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SAMOFAR Final Meeting

4 July 2019

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CIRTEN

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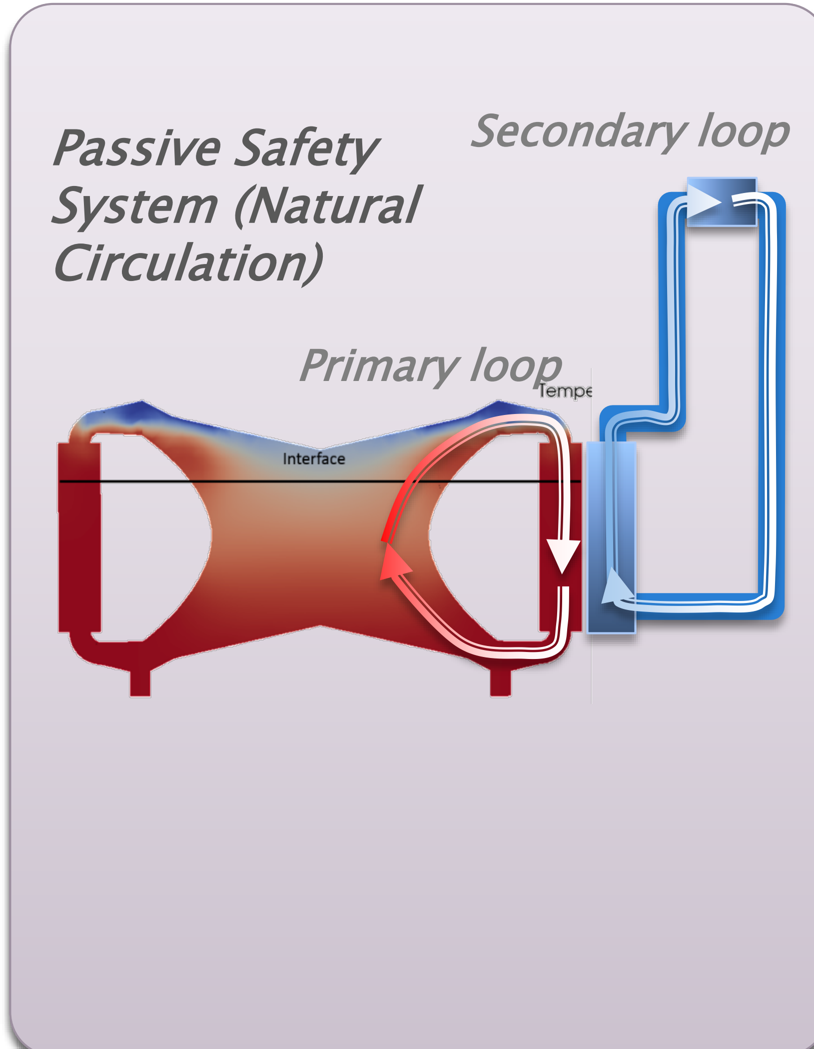
WP3: Experimental investigation of fluid-dynamic safety issues

- Main goal:
  To address key questions relevant to MSFR **safety**

1. *"How the molten salt behaves during shut-down (**fuel draining**) transients?"*
2. *"How the passive safety system (**decay heat removal**) behaves in natural circulation, with an uncommon – internally heated – fluid?"*



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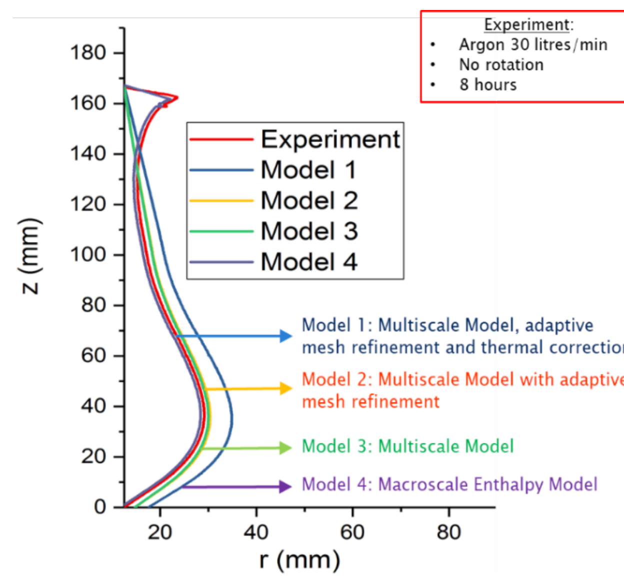
1. Modeling efforts to simulate melting & solidification

- new set of **numerical tools** needed
- **OpenFOAM** model developed, to simulate specific molten salt T&H phenomena:
  - **Macro-scale** and **meso-scale** melting/solidification models for molten salts
  - **Improved turbulence RANS models** for a suitable description of turbulent fluid-dynamics and specific molten salt phenomena near the wall
  - **Radiative** heat transfer in the salt

FLiNaK ingots obtained in the SWATH solidification experiments

Ar 30 litres/min
No rotation
4 hours

Ar 30 litres/min
9 rpm
8 hours



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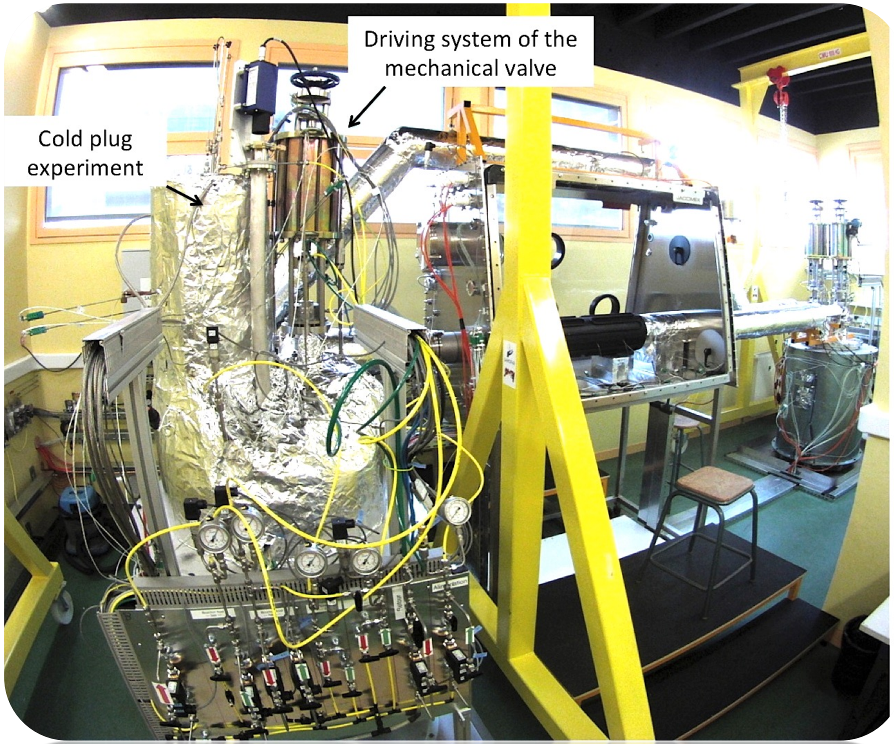
1. SWATH facilities to investigate TH & melting transients

- *Salt at WAll Thermal excHange* experiments

- Two main facilities:
  SWATH-W (Water) and
  SWATH-S (Molten FLiNak Salt)

- To investigate:
  - **Turbulence effects**
  - **Heat transfer**
  - **Melting & Solidification processes**



- To test design principles for key components of MSFR: Flow measurements, Valves (passive and active), Pipe joints and **Cold Plug**

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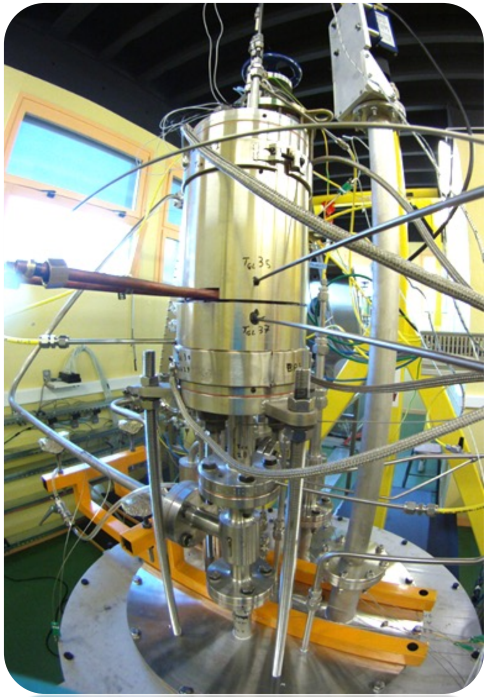
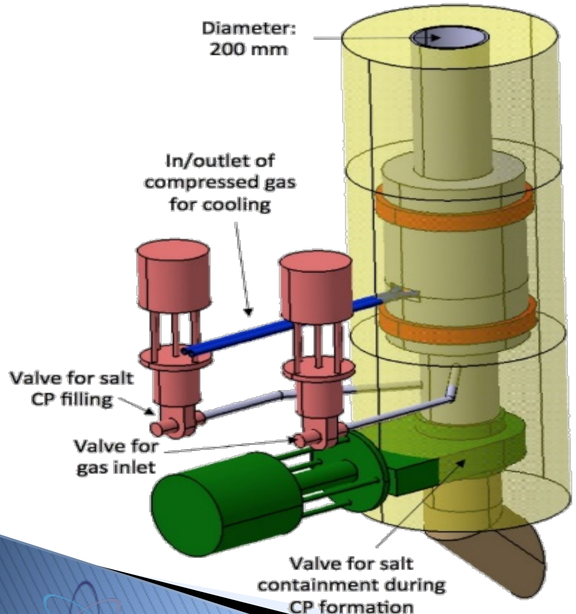
1. Design and Testing of a Cold Plug Device



- Key safety component for MSFR fuel salt draining system
- Novel cold plug design proposed by CNRS
- Working principle: **<u>control of the heat transfer balance inside the device</u>**



- Goal: to investigate the **working principle of the Cold Plug design**
- **Experiments and numerical simulations confirmed the concept:** good compromise between adequate **opening time** and very high **reliability** (avoiding unattended openings); to be scaled-up for the MSFR

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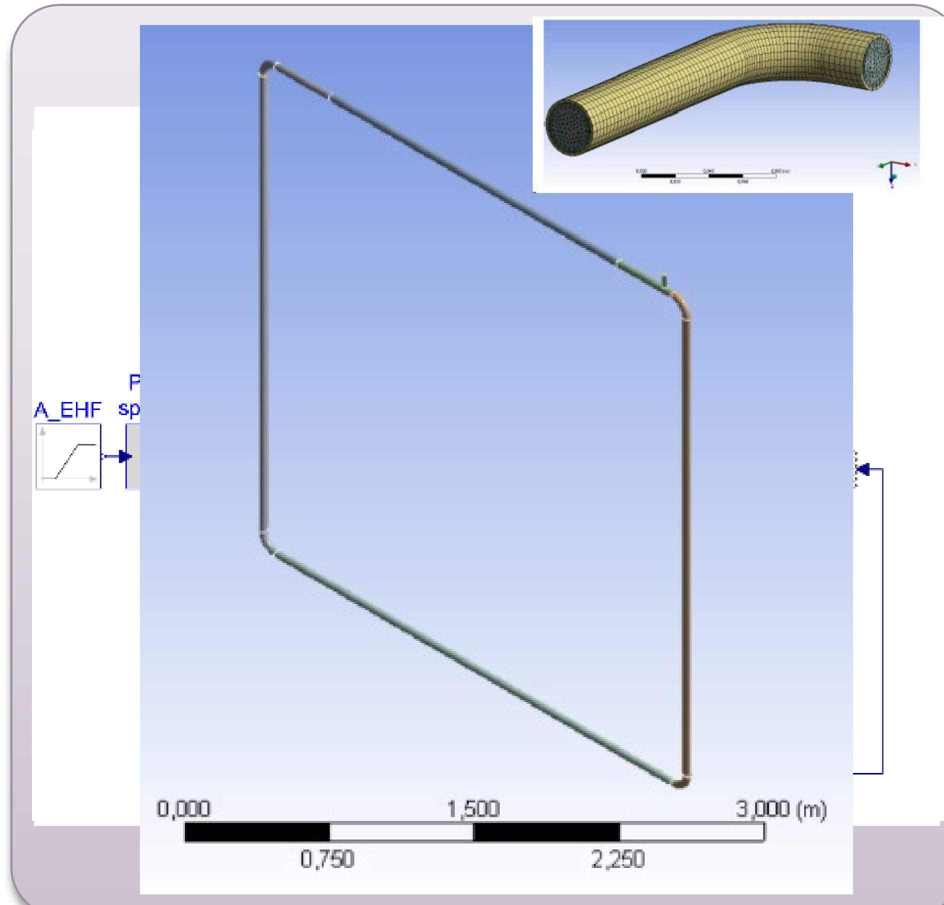
2. Physical modeling of molten salt natural circulation loop

- new set of **numerical tools** needed, to investigate both **fluid-dynamics** and **stability**
- "Progressive approach"

1. / 2. / 3. **Stability Maps / 1-D dynamic model / 3-D CFD model**
   - Preliminary design / Design optimization / Detailed analysis
   - Asymptotic behavior ("steady") / Transient behavior
   - Linear model / Non-Linear model
   - **1-D / 3-D**
   - No TH correlations / **TH correlations**



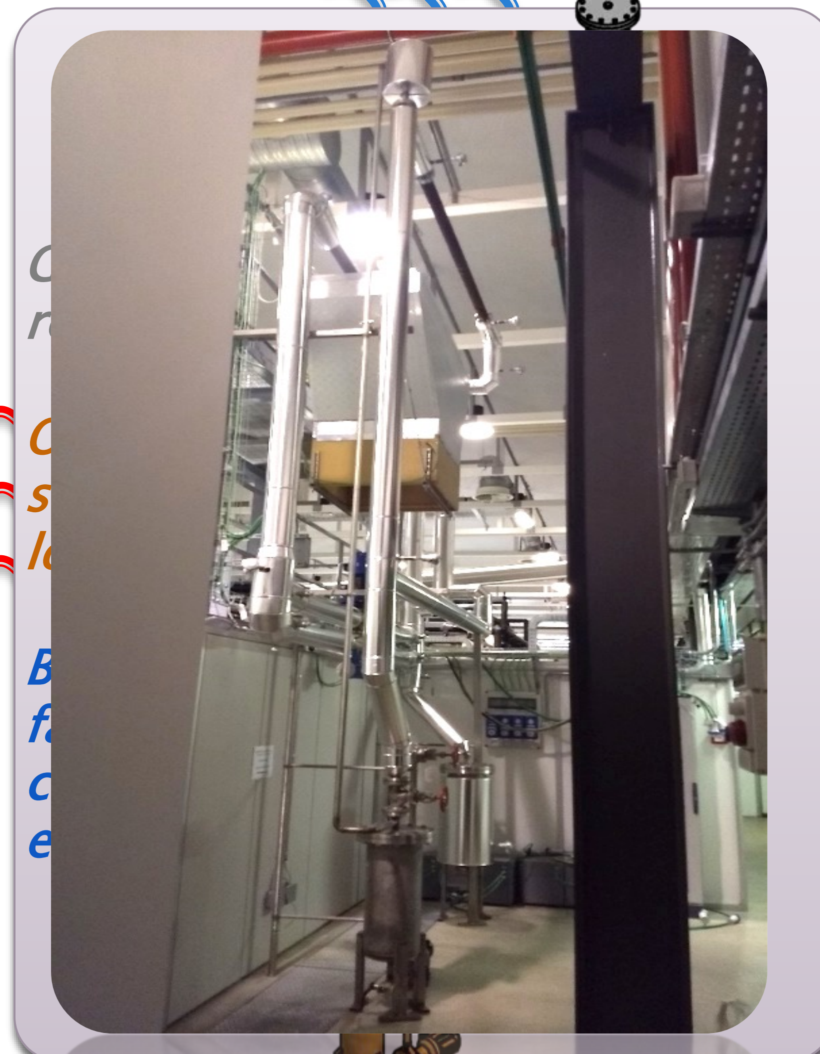
2. DYNASTY facilities to investigate TH & natural circulation behavior

- *DYnamics of NAtural circulation for molten SalT internallY heated* experiments

- **Distributed heating mode**: to simulate the decay heat of the fuel into the molten salt

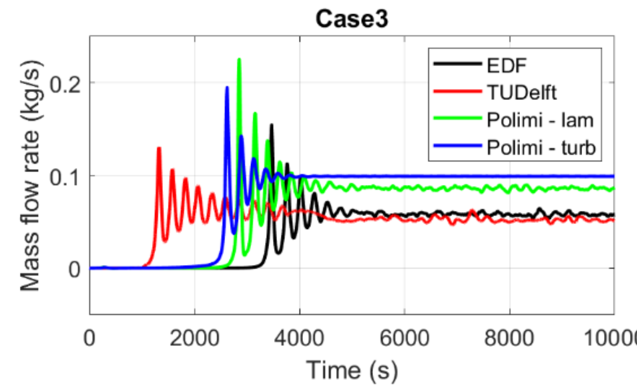
- **Working fluids**: **water, water+glycole, molten salt** (low T melting)

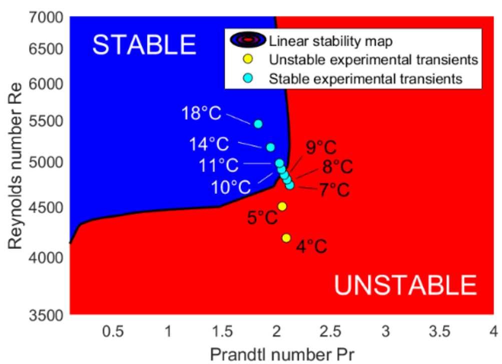
- To investigate:
  - **Transient behavior**
  - **Stability**

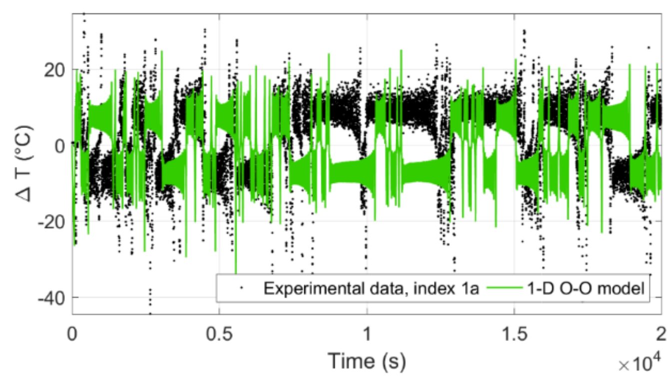


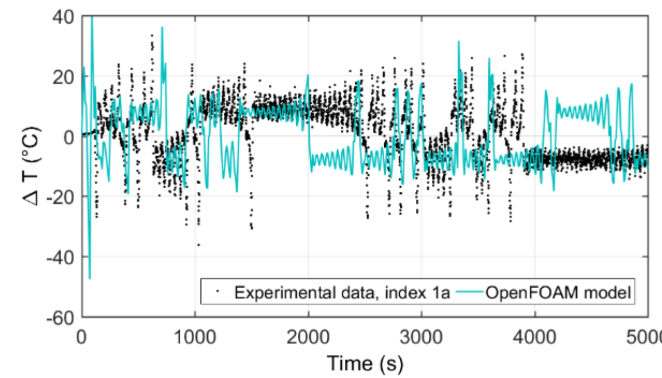
2. Assessment of natural circulation modeling by experimental data

- **Comparison** of different TH models (modeling approaches, codes, turbulence models, etc.)
- Instability trend is well predicted in terms of **max. oscillation** and **frequency**









- Goal: recommendation for DHR design (**layout to limit oscillations**); **preliminary validation** of the numerical models
- **CFD modelling** needs additional analysis/development (LES vs RANS, lam-turb transition)

Conclusions & Recommendations

- Developed **reliable models** able to simulate the **fluid-dynamics** of the **Cold Plug** device and the DHR – **Passive Safety System**
- Built and operated **experimental facilities** able to investigate the **key TH phenomena** and their **dynamics**
- **Cold Plug:**
  - Effective principle (melting process, quick and reliable)
  - Has to be able to rebuild the cold plug after opening
  - Redundancy & Diversity: different device (Mechanical? Thermal?) to perform the draining safety function for MSFR
- **DHR – Passive Safety System:**
  - Effective principle even with internally heated fluid
  - Oscillating behavior with certain boundary conditions, but net thermal power rejected
  - 3-D investigation of the "real" MSFR geometry and accident transients

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