Comparison of SOLPS-ITER and B2.5-Eunomia in the simulation of Magnum-PSI

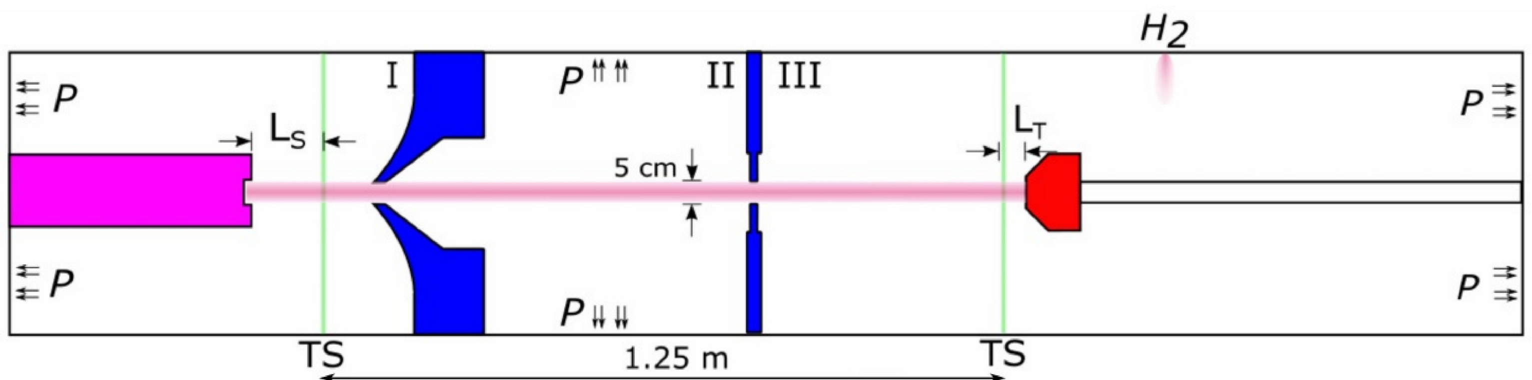
J. Gonzalez, R. Chandra, H. J. de Blank, E. Westerhof
DIFFER-Dutch Institute for Fundamental Energy Research. De Zaale 20, 5612 AJ, Eindhoven, The Netherlands.

DIFFER

SCIENCE FOR **FUTURE ENERGY**

Introduction

- Simulation of the plasma linear device Magnum-PSI is of uttermost importance to understand the complex plasma-surface interactions that would take place at ITER's divertor.
- Interactions of plasma with neutrals from recycling and gas puffing are leading phenomena in controlling the huge power exhaust in tokamaks.
- Neutral particle simulation is done with Monte-Carlo codes (Eunomia[1] and Eirene [2]) coupled with a CFD plasma code (B2.5).
- Differences in implementing collisional processes lead to different results.



Differences in neutral models

- Different implementation of collision process: Molecular Assisted Recombination (**MAR**), electron impact ionization (**EI**) and plasma-molecule elastic (**EL**) collisions.
- **MAR** is two step process:

$$H^+ + H_2 \rightarrow H + H_2^+ \quad \text{AMJUEL 3.2.3}$$

Eirene

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

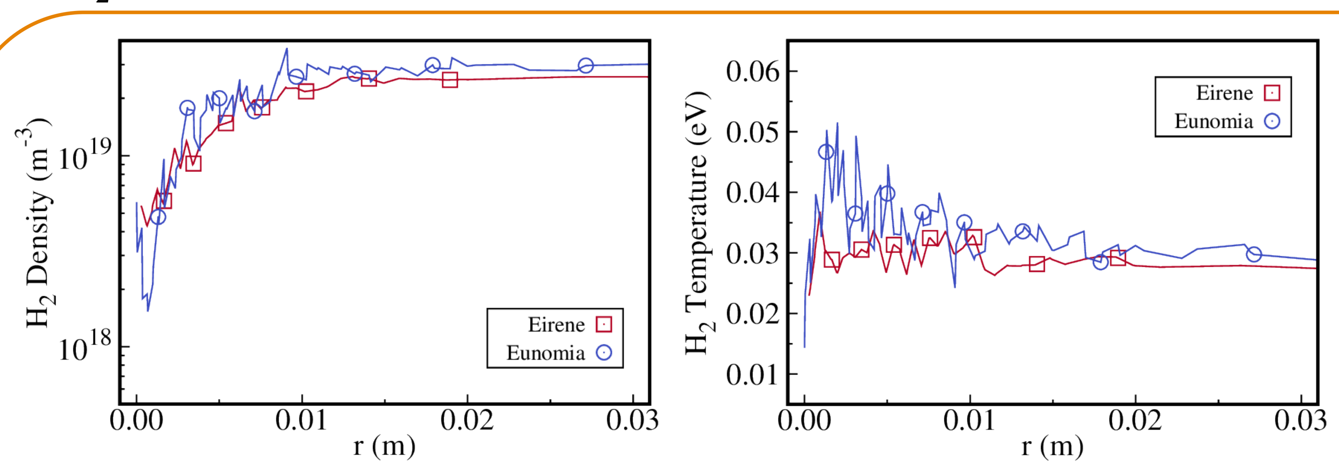
$e + H_2^+ \rightarrow e + H + H^+$ AMJUEL 2.2.12

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

Eunomia

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

In **Eunomia**, H^* can either get ionized by interaction with an electron or decay to ground state.



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

MAR. Although similar neutral profiles are obtained, the two neutral codes pass quite different sources values to the plasma code. Specially, Eirene using competing processes for H_2^+ produces a significant larger amount of ions than Eunomia simple approach.

- For **EI**:

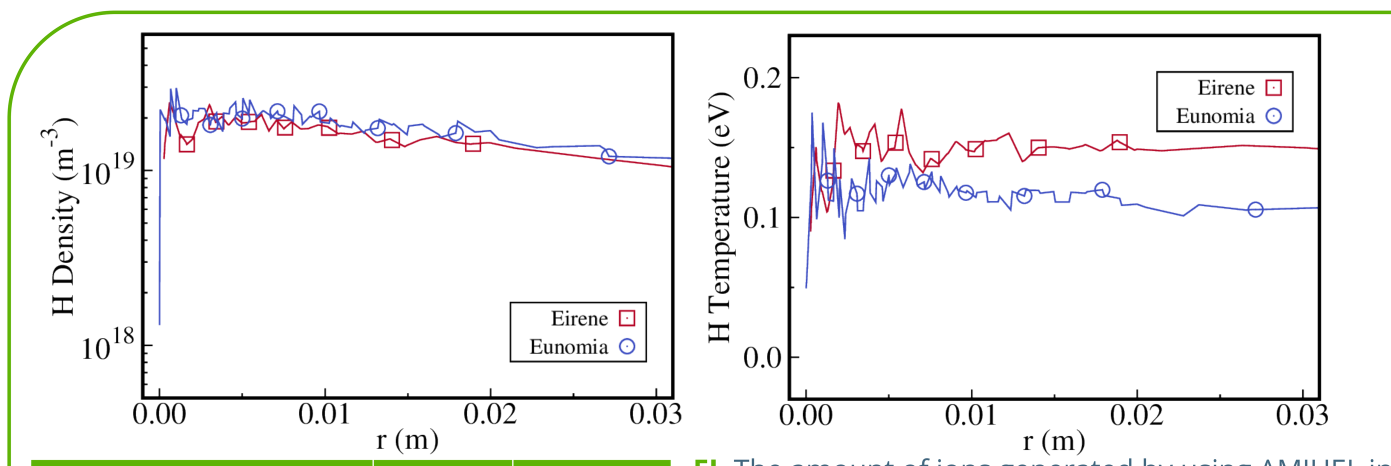
Eirene

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



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

EI. 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.

- Main difference in **EL** collisions between H^+ and H_2 is the calculation of the anisotropic post-collision angle.
- Same cross-section in both codes.

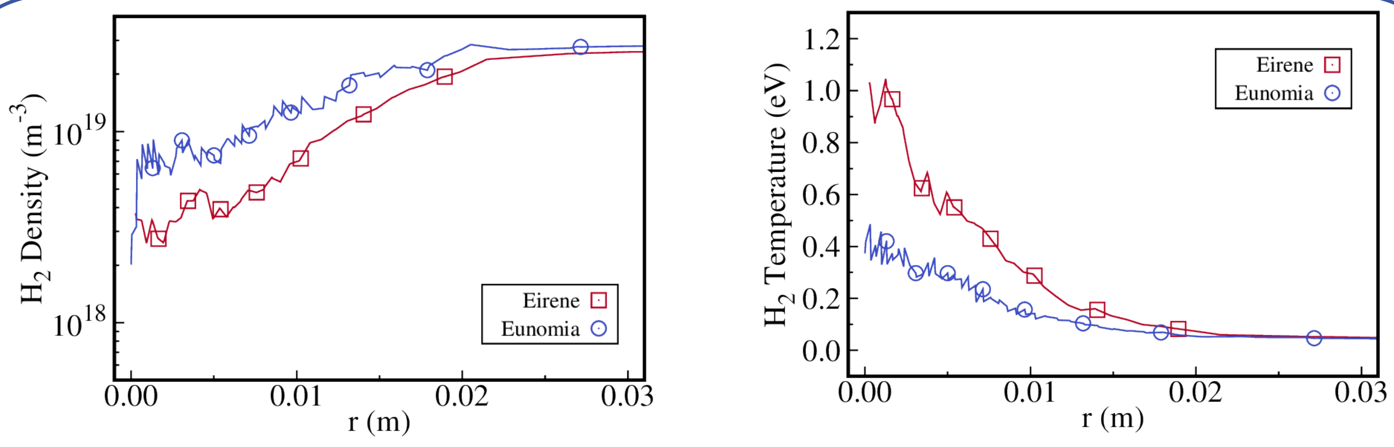
Eirene

Generalized Morse potential from Ref. [3]

Eunomia

$$\cos\theta = \frac{2 + \alpha E_r - 2(1 + \alpha E_r)^R}{\alpha E_r}$$

From Ref. [4]

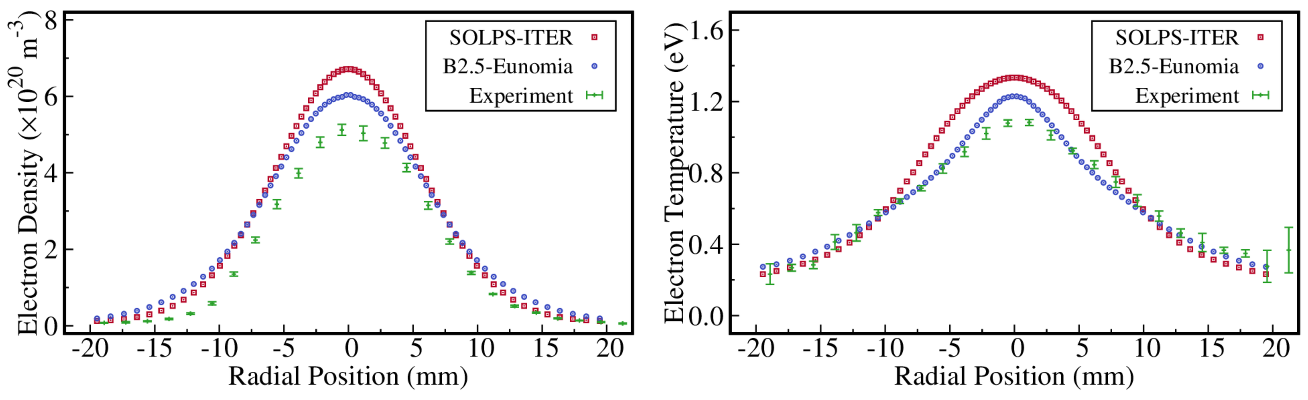


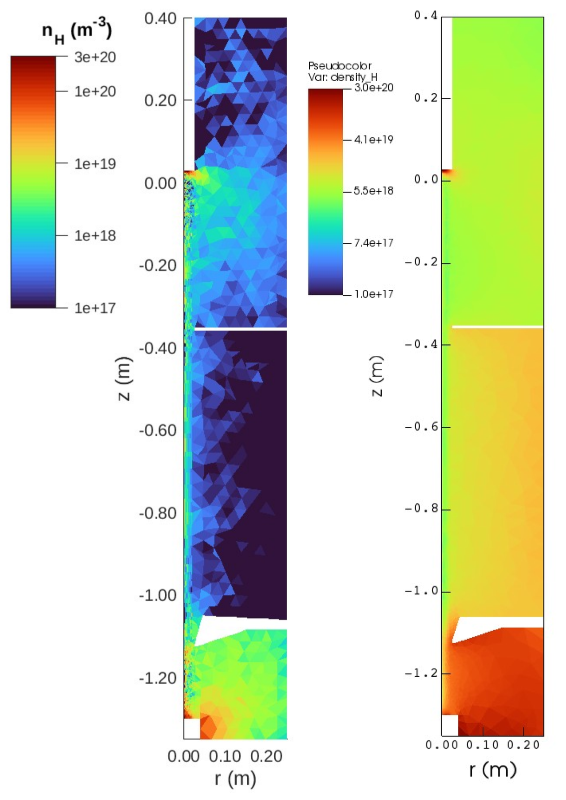
Total Source Intensity	Eirene	Eunomia
Ion energy (W)	-370	-490

EL. In the case of p + H2 collisions being considered, the ion energy sink is quite similar. However, the resulting neutral distribution is completely different, as the radial profiles show. This is caused by how the two codes compute the anisotropic angles in plasma-molecule collisions.

Coupled case

- Even with the differences between the two neutral distributions shown below, similar plasma profiles at the Thomson Scattering (TS) target position are found.
- More experimental data about the neutral distribution is required to determine which code provides the right solution.





H Density with **Eirene**

H Density with **Eunomia**

- Small differences in B2.5 version used => Different plasma solutions in coupled state.
- The pressure in each chamber is kept constant in the two codes => Quite different neutral density and neutral temperature distributions.
- Boundary condition for Electric Potential still unknown.
- Both codes require quite different potential profiles, related with Ohmic heating, to obtain electron temperatures in the order of the experiments.

Conclusions

- Simulations for Magnum-PSI are moving towards SOLPS-ITER to be inline with fusion community.
- Eirene and Eunomia produces quite different neutral distributions due to different models in collision processes.
- Nevertheless, both codes seems to be able to produce similar plasma results at the TS target position.

References

[1] R. C. Wieggers, et Al, *Simulation of the Neutral Inventory in the Pilot-PSI Beam*, Contributions to Plasma Physics 52 (5) (2012) 440-444.
[2] D. Borodin, et Al, *Fluid, Kinetic and Hybrid Approaches for Edge Transport Modelling in Fusion Devices*, IAEA FEC-2020, Nuclear Fusion, In Press.
[3] P. Bachmann, D. Reiter, Kinetic description of elastic processes in hydrogen-helium plasmas, Contributions to Plasma Physics 35 (1) (1995) 45–100.
[4] D. Tskhakaya, et. Al, *Self-Consistent Simulations of the Plasma-Wall Transition Layer*, Contributions to Plasma Physics, Wiley Online Library, 2008, 48, 121-125.

EUROfusion

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.