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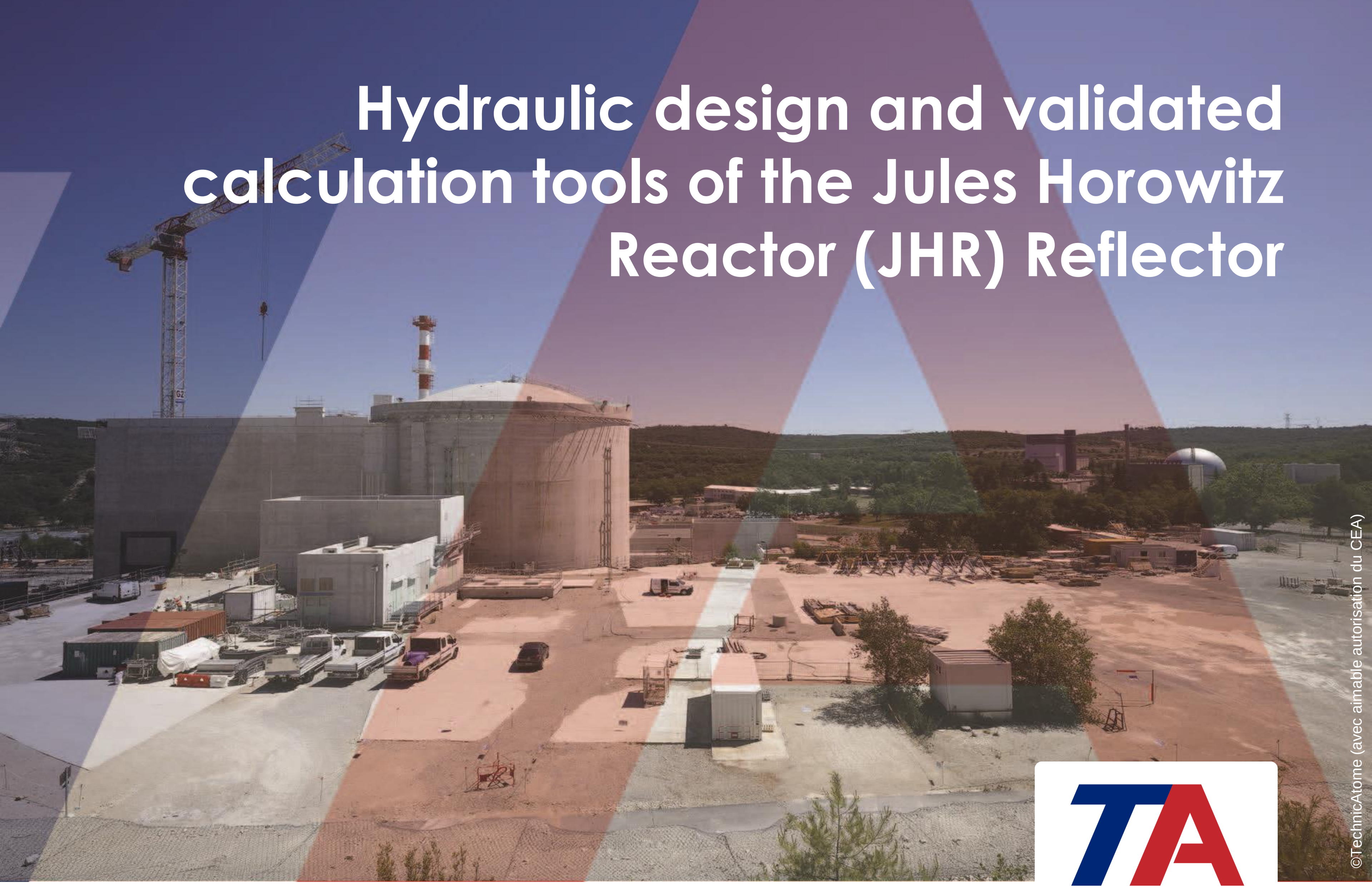
Nuclear Compact Reactors

Hydraulic design and validated calculation tools of the Jules Horowitz Reactor (JHR) Reflector



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IGORR 2017 – James YAGAPIN

Nuclear Compact Reactors

Introduction

- **TechnicAtome** has designed the Jules Horowitz Reactor (JHR): a 100 MW Research Reactor on behalf of CEA

- **Numerous experimental locations** with high performances and **a strong flexibility**, especially, in the **reflector**

- JHR reflector requirements have led to design a **complex reflector with several possible configurations**

- **Preliminary** thermal hydraulic **sizing** allowed to define the **hydraulic operating domain** strongly **reduced** by :
  - The **calculation uncertainties**
  - The margins to be considered

- For **final sizing**, **calculation tools** have to be **validated** on the reflector geometry

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Contents

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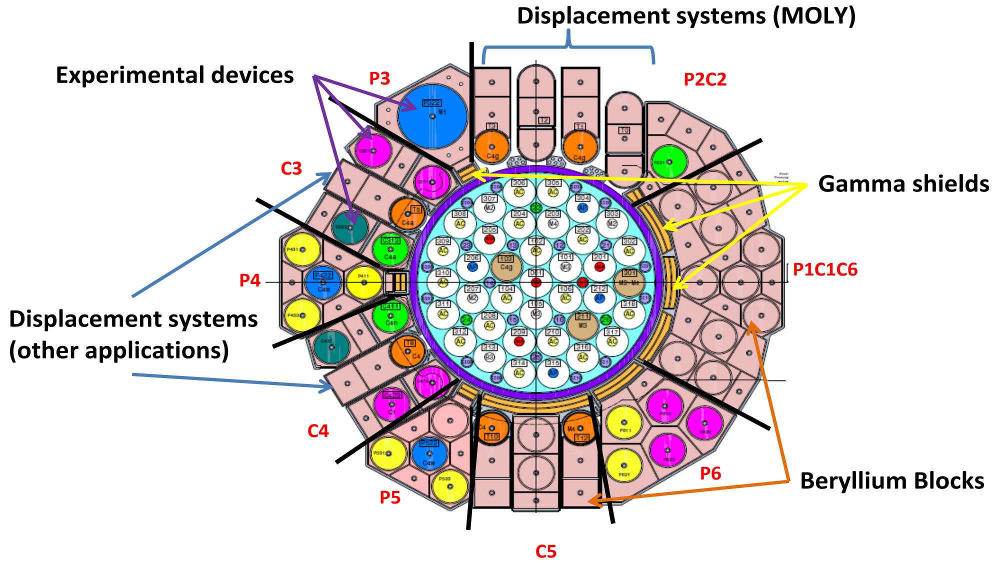
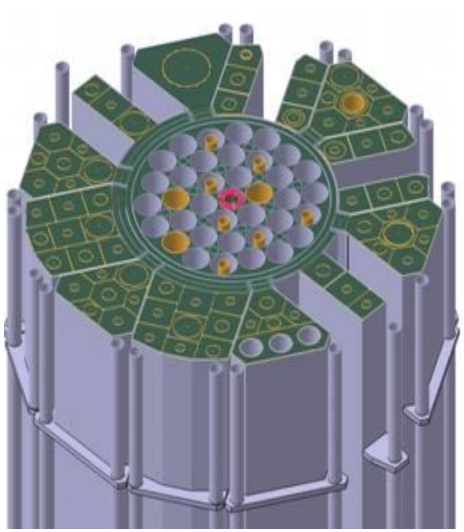
JHR reflector requirements and design options

Requirements	Design options
- Neutronic performances in-core and in-reflector - A wide range of neutron flux and spectra for irradiation devices - Isotopes production rigs	- Beryllium modular reflector - A lot of irradiation locations available dispatched in 9 sectors - Zircaloy® gamma shields installed in some reflector area
- Simulate transients occurring in incidental or accidental situations - Medical radioisotope production (MOLY)	Displacement systems in different locations
Capability to load and unload experimental devices when reactor is operating	- Reflector structures and irradiation devices cooled by the open pool cooling circuit - Downward cooling flow rate adopted





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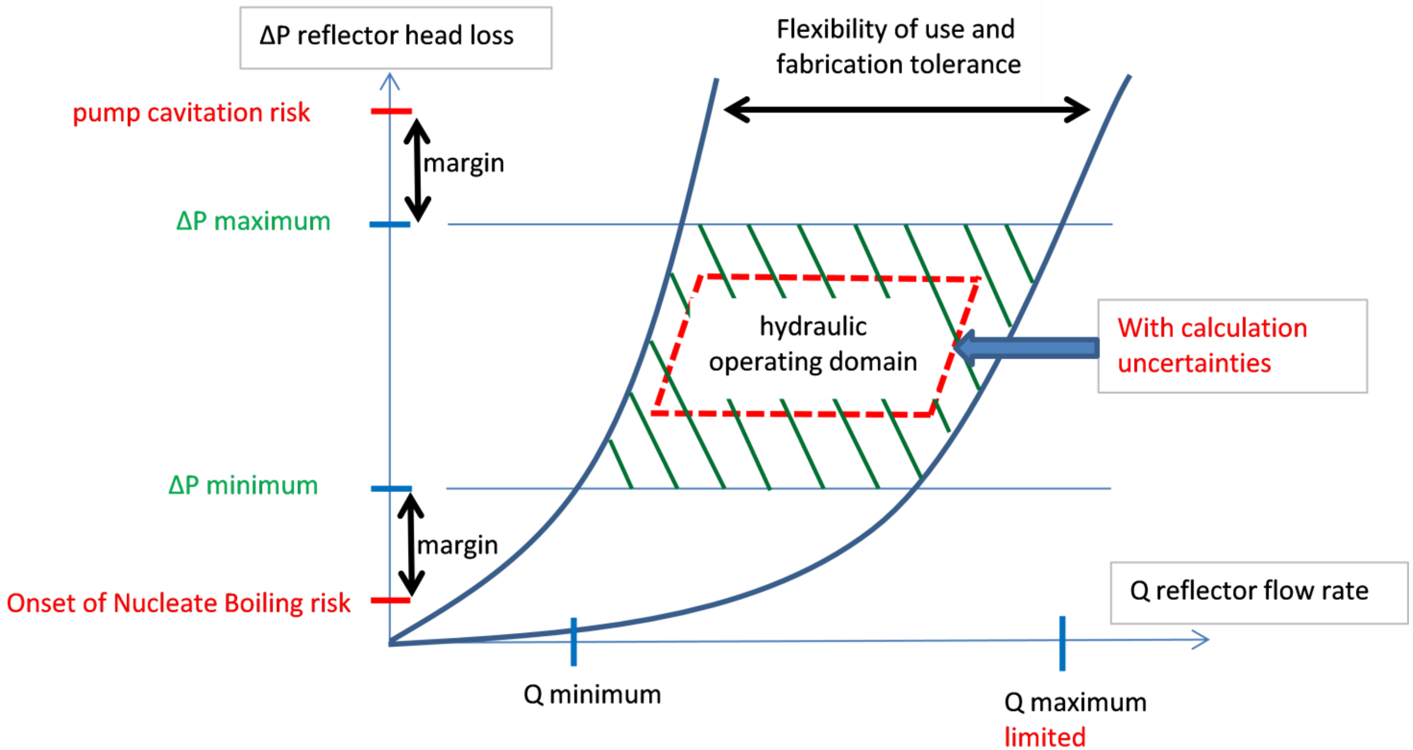
Constraints on the reflector thermal hydraulic sizing

- **Pool cooling circuit architecture:** redundant pump, plate-based heat exchanger, **reflector located at the pump suction**



- **For the final thermal hydraulic sizing, two actions are undertaken:**
  - **Adjust the necessary cooling flow rate crossing reflector structures and experimental devices**
  - **Reduce the calculation tools uncertainties**

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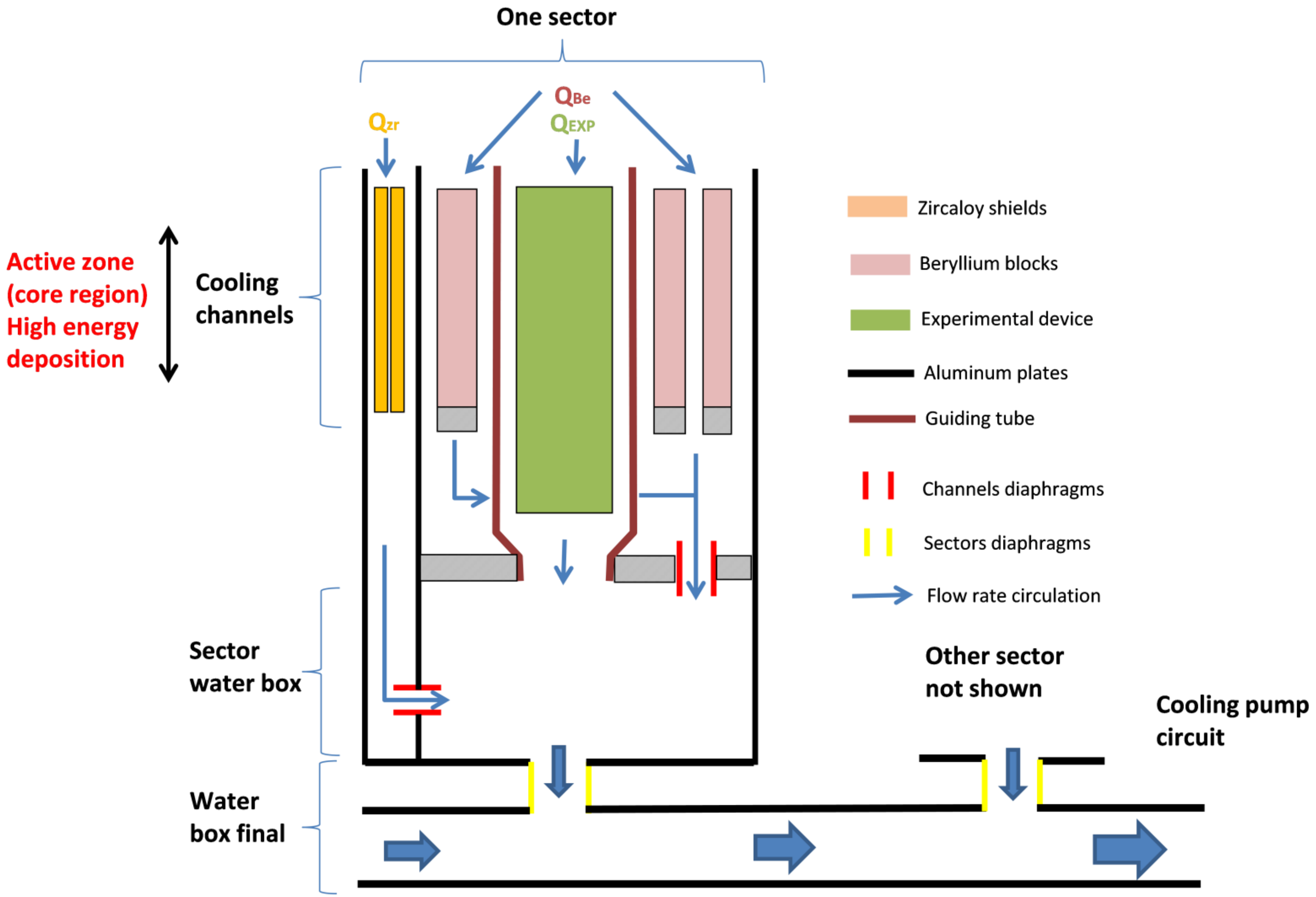
Hydraulic description of reflector



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Calculation tools

- **CATHARE (Code for Analysis of Thermal-Hydraulic during an Accident of Reactor and Safety Evaluation):**
  - Developed by CEA, EDF, IRSN and AREVA
  - Dedicated to thermal hydraulic analyses
  - Based on a "2 fluids 6 equations" model

CATHARE is used to perform the reflector thermal-hydraulic sizing

- **STAR CCM+:**
  - Computational Fluid Dynamics (CFD) tool developed by Siemens PLM Software
  - Multidisciplinary platform, used by engineer to solve complex industrial problems
  - Reference CFD code at TA: support in safety studies, design assistance

STAR CCM+ is used to characterize the hydraulics flows in the water boxes and to design the diaphragms

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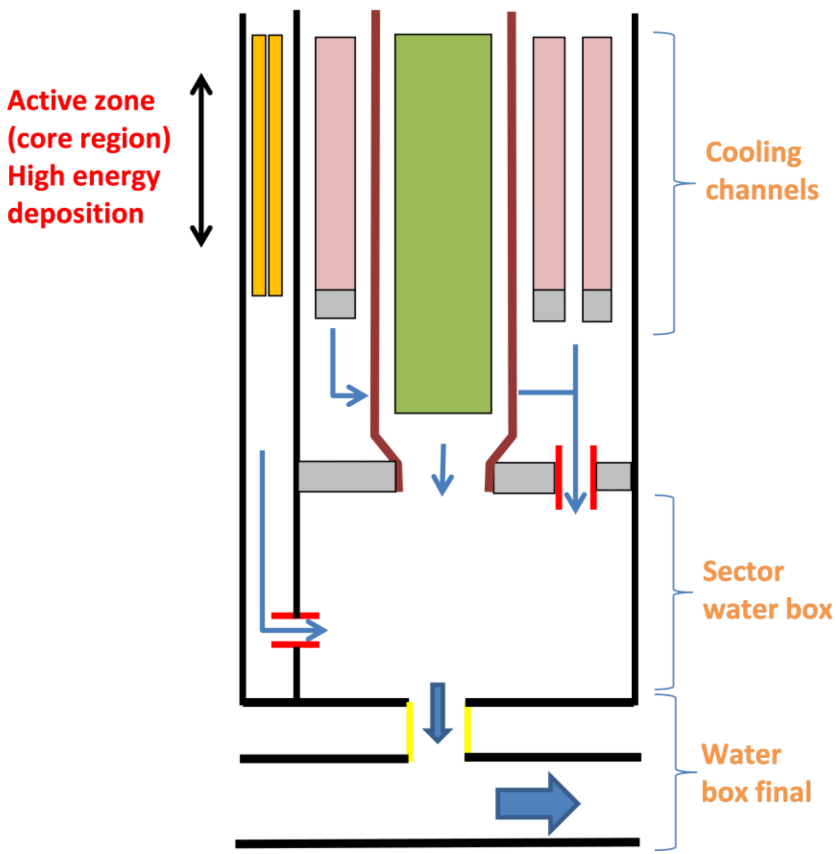
General process - Calculation tools validation



Actions

- Experimental tests performed
- Experimental tests performed to get a predictive CFD calculation tool (STAR CCM+)
- CFD Calculation (no experimental tests)

Purposes

- Validation of reflector modelling in CATHARE
- Channels diaphragms design
- Sectors diaphragms design

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Sectors water boxes – Experimental process

- **The aim of experimental tests is to qualify a CFD calculation scheme (STAR CCM+)**

- **First step: mesh rules and turbulence models**
  - One mock-up representing **the most constrained geometry of water boxes**
  - Different configurations have been tested

Front view

Water inlets

Water outlet

Differential pressure sensors

Back view

- **Second step: validation of CFD calculation scheme based on a blind test**
  - One mock-up representing a sector water box with a different geometry

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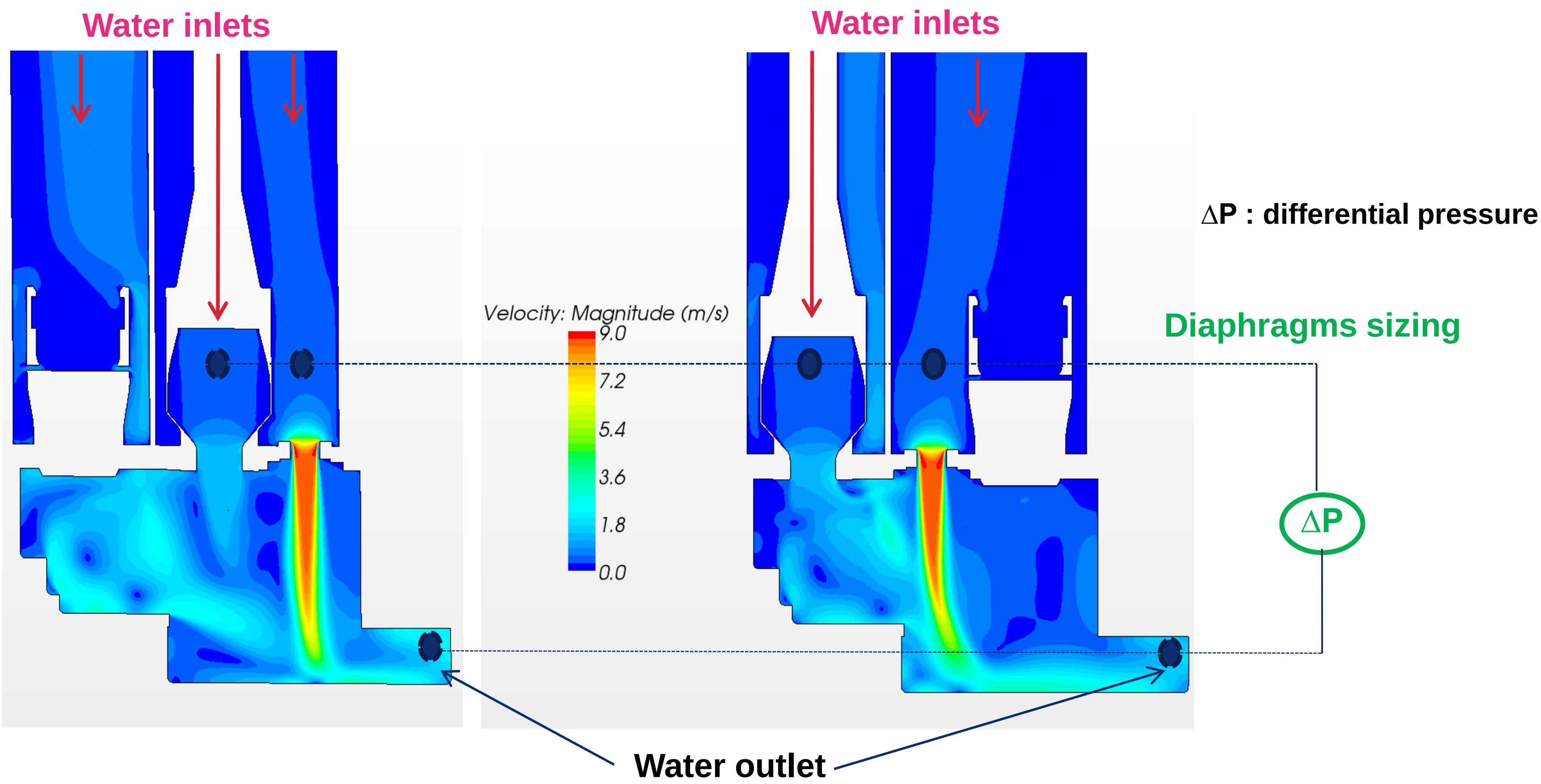
Sectors water boxes – diaphragms sizing

- CFD calculation results: **two experimental configurations**



Diaphragms diameters are well predicted with a maximum calculation uncertainty lower than 8% on the target head loss

Without qualification of CFD code: 30% calculation uncertainties retained

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Conclusions

- JHR reflector is intended to provide high flux performances and a strong experimental flexibility

- The challenge of the thermal-hydraulic sizing is to ensure **the reflector cooling** with **the expected flexibility**

- **For final** thermal hydraulic **sizing**, it is important to define with **accuracy** the hydraulic operating domain

- All the actions undertaken for calculation tools validation have led to:
  - **Reduce** significantly the calculation **uncertainties**
  - **Finalize** the reflector design (all the diaphragms)

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