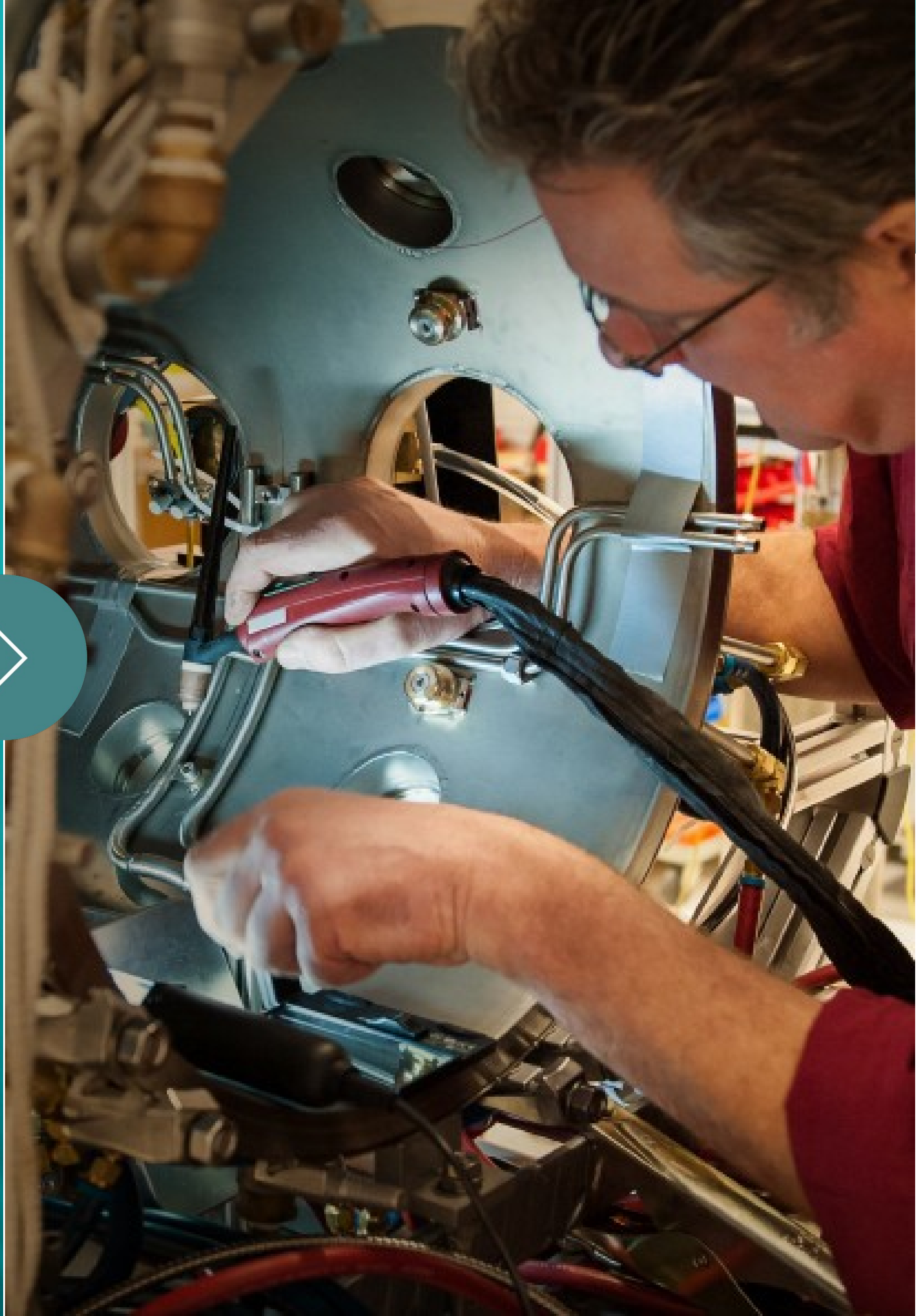
Comparison of A&M processes between Eirene and Eunomia // Coupling of SOLPS-ITER with Finite Element Wall Model

J. Gonzalez; 08-07-2022



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Standalone comparison between Eirene and Eunomia

Electron Impact Ionization (EI)

Eirene

$e + H \rightarrow 2e + H^+$ AMJUEL 2.1.5 H.4 and H.10

Eunomia

$e + H \rightarrow 2e + H^+$ HYDHEL 2.1.5

$e + H \rightarrow e + H^*$ HYDHEL 2.1.1

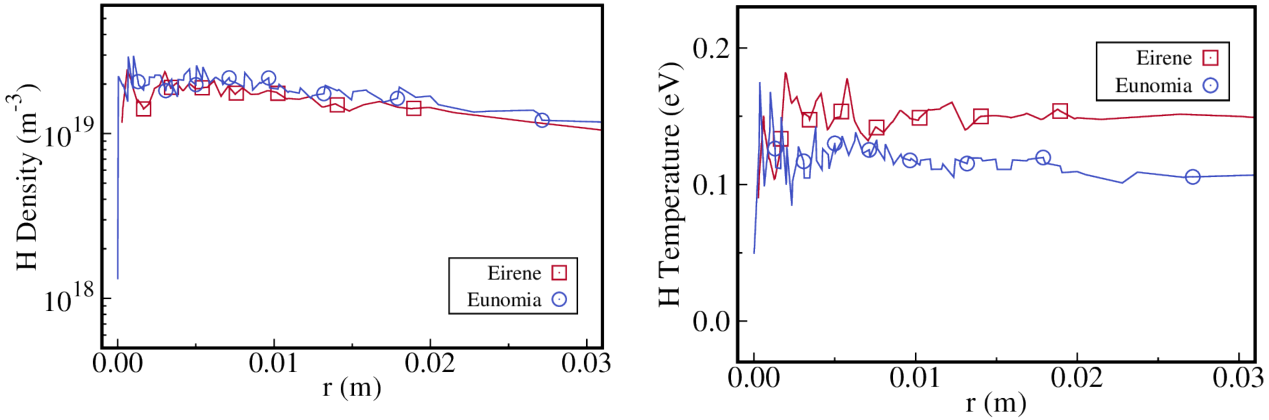


Fig. 1: Radial plot at z=0m of the H density (left) and temperature (right) for a situation in which only EI is considered with a frozen plasma background.

Total Source Intensity	Eirene	Eunomia
Electron energy (W)	-589	-193
Ion Particle (part s^-1)	1.3e19	1.9e19

- The amount of ions generated by using AMJUEL in Eirene or HYDHEL in Eunomia is basically the same. However, the energy lost by electrons is quite different as Eunomia assumes a constant lost per ionization/excitation process and in Eirene this is dependent.
- Thus, the Eunomia implementation is not equivalent to the effective rate in AMJUEL => Possible effect at low T_e.
- The excited state in Eunomia is either de-excitated or ionized.

Molecule Assisted Recombination (MAR)

$$H^+ + H_2 \rightarrow H + H_2^+$$ AMJUEL 3.2.3

Eirene

$$e + H_2^+ \rightarrow 2e + H^+ + H^+$$ AMJUEL 2.2.11

$$e + H_2^+ \rightarrow e + H + H^+$$ AMJUEL 2.2.12

$$e + H_2^+ \rightarrow H + H$$ AMJUEL 2.2.14

Eunomia

$$e + H_2^+ \rightarrow H + H^*$$ Spontaneous

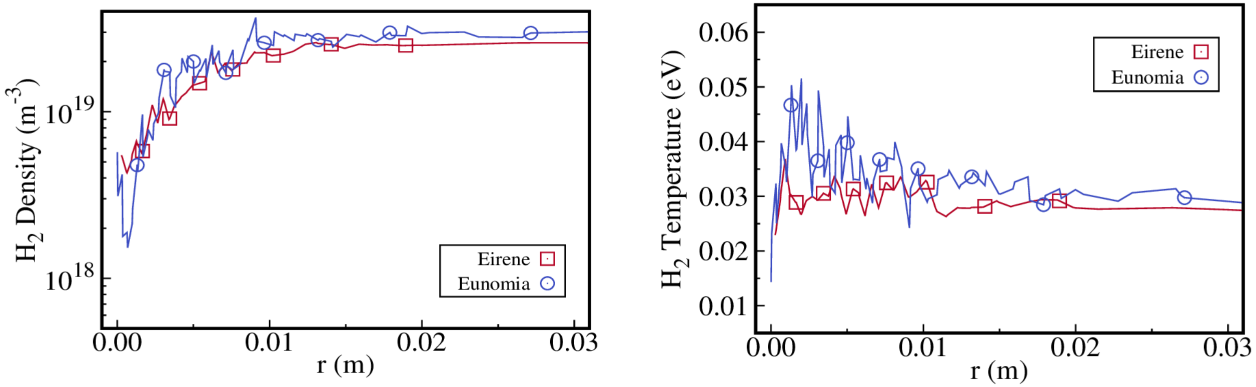
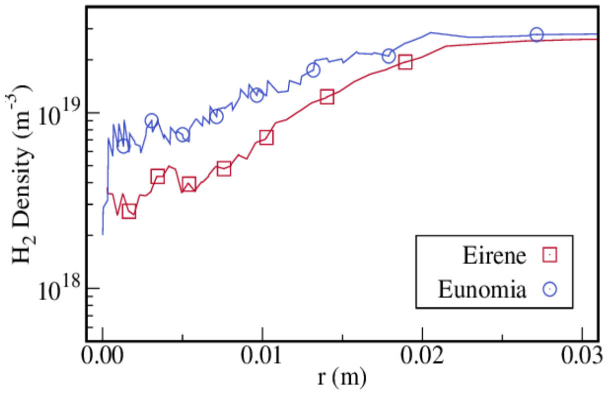


Fig. 2: Radial plot at z=0m of the H_2 density (left) and temperature (right) for a situation in which only MAR is considered with a frozen plasma background.

Total Source Intensity	Eirene	Eunomia
Electron energy (W)	-1427	-457
Ion Energy (W)	191	-533
Ion Particle (part s^-1)	-1.3e20	-2.9e20

- Eirene deals with dissociation of H_2^+ in a more involved way than Eirene. This produces some differences in the sink of ions and large differences in the energy terms.
- Differences are related to the way Eunomia deals with excited states (like in EI).
- Eirene considers multiple outcomes from the dissociation.

Proton-Molecule Elastic Interaction



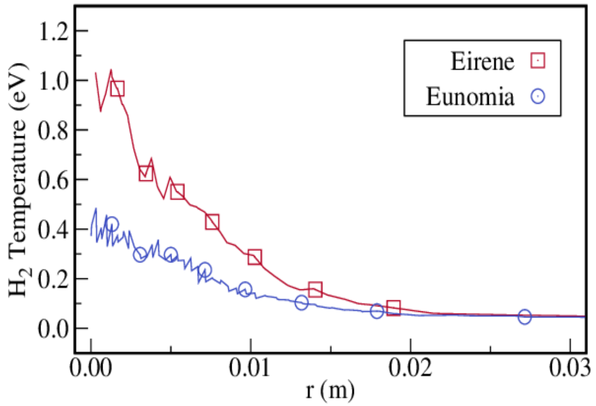


Fig. 3: Radial plot at z=0m of the H_2 density (left) and temperature (right) for a situation in which only EI is considered with a frozen plasma background.

- Differences in the calculation of the post-collision angle distribution lead to differences in the neutral profiles and the sink of energy computed by each module.
- Eirene: Morse Potential
  Eunomia: Tskhakaya

Total Source Intensity	Eirene	Eunomia
Ion energy (W)	-370	-490

Comparison of coupled runs

SOLPS-ITER vs B2.5-Eunomia: High Density Case

- Both codes produce values comparable with TS measurements.
- Different electric potential as a BC at the source.
- Different axial distributions of the plasma beam
- Different neutral distributions
- Not a good match in high pressure cases

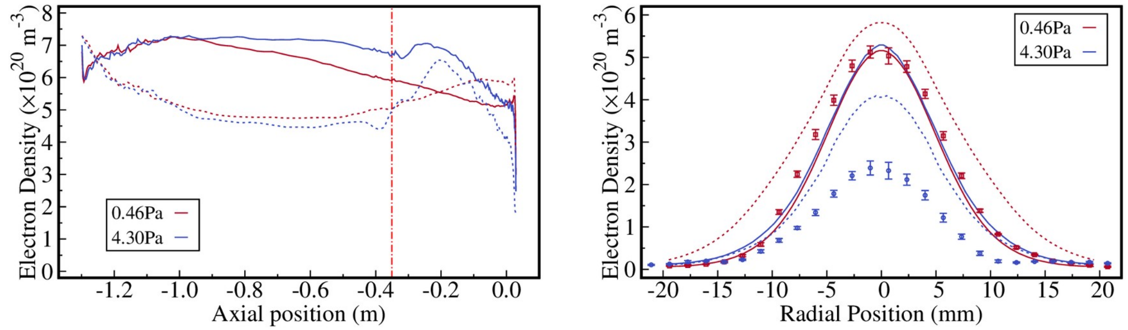


Fig. 4: Axial (left) and radial profile at the TS target position (right) of the electron density. Solid line is SOLPS-ITER, dashed line is B2.5-Eunomia and points represent the TS measurements.

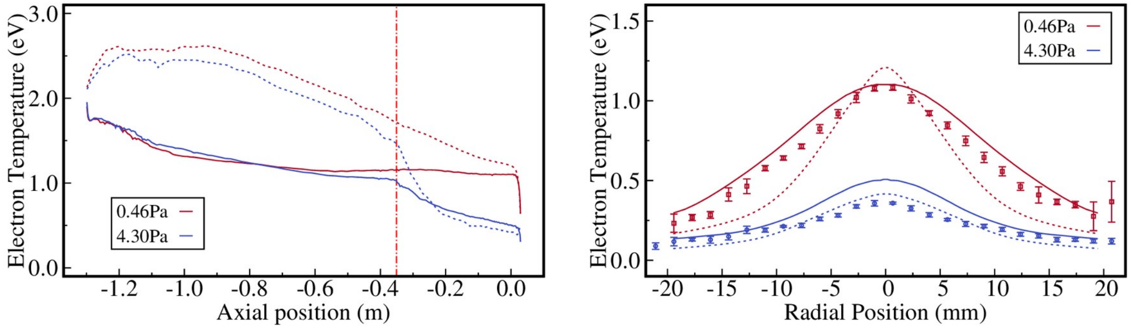


Fig. 5: Axial (left) and radial profile at the TS target position (right) of the electron temperature. Solid line is SOLPS-ITER, dashed line is B2.5-Eunomia and points represent the TS measurements.

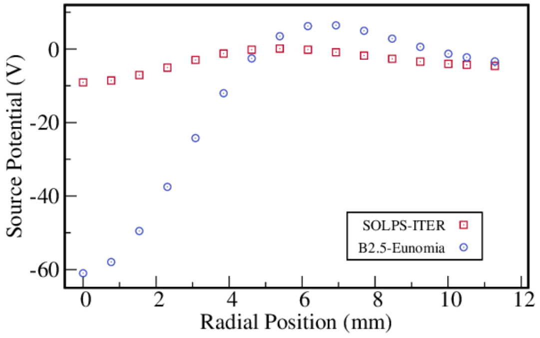


Fig. 6: Electric potential profile used as a BC at the source.

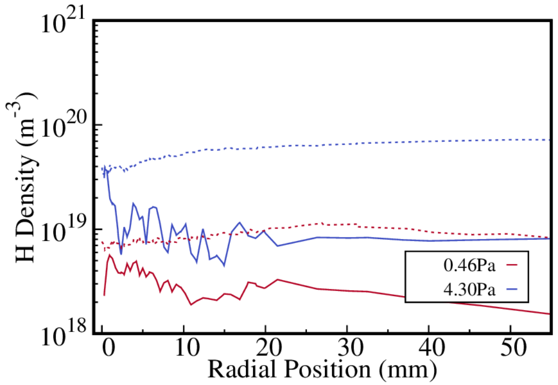


Fig. 7: Radial distribution density of atomic hydrogen at z = 0m.

SOLPS-ITER vs B2.5-Eunomia: Low Density Case

- Good agreement in temperature at TS position.
- Different electric potential as a BC at the source.
- Different axial distributions of the plasma beam.
- Different anomalous transport coefficients.
- Different neutral distributions.
- SOLPS-ITER produces a better match than B2.5-Eunomia.

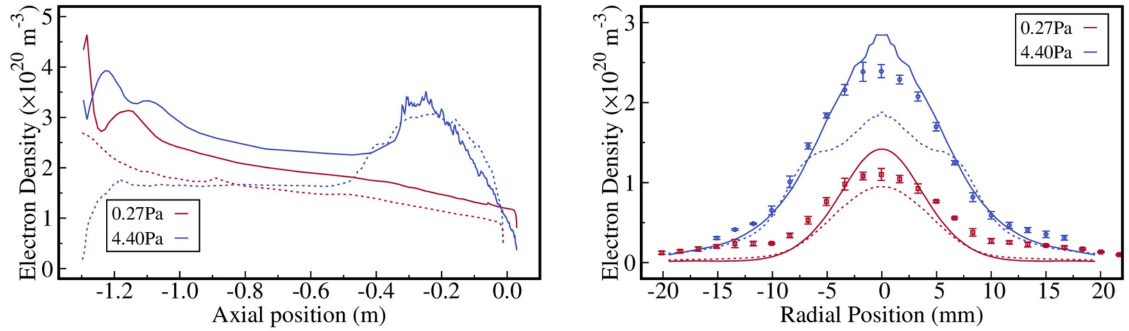


Fig. 8: Axial (left) and radial profile at the TS target position (right) of the electron density. Solid line is SOLPS-ITER, dashed line is B2.5-Eunomia and points represent the TS measurements.

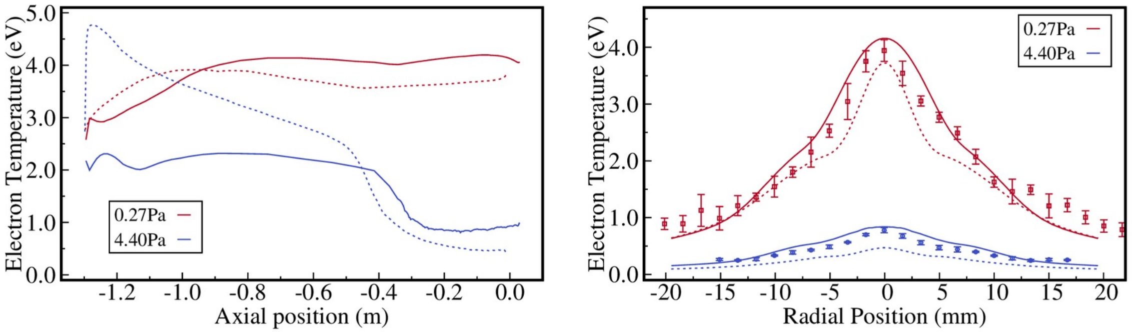


Fig. 9: Axial (left) and radial profile at the TS target position (right) of the electron temperature. Solid line is SOLPS-ITER, dashed line is B2.5-Eunomia and points represent the TS measurements.

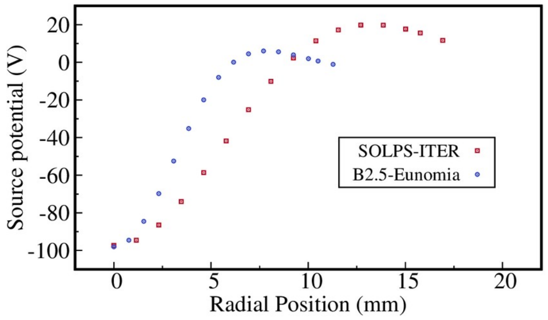


Fig. 10: Electric potential profile used as a BC at the source.

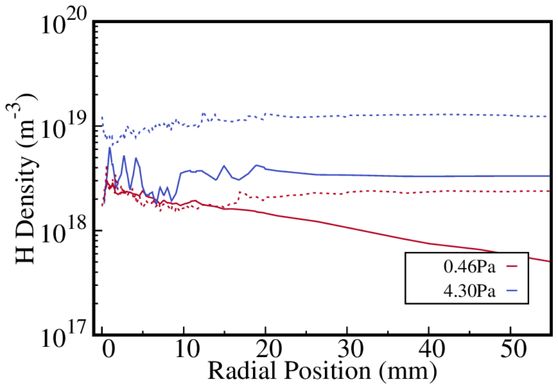


Fig. 11: Radial distribution density of atomic hydrogen at z = 0m.

SOLPS-ITER vs B2.5-Eunomia: Conclusions

- Both codes seems to produce results close to TS measurements.
- Nevertheless, this is achieved with completely **different neutral distributions** and **electric potential at the source**.
- This is caused by the different implementation of relevant plasma-neutral collision processes.
- Thus, there are still too many ***free parameters*** that need to be reduced:
  - Measurement of electric potential at the source TS position.
  - Independent calculation of transport coefficients in low density cases (currently in progress).
  - Measurement of neutral distributions to find which neutral module provide a better match.
- Based on the limited experimental data and how collision process are implemented, it seems that SOLPS-ITER provide more accurate results, but more data for comparison is required.
- Currently analysis higher pressure cases with SOLPS-ITER (convergence issues in B2.5-Eunomia) and molecule collision effects missing in Eunomia (mostly EI) until new experimental data is available.

Coupling of SOLPS-ITER with a Finite Element Wall Model

Finite Element Wall Model

- SOLPS-ITER is currently being expanded to allow coupling with a Finite Element Wall Model.
- The aim of this model is to self-consistently calculate target parameters that are of relevance for SOLPS-ITER.
- Current focus: **target temperature**, **evaporation flux for a liquid metal**.
- Being done in the frame of Magnum-PSI.
- Working on making it more general (currently the implementation is extremely ad-hoc)
- First objective: Pass plasma heat flux from B2.5 to Target Model. **Achieved**
- Now: Pass surface temperature to Eirene reflection model. **Testing**
- Future: Standarize the passing of information between codes and increase the amount of data exchanged.

Results FEWM

- First test: check the change in surface temperature with a dummy target at two neutral pressures (two heat fluxes).
- Target bottom temperature constant (180C) to represent active cooling. Not quite realistic, testing new boundary conditions now based on heat flux through the Magnum-PSI cooling system.

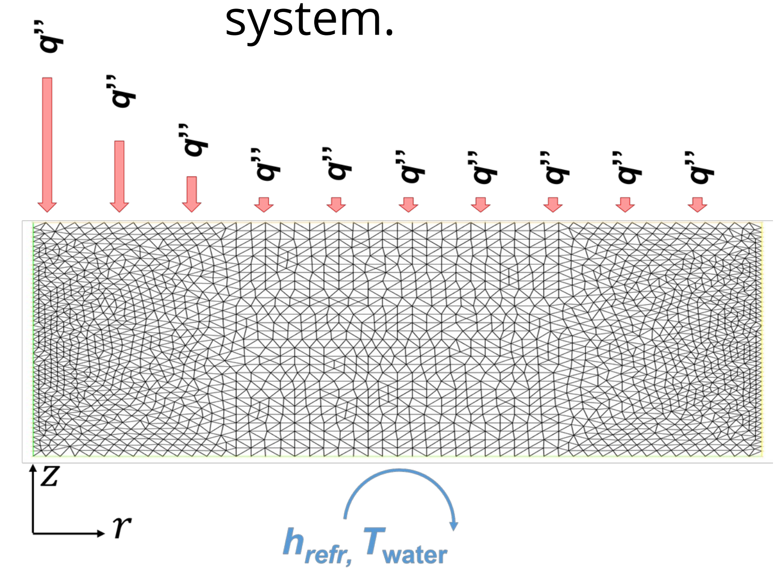


Fig. 12: Mesh of the 2D axial-symmetrical target employed. For testing.

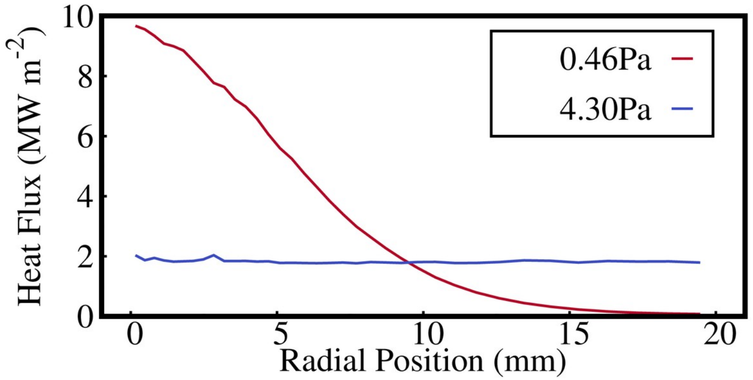


Fig. 13: Radial profile at the target of the Heat flux passed from B2.5 at two neutral pressures.

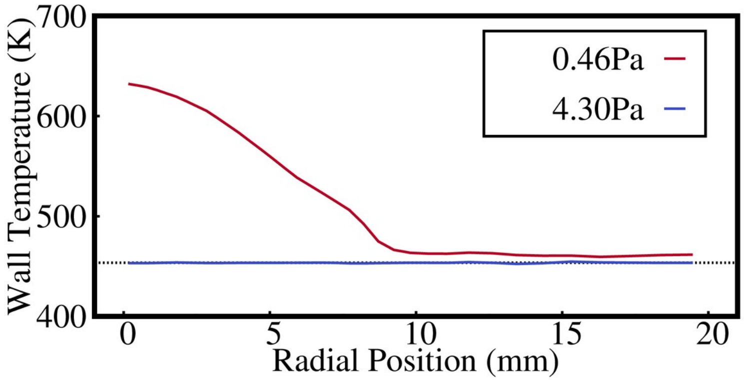


Fig. 13: Radial profile at the target of the target surface temperature self-consistently computed.

Thank you for your attention

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