WPPRD-LMD 2022 KoM: PoliTo

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This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Outline

- PoliTo task
- Overview of the modelling strategy
- 2021 activities
- Plan for 2022
- Perspective

PoliTo task

- LM **erosion** →
  - beneficial vapor shielding of the target …
  - … **but** possibly excessive **core plasma cooling/dilution**

- Target, SOL and core plasma must all be included in a **self-consistent model** to:
  - Assess compatibility with EU DEMO plasma scenario and support LMD design
  - Analyze LMD experiments in tokamaks (→ interpretation, model calibration and validation)

Aim: to develop and apply the necessary knowledge and tools to simulate the EU DEMO plasma in the presence of an LMD using a state-of-the-art **edge plasma code** (SOLPS-ITER) and a **core transport code** (ASTRA).

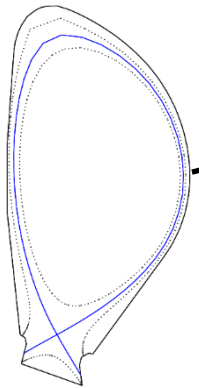
Overview of modelling strategy (I)

Core plasma: couple to ASTRA.
- One-way (TBC in FP9-2022)
- Self-consistent coupling (FP9 – 2022)

Pedestal: B2.5 with adjusted transport coefficient profiles to reproduce ETB (FP8 – 2018/2019)

SOL plasma: B2.5 (FP8 – 2018/2019)

Neutral transport, interaction with plasma, pumping/redeposition: EIRENE (FP8 – 2020)



SOL plasma domain boundaries

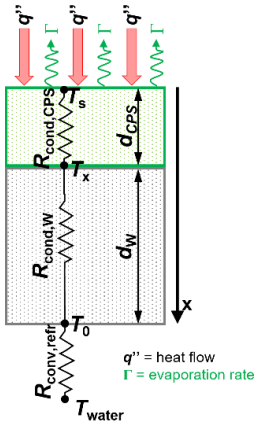
Wall

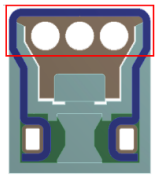
Target erosion:
- Implemented in B2.5 (FP8-2018/2019).
- For EIRENE:
  - One-way coupling (FP9-2021).
  - Self-consistent coupling: ongoing (TBC in FP9-2022)

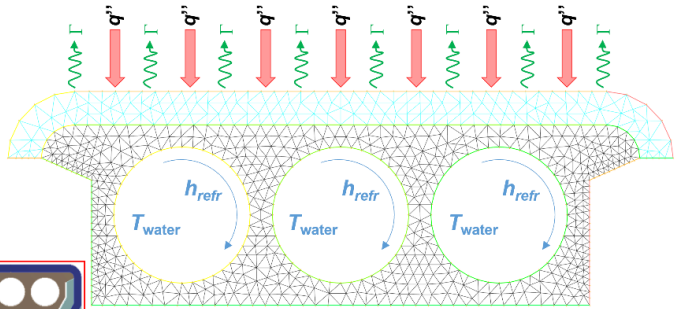
Erosion flux

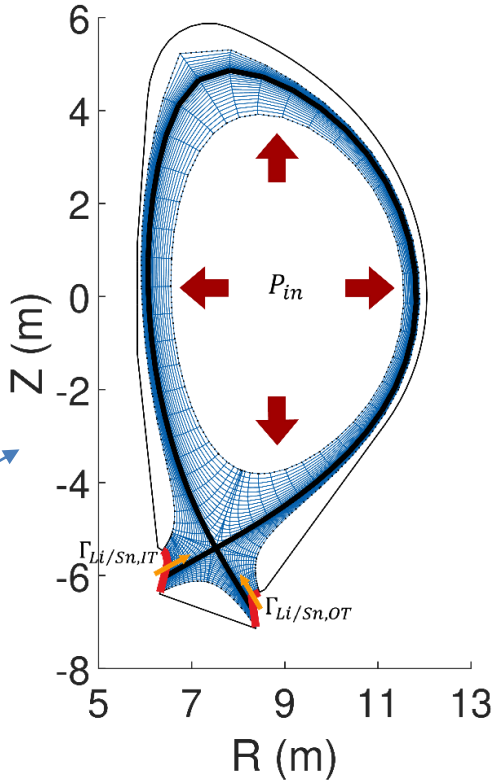
SOLPS-ITER (B2.5 + EIRENE) simulation domain

Overview of modelling strategy (II)









Heat and particle flux from main plasma

LM source model

Evaporation rate

Temperature-enhanced sputtering rate

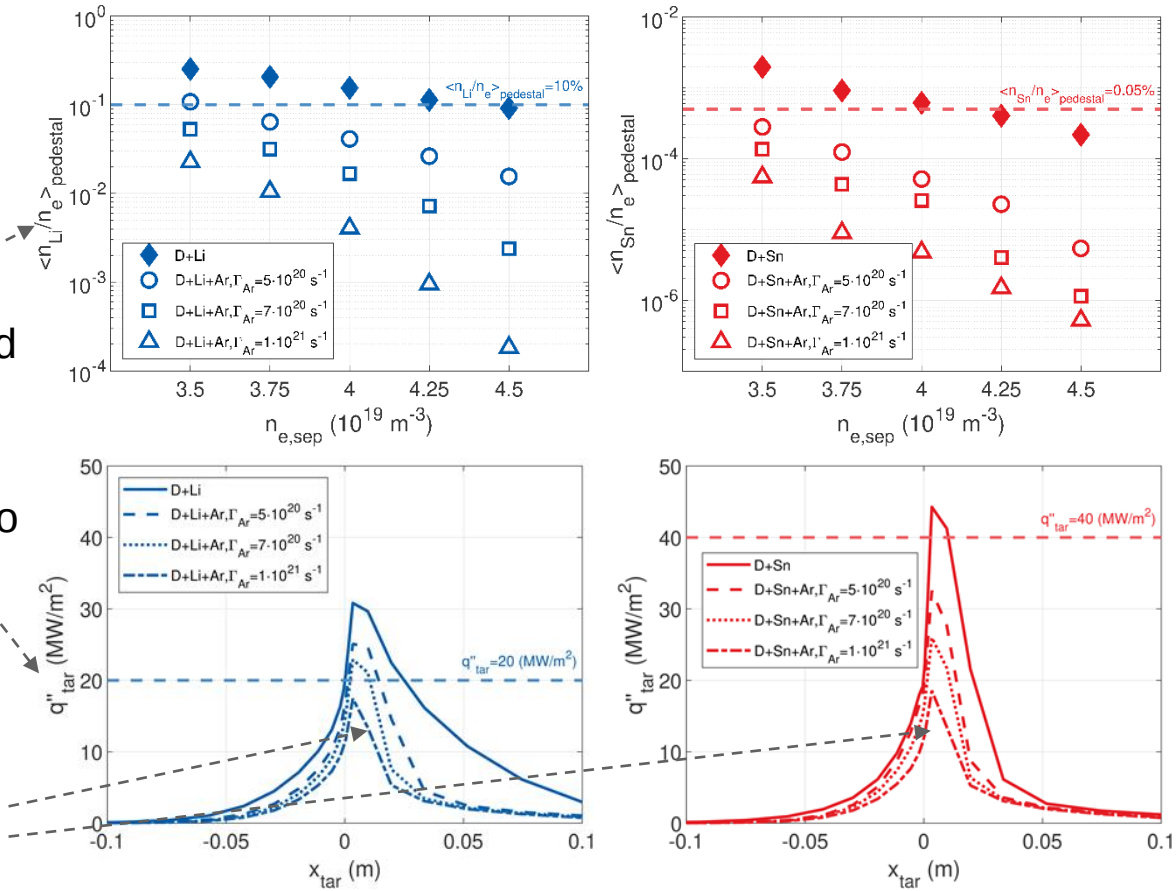
2D SOL model

Impurity flux to core plasma

Heat flux distribution on LM target

Summary: previous SOLPS-ITER results

- Operational window significantly widened thanks to Ar seeding, for both Li and Sn, in terms of:
  - Core plasma contamination (but need more detailed assessment → couple to ASTRA in FP9)
  - Target peak heat flux (to be compared to power handling capability of different LMD designs)
- For sufficiently large Ar seeding rates, same heat flux profile for Li and Sn (Ar radiation dominates the power balance)



Objective of 2021 – 2022 activities: Integrated EU DEMO scenario with Sn

- Run integrated simulations to characterize an EU DEMO scenario with liquid Sn divertor:
  - Interact with other WPs to update input data (e.g. vessel shape, fueling and pumping strategy, etc.)
  - Rely on previous experience from COREDIV simulations
  - Assess core plasma compatibility and closed loop requirements (is low erosion operation credible?)

Ongoing activities (TBC in 2022)

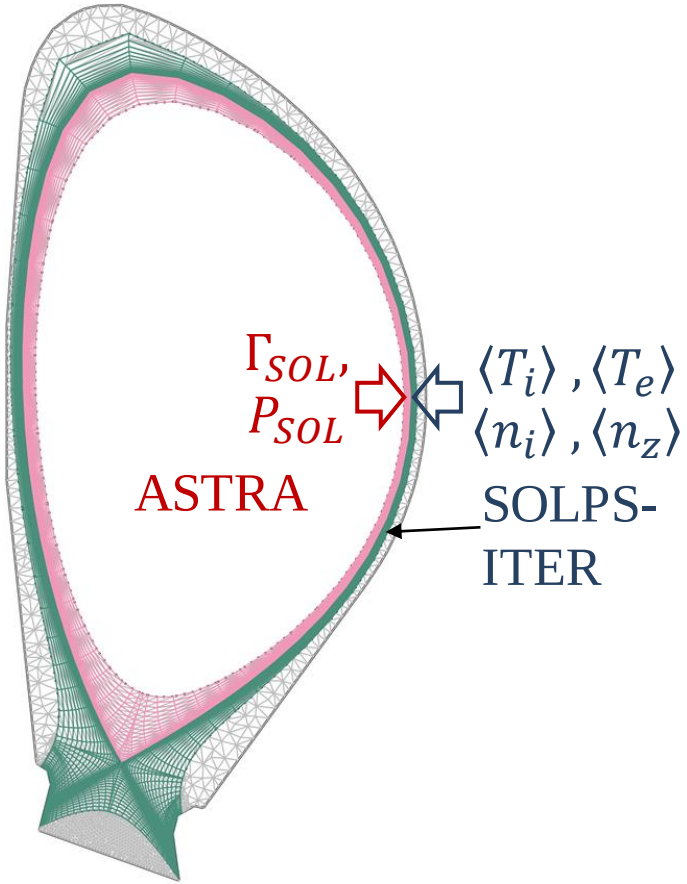
- Self-consistent coupling of target erosion model to EIRENE (*collaborations with other WPs*)
  - Required modelling developments:
    - Target emission profile consistent with the impinging power/particle fluxes (done in B2.5 fluid neutral model, ongoing for EIRENE kinetic model)
    - Species-specific pump for Sn on FW → simulate condensation
  - First studies to be performed:
    - Assess impact of thermal sputtering formulation and compare with TECXY results
    - Compare performance of different target designs

- Integration of core plasma in the model:
  - Application of ASTRA-STRAHL to assess effect of impurity fluxes as computed by SOLPS-ITER → align with COREDIV settings and compare results
  - Self-consistent coupling SOLPS-ITER with ASTRA-STRAHL (collaborations with other WPs)

ASTRA + SOLPS-ITER coupling

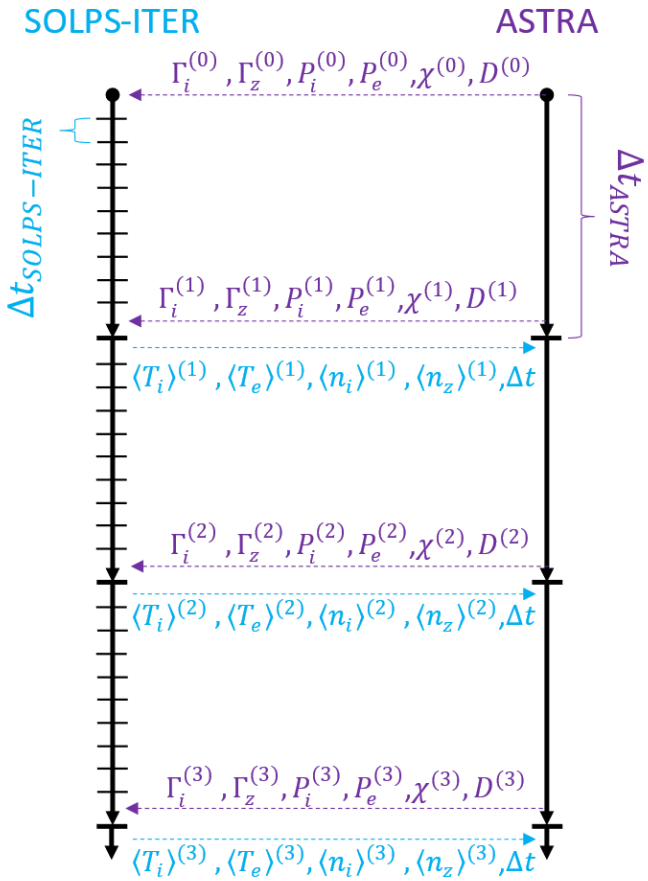
- Aim: to assess the effect of impurities on core plasma performance and the feedback on the power entering the SOL → integrated EU DEMO scenario with liquid Sn divertor

- Strategy: SOLPS-ITER up to pedestal region, ASTRA for core region



ASTRA + SOLPS-ITER coupling strategy

- Define a boundary point: pedestal top (pedtop, $\rho_N \sim 0.9$)
  - Up to pedtop: ASTRA. BCs: flux-averaged temperatures and densities from SOLPS-ITER
  - From pedtop on, up to the SOL: SOLPS-ITER. BCs: fluxes from ASTRA
- SOLPS-ITER needs to include adaptive transport coefficients in the pedestal, to be computed based on input from ASTRA
- Implementation: C routine using semaphores (caller), synchronized time advance with data exchange on shared memory location
  - Called by SOLPS-ITER via ad-hoc Fortran interface
  - Calls ASTRA as a library, regulates semaphores
- In perspective: standardize interface (IMAS framework)



Summary of extra-WP collaborations

- Ongoing collaborations:
  - Self-consistent coupling of EIRENE to surface erosion model (J. Munoz, E. Westerhof - DIFFER)
  - Using ASTRA-STRAHL with fixed fluxes computed by SOLPS-ITER (C. Marchetto – IFP-CNR Turin)
  - SOLPS-ITER + ASTRA self-consistent coupling at pedestal top (E. Fable – IPP Garching + discussions with other WPs)

- Perspective collaborations:
  - Preparation for Compass-Upgrade LMD experiments (J. Horáček, J. Čečrdle – Prague)

(In perspective) support experiments

Context:

- Experiments in **AUG** (module insertion) and later in **COMPASS-U** and **DTT** (full divertor) are foreseen in FP9
- (Design and) interpretation of experiments requires **integrated plasma simulations**

Proposed activities:

- Apply **SOLPS-ITER + ASTRA** to support the (design and) interpretation of the experimental campaigns foreseen in **AUG**, **COMPASS-U** and **DTT**

Recent PoliTo publications

IAEA nuclear fusion

ACCEPTED MANUSCRIPT

SOLPS-ITER simulations of a CPS-based liquid metal divertor for the EU DEMO: Li vs. Sn

Giuseppe Francesco Nallo[1], Giuseppe Mazzitelli[2], Matteo Moscheni[3], Fabio Subba[4] and Roberto Zanino[5]

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Technical Papers

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A. C. Uggenti, G. F. Nallo, A. Carpignano, N. Pedroni & R. Zanino

Received 31 Mar 2021, Accepted 20 Sep 2021, Published online: 15 Feb 2022

Download citation https://doi.org/10.1080/15361055.2021.1984720 Check for updates

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Politecnico di Torino
10 September, 2021

Thanks for your kind attention.

Comments or Questions?