Clean Hydrogen Partnership

European Hydrogen Safety Panel (EHSP)
Clean Hydrogen JU Webinar "Computational Fluid Dynamics (CFD) for hydrogen safety analysis “, 07 December 2022

CFD for hydrogen tanks refuelling

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PRHYDE
Protocol for heavy-duty Hydrogen refuelling

ENGIE

Air Liquide

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Introduction

The objectives of the **PRHYDE** project is to **develop recommendations and standardization** for **heavy duty** refuelling protocol for compressed gaseous hydrogen up to 700 bar. The protocol needs to be **safe**, **fast**, **efficient with reasonable costs**.

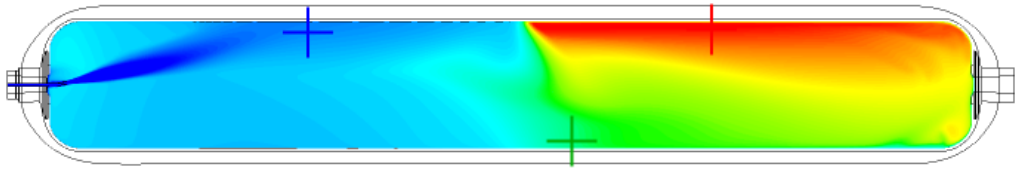
driving range: 800-1000 km
fueling time: 10-15 min
CHSS size: up to 100 kg
mass flow: 120-300 g/s
SoC: > 97%

Formulate recommendations for development & standardization of future protocols

External experts: HEXAGON, NREL, FirstElementFuel, Honda…

Methodology: **Experimental** and **numerical approaches** are used for the development of new refueling protocols. Numerical approaches can be:

- 0D/1D solving energy and mass balance in the tank (ex: SOFIL)
- 2D/3D CFD, to capture temperature gradient in the tank



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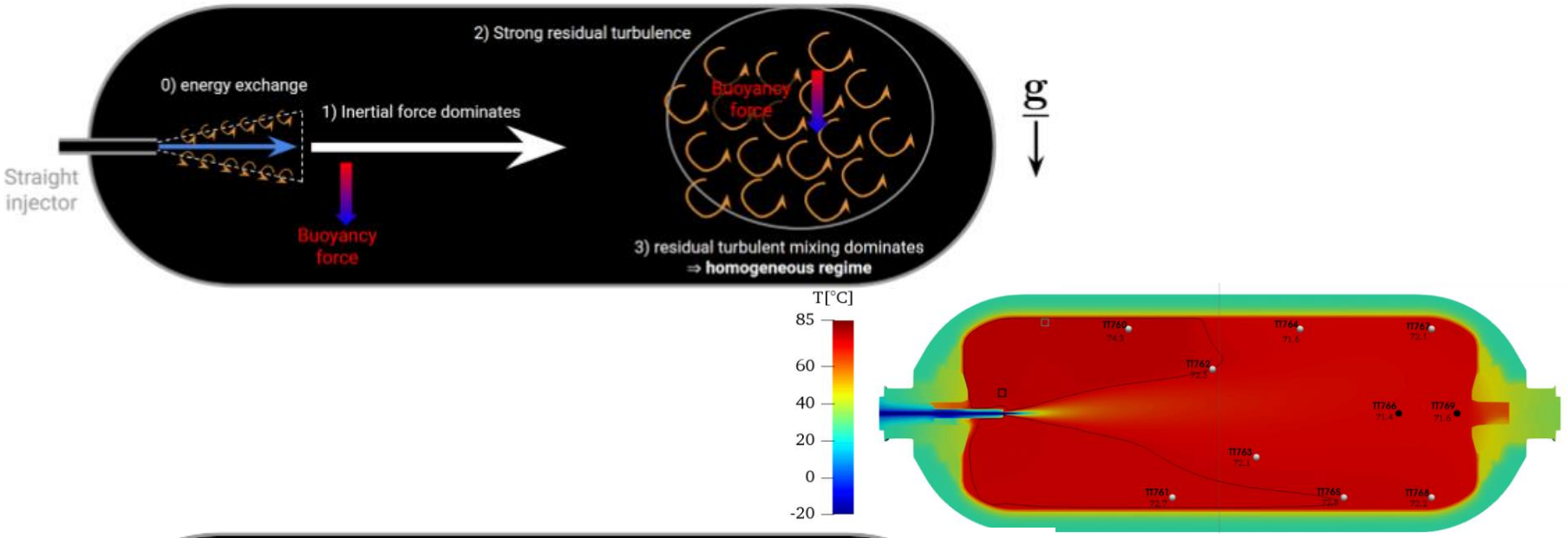
Phenomenology: Straight injector

Homogeneous gas temperature

- Small injection diameter
- High filling rate

→ Predominance of convection forces
→ Good mixing and no stratification

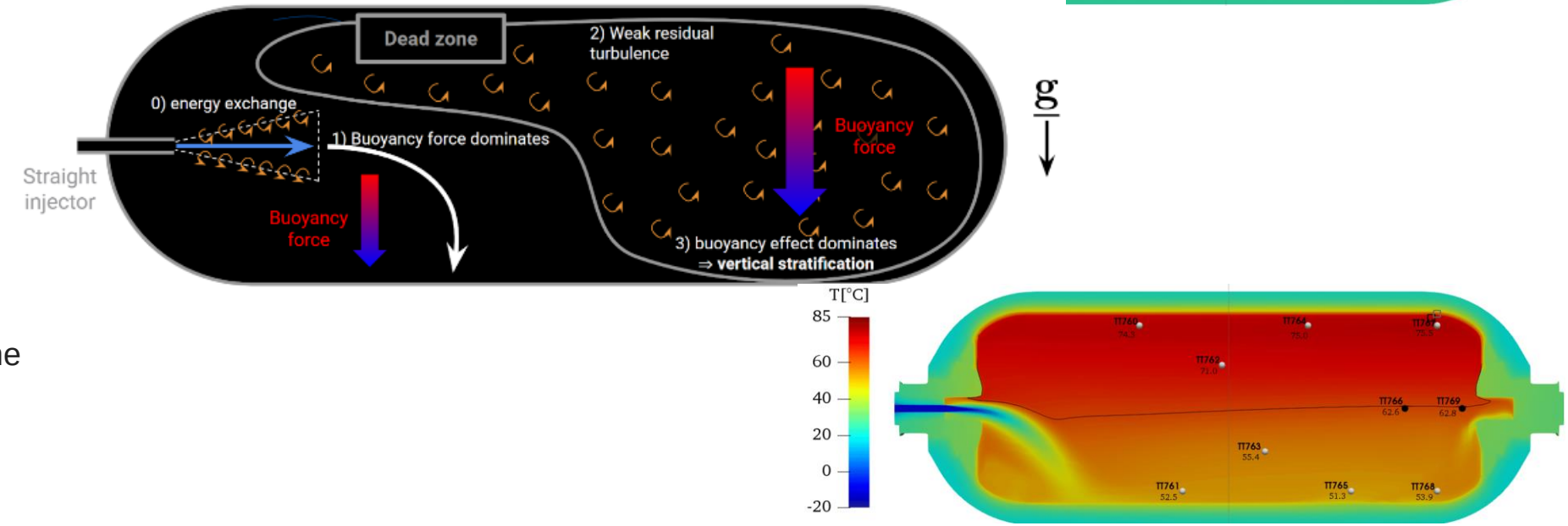


Heterogeneous gas temperature

(thermal stratification of gas)

- Large injection diameter
- Low filling rate

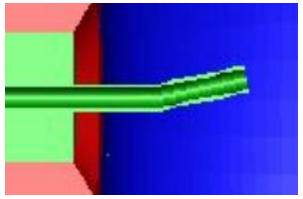
→ Predominance of buoyancy forces
→ Presence of dead zones that limits the mixing which creates temperature stratification



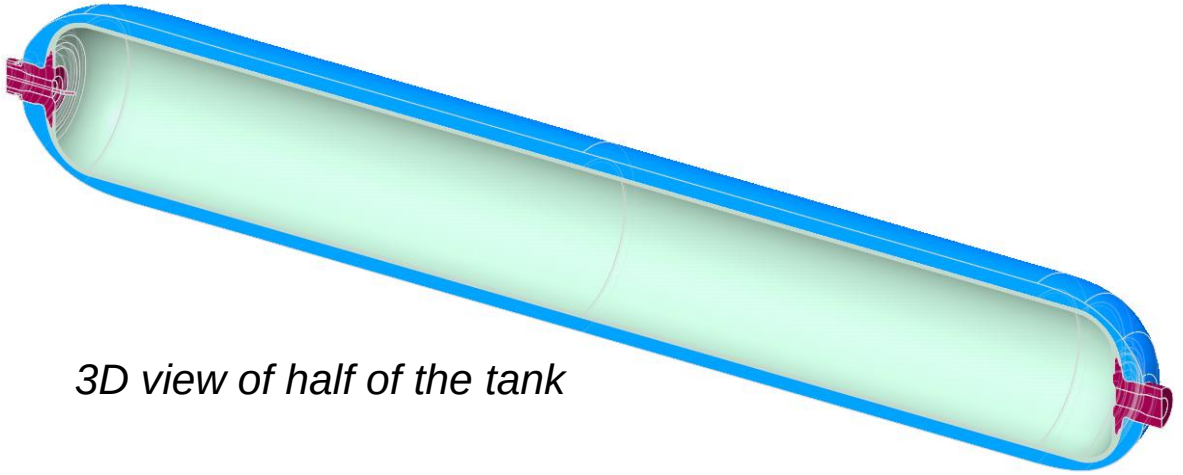
Experimental conditions

Tank characteristics of a tank

- Volume: 165L, L/D ~ 8
- Type IV
- **Injector tilted 12°C upwards**



Zoom on the tilted injector



3D view of half of the tank

Refuelling conditions (experimental test)

Initial pressure [bar]	Ambient temperature [°C]	Precooling temperature [°C]	Pressure profile [MPa/min]	Final pressure [MPa]	Final temperature [°C]	Total duration [s]
20	50	-40	8	789	75	600

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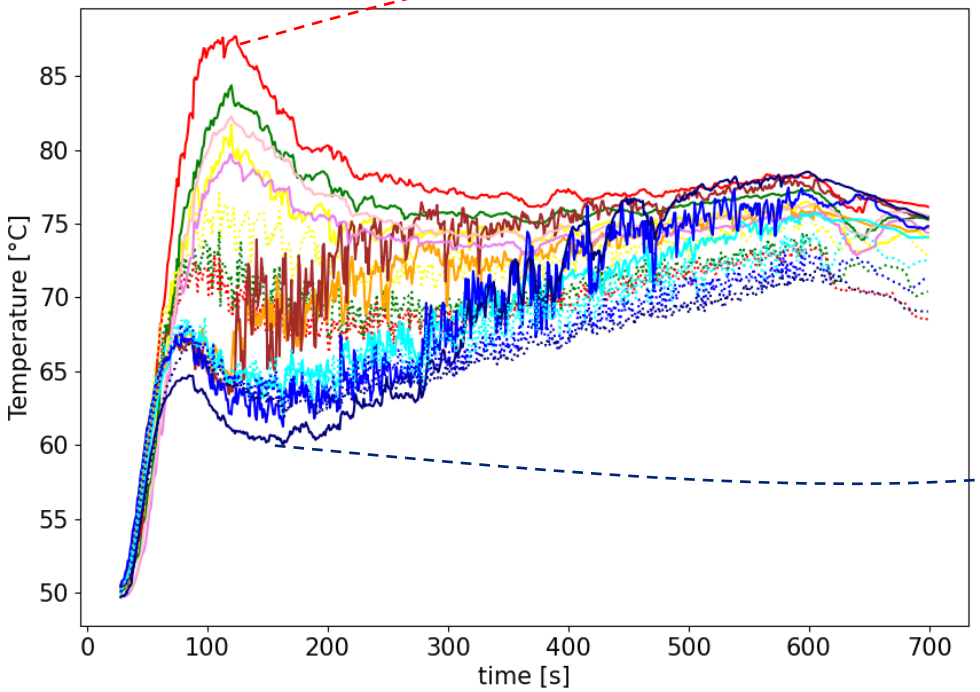
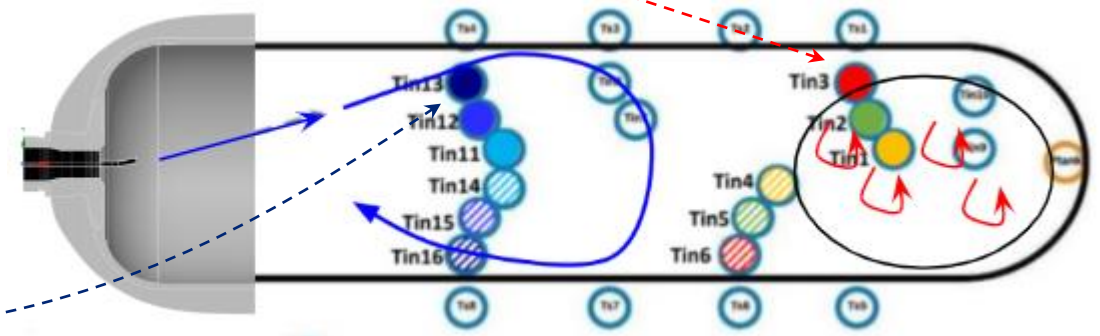
Experimental results



Temperature at the different probes from experiment



Expected flow behaviour

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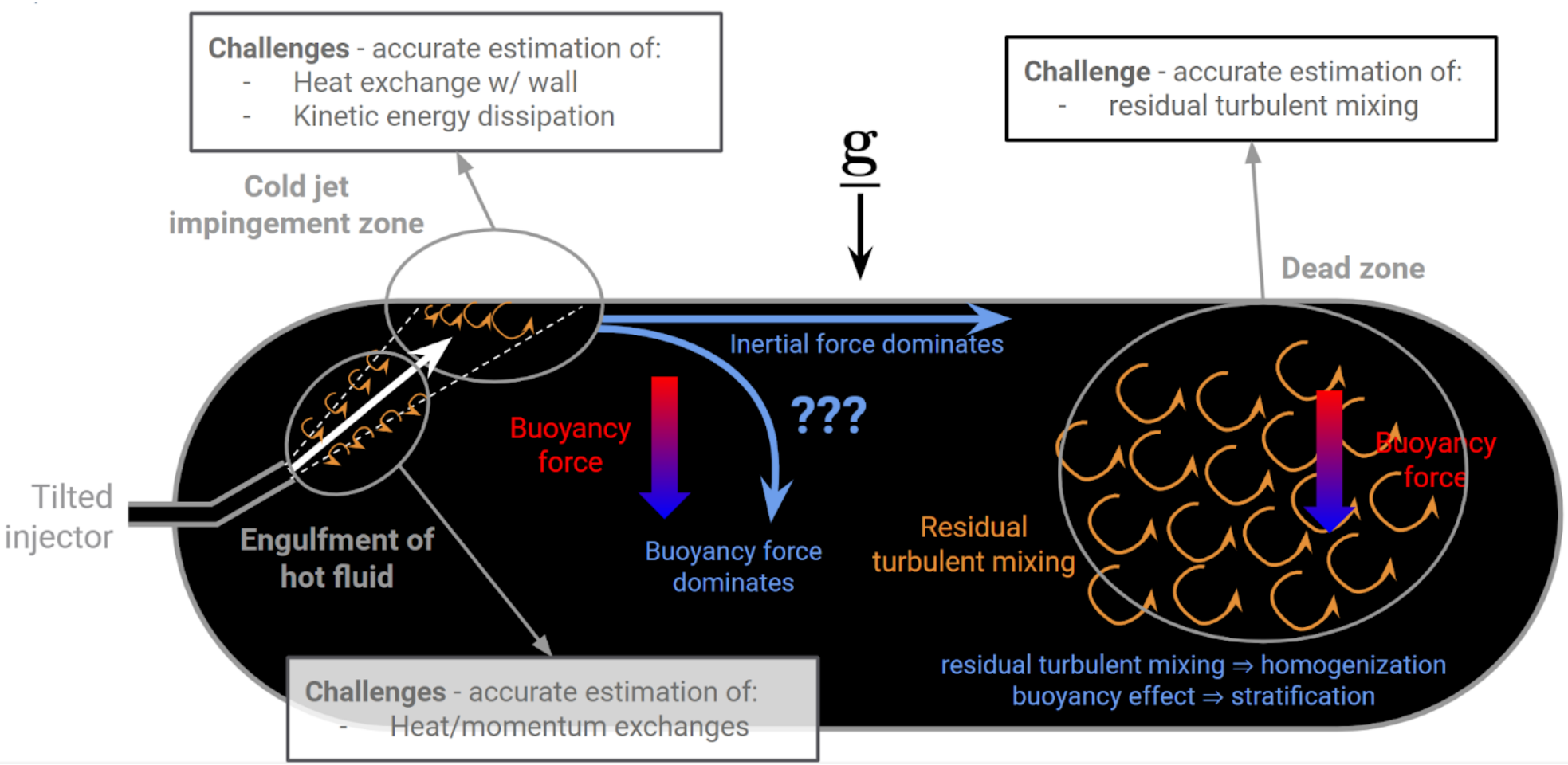
Modelling challenges



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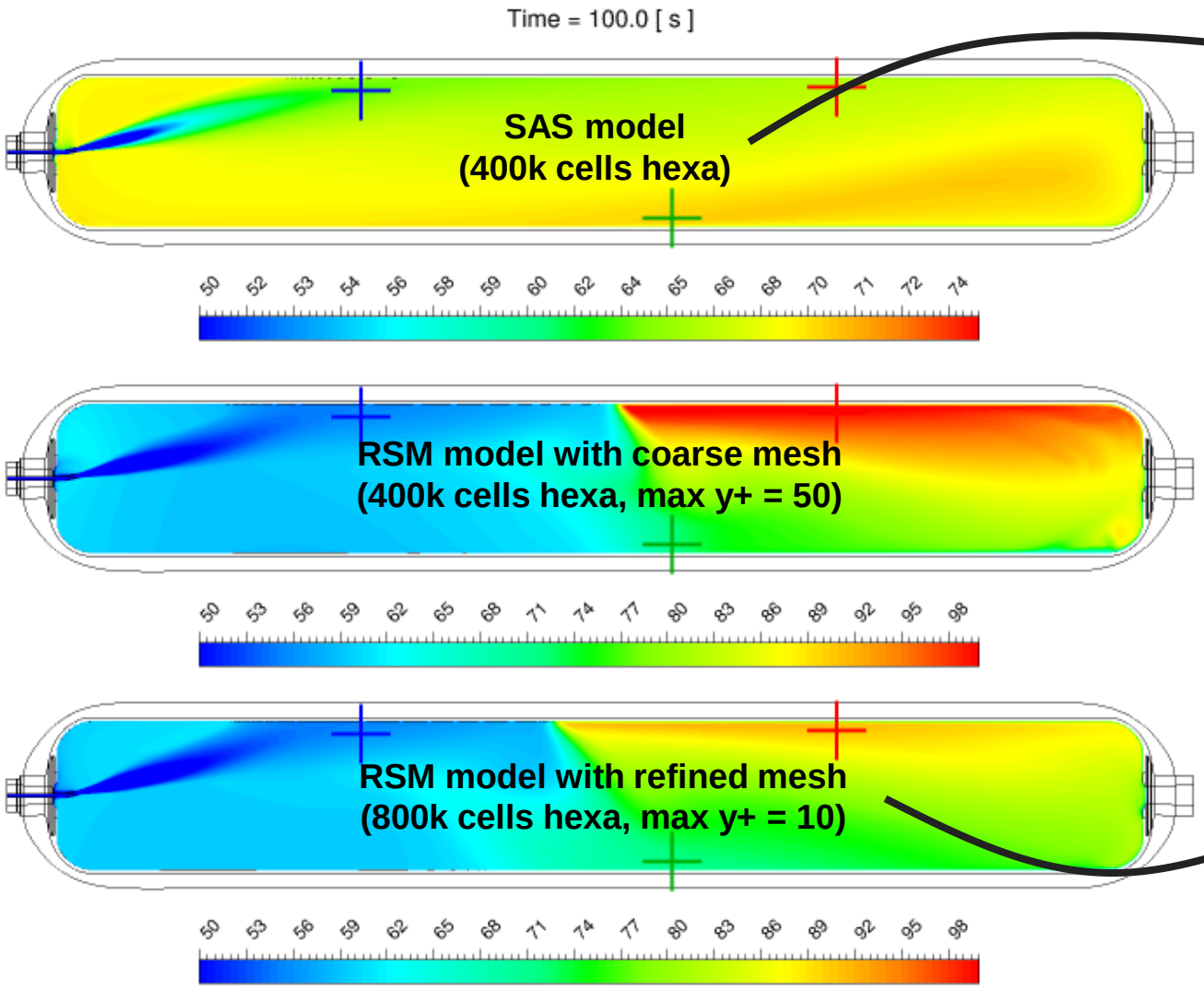
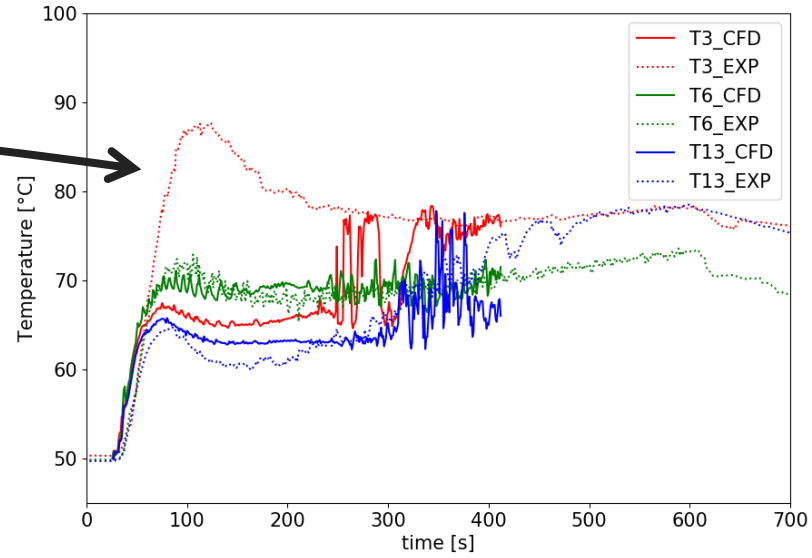
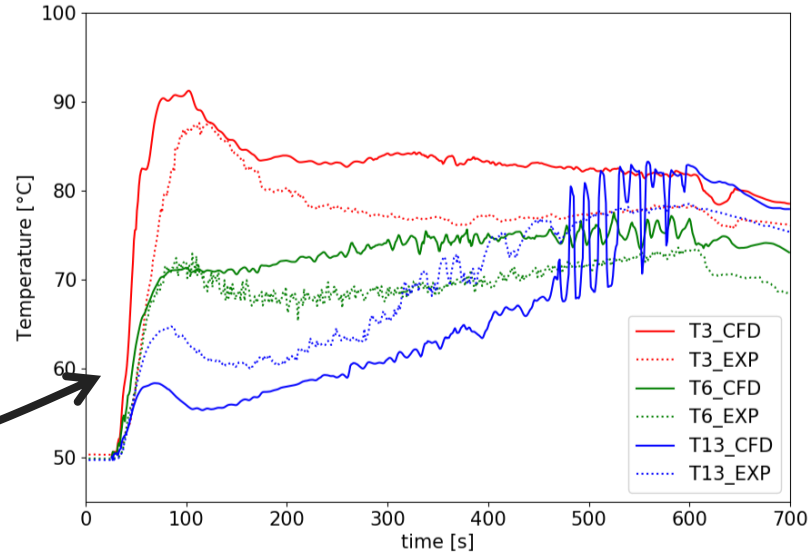
Simulation results







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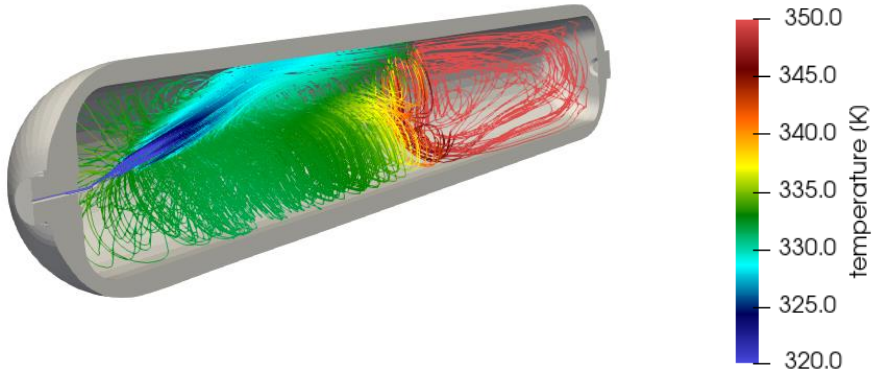
Conclusions & recommendations

Conclusions

- **The RSM turbulence model** captures the jet impingement and accurately predicts temperature gradients
- The computational time is reasonnable (~1 month for 500s of refueling)



Recommendations for CFD

- Special attention should be paid to
  - the turbulence model
  - the mesh
  - CPU time/accuracy trade-off
- Validate CFD against experimental results in similar conditions:
  - Injector geometry: diameter, orientation, length…
  - Configuration: horizontal/vertical

Keep in touch/Thank you

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For further information
https://www.clean-hydrogen.europa.eu/

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