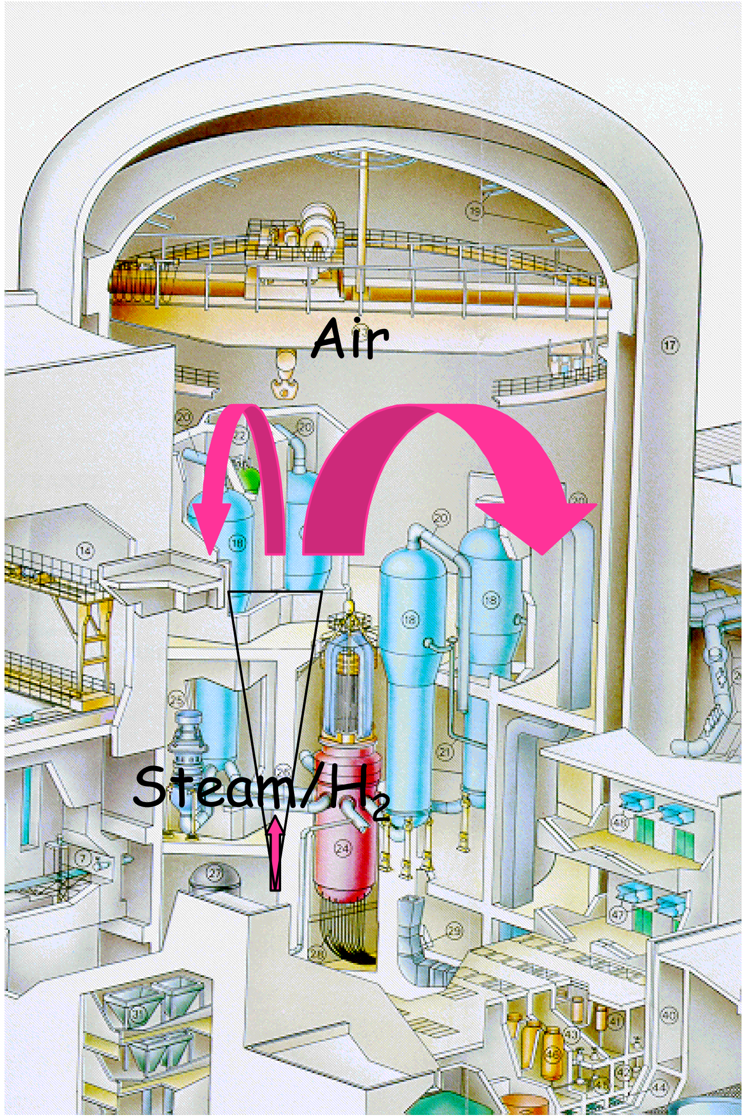
PAR elevation influence study

F.Dabbene

Club CAST3M 2009

26 novembre 2009 • PARIS, FRANCE

Context



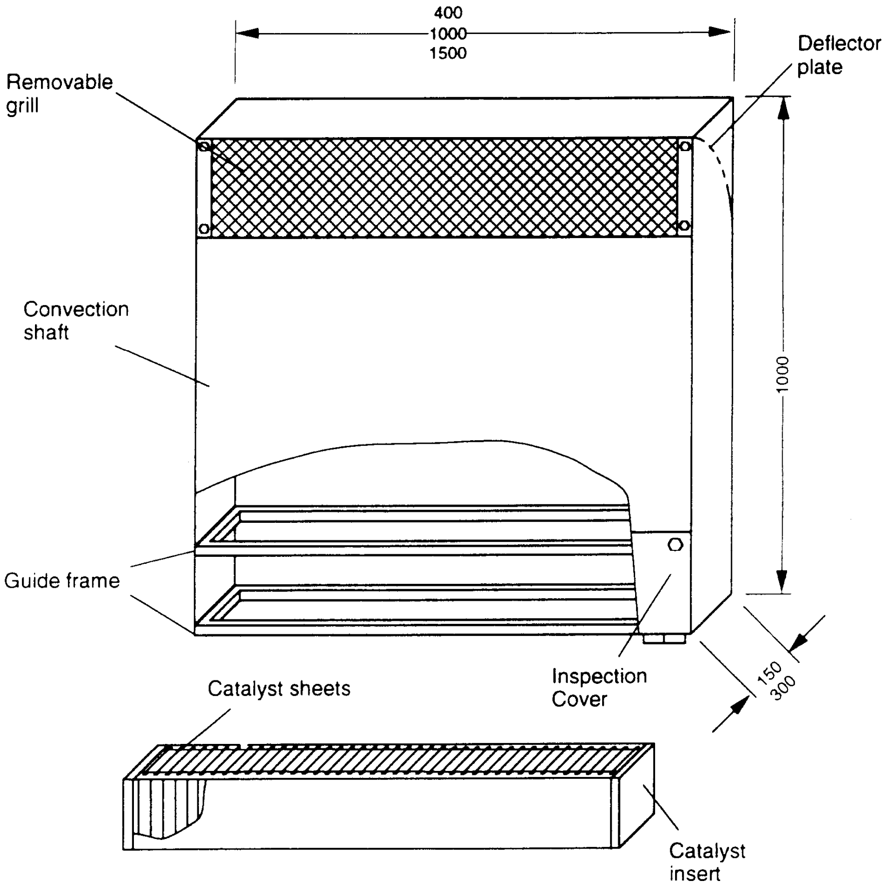
- **Containment Thermalhydraulics during severe accident**

- Containment initialy filled with Air (50 to 80000 m3)

- Before core degradation:
  - Hot steam released into the containment (jet/plume)
  - Bulk condensation and wall condensation in presence of non-condensible gases (Air)
  - Natural or mixed convection flows

- Core degradation:
  - Hydrogen (reduction of steam by Zircaloy claddings) released into the containment (with or without steam)
  - **H2 risk**

Principle of Passive Autocatalytic Recombiner (PAR)



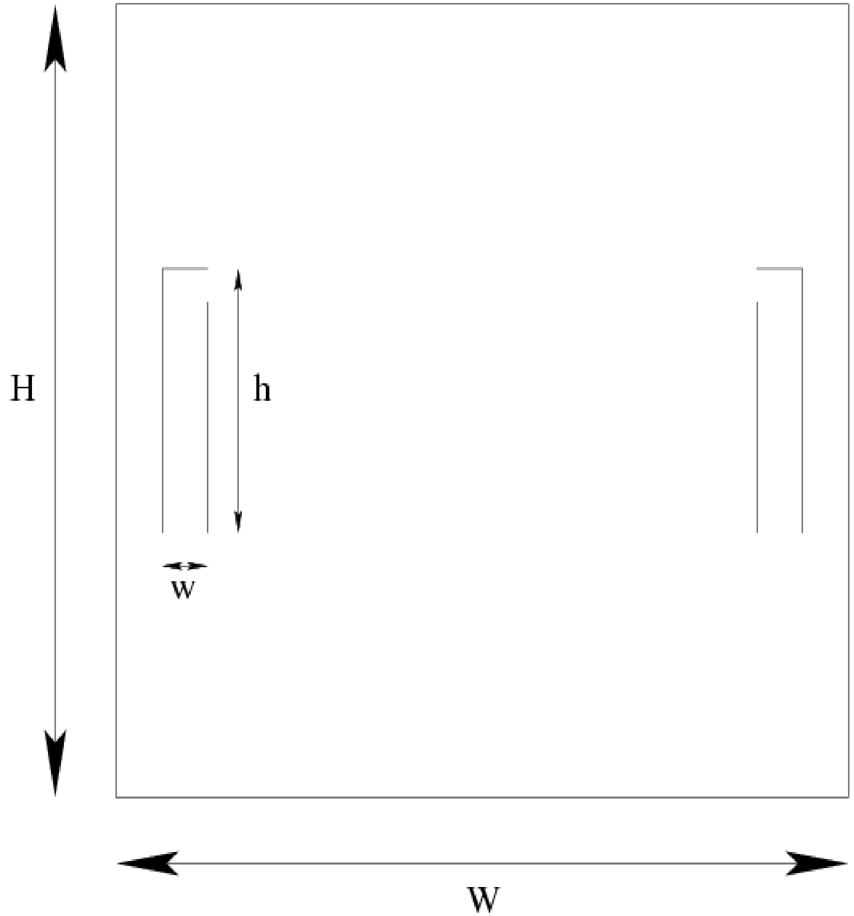
1. Gas enters at the PAR bottom
2. Hydrogen contacts the plates
3. Catalytic reaction begins
4. Reaction heats the gas and the PAR housing
5. Gas rises and leaves at the top of the PAR
6. Natural convection takes place (pumping effect)

Outline

- PARIS benchmark
- Flow structure analysis
- PAR elevation influence

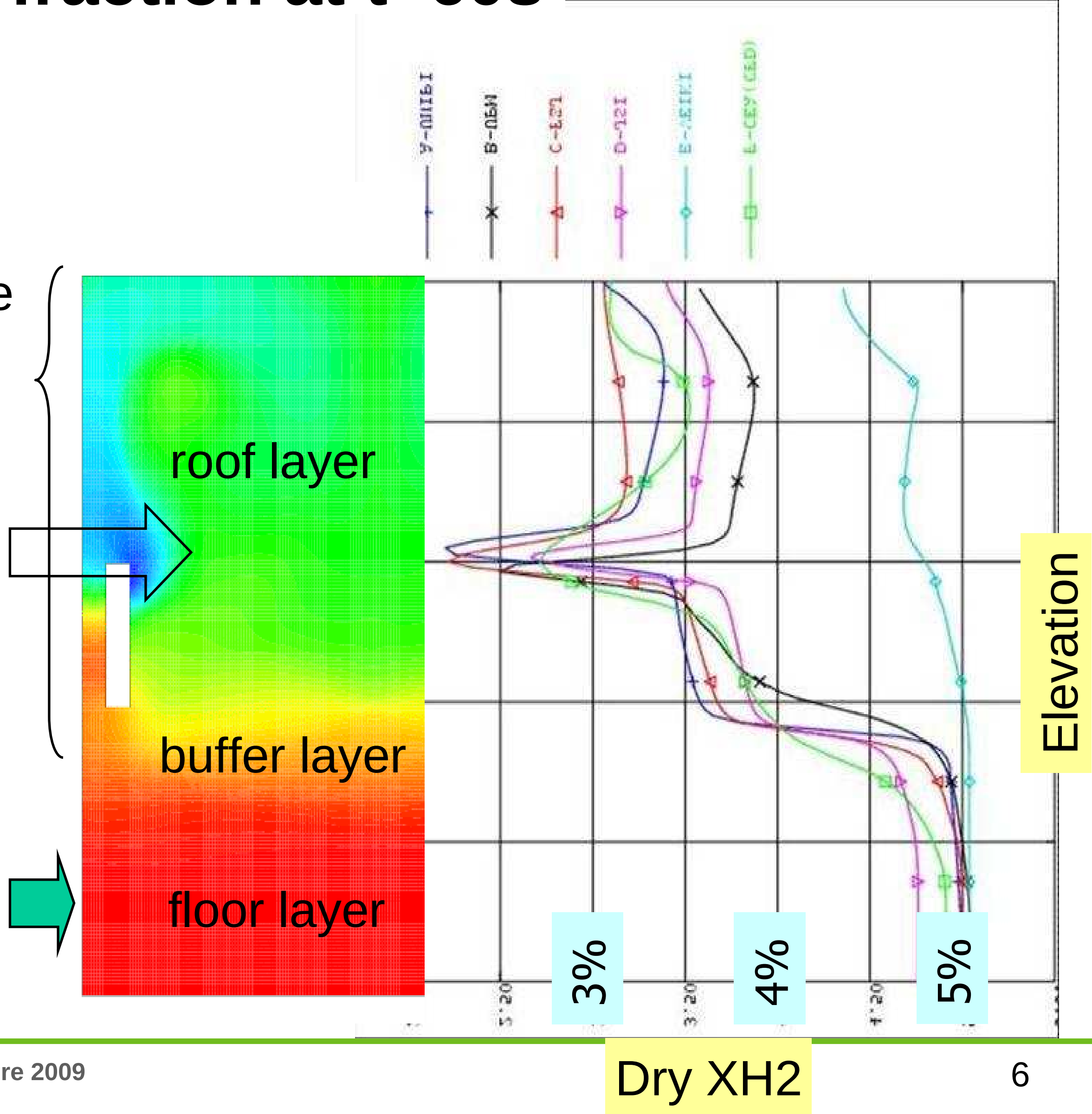
PARIS benchmark (SARNET, WP12.2)

- PAR elevation influence on hydrogen distribution: set the PAR at the half box elevation
- Natural convection loop interaction: one PAR on each side
- PAR is a SIEMENS FR90/1-150 like one (h=1m, w=0.2, 15 plates)
- SIEMENS H2 consumption (kg/s) given by *min(Xh2,Xo2,0.08)(Ap+B) with A=0.48E-8 and B=0.58E-3*
- Homogeneous initial mixture at 393K, saturated steam, dry Xh2=5% and air mass the one at 1bar and 298K
- No heat and mass transfer through walls

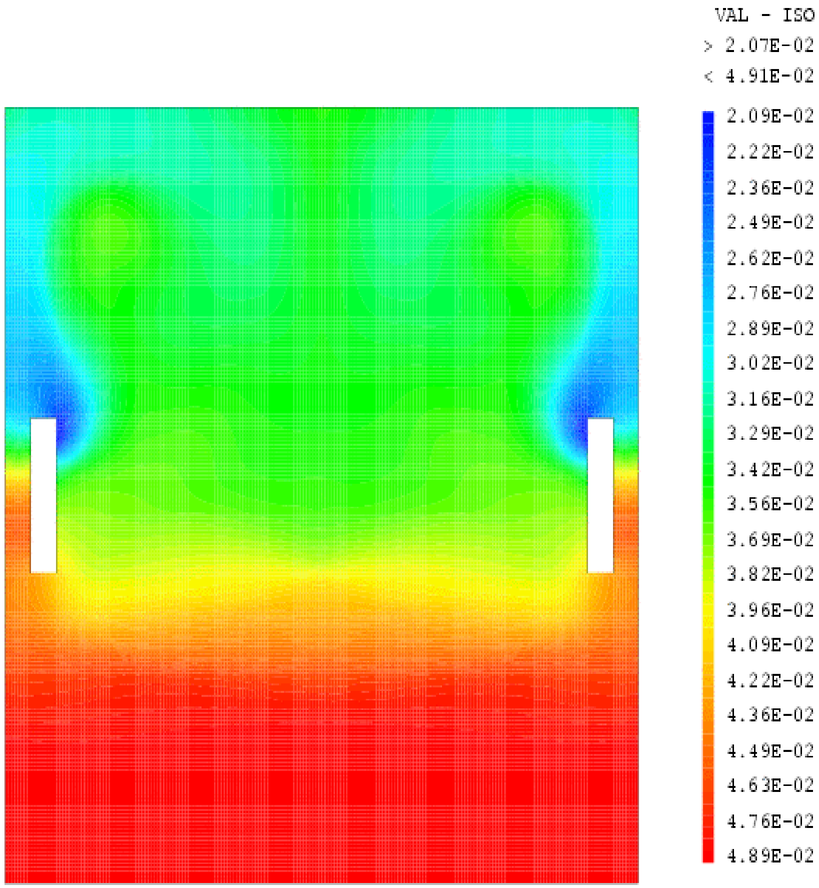


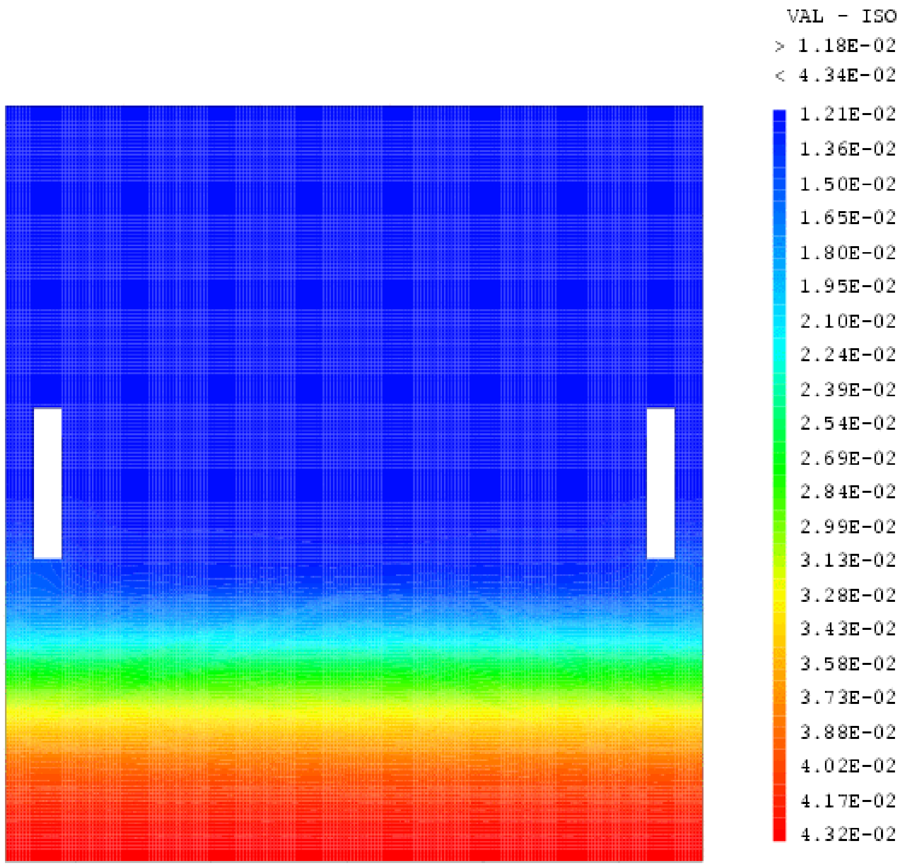
Dry H2 molar fraction at t=60s

- Fast H2 depletion from the ceiling to 0.5m below the PAR (roof layer).
- PAR exit interaction with the atmosphere remains unclear and modify H2 depletion (inertia and buoyancy balance, turbulence, etc.).
- Stable H2 stratification in the floor layer due to adiabatic wall boundary conditions.

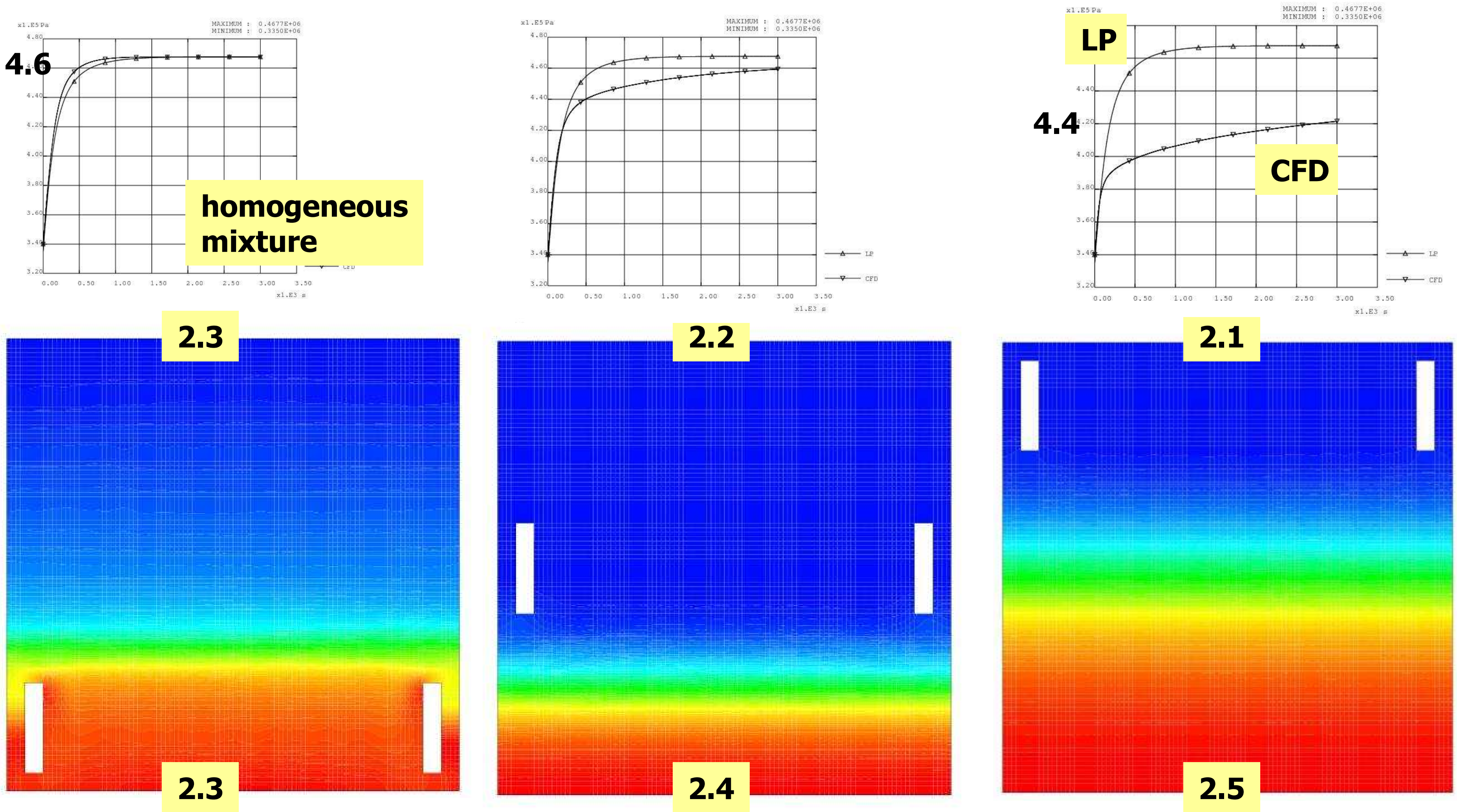


Dry H2 molar fraction at t=60s and 600s



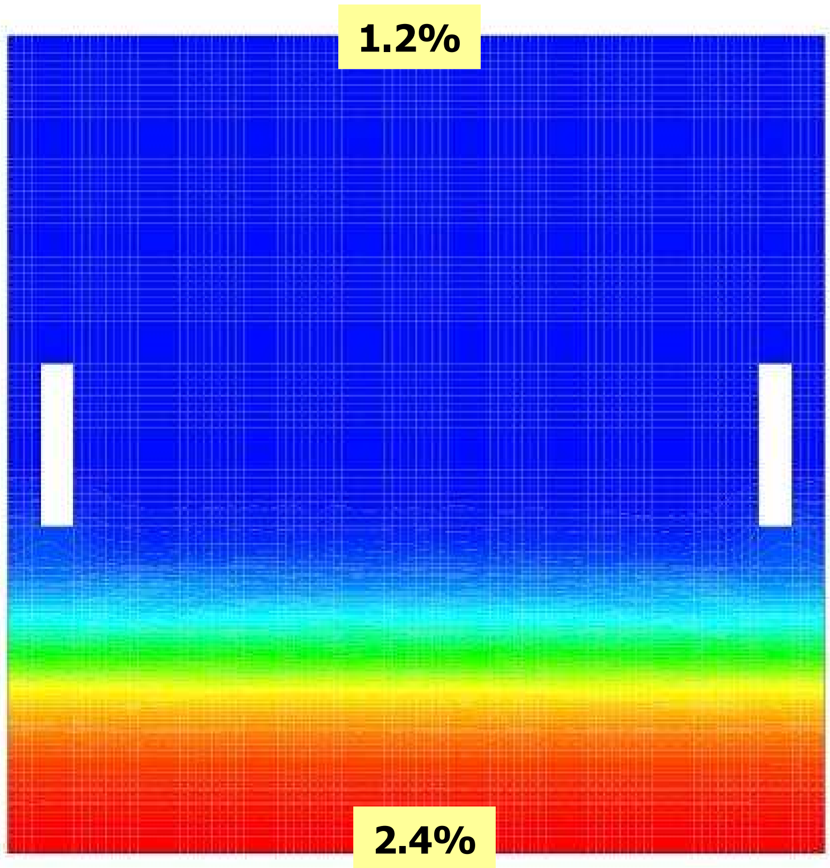


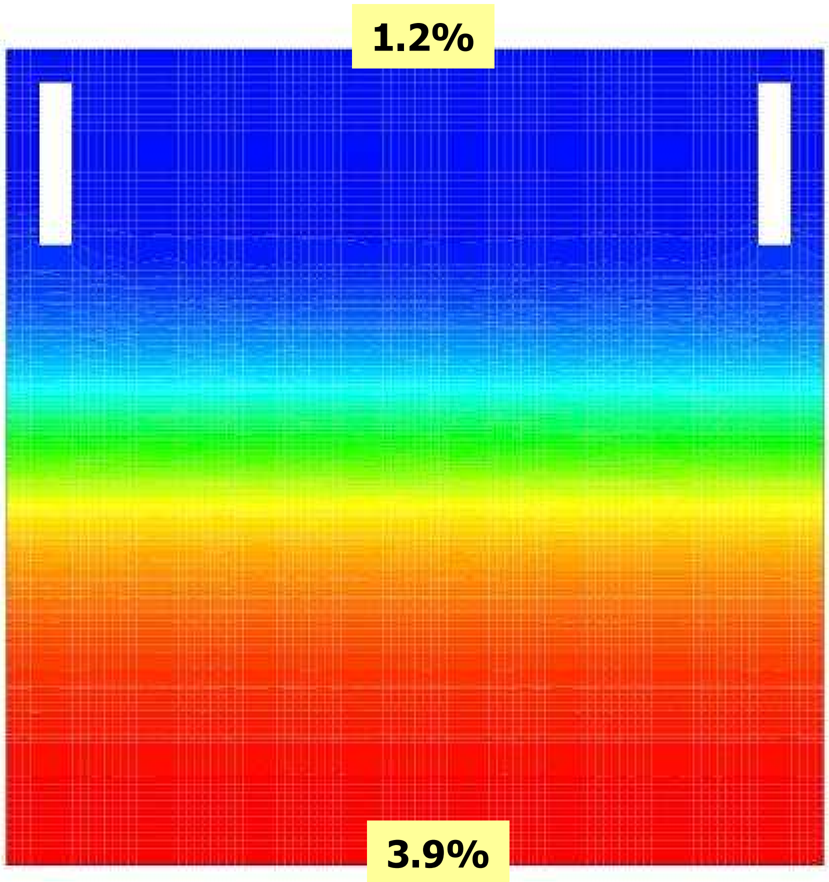
Pressure evolution and density at t=3000s



Dry Xh2 at t=3000s

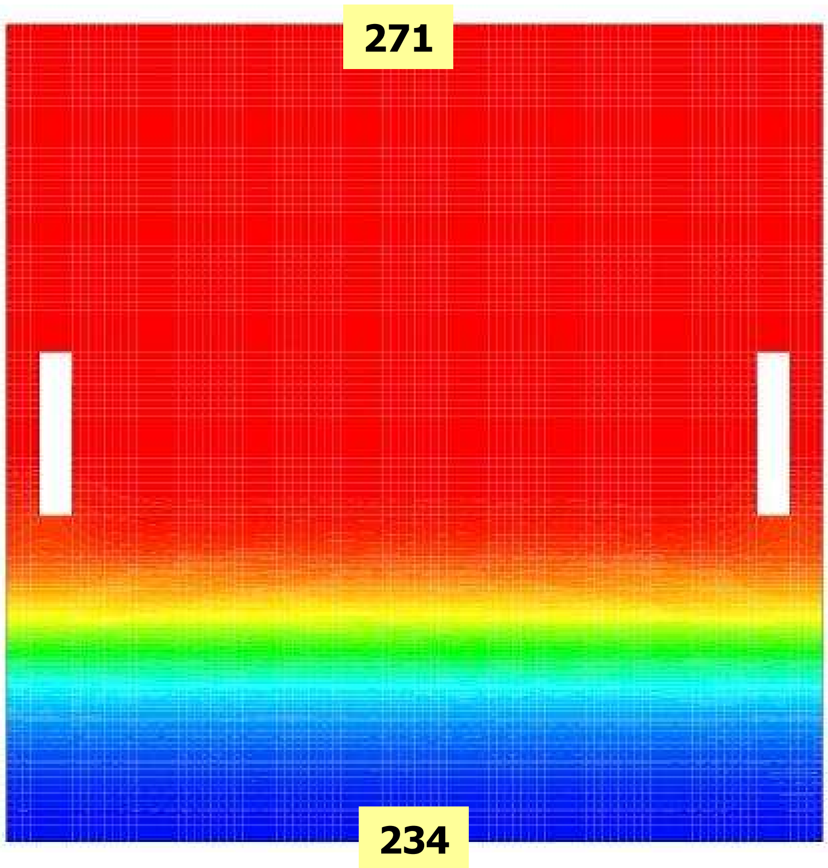
• No stratification only for the lower elevation (not shown, homogeneous dry hydrogen fraction of ≈ 1.3%)

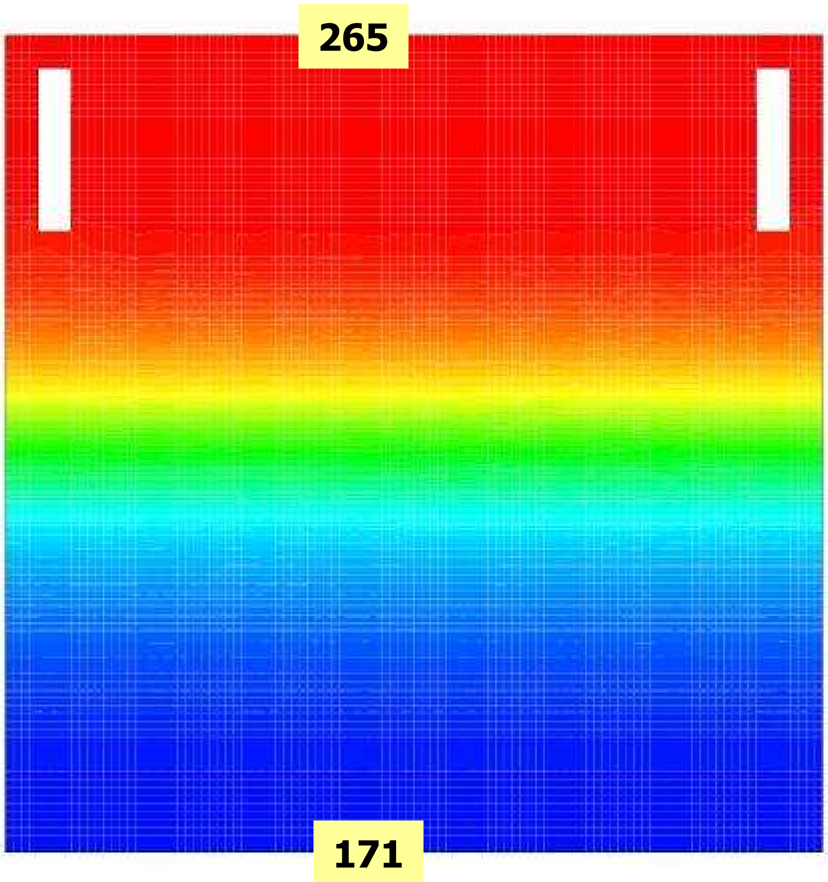




Temperature (C) at t=3000s

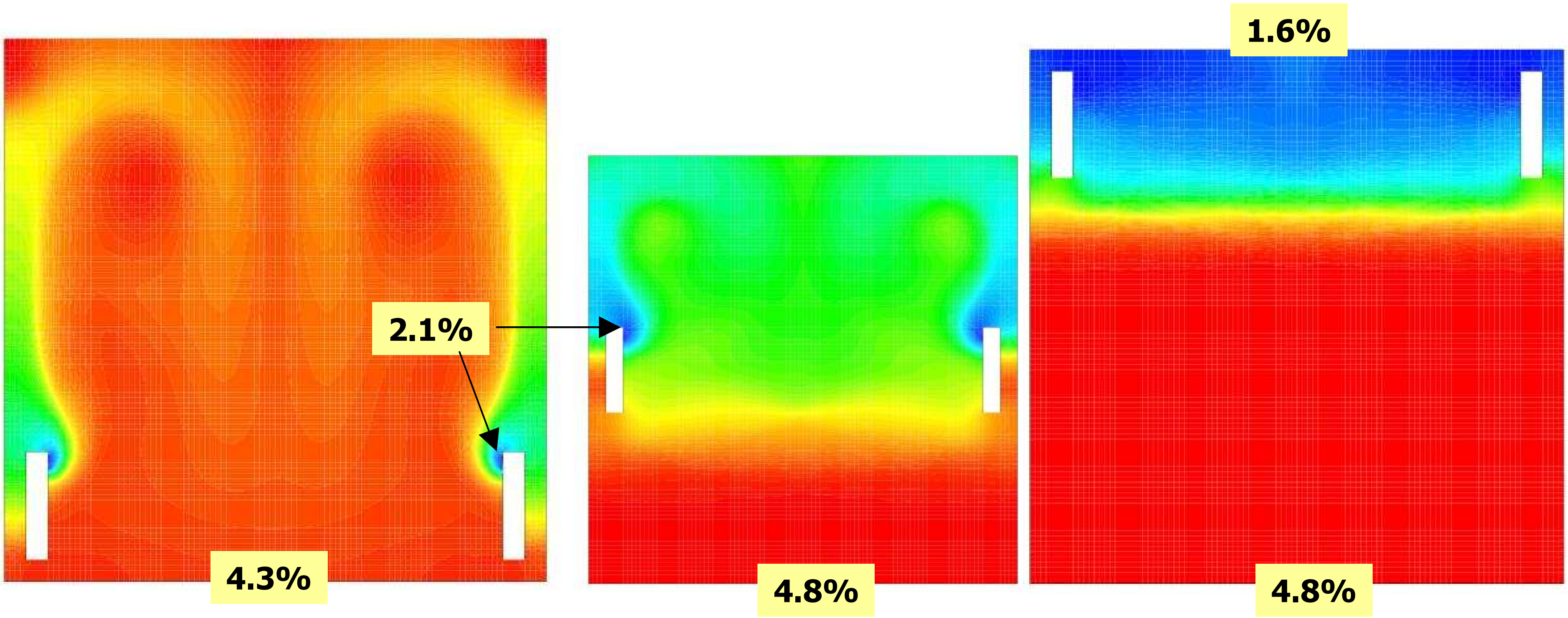
- No stratification only for the lower elevation (not shown, homogeneous temperature of 272C





Dry Xh2 at t=60s

- Lower the PAR elevation is, larger the hydrogen mobilization is, longer burning and mixing processes are



Conclusion

PARIS

- Fast H2 depletion rate but low mobilization below the PAR: an additional process is necessary to enhance mixing process and limit thermal and mass stratifications (wall heat and mass transfer, etc.)
- Code-to-code comparisons exhibit some differences:
  - For the transient phase, the flow pattern at the PAR outlet (plume or jet behaviour)
  - At the quasi steady-state, the floor layer diffusion

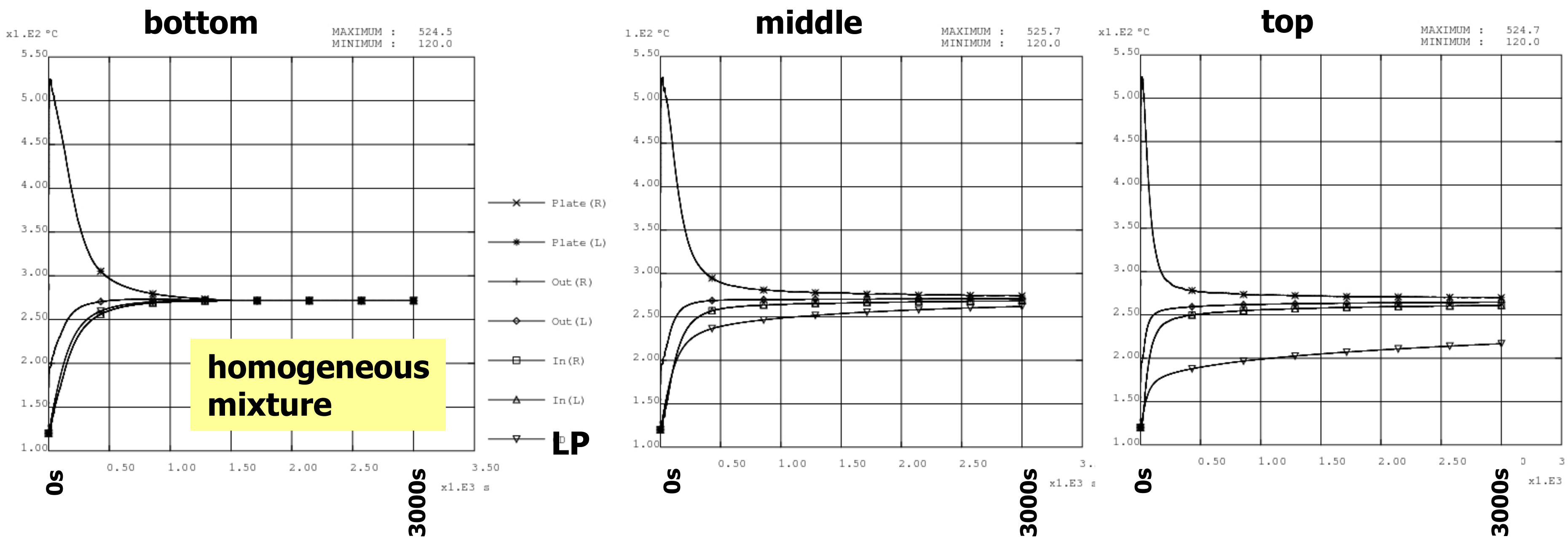
- Several interaction levels
  - PAR level (H2 consumption rate, plates/flow interactions)
  - Nearfield level (PAR/atmosphere interactions)
  - Farfield level (H2 distribution)
- Difficulties to deal with all space and time scales
  - Separate effect analysis is necessary
  - Farfield and nearfield connexions have to be understood
- Lack of experimental data
  - Lumped approaches of the KALI and H2PAR programs
  - REKO (FzJ) dedicated to H2 consumption rate (plate interactions)
  - In project or in progress, larger scale programs dedicated to CFD code: PANDA (SETHII) and REKO 4 (FzJ) for example

Acknowledgment

- Thanks to IRSN, AREVA TA and EU for they financial support
- Thanks for your attention

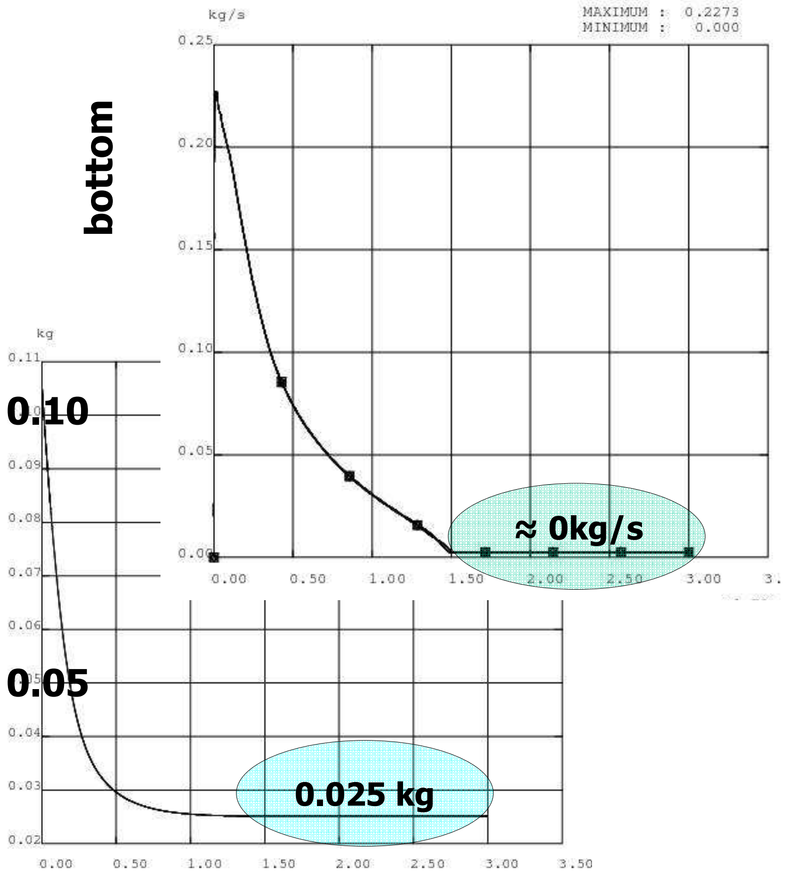
PAR inlet/outlet and LP temperature evolution with time

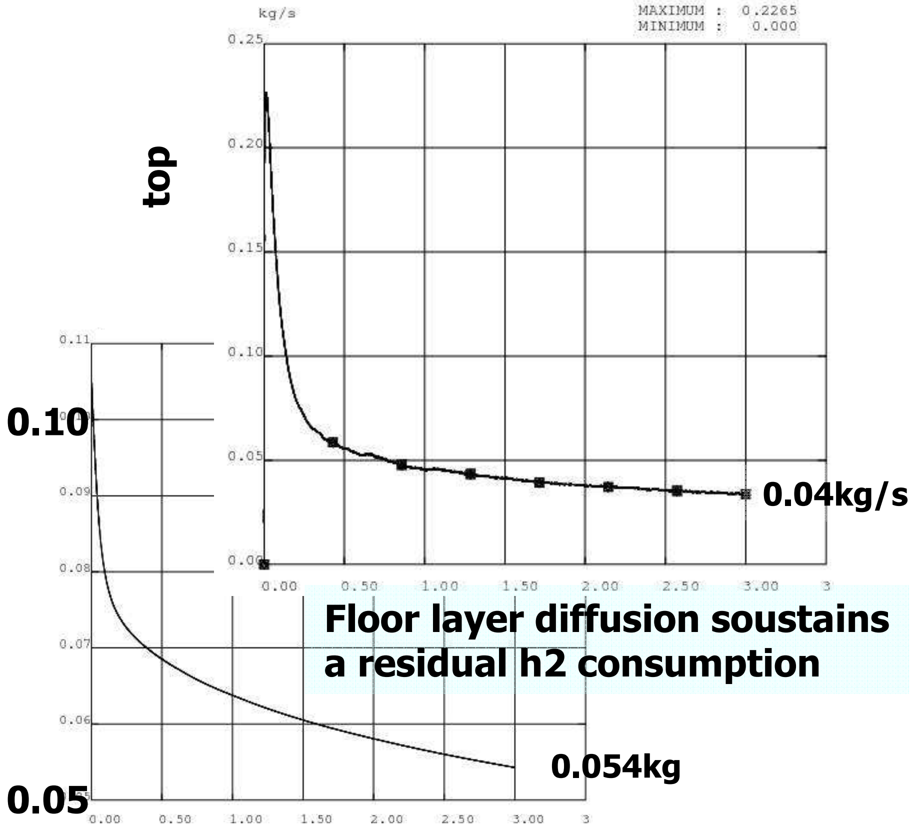
- No stratification only for the lower elevation (homogeneous, T=272℃)
- Higher the PAR elevation is, larger the thermal stratification is
- More than 50℃ of inlet/outlet temperature differe nce for the transient
- Decreasing plate temperature with time due to decreasing of H2 consumption rate and mass flow rate through the PAR
- Left/right PAR symmetry is conserved



PAR mass flow rate and H2 mass evolution with time

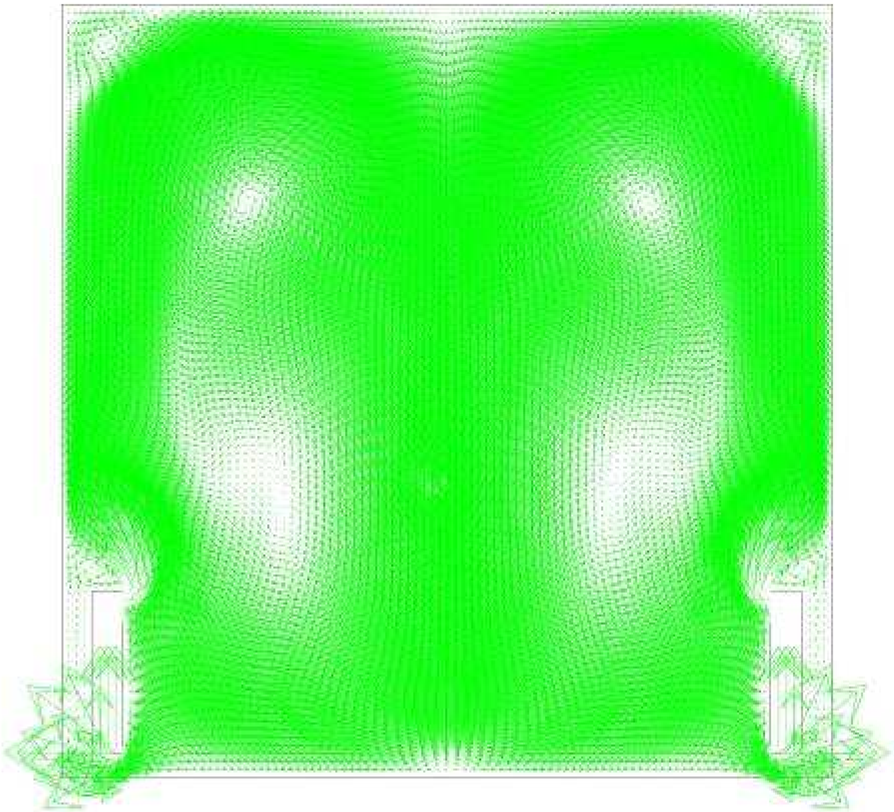
- At the lower elevation, the hydrogen molar fraction goes below the threshold value of 0.5%. Thus, the H2 consumption rate goes to 0. So the mass flow rate because there is no more heat release.

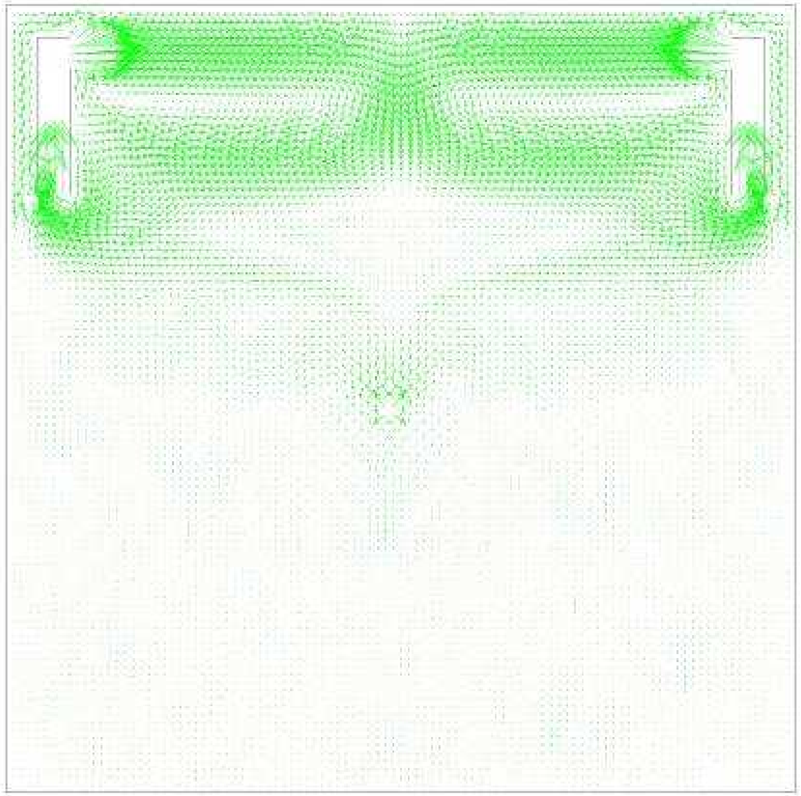




Velocity at t=60s

- Lower the PAR is, larger the hydrogen mobilization is





Dry Xh2 evolution along the left vertical line x=3w

- No stratification only for the lower elevation (homogeneous T of 272℃)
- Higher the PAR elevation is, larger the mass stratification is