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

Nicolas Rivals, Patrick Tamain, Y Marandet, X. Bonnin, Hugo Bufferand, G. Falchetto, Hao Yang, Guido Ciraolo, R.A. Pitts

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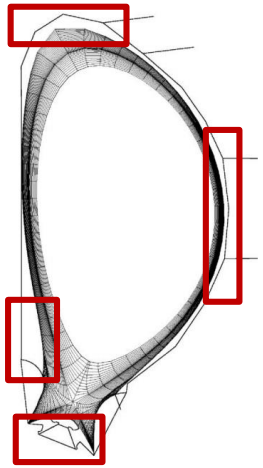
DE LA RECHERCHE À L'INDUSTRIE

Nicolas RIVALS (CEA IRFM)

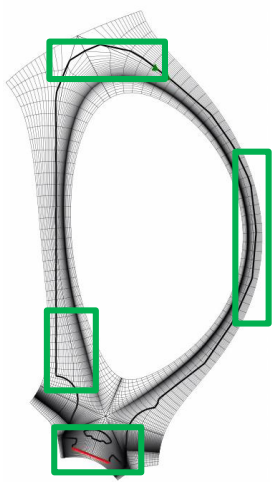
P. TAMAIN (CEA IRFM), Y. MARANDET(CNRS, Aix-Marseille Université), X. BONNIN (ITER Organization), H. BUFFERAND (CEA IRFM), G. FALCHETTO (CEA IRFM), H. YANG (CEA IRFM), G. CIRAOLO (CEA IRFM), R.A. PITTS (ITER Organization)

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, TI05
« 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.)

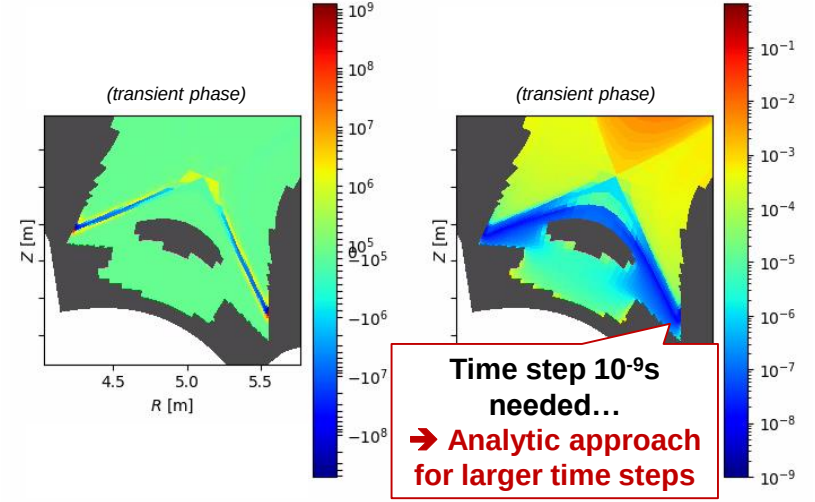
Improvements had to be made in SOLEDGE3X to enable simulation of the right physics of cold detached divertors

Collisional electron-ion energy exchange:

$$Q_{e\to i} = \frac{m_e Z^2 e^4 \boldsymbol{\Lambda}}{m_i (2\pi)^{\frac{3}{2}} \varepsilon_0^2 \sqrt{m_e}} n_e n_i \frac{1}{\boldsymbol{T_e^{\frac{3}{2}}}} (T_i - T_e)$$

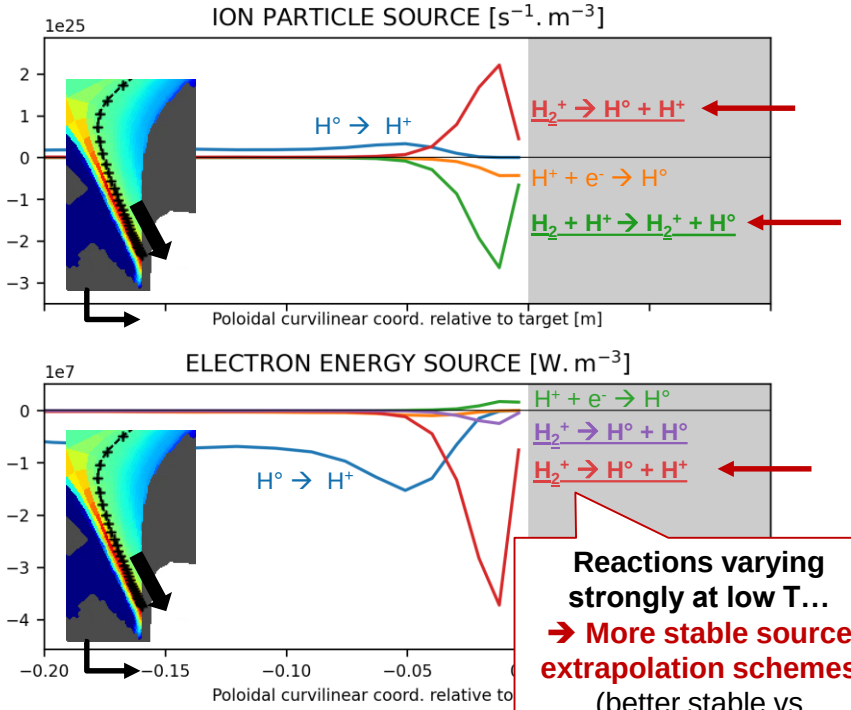
Quantum effects required for asymptotics OK at low T
[Raghunathan et al, 2021, Hahn et al., 1971]

Strong term at low T



Time step 10^{-9}s needed…
➔ Analytic approach for larger time steps

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



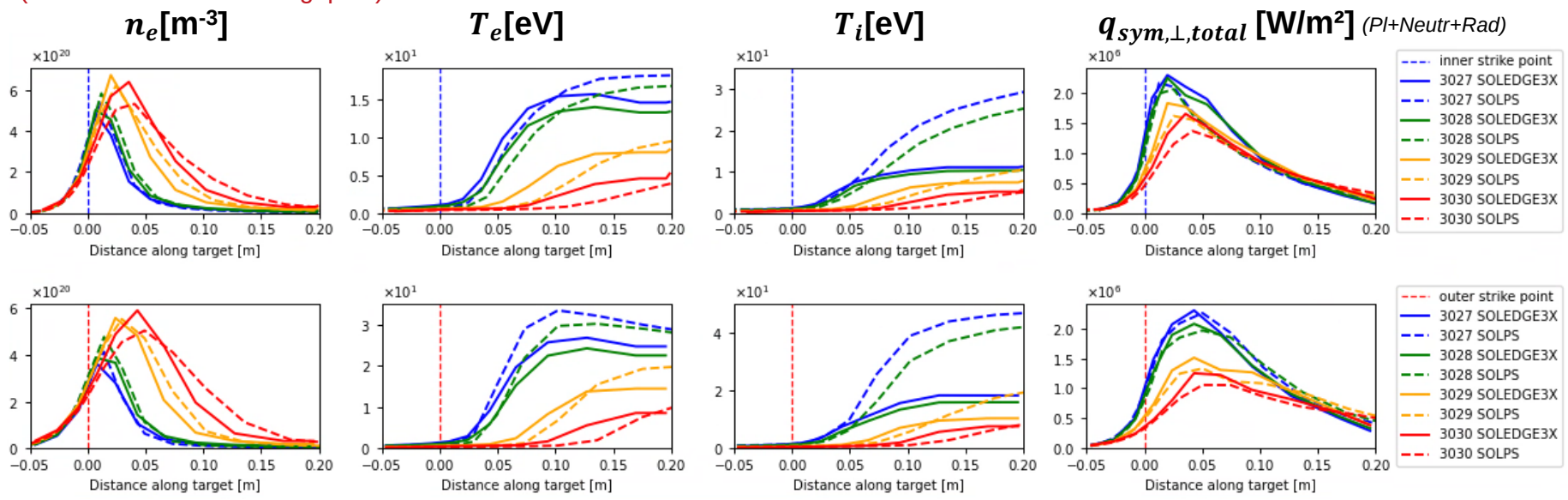
Reactions varying strongly at low T…
➔ More stable source extrapolation schemes
(better stable vs computation time trade-off)

Good quality benchmark is obtained between SOLEDGE3X and SOLPS-ITER

Throughput scan, from attached to partially detached

(colors are different throughputs)

Solid lines: SOLEDGE3X — Dashed lines: SOLPS-ITER



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

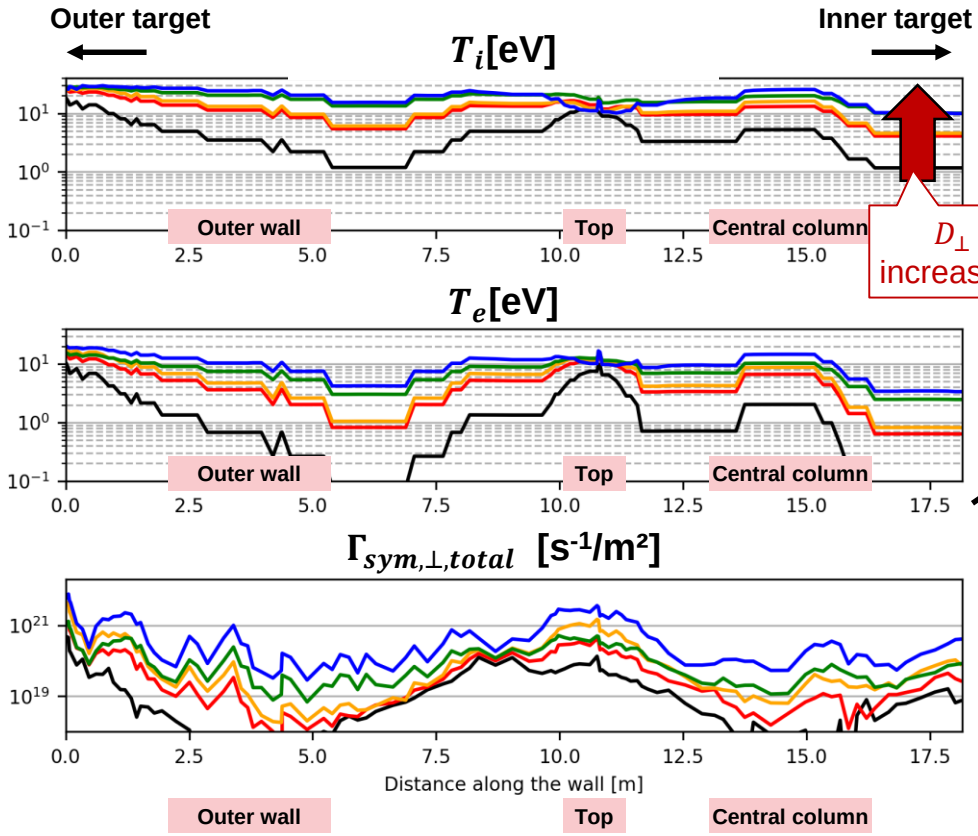
Under investigation:

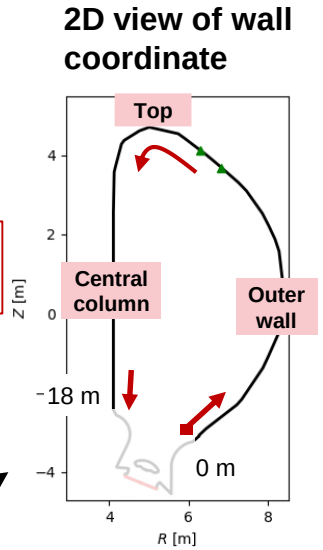
- Lower T_i away from strike points in SOLEDGE3X for attached cases
- Some discrepancy in divertor neutral pressure at high throughput

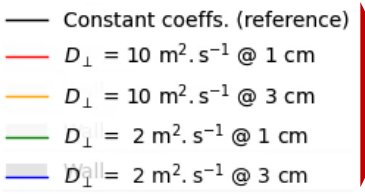
First wall particle fluxes and energies are key to erosion-migration simulations

Magnetic eq. from recent DINA scenario

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



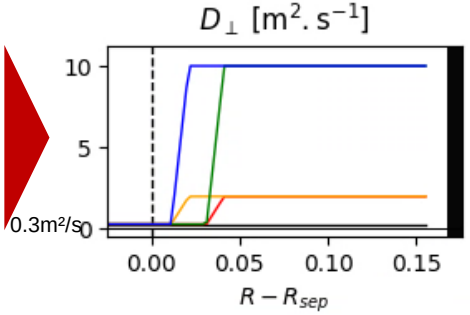




When strongly enhanced far-SOL transport:

- FW fluxes x 10-20
- $T_{i,wall}$ ↗ : 20 - 30 eV
- $T_{e,wall}$ ↗ : 10 - 20 eV
- $q_{sym,\perp,total}$ = 40kW/m² @ machine top
- 30% of P_{in} on FW

Diffusivity coeff. profile at midplane



Summary

- 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