ECWC experiments and modeling on TCV

J. Buermans[1], J. Cavalier[2], S. Coda[3], S. Gorno[3], E. Huett[3], R. Ragona[4]
T. Wauters[5], the TCV Team* and the EUROfusion MST1 Team†

[1] Laboratory for Plasma Physics LPP-ERM/KMS, Brussels, Belgium [2] Institute of Plasma Physics of the Czech Academy of Sciences, Prague, Czech Republic
[3] Ecole Polytechnique Fédérale de Lausanne, Swiss Plasma Center, Lausanne, Switzerland [4] Department of Physics, Technical University of Denmark, Kgs. Lyngby, Denmark
[5] ITER Organization, St Paul Lez Durance, France * See author list of H. Reimerdes et al 2022 Nucl. Fusion **62** 042018 † See author list of B. Labit et al. 2019 Nucl. Fusion **59** 086020

Abstract

During the first stage of ITER operation (PFPO-1), Electron Cyclotron Wall Conditioning (ECWC) will be the only available conditioning technique in the presence of a toroidal field. The limited experience with this technique calls for dedicated modeling and experiments to ensure that ECWC can be an efficient conditioning tool for ITER.

The TOMATOR 1D hydrogen helium plasma simulator numerically describes the evolution of currentless magnetized RF plasmas in a tokamak based on Braginskii's standard continuity and heat balance equations. This code was initially benchmarked with experimental data from TCV Helium plasmas to determine the transport coefficients used in the diffusion-convection-reaction equation of the simulation [1].

The density profiles, measured with the Far Infrared Interferometer, and the particle fluxes, measured with Langmuir probes, are compared to the modeling with the TOMATOR 1D simulator to benchmark the code also for deuterium plasmas.

Model Description [2]

$$\frac{\partial}{\partial t}n(r,t) = \frac{1}{r}\frac{\partial}{\partial r}\left(rD(r,t)\frac{\partial}{\partial r}n(r,t)\right) - \frac{1}{r}\frac{\partial}{\partial r}\left(rV(r,t)n(r,t)\right) + S(r,t)$$

$$\frac{\partial}{\partial t}E(r,t) = \frac{1}{r}\frac{\partial}{\partial r}\left(r\gamma_D D(r,t)\frac{\partial}{\partial r}E(r,t)\right) - \frac{1}{r}\frac{\partial}{\partial r}\left(r\gamma_V V(r,t)E(r,t)\right) + S_E(r,t)$$

$$D_r = \frac{1}{3}\cdot f_D \cdot \nu_{c,i}\cdot\left(r_i + \lambda_i\cdot\frac{B_r}{B_\varphi}\right)\cdot\lambda_i$$

$$V_r = f_V \cdot \frac{(T_e+T_i)}{B_r} \qquad \sim E\times B \text{ drift}$$

Benchmarking

Input parameters:

- Machine parameters: $R, a, b, B_r, B_\varphi, B_z$
- Heating power (ECRF-X2: 82.7 GHz)
- Neutral pressure (measurement)

Tuning Parameters:

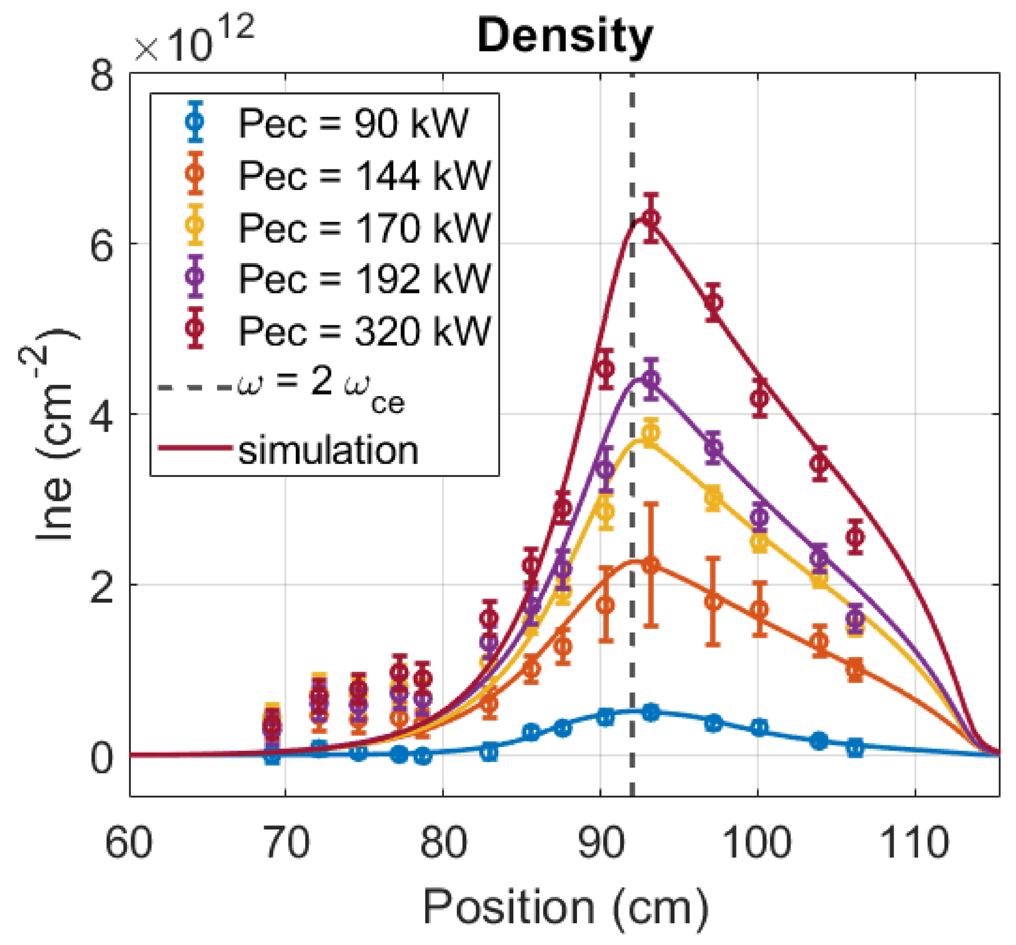
- Convection: f_V
- Diffusion: f_D (Bohm: 0.06 / Spitzer: 0.21)

Output:

- Density and temperature profiles
  ⇒ to be compared with experiments
- Power deposition profiles

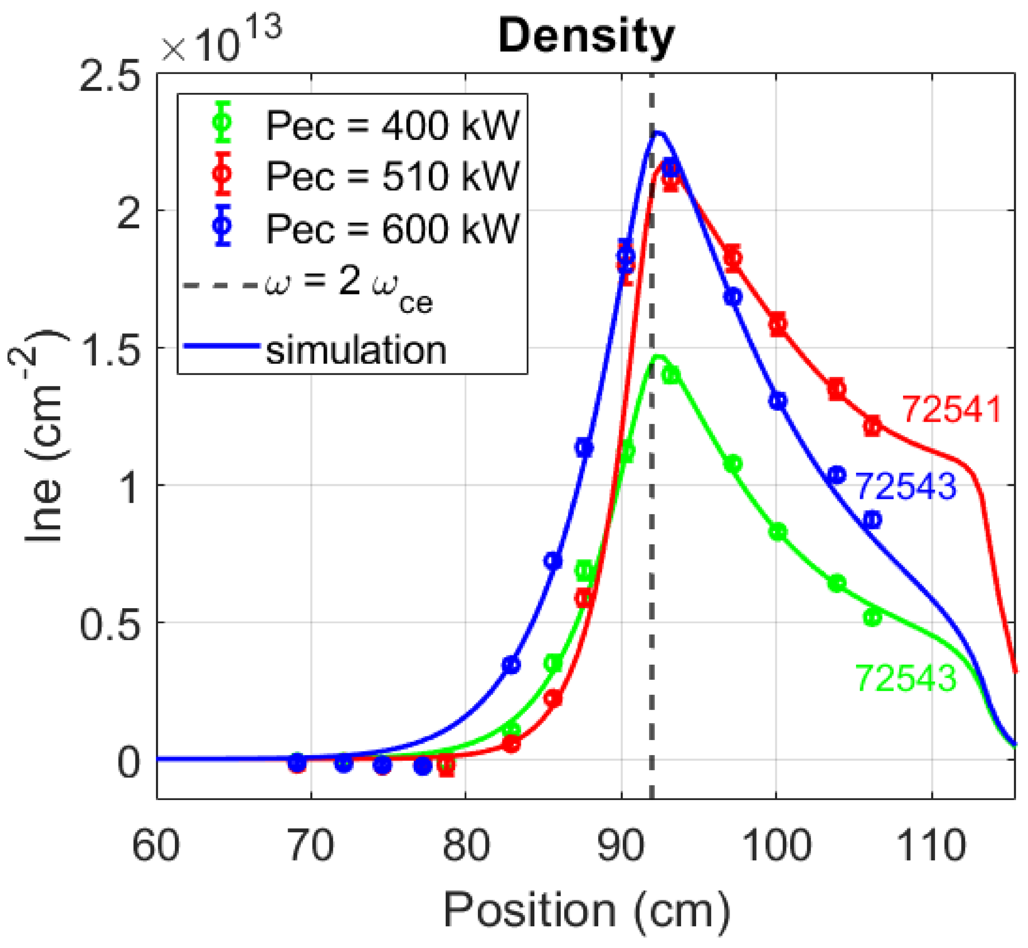
Transport coefficients in Helium and Deuterium

Helium experiments
(TCV shots #51513–51517)



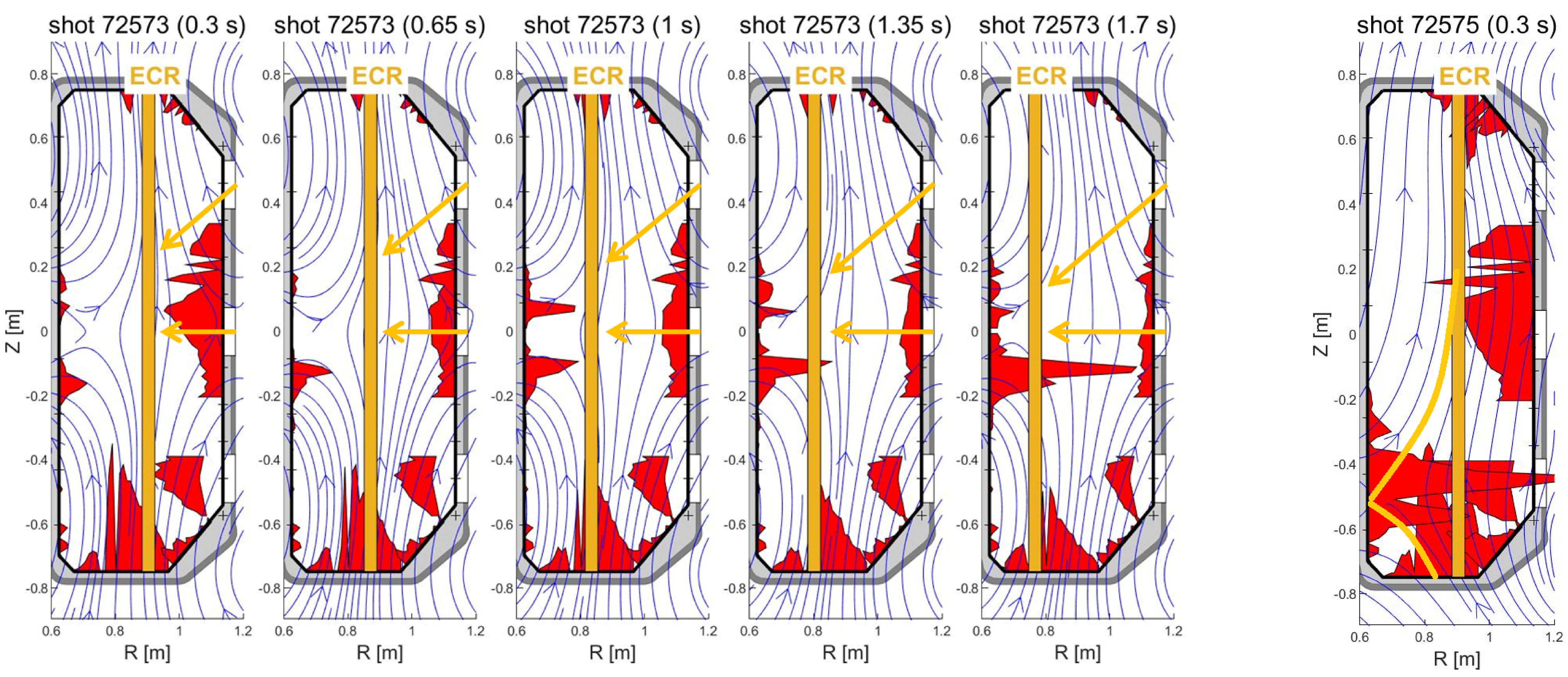
- Power scan at 82.7 GHz (X2)
  Upper launch: $\theta = -10°, \phi = 5°$
- $B_t = 1.54$ T and $B_v = 0$ mT
- Diffusion: $f_D = 0.210 - 0.136$ with a clear downward trend
- Convection: $f_V = 0.15 - 0.50$ with a clear upward trend

Deuterium experiments
(TCV shots #72541/72543)



- Power scan at 82.7 GHz (X2)
  Equatorial launch: $\theta = 8°, \phi = 90°$
- $B_t = 1.54$ T and $B_v = 7.55$ mT
- Diffusion: $f_D = 1.27 \pm 0.15$
- Convection: $f_V = 10.0$ [72541]
- Convection: $f_V = 3.5$ [72543]

Wall Conditioning: Langmuir probe measurements



72573: Quadrupole B_t scan (1.54 to 1.20 T)

- Upper + equatorial launch (510+510 kW)
- Gas: Deuterium @ $2.5\cdot10^{-4}$ mbar

72575: Adapted field configuration

- Linking the plasma creation location to the desired area

Conclusions

- The magnetic field, hence the position of the electron cyclotron resonance layer, plays an important role in the location and the intensity of the particle fluxes
- The HFS of the machine can be reached with a high particle flux
- The flux can be directed to different positions at the HFS and the divertor

[1] T. Wauters et al., Plasma Phys. Control. Fusion, Vol. 62, No. 10, 105010 (2020)
[2] T. Wauters et al., Plasma Phys. Control. Fusion, Vol. 53, No. 12, 125003 (2011)

Email johan.buermans@rma.ac.be
Phone +32 (0)2 44 14 122

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