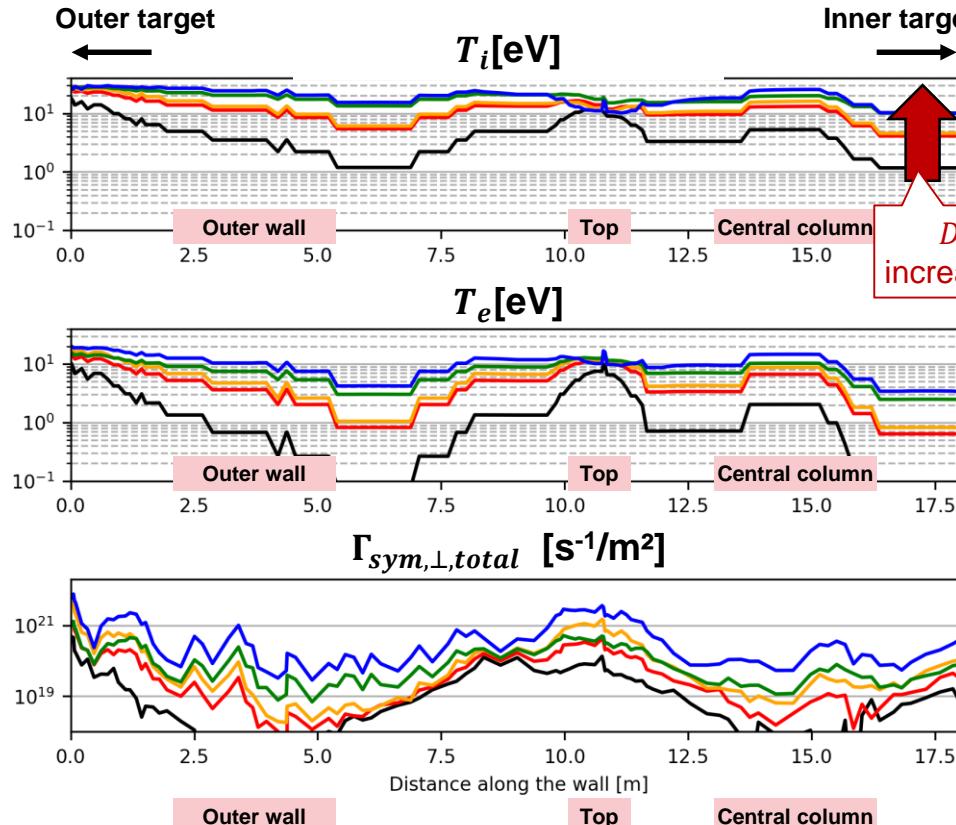


- $D_\perp = 0.3 \text{ m}^2/\text{s}$   $\chi_e = \chi_i = 1.0 \text{ m}^2/\text{s}$  constant everywhere
- Good agreement on upstream mid-plane profiles



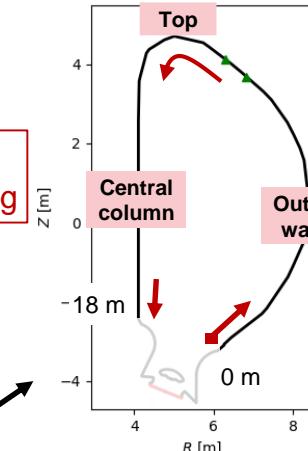
# First wall particle fluxes and energies are key to erosion-migration simulations

## Impact of high far-SOL transport (medium throughput):



Magnetic eq. from recent DINA scenario

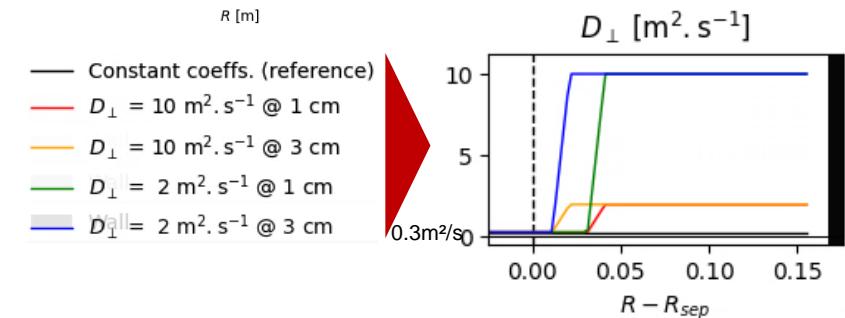
## 2D view of wall coordinate



When strongly enhanced far-SOL transport:

- FW fluxes  $\times 10-20$
- $T_{i,\text{wall}} \nearrow : 20 - 30 \text{ eV}$
- $T_{e,\text{wall}} \nearrow : 10 - 20 \text{ eV}$
- $q_{\text{sym},\perp,\text{total}} = 40 \text{ kW/m}^2$  @ machine top
- 30% of  $P_{\text{in}}$  on FW

## Diffusivity coeff. profile at midplane



- Started to **expand ITER simulation database** with **first SOLEDGE3X runs**, including **self-consistent 2D up-to-the-wall plasma description** with an **extended grid**.
- **Good quality benchmark** on a detachment throughput scan on common simulation domain with **SOLPS-ITER**
- First study complete on the **impact on particle fluxes** and **energies** in the case of **enhanced far-SOL transport**

#### Acknowledgement:

*This work was performed under the auspices of the ITER Scientist Fellow Network. The views and opinions expressed herein do not necessarily reflect those of the ITER organization.*

*This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.*

# THANK YOU