

Modelling Transport in the Scrape-Off Layer with Hermes-3

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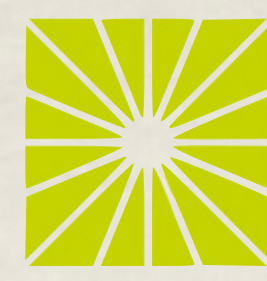
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Introduction and Motivation

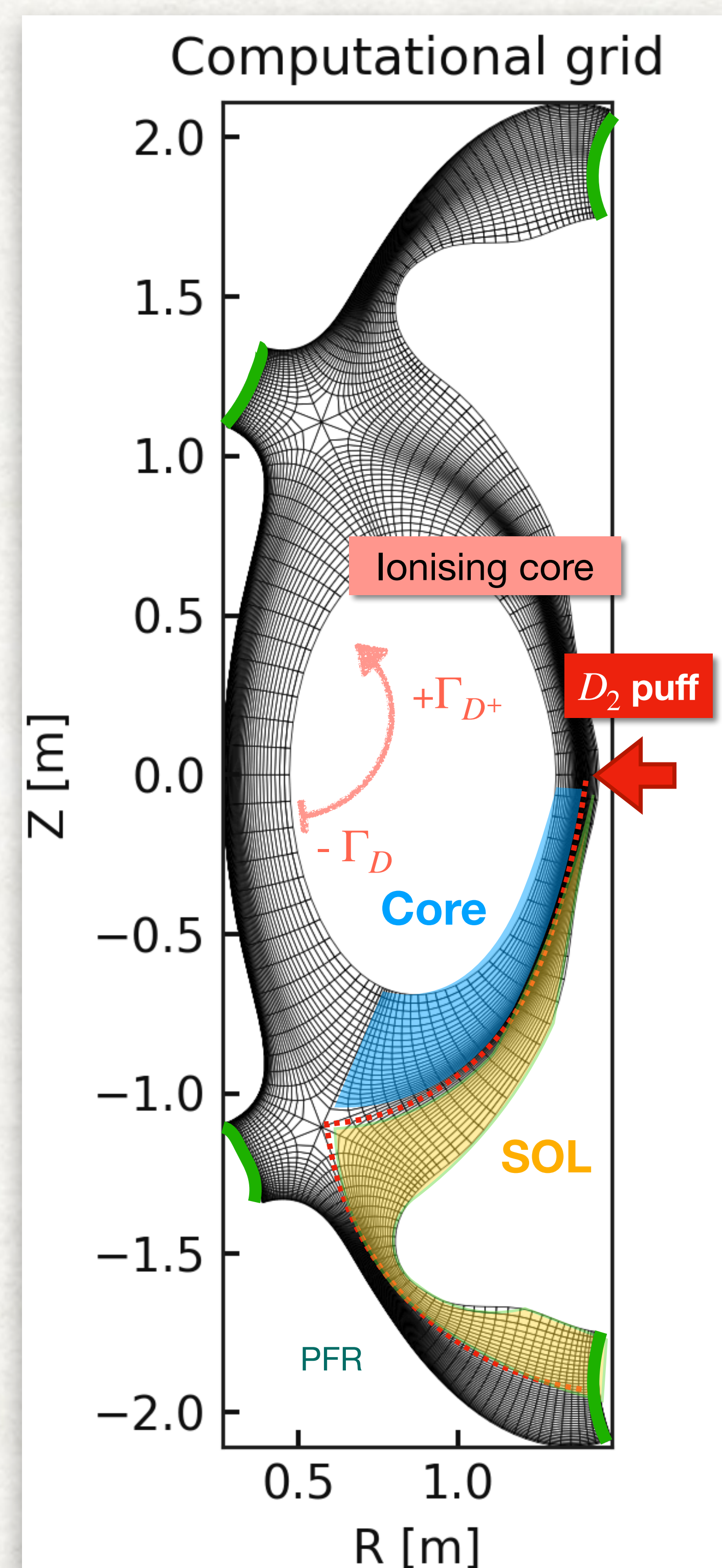
- Power exhaust must be controlled to protect plasma-facing components from high heat loads, so understanding SOL transport is essential for future fusion reactors.
- Hermes-3 [1] solves the Braginskii equations [2] with an advanced fluid neutral (AFN) model (continuity, pressure and parallel momentum equations) [3,4], however, the fluid approximation is only valid in high collisionality.

Code	SOLPS-ITER	Hermes-3
Plasma model	Braginskii fluid equations	Braginskii fluid equations
Neutral model	Kinetic Model (EIRENE)	AFN equations with flux limiter applied
Pros	Realistic, accurate	Smooth and fast
Cons	Computational expensive, noisy	Inaccurate at low ion-neutral collisional region

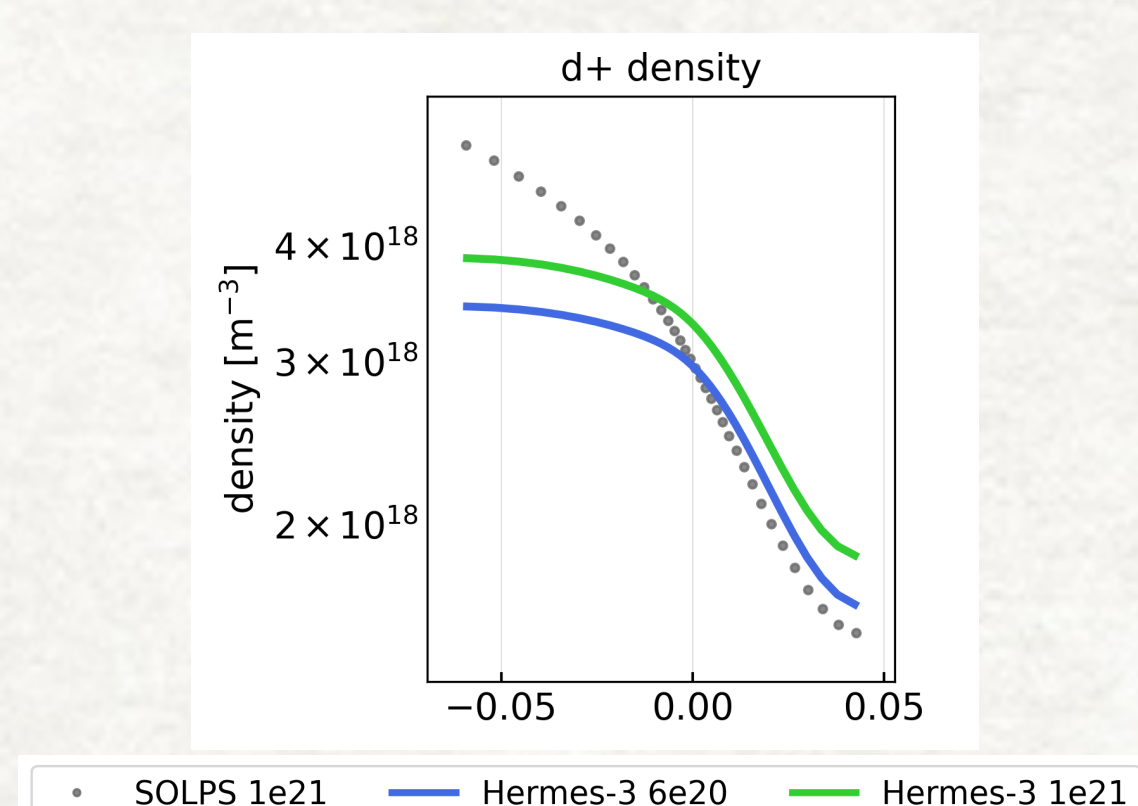
- ➔ This work assess how fluid vs. kinetic neutrals affect SOL transport predictions by comparing Hermes-3 (AFN) against SOLPS-ITER/EIRENE [5].

Simulation Setup

- 2D steady-state, attached MAST-U #46895 super-X connected double-null, 1 MW input power.
- SOLPS was simplified to match Hermes-3 assumptions (e.g. no molecules), making the two codes more comparable.



- D_2 puff rates differ between the codes with $6 \times 10^{20}/s$ for Hermes-3 and $10^{21}/s$ for SOLPS so that the upstream density matches.



Boundary conditions:

- Sheath boundary at target for plasma
- Zero gradient elsewhere for all species
- Neutral reflection everywhere with various fraction
- Plasma fast recycling $R=0.8$ and thermal recycling $R=0.99$ at target
- Neutral pump $R=0.99$ at target

Neutral flux limiter:

- Separate limiters are applied to cross-field diffusion and to parallel conduction and viscosity, preventing unphysically large neutral fluxes in low-collisionality regions.
- Each limit is derived from the Maxwellian one-way flux, i.e. the maximum free-streaming flux of the particles.

Anomalous transport

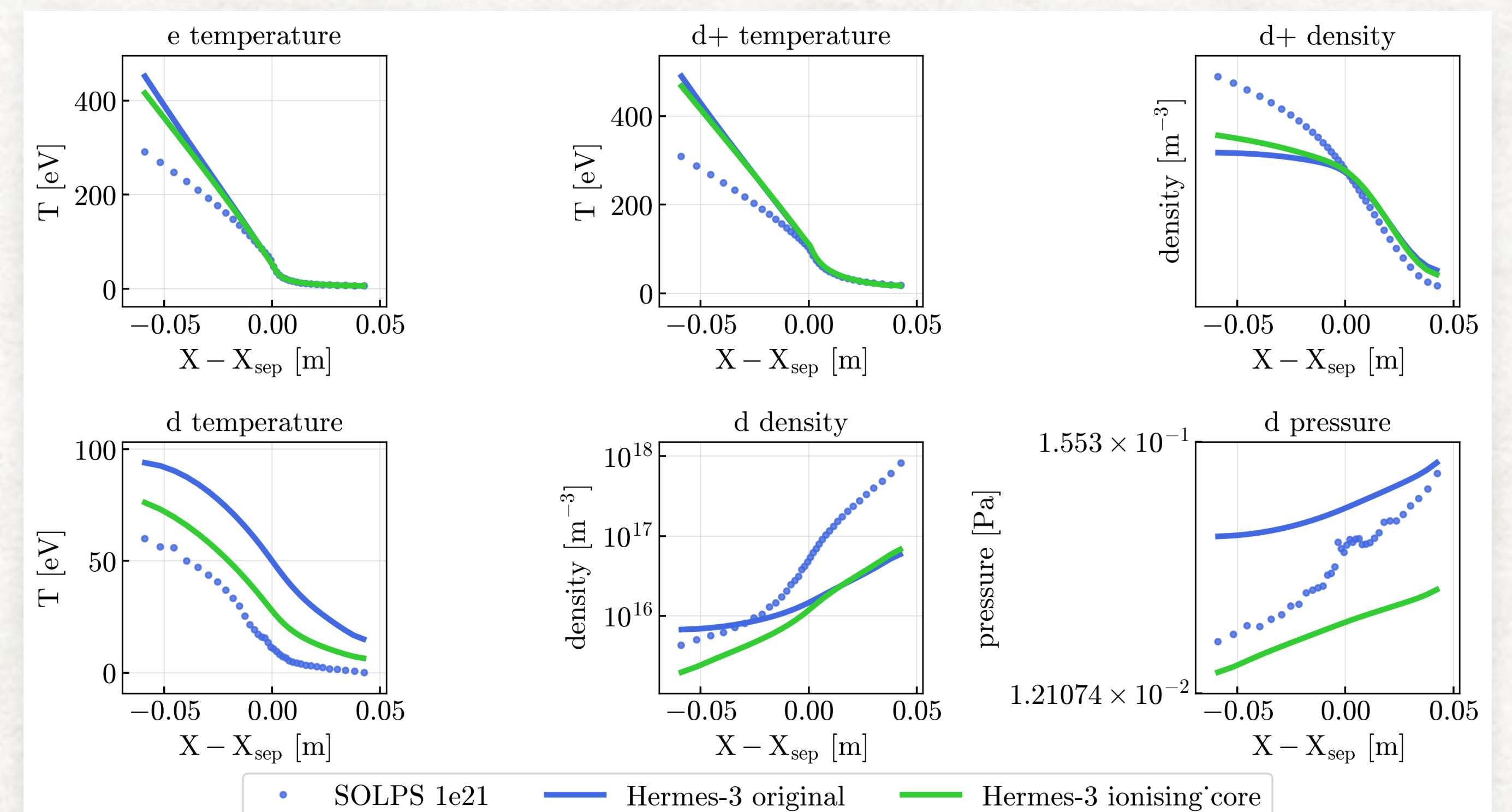
$$D_{all} = 4 \text{ m}^2/s, \nu_{all} = 2 \text{ m}^2/s$$

$$\chi_{core,i/e} = 10 \text{ m}^2/s, \chi_{SOL,i/e} = 4 \text{ m}^2/s$$

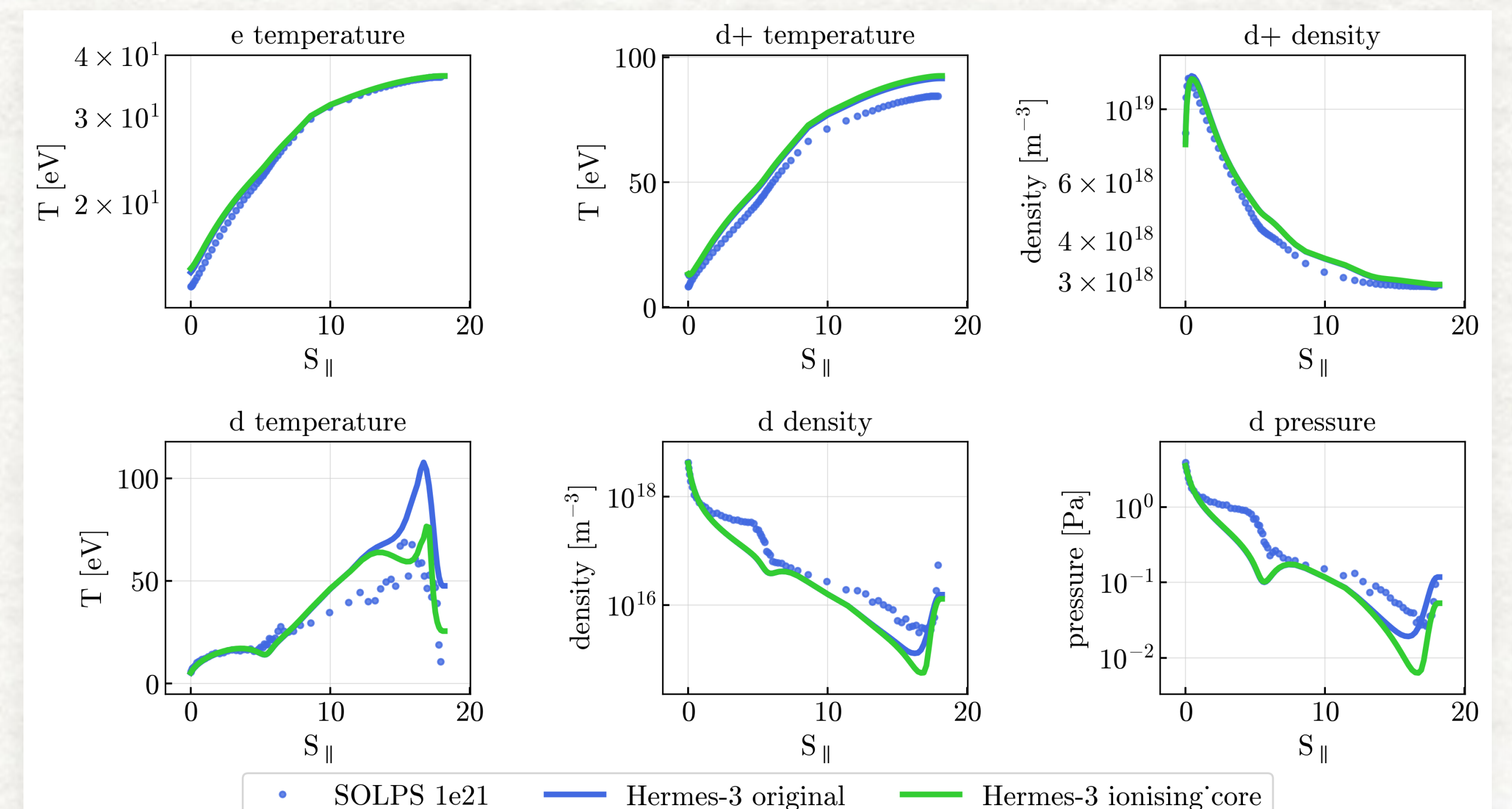
Profiles Comparison

- An ionising core boundary, matching a SOLPS-ITER feature, has recently been implemented in Hermes-3 and improves the OMP discrepancy.
- The remaining discrepancy may be due to fast kinetic neutrals penetrating deeper into the core in SOLPS, while high ion-neutral collisionality limits penetration in the fluid model.

Radial profile at outboard midplane (OMP)

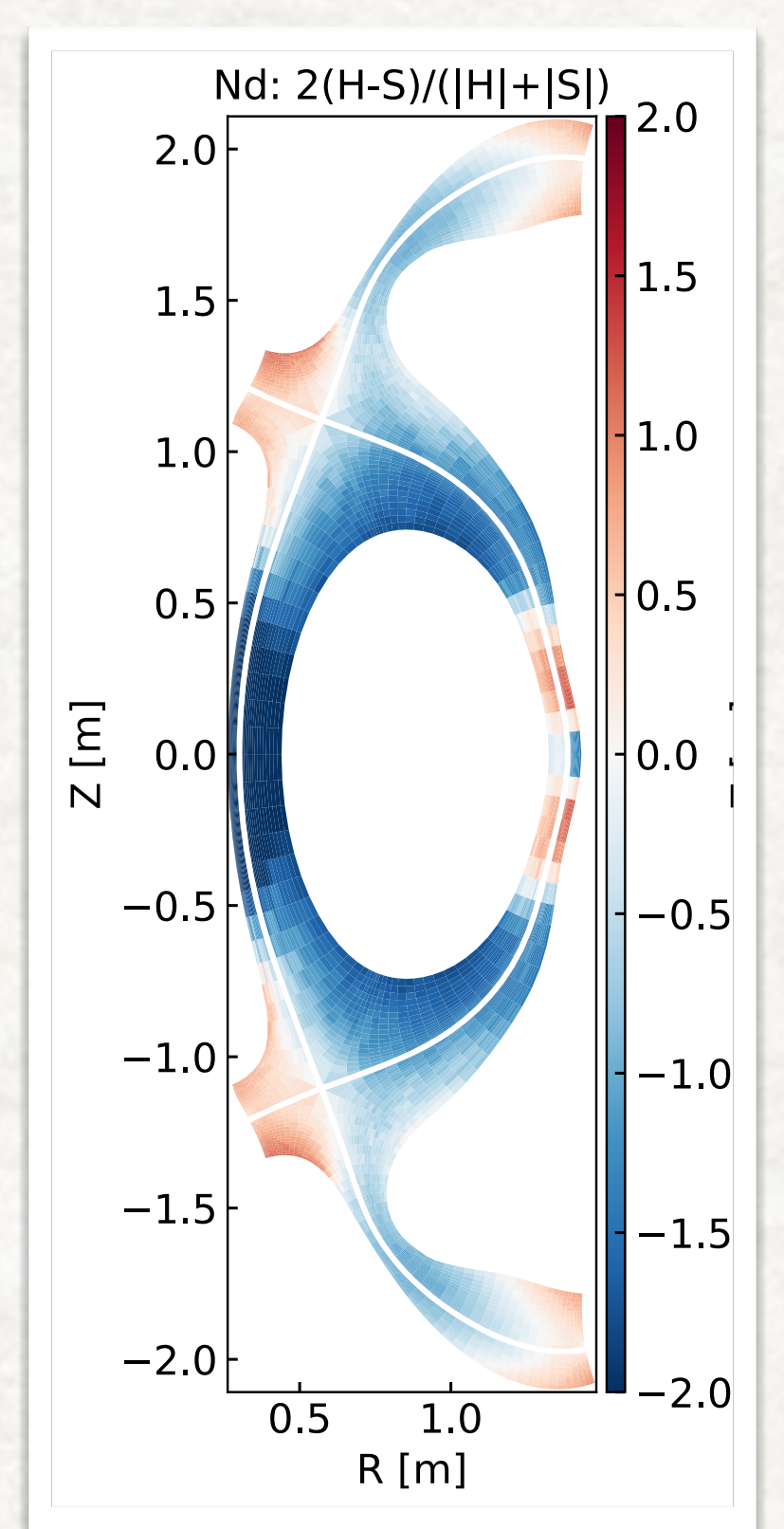
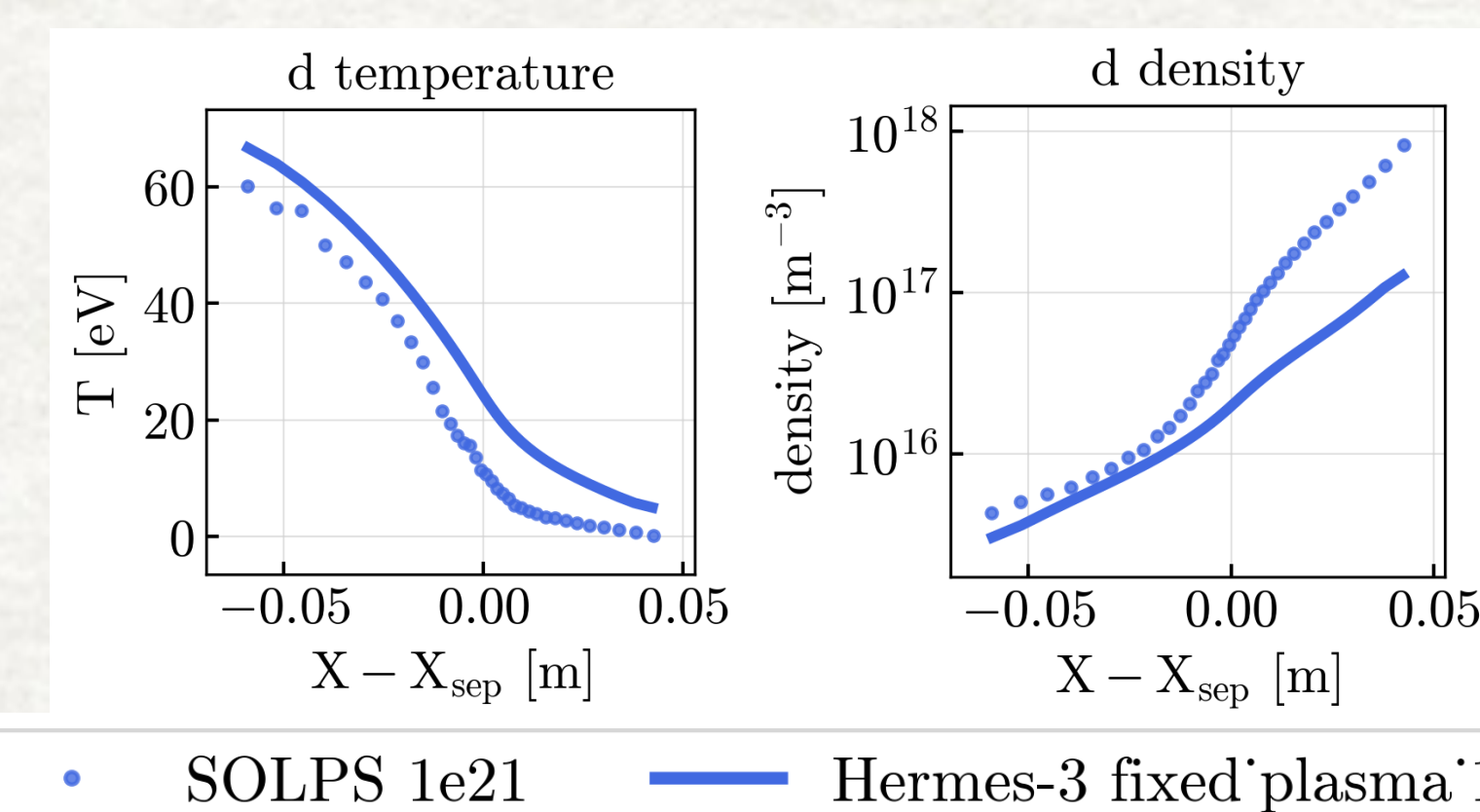


First SOL ring profile



Freezing plasma background

- Freeze the plasma background from SOLPS in Hermes-3 to isolate neutral transport
- SOLPS neutral concentrate more at puff location, while Hermes-3 neutral is more spread out in SOL region.



Conclusion and future work

- With a tuned puff, the codes agree well in the SOL, but under-predict core densities
- Core boundary ionisation reduces the OMP discrepancy; the remainder may stem from kinetic neutral effects, which are under investigation.

Reference

- [1] B. Dudson et al., Comput. Phys. Commun., 2024
[2] Braginskii S.I., Reviews of Plasma Physics 1965
[3] N. Horsten, Nucl. Fusion, Aug. 2017

- [4] W. Van Uytven et al., Nucl. Fusion, 2022
[5] R. Schneider et al., Contributions to Plasma Physics, 2006

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