

3D Rarefied molecular flow simulation to understand measurements performed In Deuterium plasmas

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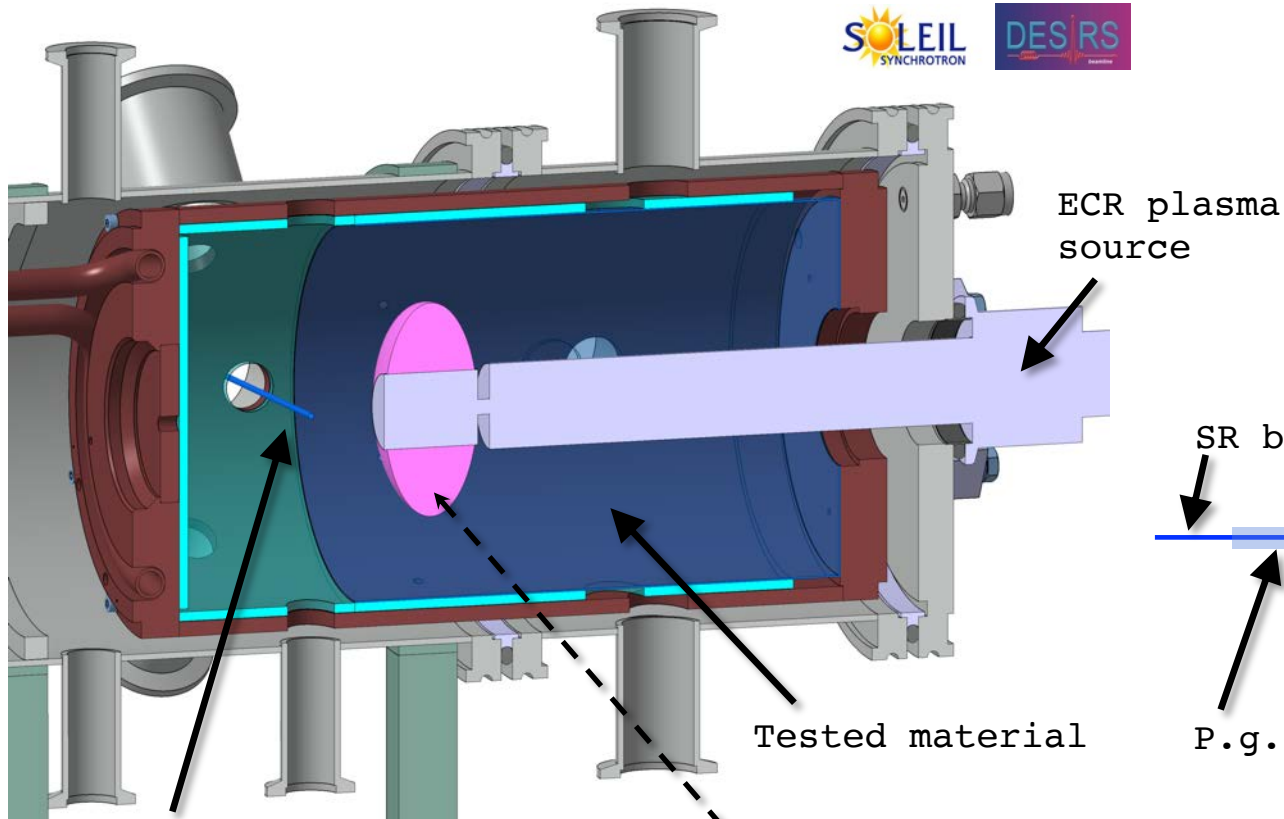
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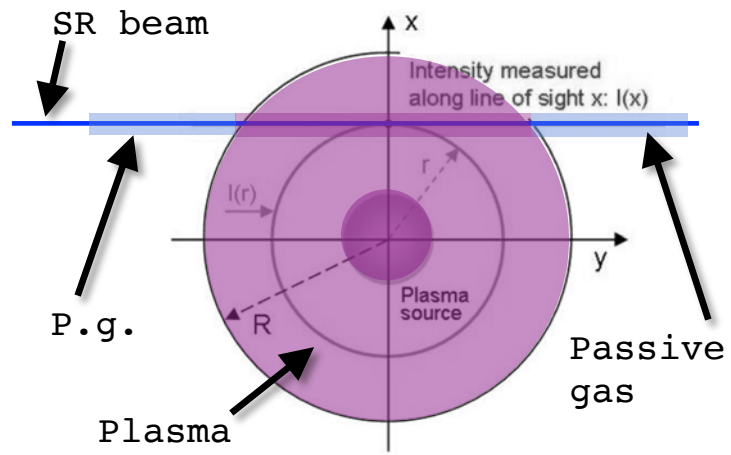
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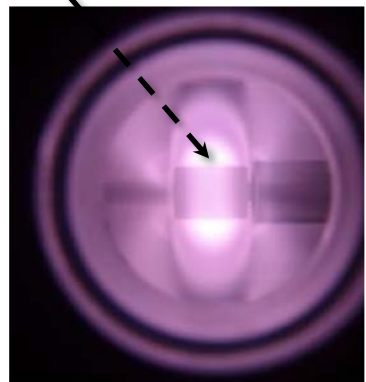
Experimental set-up and plasma diagnostic



VUV absorption, at SOLEIL synchrotron, reveals absolute densities of D_2 molecules

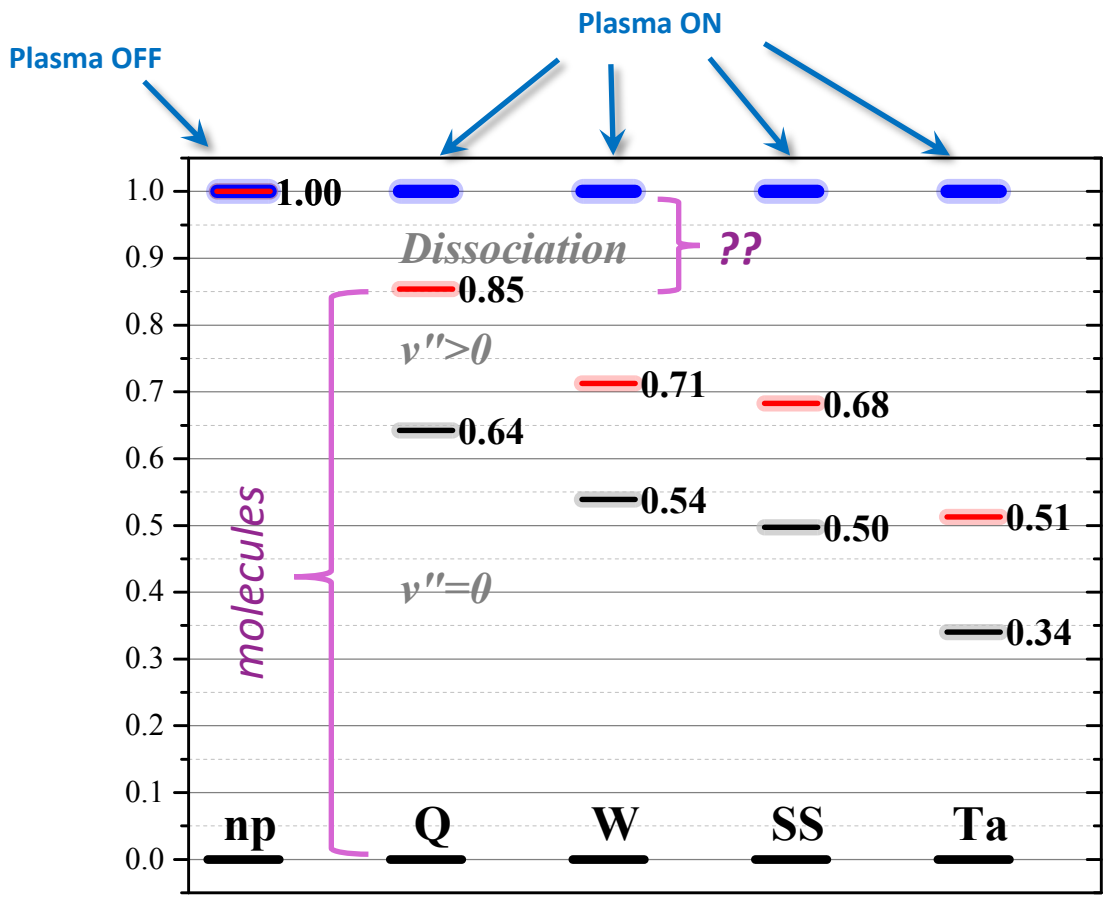


Cold plasma, an ionized gas where electrons, ions, molecules, atoms are found with different energies ...



Contribution of the passive gas should be limited

Un-expected results



Plasma:

- D_2, D_2^*
- $D \approx 0.01 \times D_2$
- $D^+, D_2^+, D_3^+ \approx 0.001 \times D_2$
- $D^- \approx 0.0001 \times D_2$

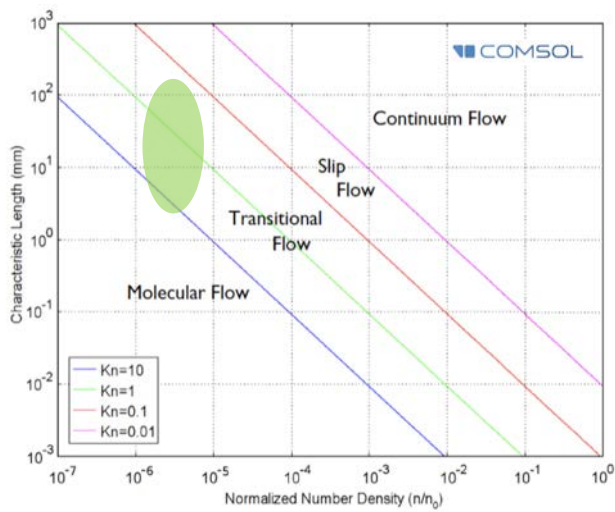
The decrease of 15% of the molecular density when plasma ON was difficult to explain

COMSOL
Molecular flow

Calculation of the particles density distribution

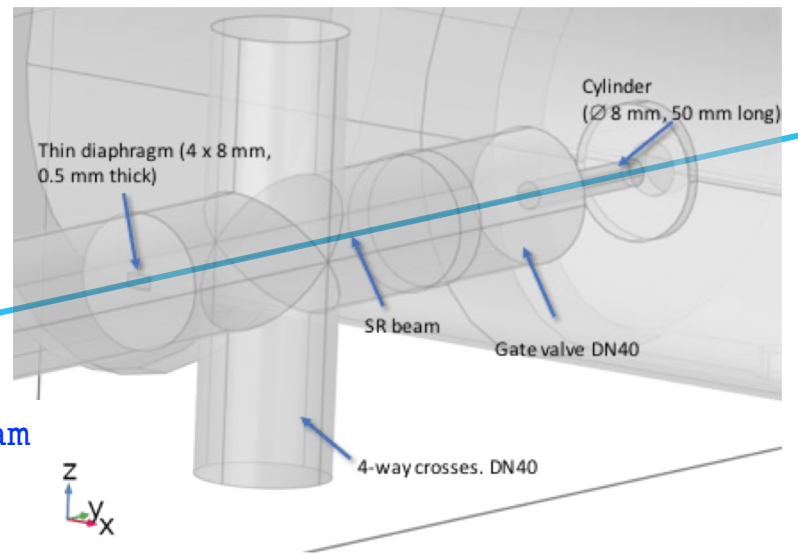
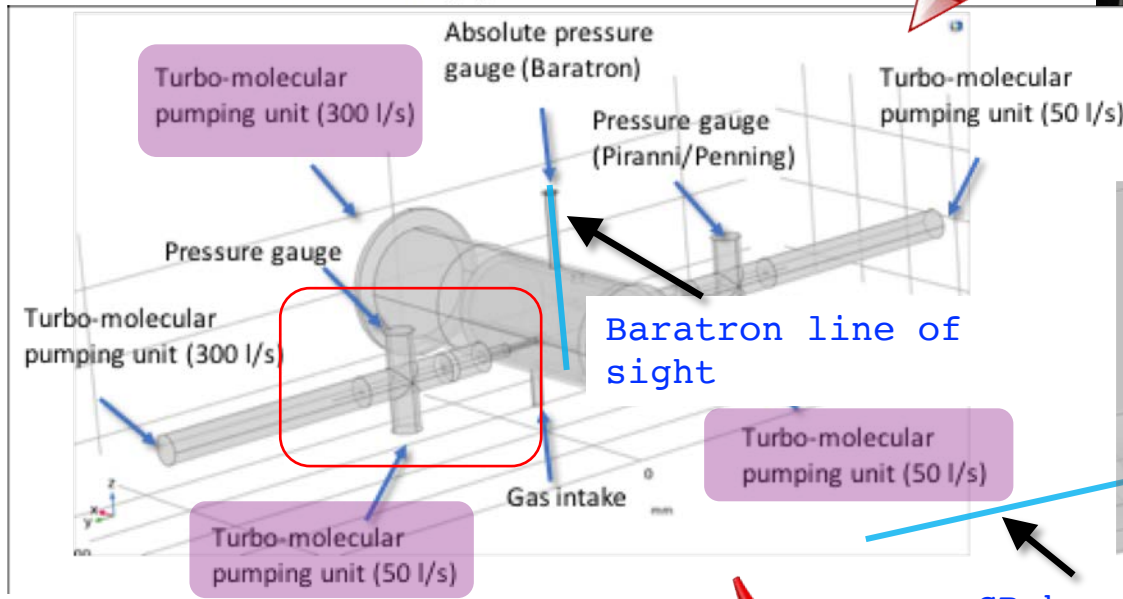
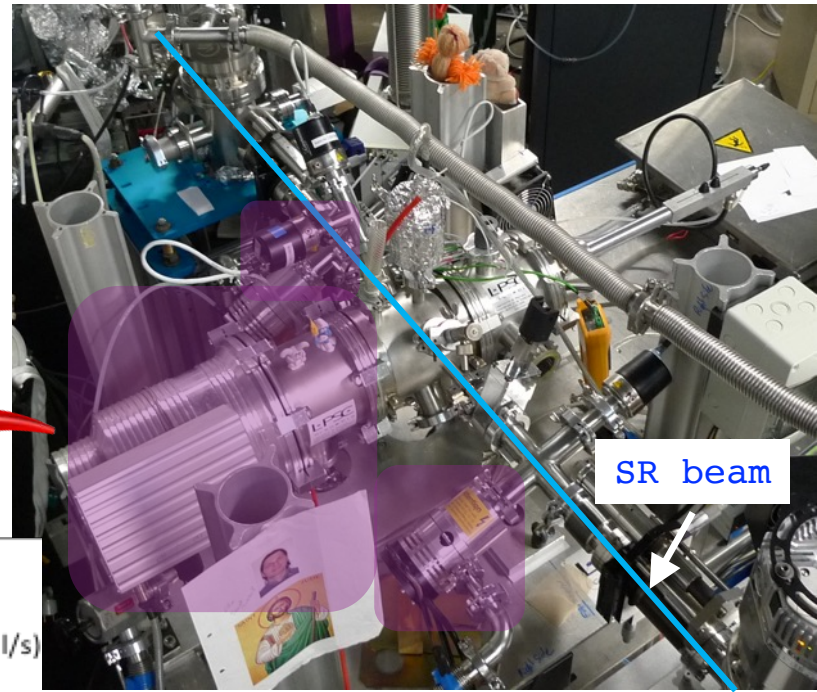
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Application of the Molecular Flow Module to our setup

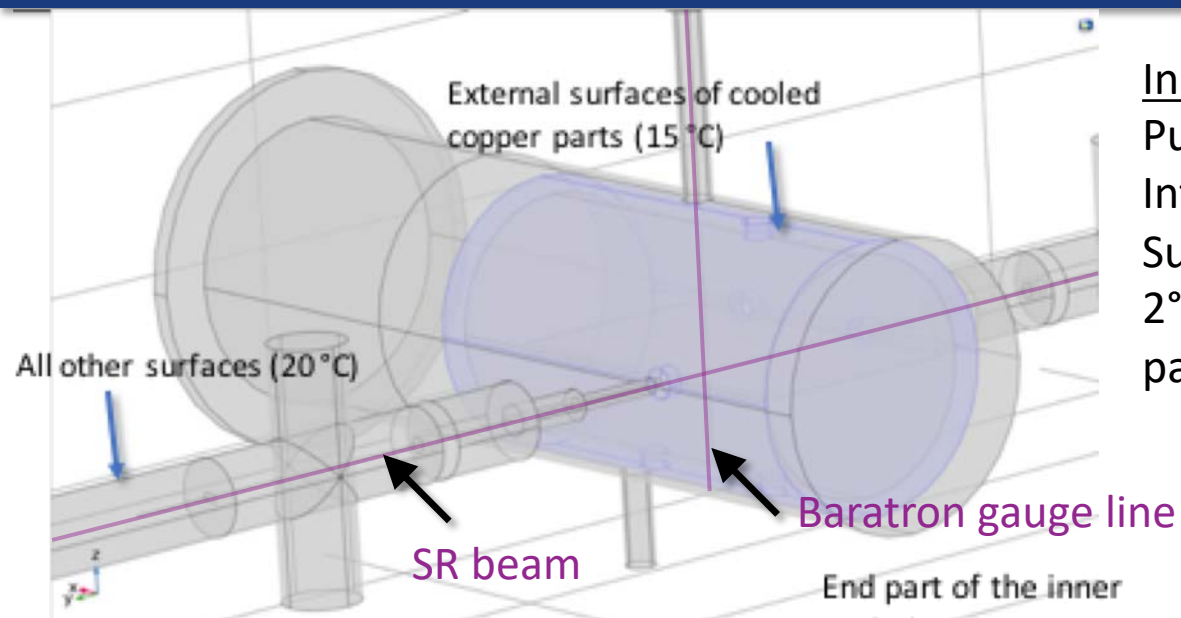


Low pressure : 6 mTorr
($1.4 \times 10^{18} \text{ m}^{-3}$ @ 150 °C
– $n/n_0 = 5 \times 10^{-8}$)
Small Dimensions :
∅ 150 mm, 220 mm long

From real exp. Setup
to the model



Initial data and output results



Input parameters:

Pumping speed (data sheet for H₂)
 Intake Flux (mass flow meter)
 Surfaces temperature (chiller set at 2°C and thermocouples set on copper parts)

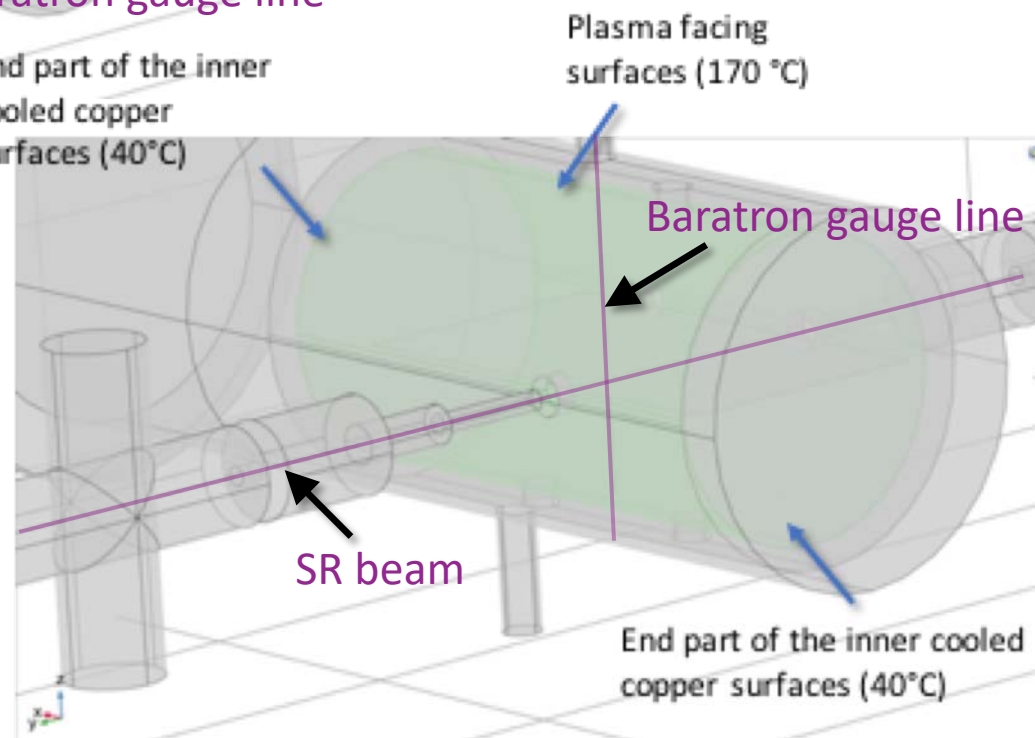
Output results of Molecular module:

Distribution of particles density along a defined paths:

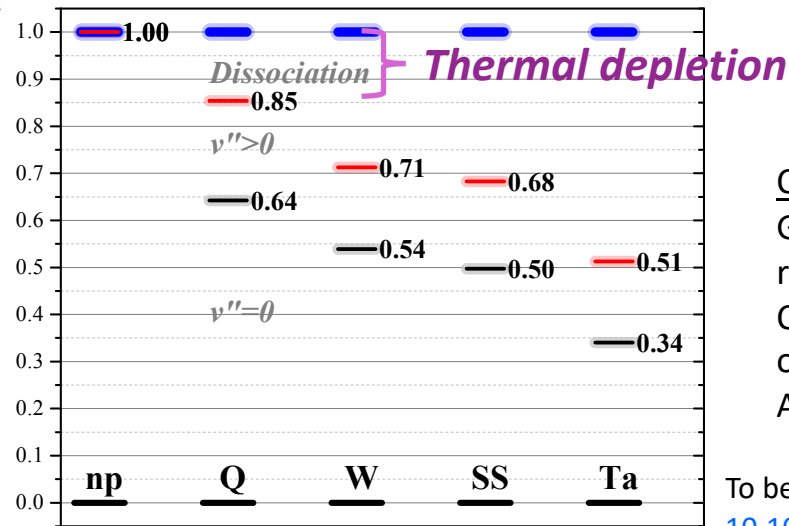
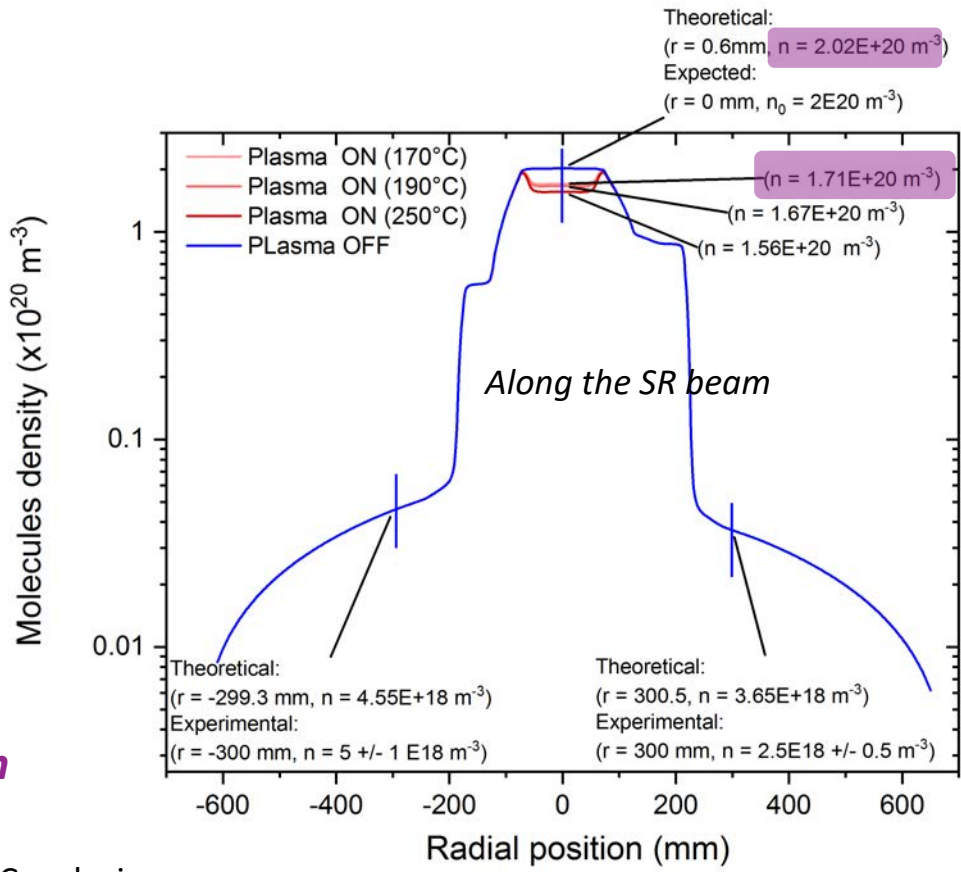
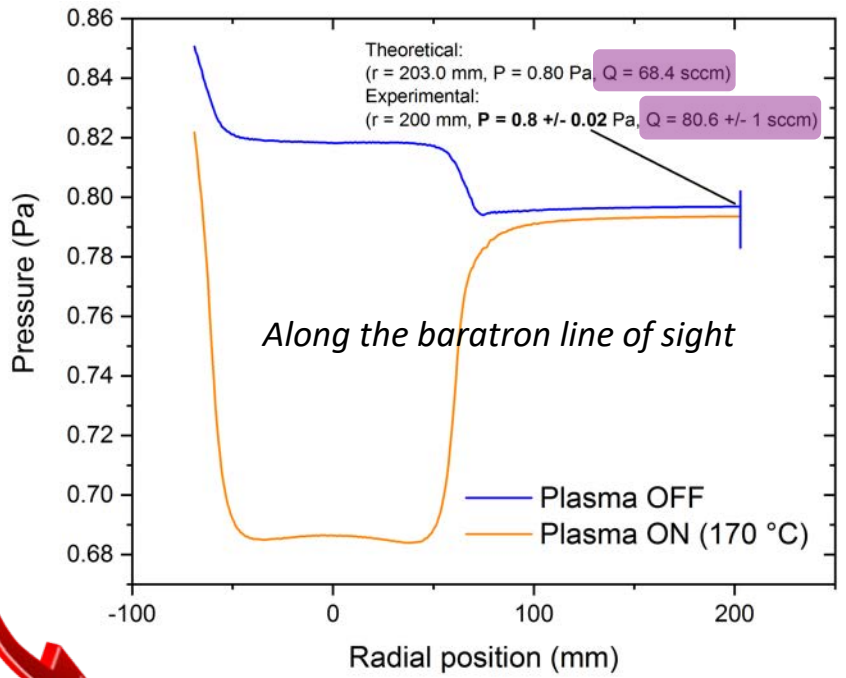
- SR beam
- Baratron gauge

... are compared to absolute gas pressure measurements

End part of the inner cooled copper surfaces (40 °C)



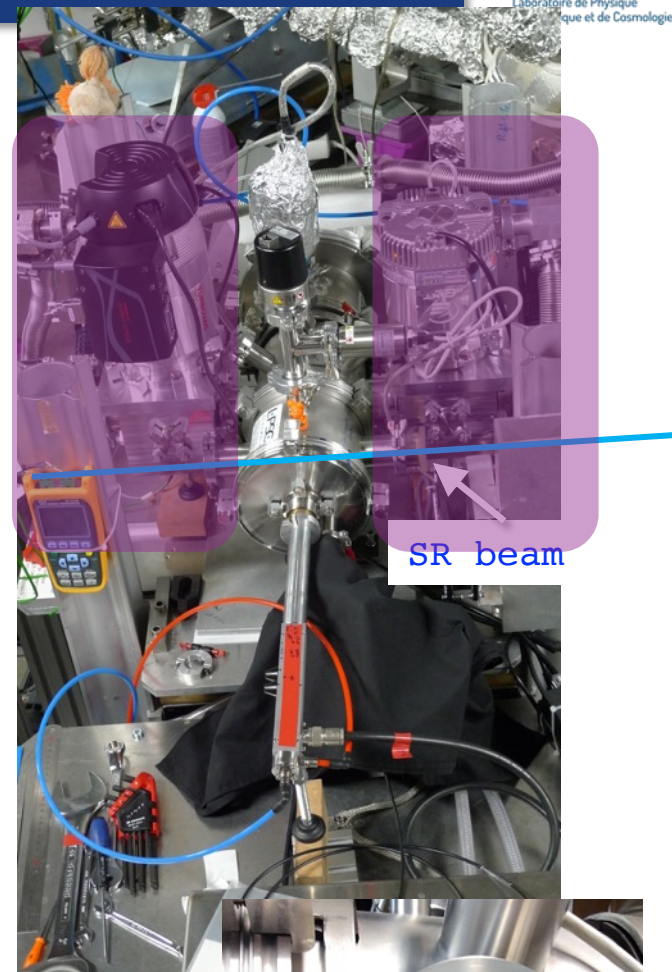
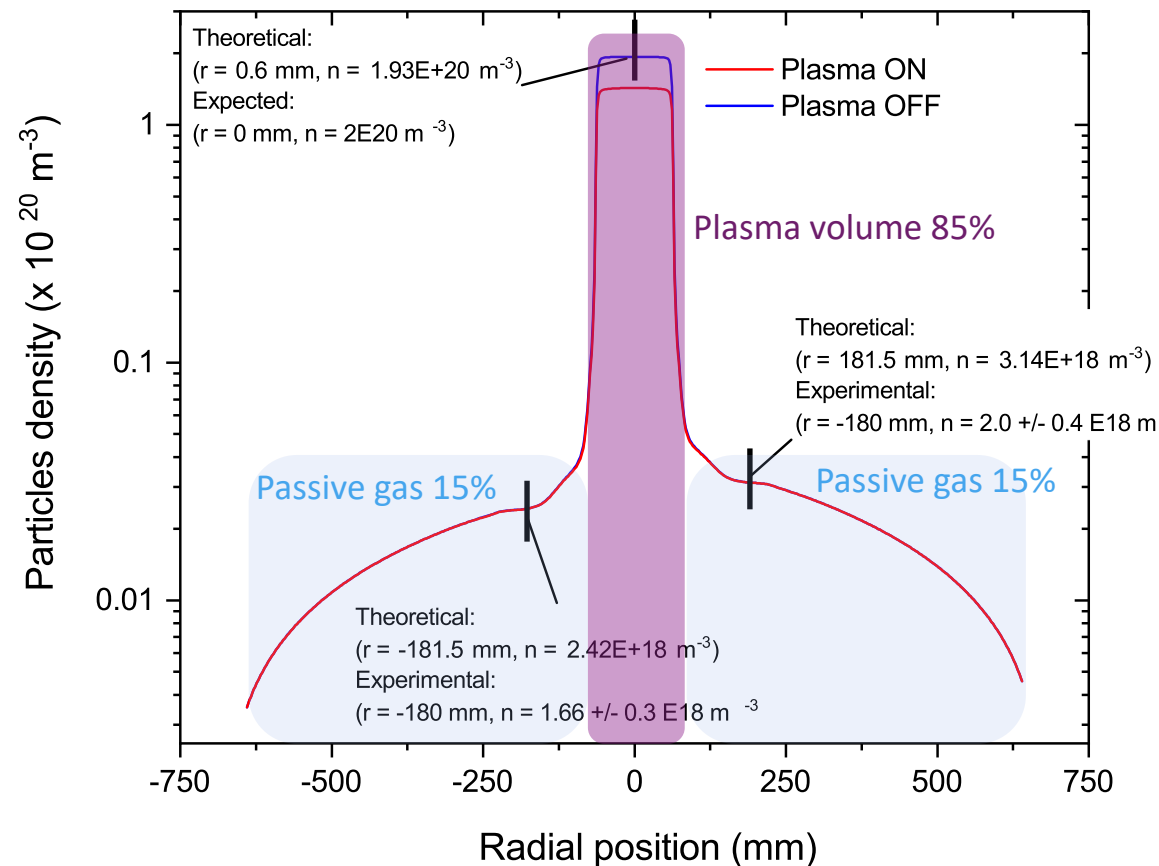
Results of 3D modelling



Conclusion:

- Good accordance between experimental measurements and results:
- Calculation of the passive gas contribution (41 %) and design of a new structure
- An explanation raises for experimental results

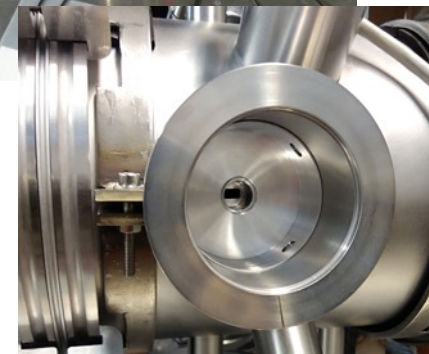
New design of the setup



Conclusion:

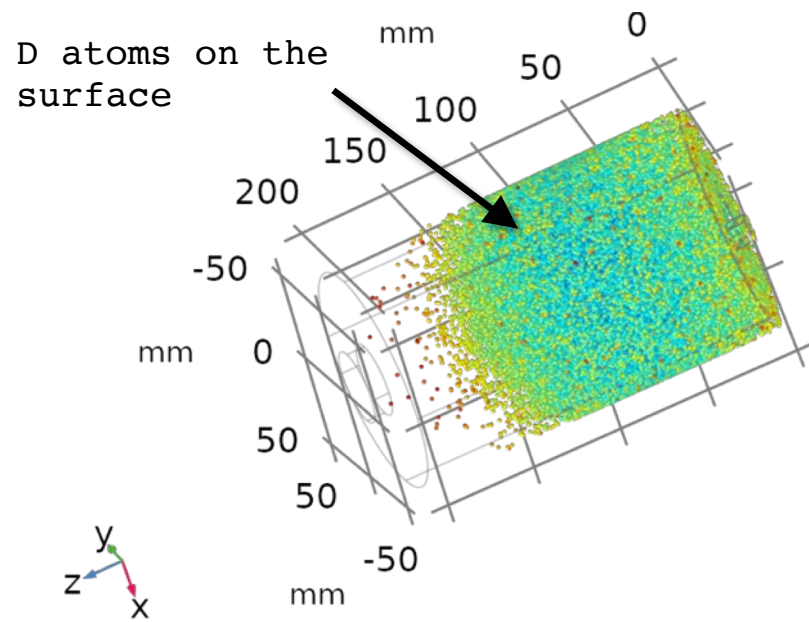
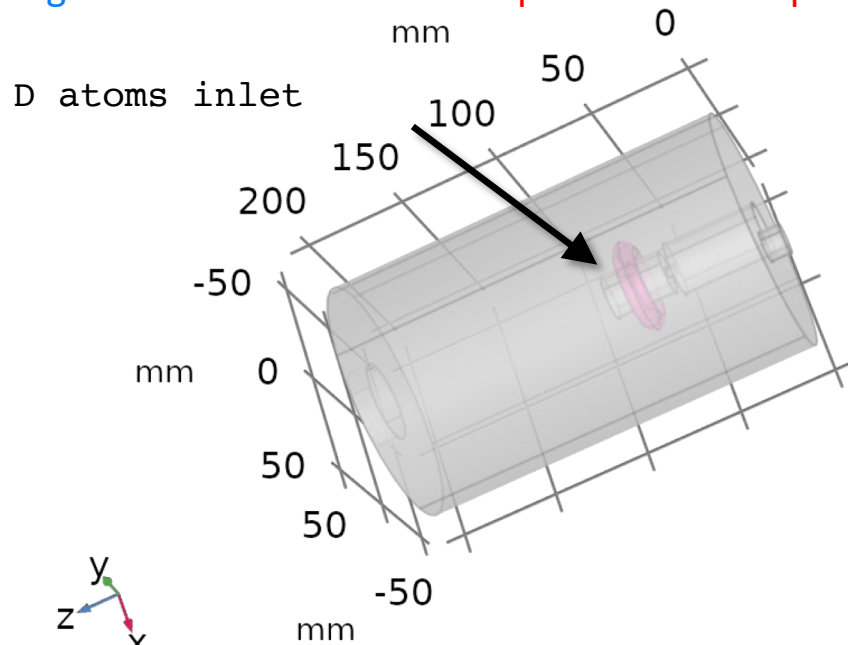
- Good accordance between experimental measurements and results is maintained: **0.8 Pa** is obtained experimentally with **Q = 34 +/- 1 sccm** and with **Q = 39 sccm** with the model
- The passive gas contribution decreased from 41 % to **15 %**

New diaphragm closer to the plasma volume than previous one



Conclusions & future modelling

- ✓ COMSOL Multiphysics allows complex 3D structure modelling in large structure (1200 mm long)
- ✓ Molecular flow module modelling showed good accordance between theoretical results and measurements performed
- ✓ Improvements have been obtained between the previous structure and the new one
- Coupling of molecular flow and particle tracing module → position of D atoms impinging on the surface
- Coupling with heat module → temperature of the plasma facing material estimation



Thanks for your attention !

It's time for questions ...



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