



HAL
open science

Multidimensional, multi-material and multiphysics modelling of Hydrogen transport in ITER

Rémi Delaporte-Mathurin, Jonathan Mougenot, Etienne A Hodille, Y. Charles, Christian Grisolia

► **To cite this version:**

Rémi Delaporte-Mathurin, Jonathan Mougenot, Etienne A Hodille, Y. Charles, Christian Grisolia. Multidimensional, multi-material and multiphysics modelling of Hydrogen transport in ITER. 24th International Conference on Plasma Surface Interactions in Controlled Fusion Devices, Jan 2021, Jeju Island, South Korea. hal-03120261

HAL Id: hal-03120261

<https://hal.science/hal-03120261v1>

Submitted on 25 Jan 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

INTRODUCTION

- Reproducing experimental results can be **long** and **tedious**
- Is it possible to **automatically fit** a thermal desorption spectrum and **identify materials properties**?
- Can these properties be used to **perform complex multidimensional simulations**?
- Is there a **discrepancy** between 2D and 1D simulations?

METHODOLOGY

Hydrogen transport

$$\frac{dc_m}{dt} = \nabla(D\nabla c_m) + S - \sum_i \frac{dc_{t,i}}{dt}$$

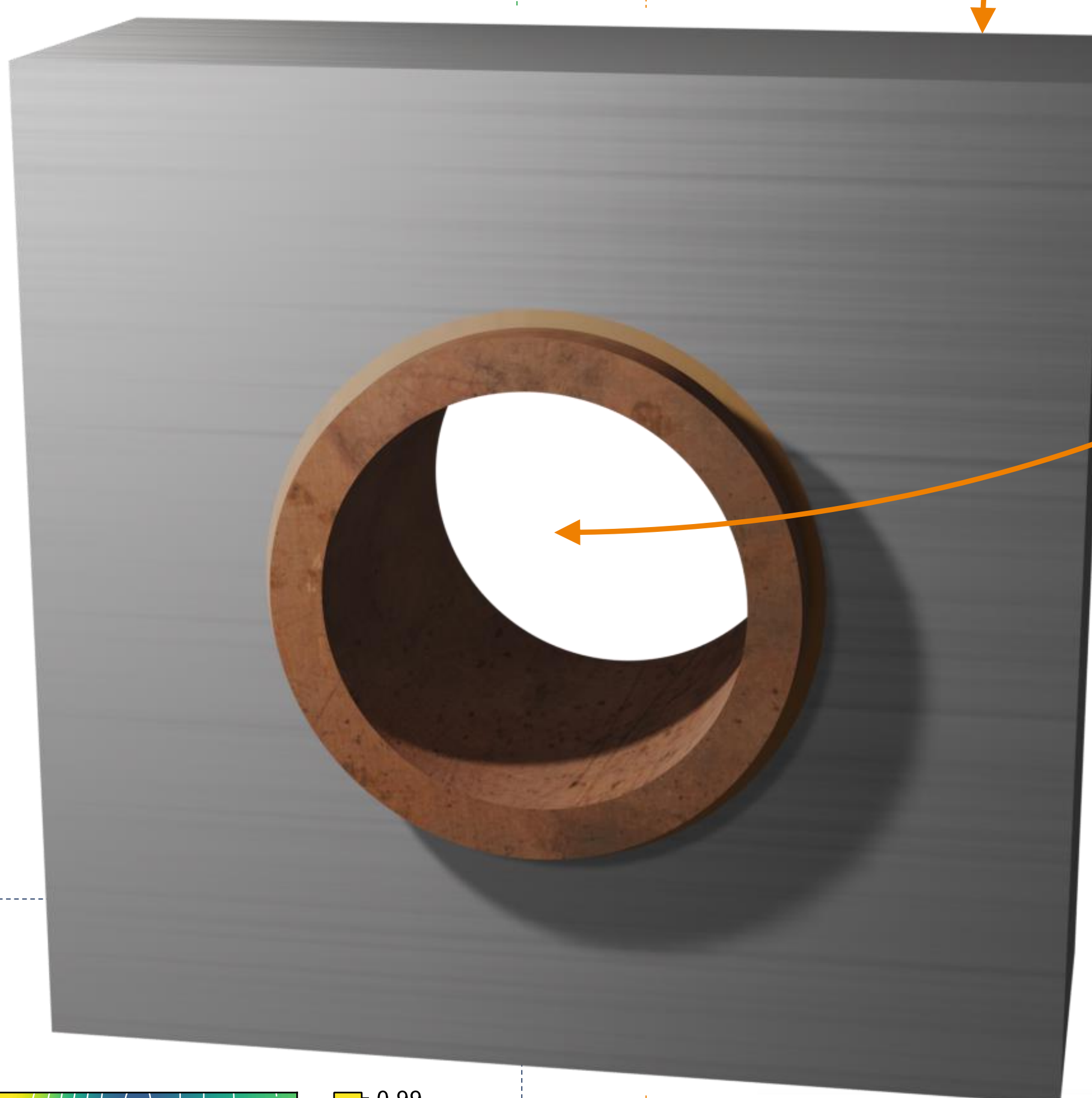
$$\frac{dc_{t,i}}{dt} = k c_m (n_i - c_{t,i}) - p c_{t,i}$$

- Finite Element Methods
- FEniCS backend
- FESTIM code [1]



Heat transfer

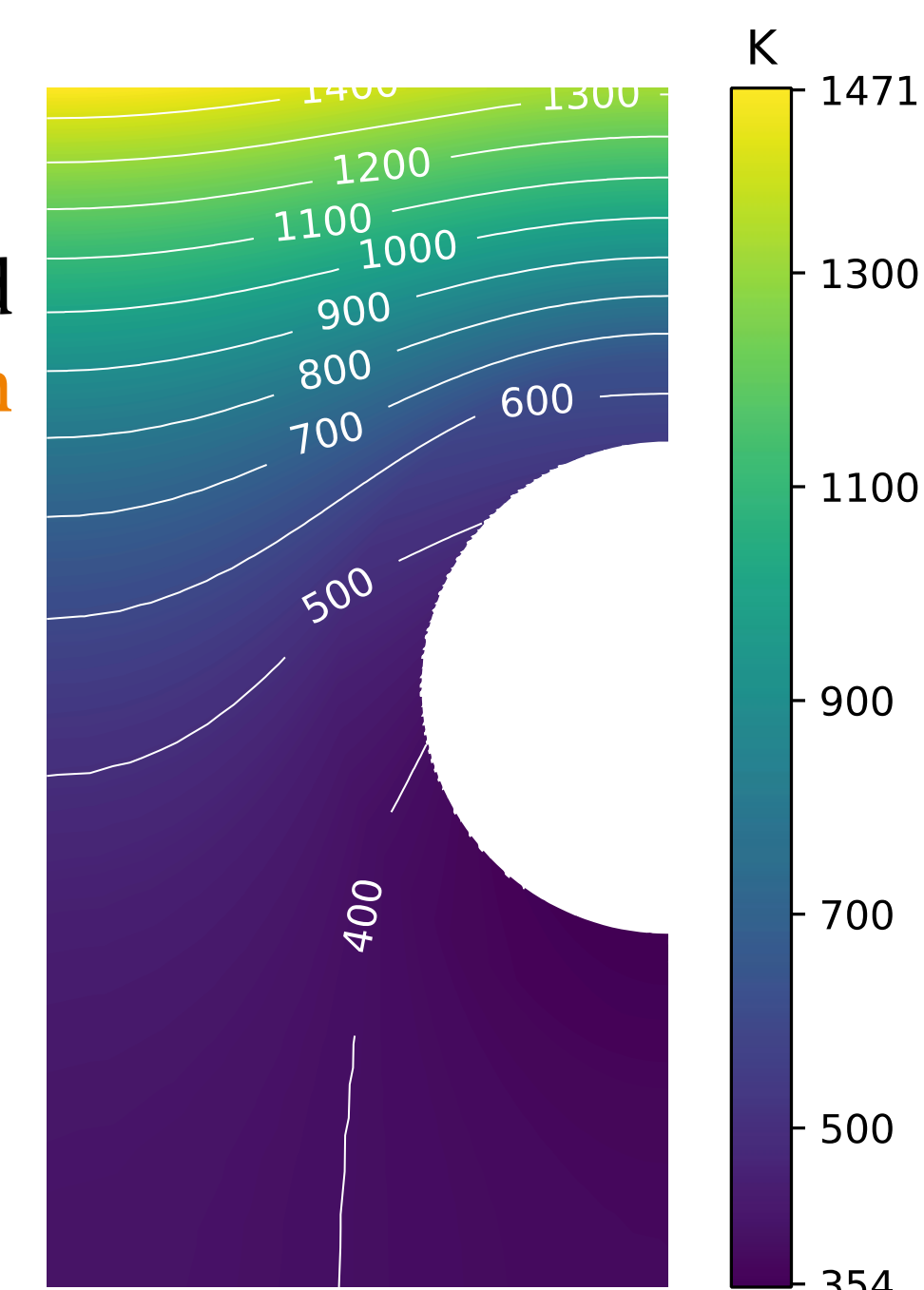
$$\rho C_p \frac{dT}{dt} = \nabla(\lambda \nabla T) + Q$$



- Convective exchange
- Recombination

Temperature field during implantation

- Maximum surface temperature 1471 K
- Homogeneous temperature during rests

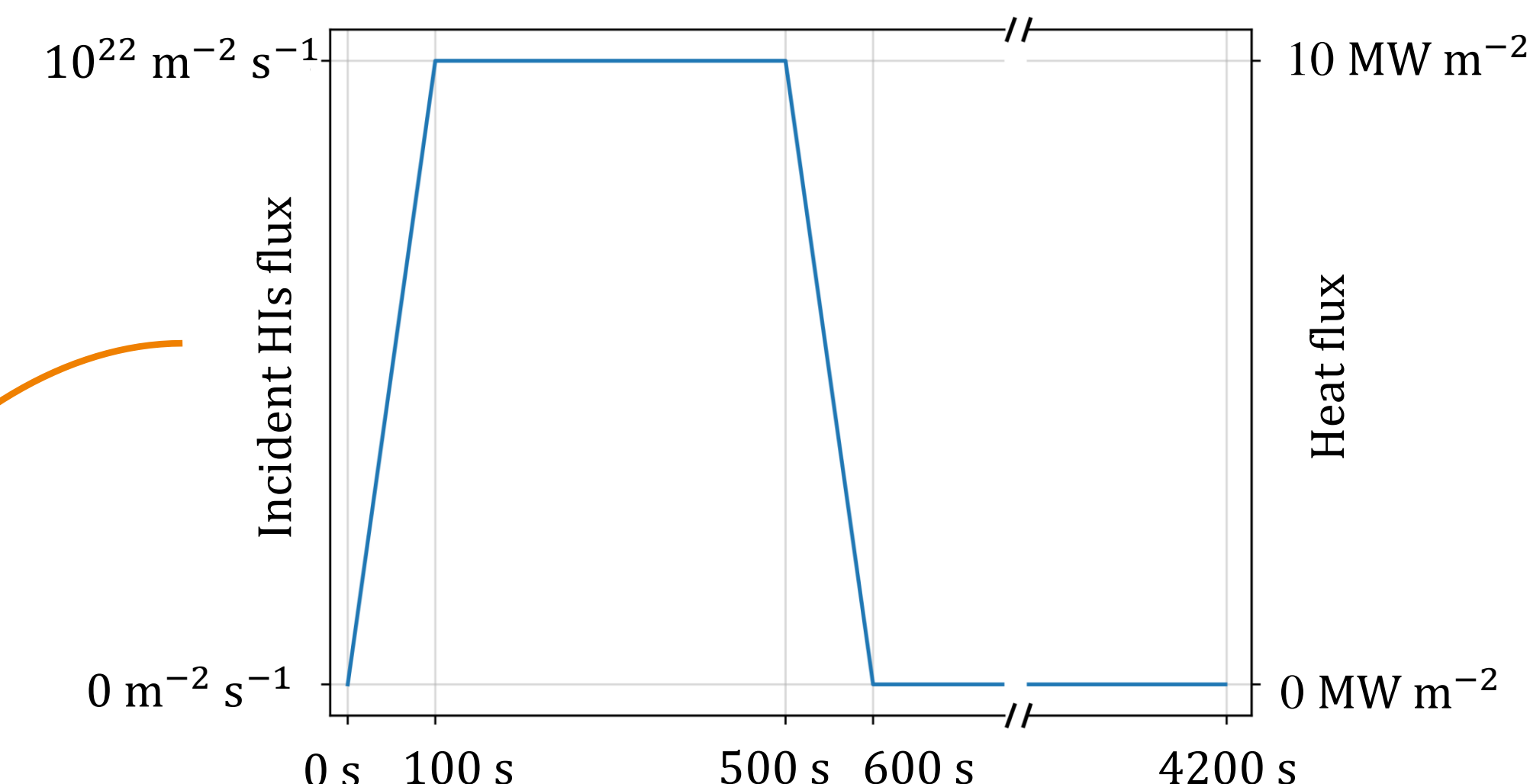


APPLICATION: ITER MONOBLOCKS

Simulation parameters

- 2 traps in W
- 1 trap in CuCrZr

W
Cu
CuCrZr



PROPERTIES IDENTIFICATION

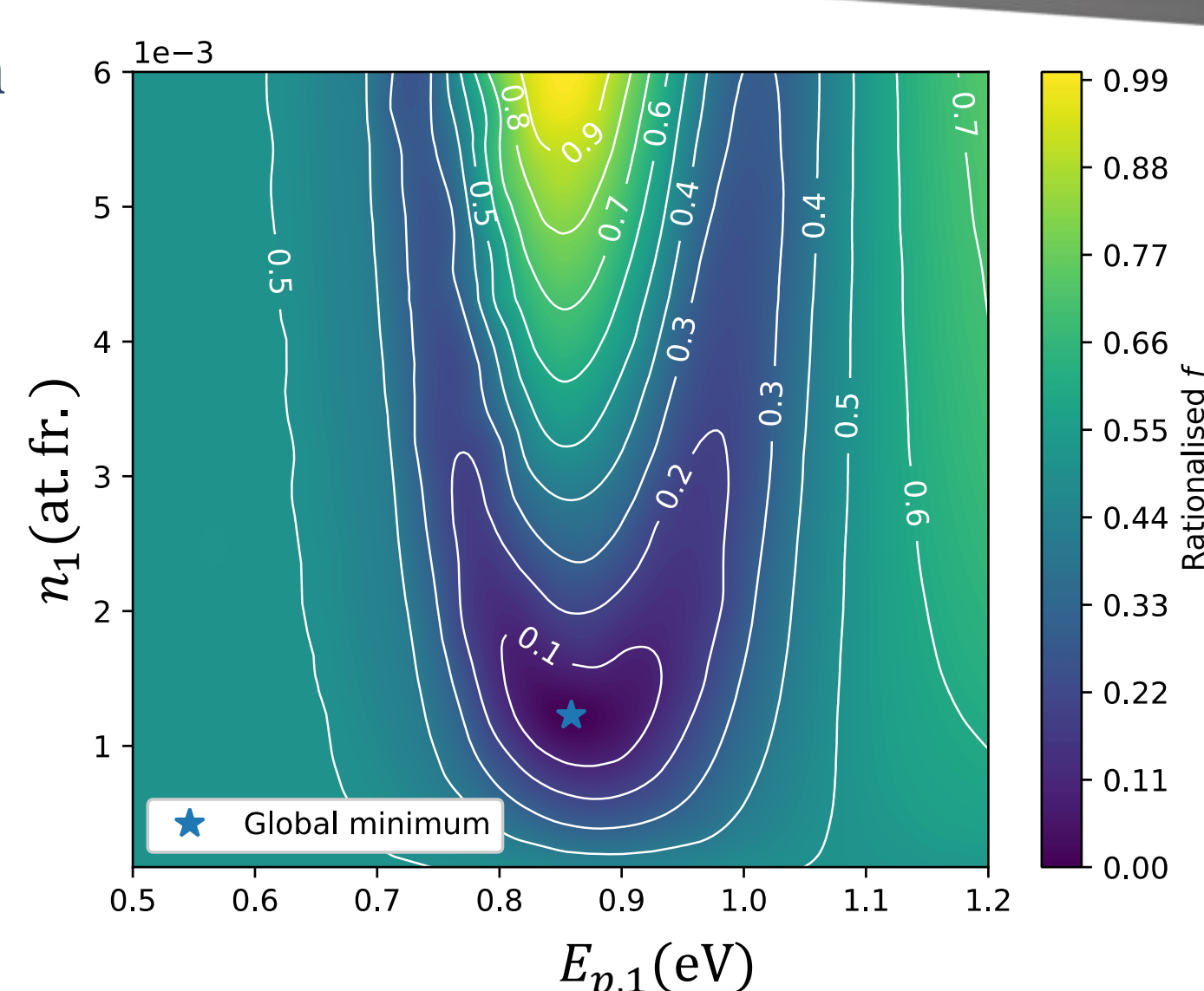
Example cost function

- Error function based on W TDS spectrum

$$f(\mathbf{x}) = \frac{\sum_i \alpha_i |d_i - d_{sim}|}{\sum_i \alpha_i}$$

- α_i : weights
- d_i : experimental data
- d_{sim} : simulated data

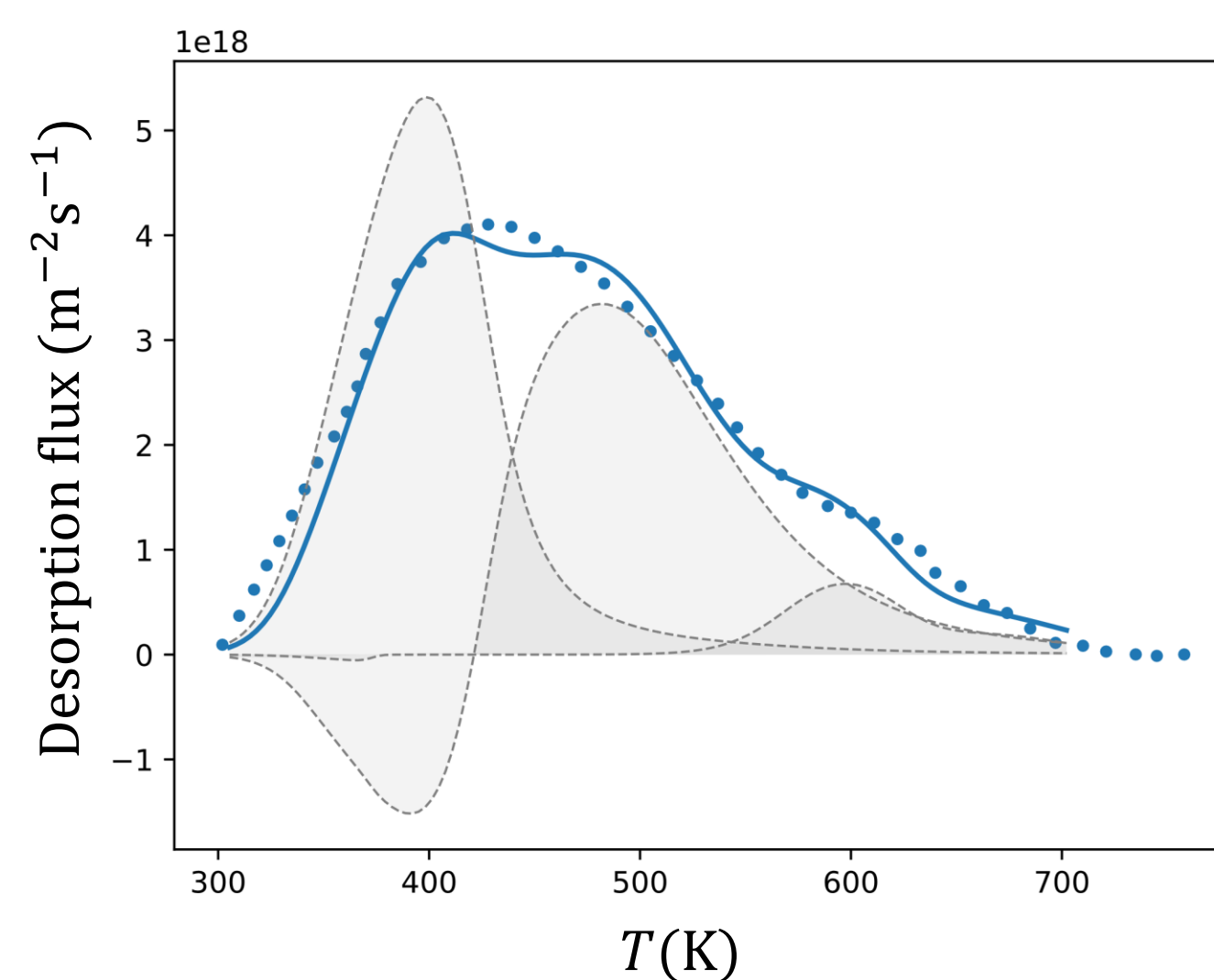
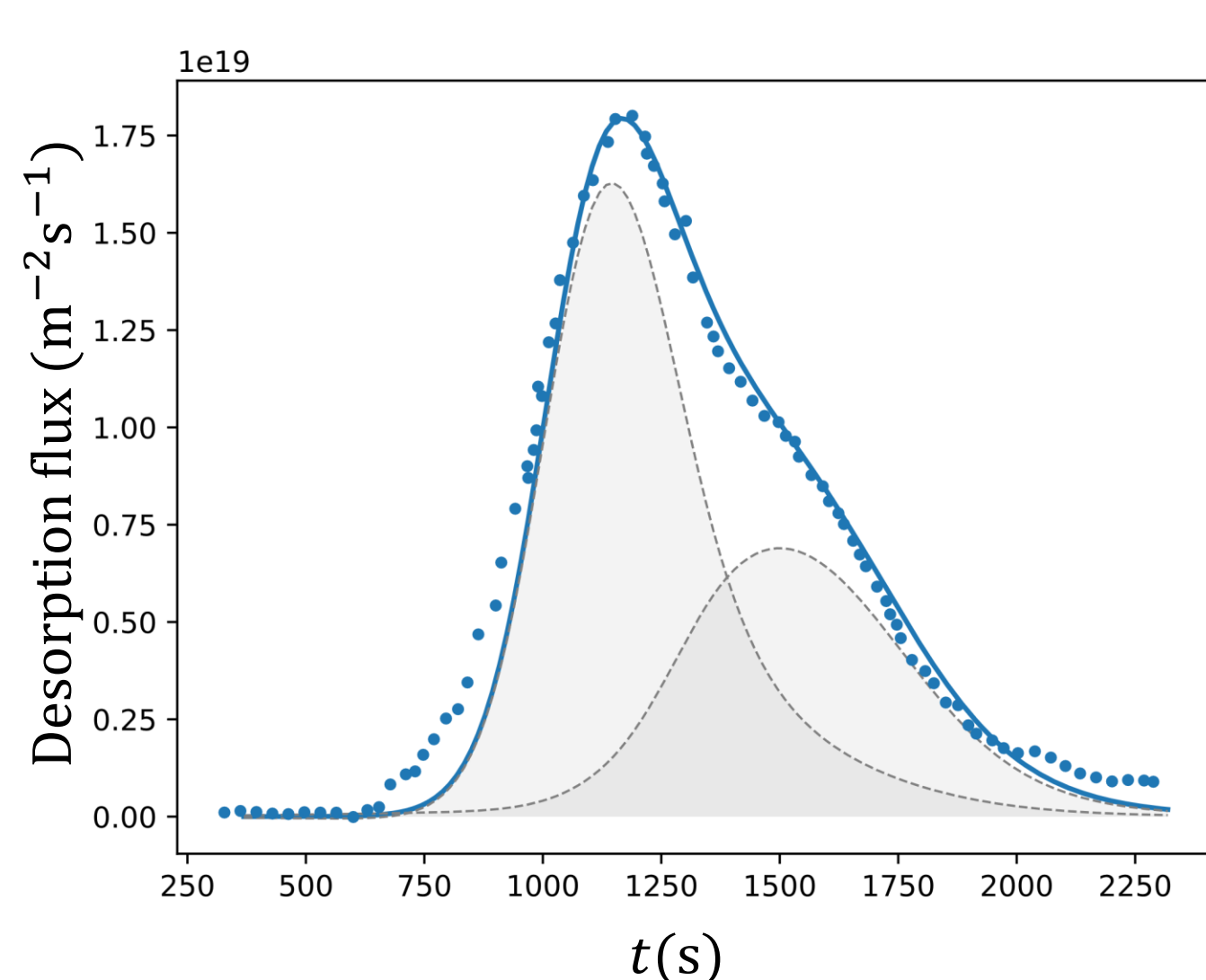
- Objective: find the minimum



Tungsten

- W under 200 eV D⁺ at 300K [2]
- 5D optimisation (3 energies, 4 densities)
 - $E_{p,1} = 0.83$ eV ; $E_{p,2} = 0.97$ eV
 - $E_{p,3} = 1.51$ eV
 - $n_1 = 10^{-3}$ at.fr. ;
 - $n_2 = 7 \times 10^{-4}$ at.fr.

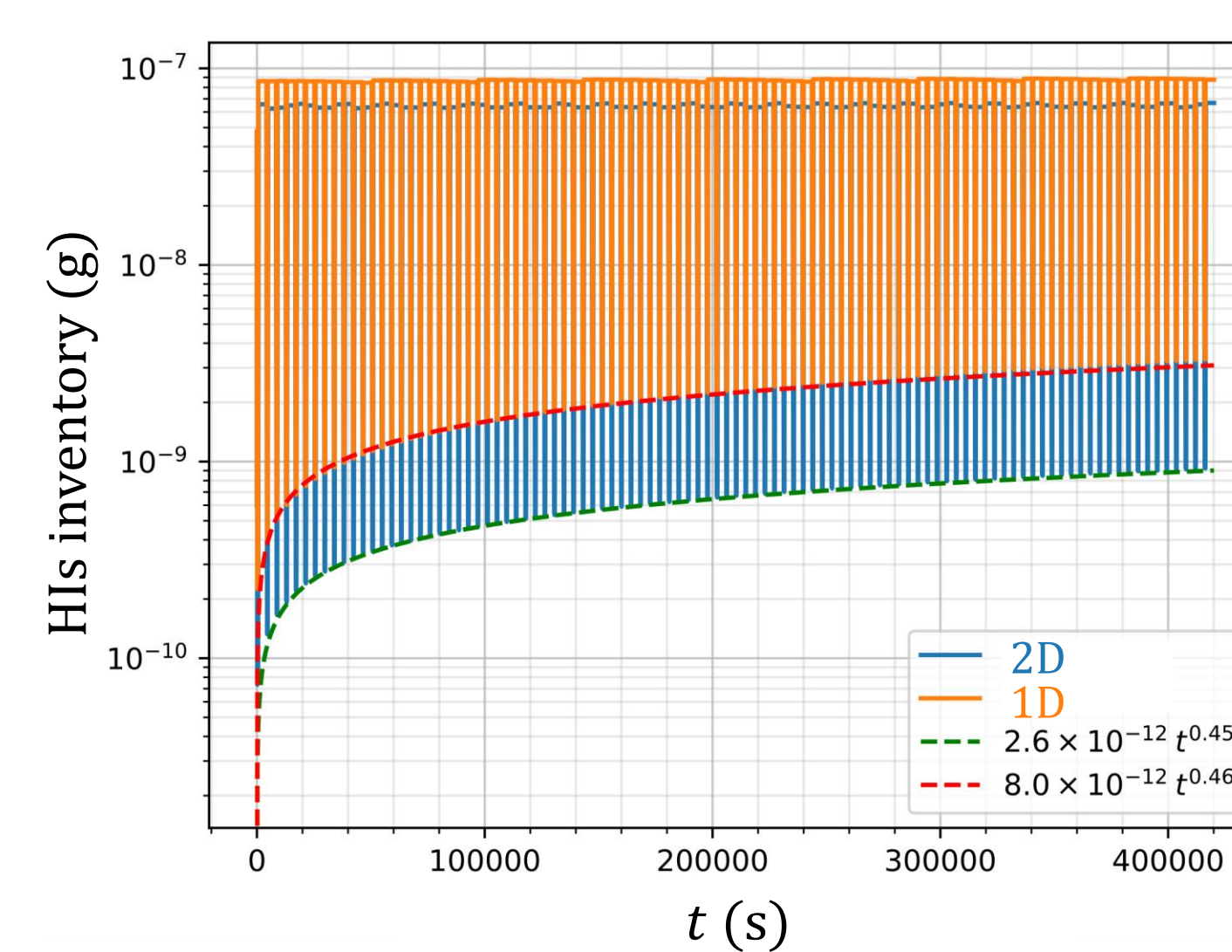
→ Convergence reached in a few hours



Co-deposited Be-D

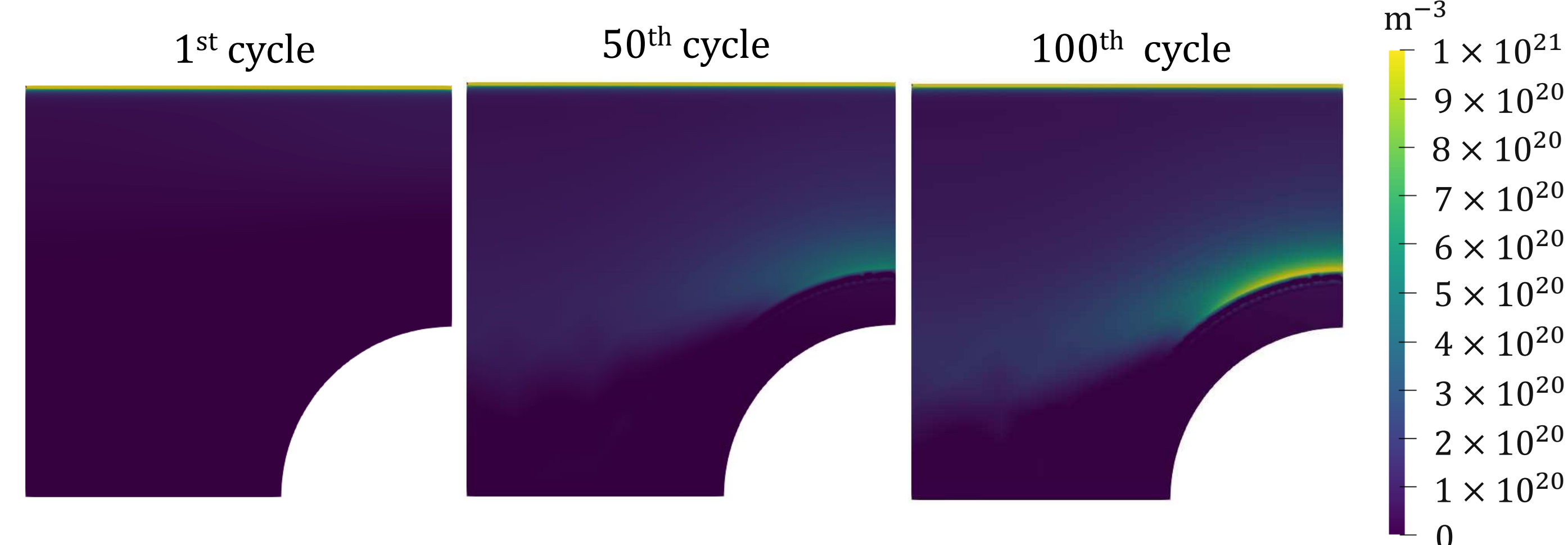
- Co-deposited 1μm-thick Be-D under at 330K [3]
- 6D optimisation (2 energies, 2 densities, 2 initial occupancies)
 - $E_{p,1} = 0.75$ eV ; $E_{p,2} = 0.93$ eV
 - $n_1 = 10^{-1}$ at.fr. ;
 - $n_2 = 4 \times 10^{-2}$ at.fr.
 - $f_1 = 0.73$; $f_2 = 0.28$

→ Convergence reached in a few minutes



HIs Inventory over time

- Inventory limited by near surface retention zone
- Inventory during implantations **keeps increasing**
- Up to **95% error** between 1D and 2D



HIs retention field during resting phases

CONCLUSIONS

- FESTIM**: a modelling tool for hydrogen transport modelling
- Well suited for **high-dimensional optimisation**
- High inventory in ITER PFCs during resting phases
- 1D** modelling is **not sufficient** for **quantitative estimation** of PFC inventory

References:

- Delaporte-Mathurin et al. (NME, 2019)
- Ogorodnikova et al. (JNM, 2003)
- Baldwin, Schwarz-Selinger, and Doerner (Nucl. Fusion, 2014)
- Hollingsworth et al. (Nucl. Fusion, 2019)