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## UO<sub>2</sub>-ZrO<sub>2</sub> melting in a cold crucible induction furnace: simulation and experiments

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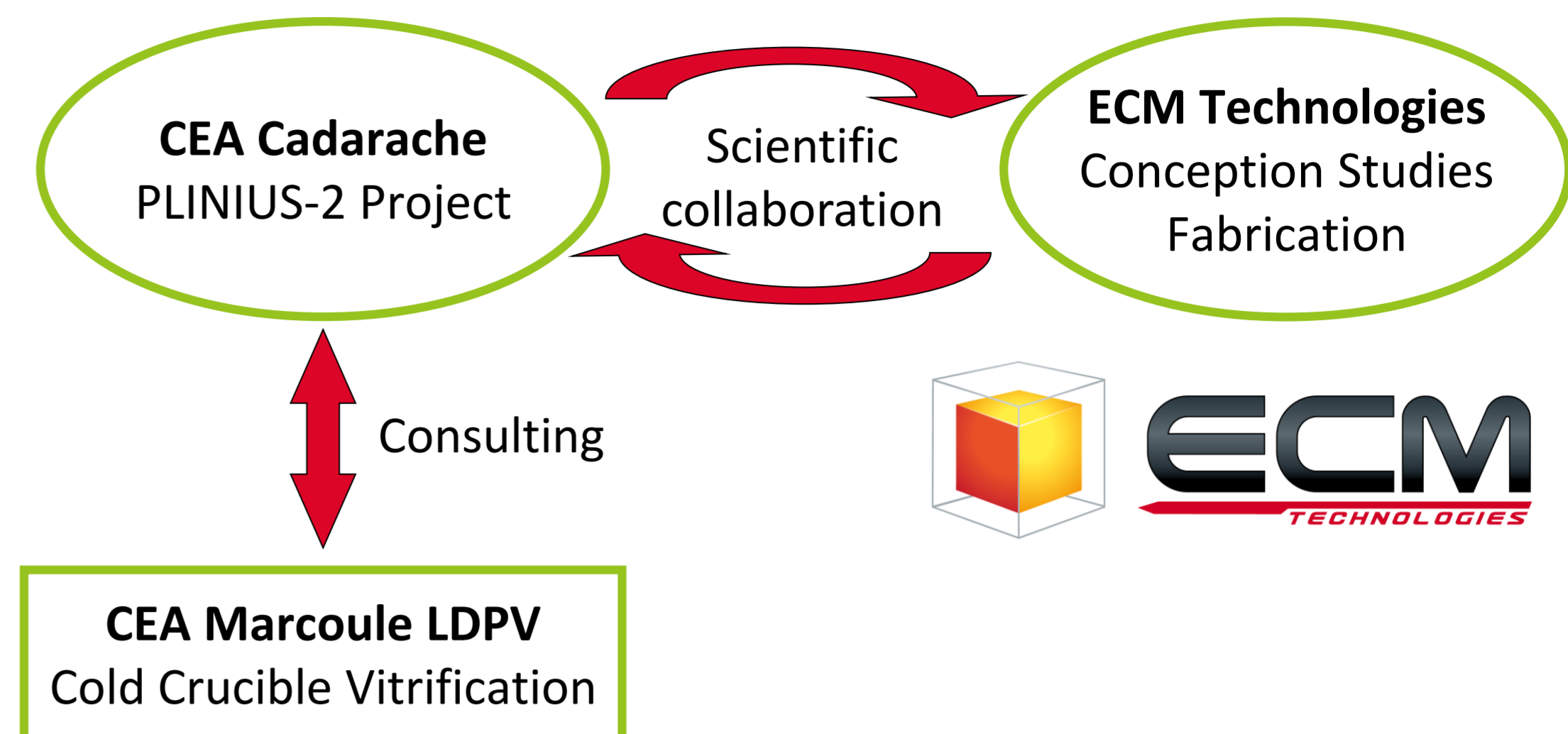
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## Plinius-2 project

In the field of severe accident studies for generation 2, 3 & 4 nuclear reactors, the Plinius-2 project aims to build a new facility to perform experiments of corium interactions tests at a large scale until 2020. In this context, the project, in collaboration with ECM Technologies, has to define and build a furnace able to melt up to 500 kg of different compositions of corium surrogates.

This poster presents the work achieved in the CEA Marcoule.



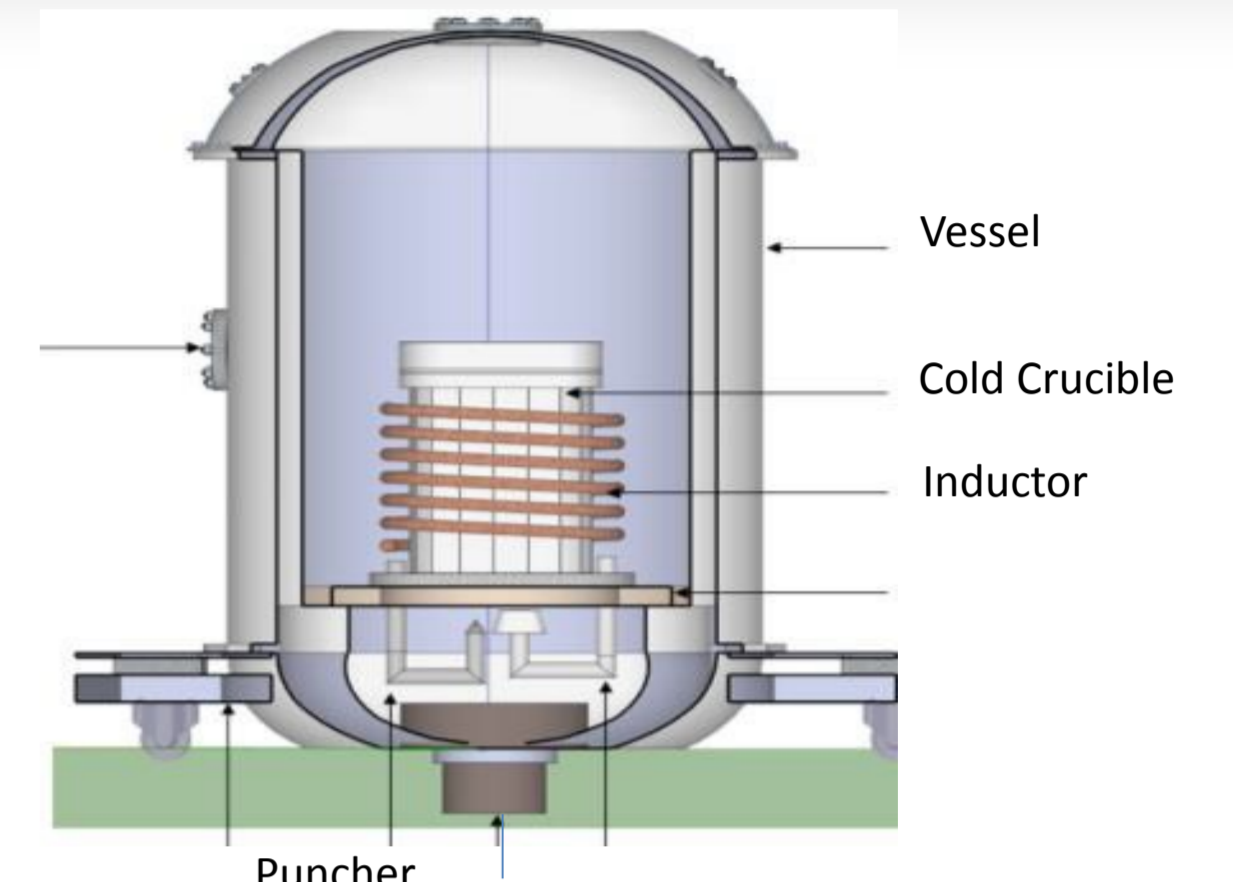
## Corium interactions studies

- Corium composition
  - oxides mix (UO<sub>2</sub>, ZrO<sub>2</sub>, SiO<sub>2</sub>)
  - with or without a metallic fraction (U, Zr, Fe, Ni etc.) from 0 to 30%wt
- Melting temperature > 2500°C
- Cold crucible technology has been chosen

Building project (CEA Cadarache)



Concept of the future furnace



## Experimental setup

CEA Marcoule

## Numerical Simulation

- Small scale experiments with ZrO<sub>2</sub> to check :

- Wall heat fluxes
- Loading feasibility
- Pouring feasibility
- Crust properties

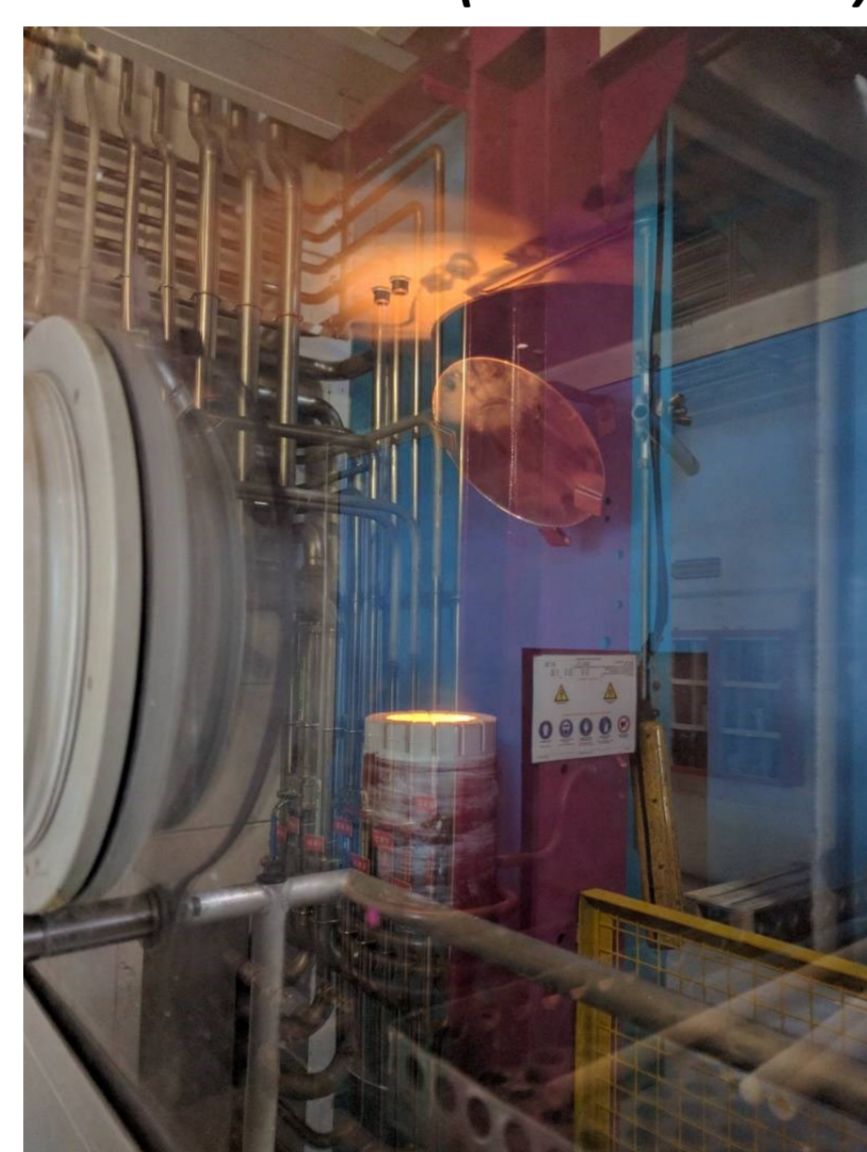
- Lamp HF generator

- 80 kW
- 2.8 MHz

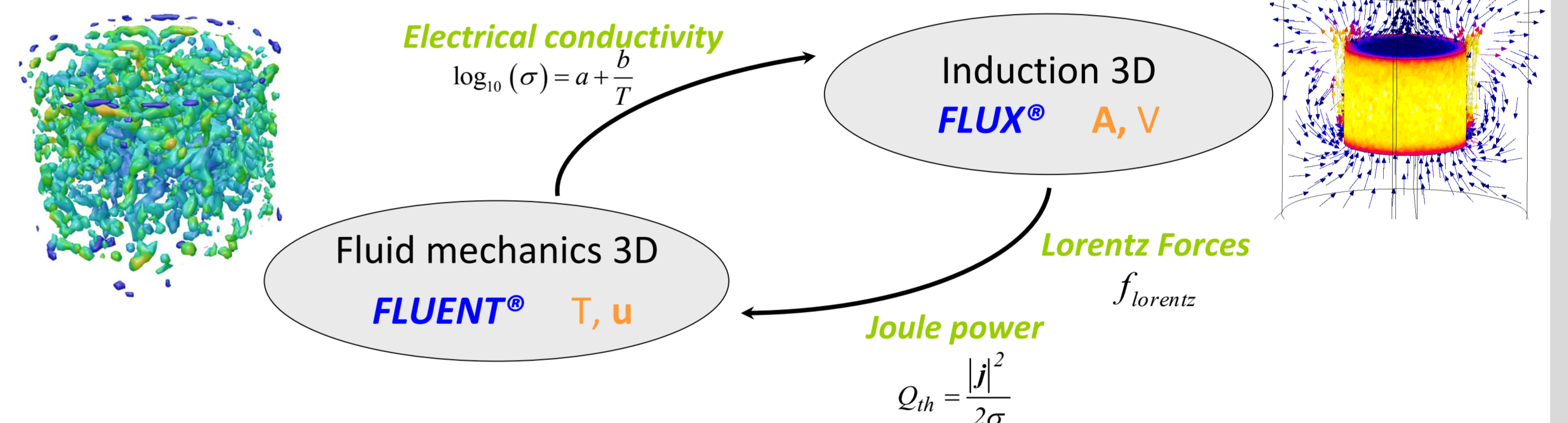
- Cold Crucible

- Inner diameter 8 cm
- Coated stainless steel

Fusion cell (Marcoule)



- Simulations are performed to bridge the gap between the « small scale experiments with ZrO<sub>2</sub> » and the « large scale with complex corium ». See [3] for more details.

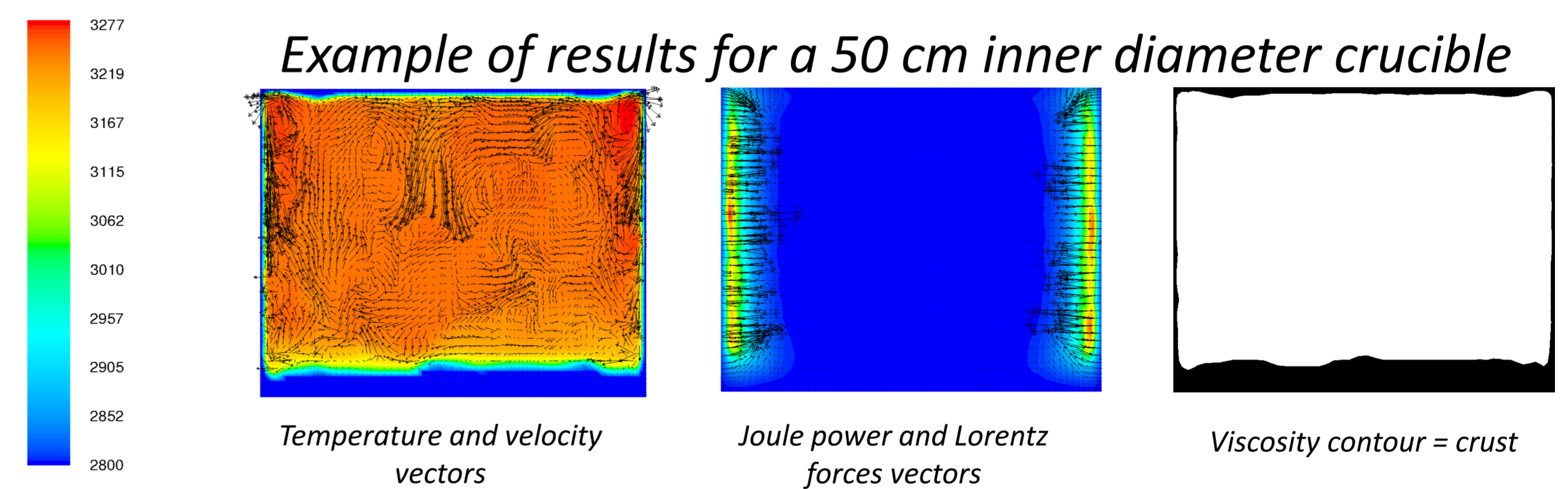


- Incompressible Navier-Stokes equation with turbulence modelling : LES

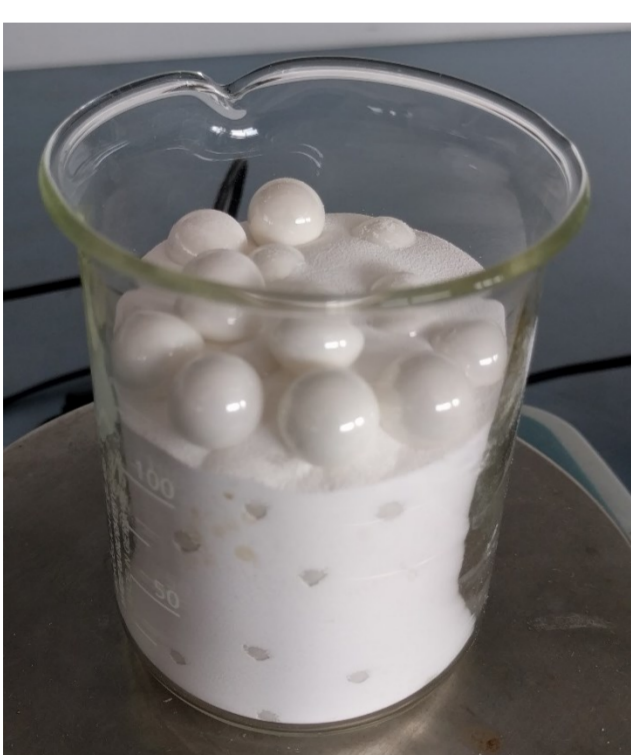
- Files transfer between Fluent and Flux with interpolation

UO<sub>2</sub> data set from [2]

Properties	Unit	Value / Law
Density	kg m <sup>-3</sup>	10900 – 0.7*T
Heat capacity	J kg <sup>-1</sup> K <sup>-1</sup>	480
Thermal conductivity	W m <sup>-1</sup> K <sup>-1</sup>	9
Viscosity	kg m <sup>-1</sup> s <sup>-1</sup>	T>3120K : 0.004 else 10 <sup>4</sup>
Electrical conductivity	Ω <sup>-1</sup> m <sup>-1</sup>	3.569*10 <sup>5</sup> *exp(-13345/T)



Initial load



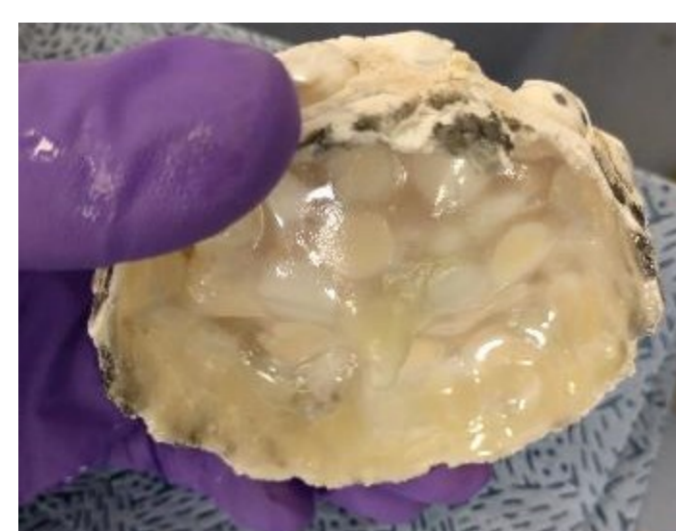
Mix of solid balls and powder to enhance apparent density (ZrO<sub>2</sub>+Y<sub>2</sub>O<sub>3</sub> 5%)

Melting process



Melting at T > 2800 °C  
Reloading during melting

After melting



Upper crust

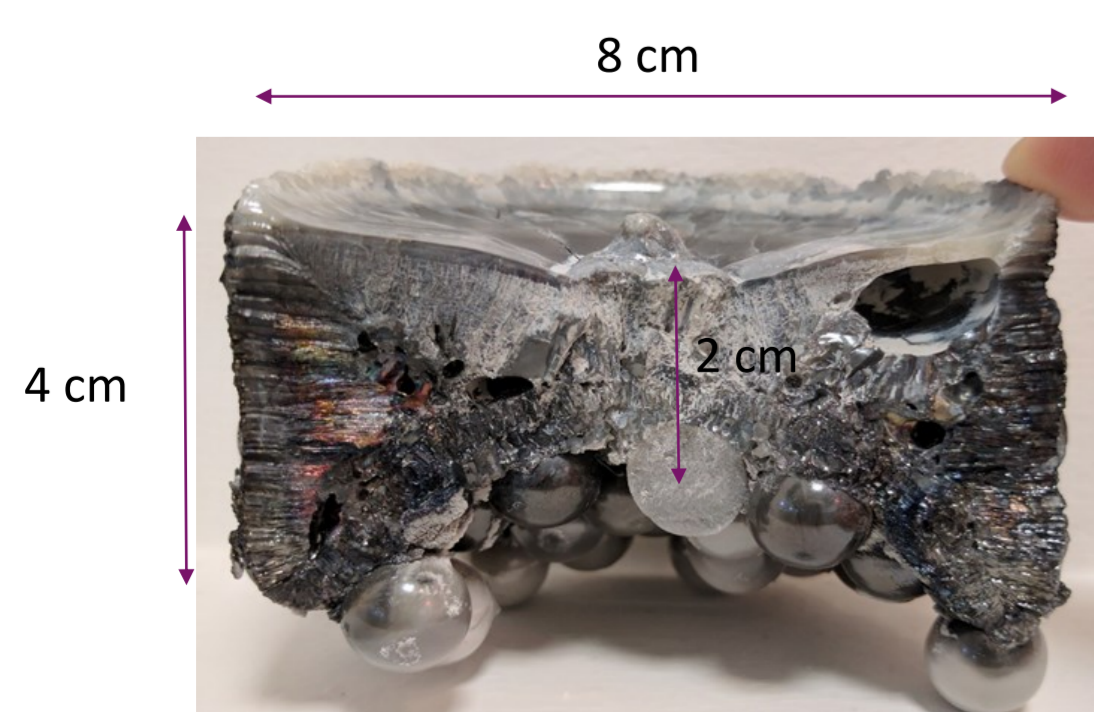


ZrO<sub>2</sub> ingot (950 g)

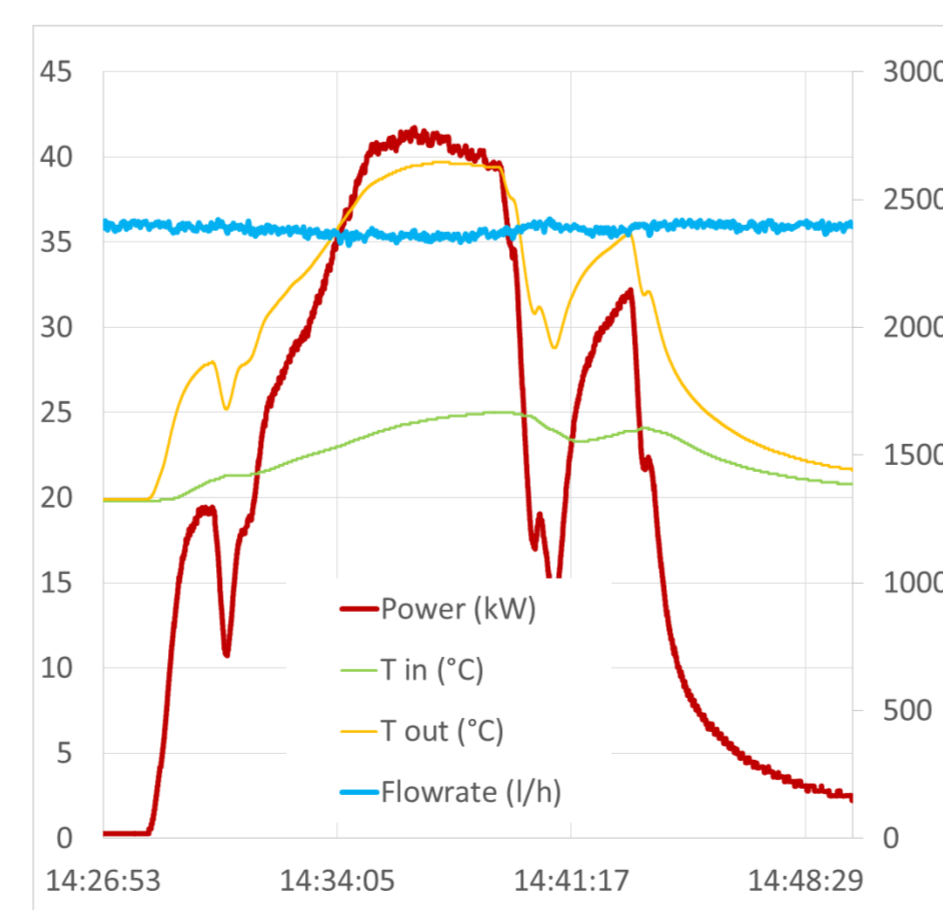
## Contributions to the project

- Estimation of the wall heat flux between the melt and the crucible

- Power received by the crucible
- Flux about 120 W/cm<sup>2</sup>



View of the ingot after slicing



Thermal power of the crucible during a melting

- Repartition of crust thickness is a function of injected Joule power
- Thermal condition at the wall is of great importance to catch the appropriate heat flux. A mixed convection-radiation is used.

Total Joule Power	MW	0.7	0.9	1.1	1.3
Melt fraction	%	78	83	90	94
Mean temperature	K	3021	3103	3207	3382
Bottom crust thickness	cm	7	5.5	3	2

Parametric study for a 500kg furnace with UO<sub>2</sub>

- Design and sizing of a 120kg furnace are now completed, construction is under progress. First melting scheduled during 2018 in ECM (Grenoble)

## Reference

1. E. Sauvage, A. Gagnoud, Y. Fautrelle, P. Brun and J. Lacombe. Thermoconvective flow of molten glass heated by direct induction in a cold crucible. *MagnetoHydrodynamics*, vol. 45 (2009), no. 4, pp. 535-542.
2. IAEA. Thermophysical properties database of materials for light water reactors and heavy water reactors, vol. IAEA-TECDOC-1496 (IAEA, 2006).
3. E. Sauvage, P. Brun, J. Lacombe and L. Aaufore. 3D simulation of a 500kg UO<sub>2</sub> melt in a cold crucible induction furnace. *MagnetoHydrodynamics*, vol. 53 (2017), to be published.