EUROfusion

“THEORY, SIMULATION, VERIFICATION AND VALIDATION”

TSVV TASK 7: PLASMA-WALL INTERACTION IN DEMO

THRUST 2 Meeting

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JSI · University of Helsinki · KTH Vetenskap och Konst · cea · Université Sorbonne Paris Nord · IPP CAS CR · IPP · Jülich Forschungszentrum

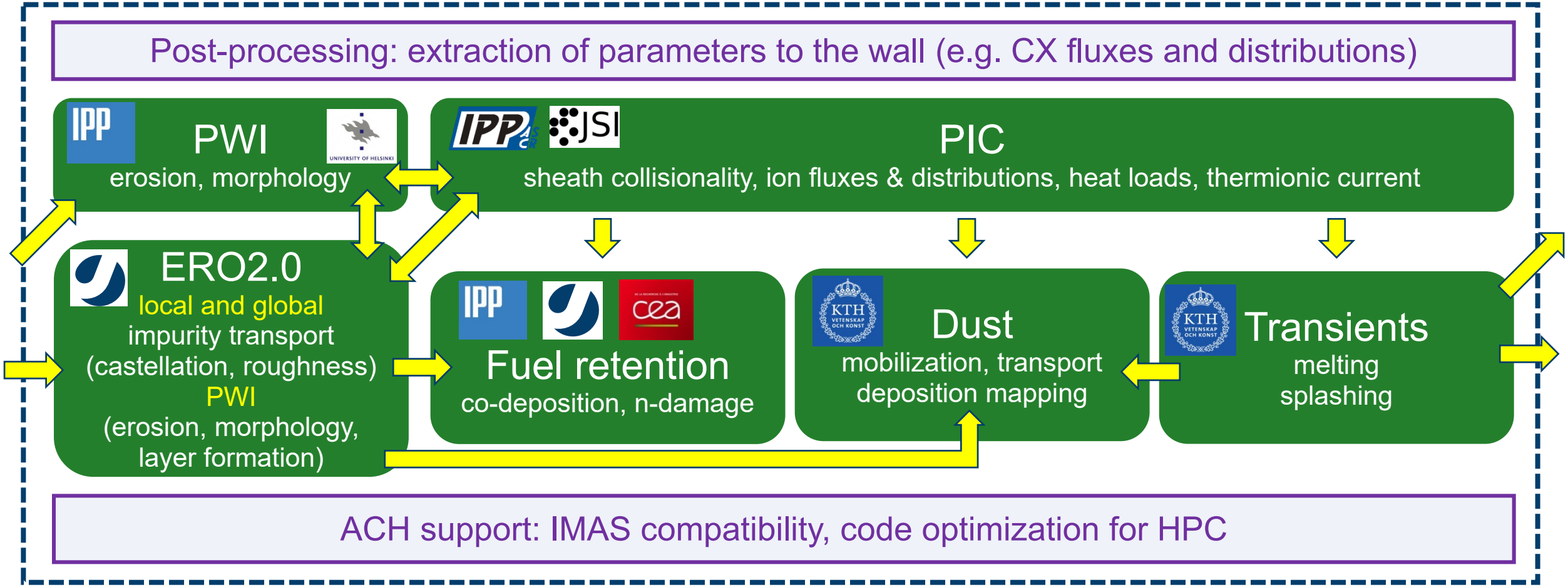
TSVV TASK 7

PWI in DEMO

Plasma background, wall geometry, material choice, steady-state and transient heat loads – interaction with WP PWIE, WP DES, WP MAT, …

certain activities will be initiated with available full-W ITER background plasma and vessel geometry

Interaction scheme



TSVV-07 PROGRESS REPORT

Tasks for 2021 (1/2)

1. Perform scoping PIC simulations with BIT-1 for DEMO-relevant very high density (ne~1e22) divertor sheath to assess the expected differences compared to the classical sheath model scaling and the necessity of new physics implementation into BIT codes (Ar, proton-plasma interaction) and provide relevant input for erosion and dust transport simulations by ERO2.0 and MIGRAINe.

2. Perform SPICE (PIC) simulations of ITER-like intra-ELM plasma with inclined magnetic field using detailed models of secondary electron emission and electron backscattering to assess their influence on the thermionic emission.

3. Based on the interaction with/within Thrust 2, DCT, WPDES and WPADC, conclude whether available DEMO single null plasma solution can be acceptably used for ERO2.0 and MIGRAINe simulations in 2021 / early 2022. Otherwise step back to available ITER solutions and adapt them for DEMO. Implement DEMO geometry in ERO2.0 and MIGRAINe. Post-process the plasma solution to be imported into ERO2.0 and MIGRAINe. If possible/available, kinetic neutrals from SOLPS-ITER have to be implemented in ERO2.0 – distributions of charge-exchange neutrals at PFC.

4. Perform scoping dust transport simulations with ramp-up and steady-state plasma profiles (DESMO SN or ITER-like) for postulated initial dust locations and sizes to assess the dust mobilization and survival probabilities, as well as accumulations maps.

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Tasks for 2021 (2/2)

5. Perform non-cumulative MD simulations utilizing available W-H interatomic potentials to simulate supersaturated W surfaces under ion irradiation: single impact low energy (10-100 eV) and high energy (1 keV +) at different incoming angles, surface orientations and saturation levels.
6. Implement and verify thermo-migration mechanism in TESSIM. Validate the model to the possible extent (given the lack of experimental data).
7. Verify and validate on experimental data and by cross-code comparison the equilibrium interface model in FESTIM.
8. Ensure the continuity of HLST / HPC optimization support for ERO2.0 and SPICE. Establish clear optimization plans for MIRGRAINe and RAVETIME (rather trivial effective parallelization and HPC upscaling) with clear responsible ACH and timeline. Where possible, start with actual optimization work with help of ACH.

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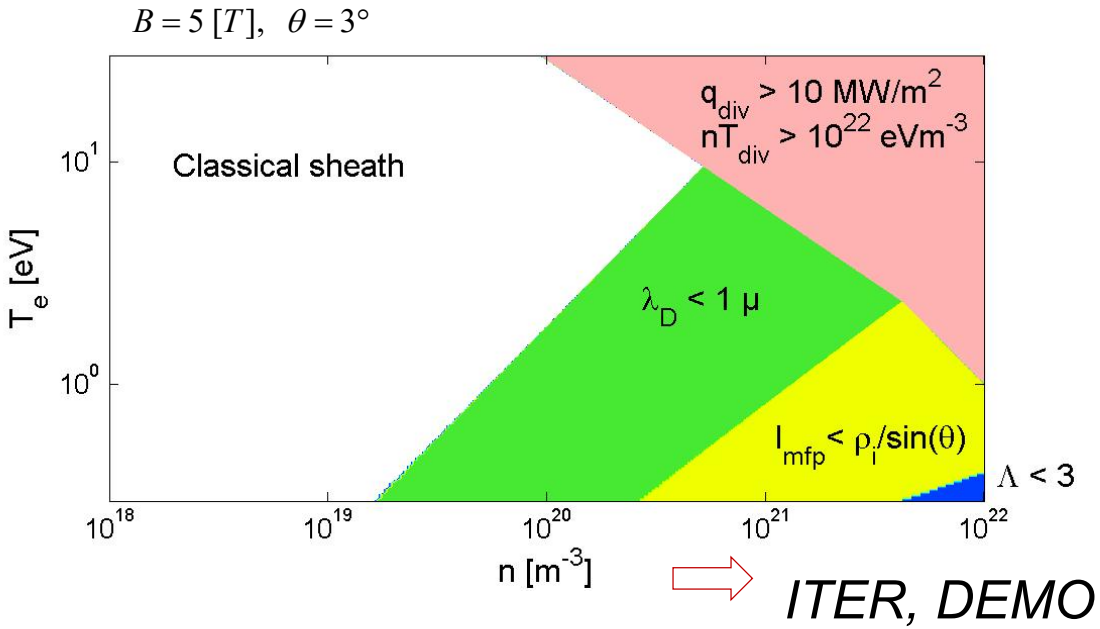
1. Scoping PIC simulations with BIT-1 for DEMO-relevant very high density divertor sheath

Modelling of the high density sheath and the development of the corresponding model has been completed and presented at the EPS (invited talk by D. Tskhakaya), paper in preparation

The scaling used for derivation of the classical sheath model: $h << \lambda_D << \rho_i << l_{mfp} \sin(\theta)$

Conclusions from PIC simulations:

- Divertor plasma sheath will be collisional in next fusion devices. Plasma flow in this sheath is sub-sonic and characterised by significantly lower plasma particle and heat fluxes to the wall than in the classical sheath.
- Neutral particles represent the main particle and heat flux curriers in the collisional sheath. The ADF and EDF of neutrals impinging the divertor surface correspond to the Maxwellian one, and can lead to different PSI rates then for ions.



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1. Scoping PIC simulations with BIT-1 for DEMO-relevant very high density divertor sheath

Implementation of new collision models (dressed "cross sections") into BIT code(s) in progress:
first step for e+Ne excitation has been completed and validated, currently working on e+Ar collisions.
Relevant for high divertor plasma densities (leading to strongly non-coronal effects).
Expected to be completed in mid 2022.

Working on the model of non-steady-state sources with BIT1, which results in convective transport (blob-filaments) that is planned to expand to larger machines. There are no DEMO relevant results yet.

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2. SPICE (PIC) simulations of ITER-like intra-ELM plasma with inclined magnetic field assessing the role of SEE and electron backscattering on the thermionic emission

Simulation are still running, results expected within weeks

Meanwhile interaction with ACH-BSC started regarding optimization of the 2D version of SPICE

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3. DEMO SN plasma solution for ERO2.0 and MIGRAINe

Currently no progress. To be clarified with WP DES in the near future.

Meanwhile interaction with ACH-BSC started regarding HPC optimization of ERO2.0

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4. Scoping dust transport simulations with ramp-up and steady-state plasma (ITER-like)

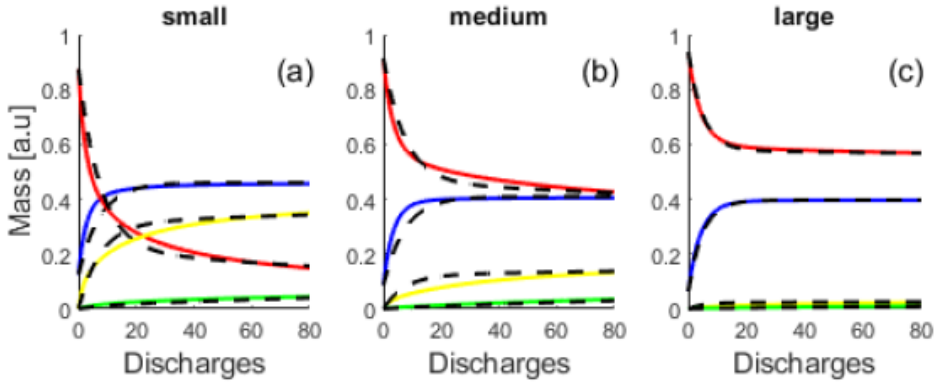
Dust re-mobilization most likely during ramp-up [PPCF 58 025009]

Low-power SOLPS-ITER plasmas used as proxy for ramp-up stage

MIGRAINe output for W dust injected from the divertor is post-treated to predict dust inventory evolution over several discharges, starting from a given mobilizable dust population and assuming no new dust is produced

For the particular case shown, in-vessel dust inventory stabilizes (amount and distribution) after a few tens of discharges

The characteristic time scale for inventory evolution depends on the size distribution of the initial dust population:
initial populations favoring large sizes (close to 50 um radius) stabilize after ~15 discharges, while smaller sizes lead to longer times, up to 50 discharges.



evolution of total in-vessel mobilizable (red), non-mobilizable (blue), splashed (green) and vaporized (yellow) dust mass, for various initial size distributions

The next step consists in repeating similar simulations using more varied input on dust size and velocity distributions.

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5. Non-cumulative MD with available W-H interatomic potentials for supersaturated W surfaces

Currently looking at different methods of generating supersaturated surfaces (W with H impurity), mainly determining the optimal insertion and relaxation method, e.g.

1) how many impurity atoms can be added in each relaxation cycle
2) at what depth from the surface and how thick should the volume be
3) how long relaxation between insertions are needed for a good relaxation
4) how many cycles are needed for a genuine supersaturated surface

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6. Thermo-migration mechanism in TESSIM and its validation

Thermo-migration is up and running in TESSIM

Testing (probably "manufactured solutions") is still to be done

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7. Validation of the equilibrium interface model in FESTIM

Interface model and Soret effect are impemented, cross-code comparison (common test cases) still to be done

Working on the model for He and He/H coupling (He bubbles act as traps for H) -> beyond 2022

3D simulations of a DEMO monoblock have been done that show the importance of the 3D calculations on H inventory (especially when the thickness is small as in the case of DEMO) -> to be presented at next PSI

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8. Continuity of HPC optimization support for ERO2.0 and SPICE

Kick-Off meetings with ACH-BSC took place in July where the requests and preliminary timelines have been discussed

ACH representatives have access to code repositories

Feedback of ACH is still expected, follow-up meetings will be organized