



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

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

25th International Conference on Plasma Surface Interaction in Controlled Fusion Devices, June 12-17, 2022

DE LA RECHERCHE À L'INDUSTRIE

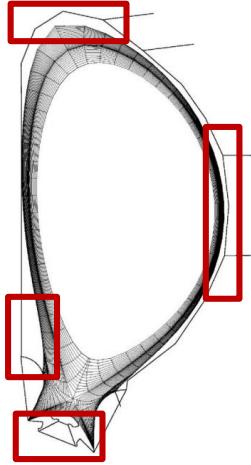
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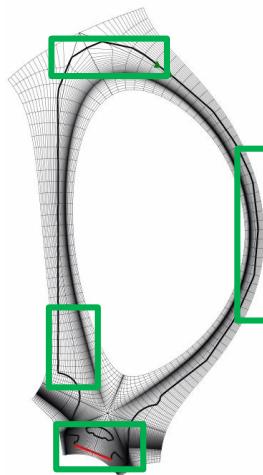


Simulating ITER plasmas with SOLEDGE3X aims at providing self-consistent up-to-the wall plasmas and fluxes

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

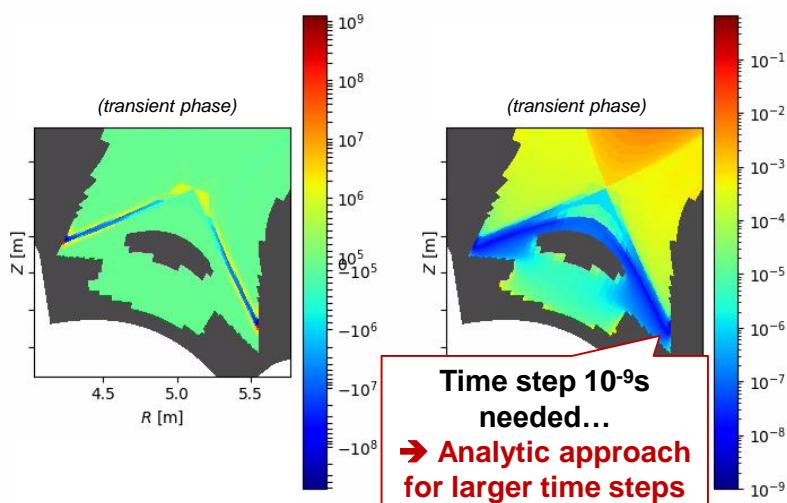
Collisional electron-ion energy exchange:

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

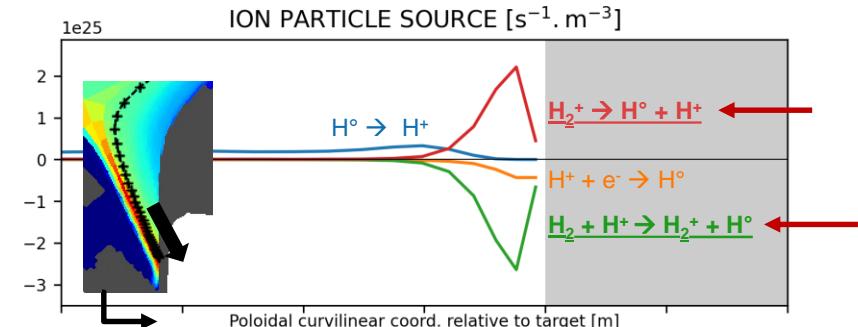
Quantum effects required for asymptotics OK at low T

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

Strong term at low T



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



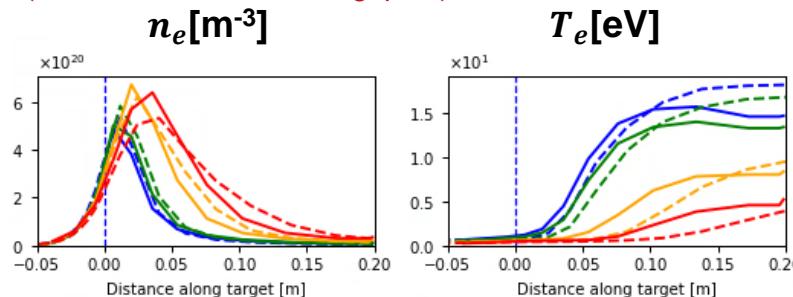
**Reactions varying strongly at low T ...
→ More stable source extrapolation schemes
(better stable vs computation time trade-off)**

Good quality benchmark is obtained between SOLEDGE3X and SOLPS-ITER

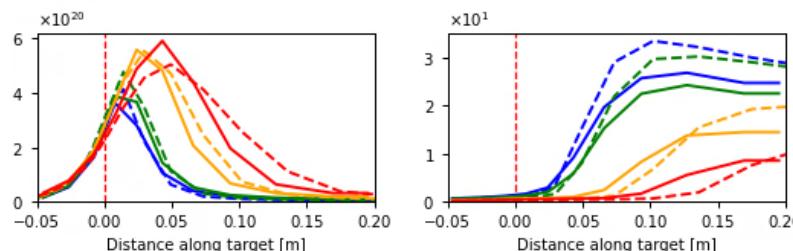
Throughput scan, from attached to partially detached

(colors are different throughputs)

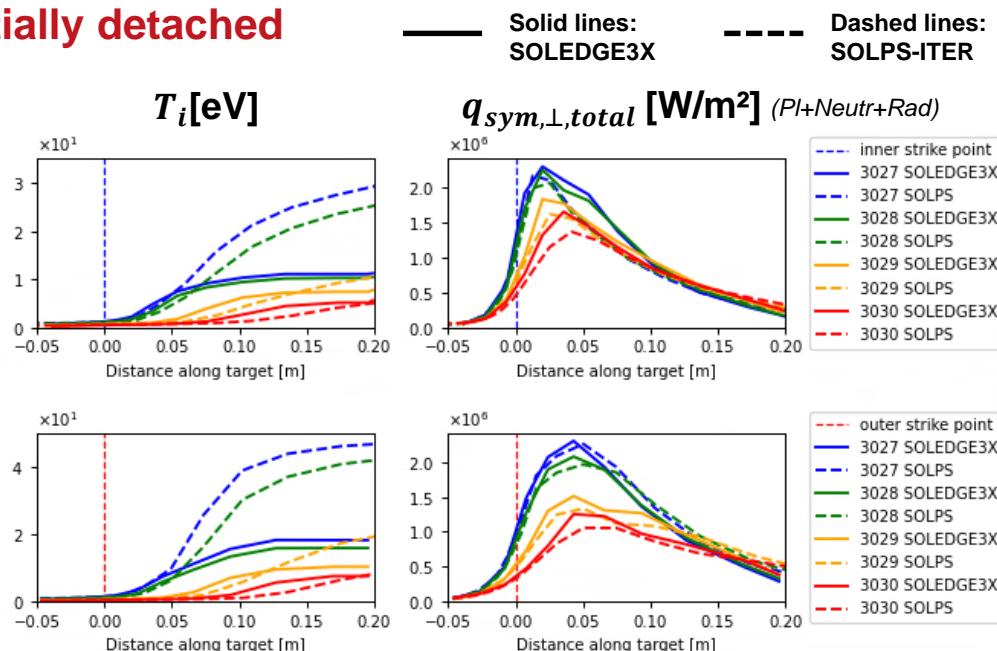
INNER Target



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

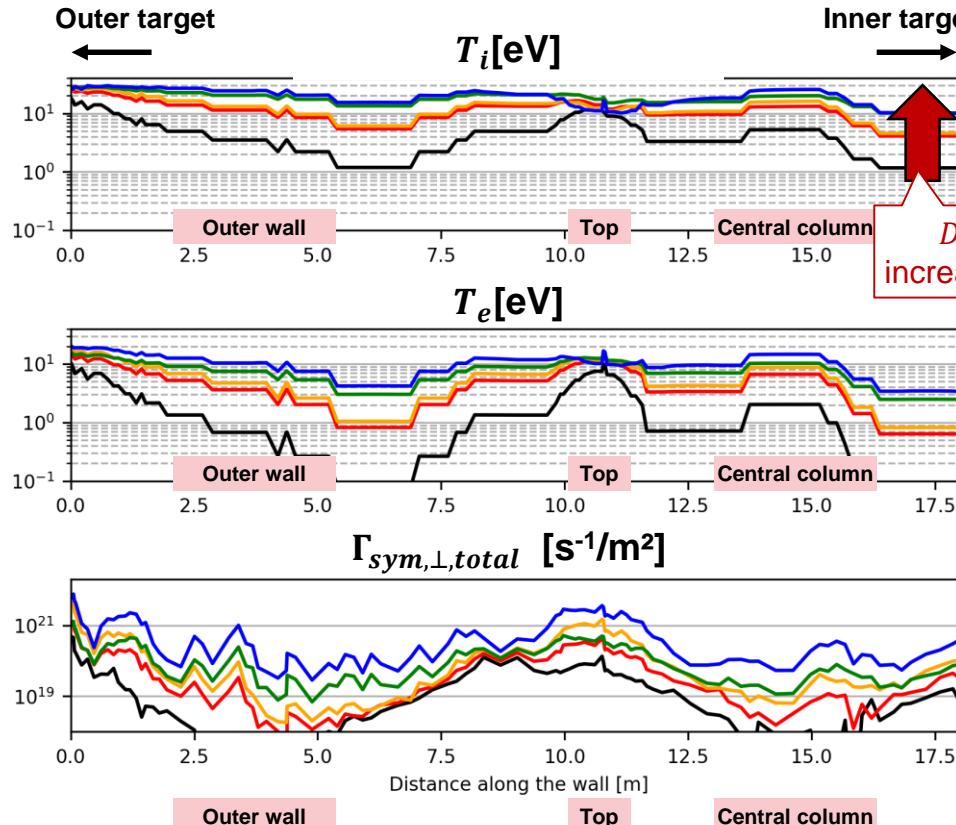


Under investigation:

- Lower T_i away from strike points in SOLEDGE3X for attached cases
- Some discrepancy in divertor neutral pressure at high throughput

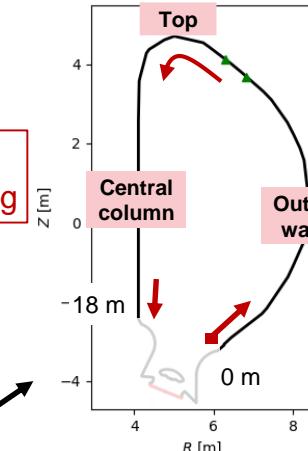
First wall particle fluxes and energies are key to erosion-migration simulations

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



Magnetic eq. from recent DINA scenario

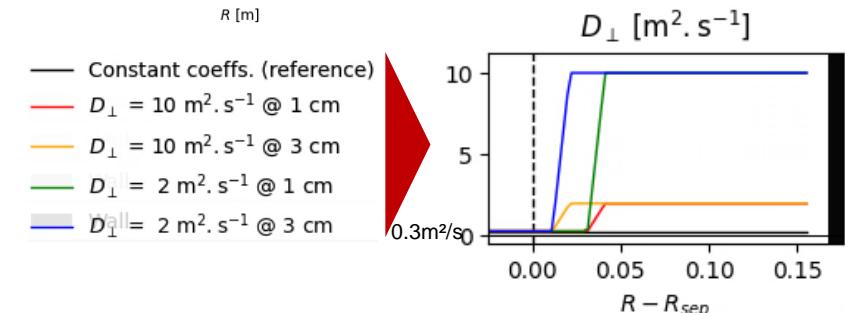
2D view of wall coordinate



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_{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**

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THANK YOU