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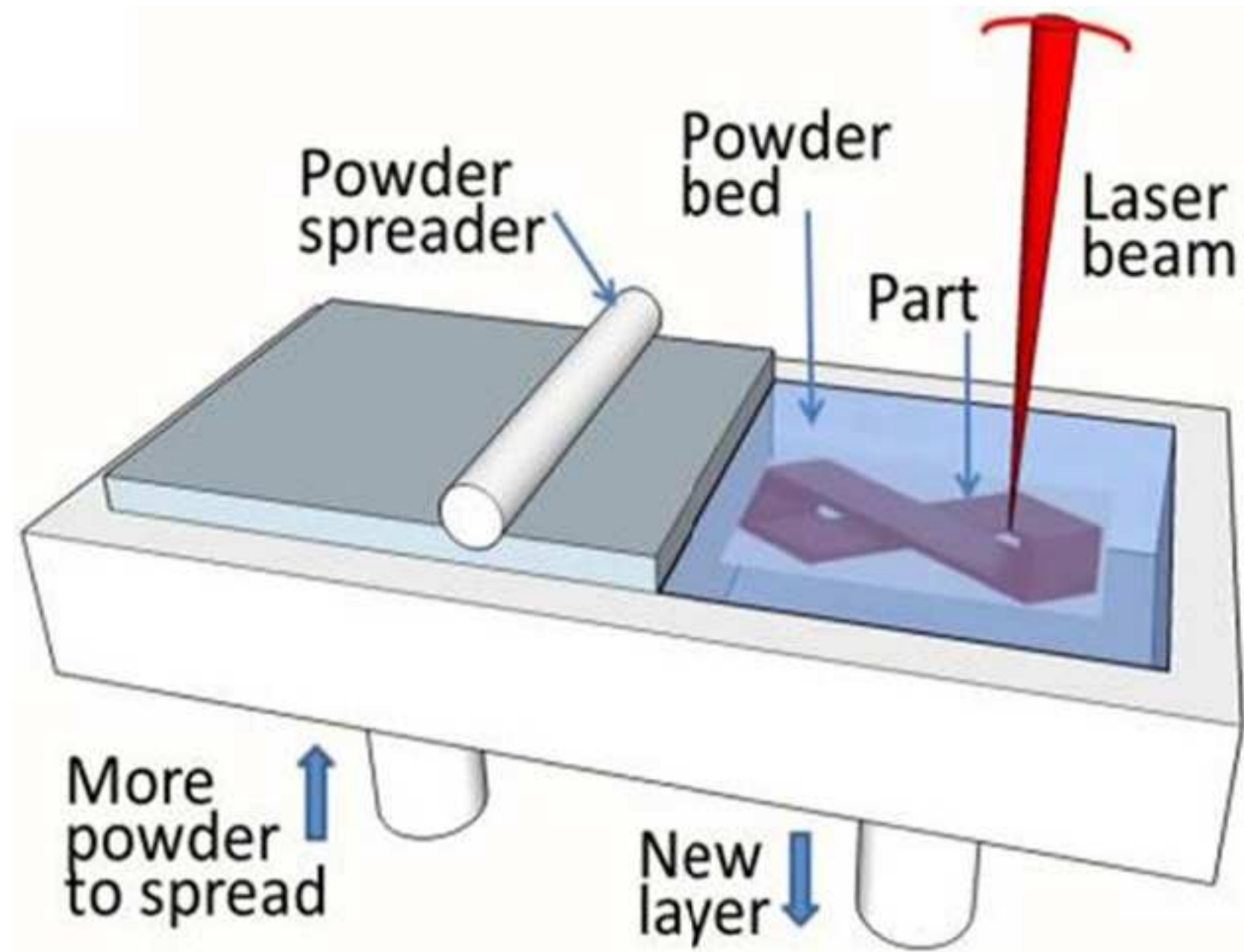


# Melt Pool Modelling for Additive Manufacturing (MOBAFA)

Stéphane Gounand<sup>1</sup>, Dihya Mezi, Guilhem Roux, Jean-Paul Garandet, Hicham Maskrot

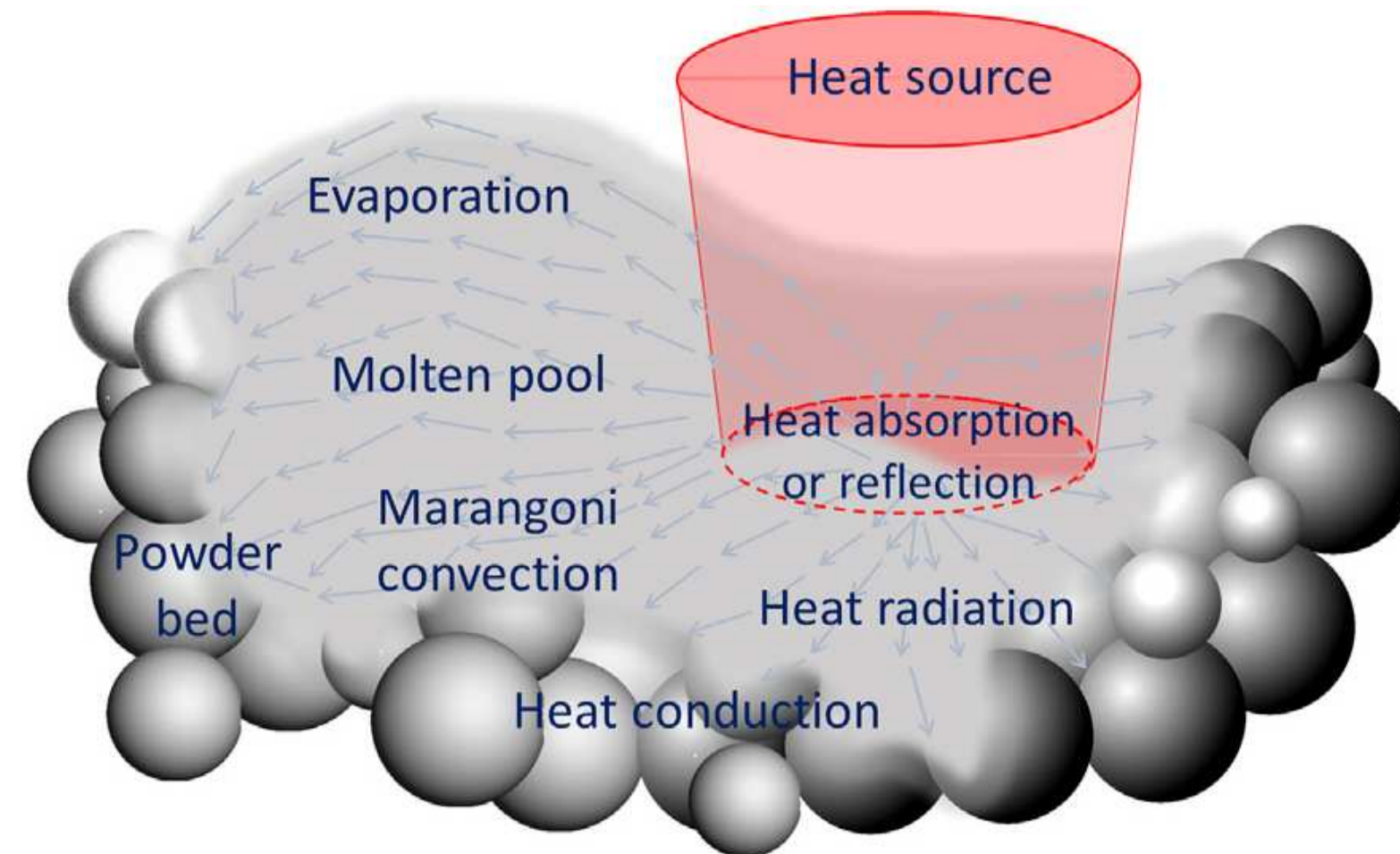
<sup>1</sup> stephane.gounand@cea.fr – <https://cv.hal.science/stephane-gounand>  
Des-Service de recherche en matériaux et procédés avancés (SRMA)  
CEA, Université Paris-Saclay, F-91191, Gif-sur-Yvette, France

## Additive Manufacturing

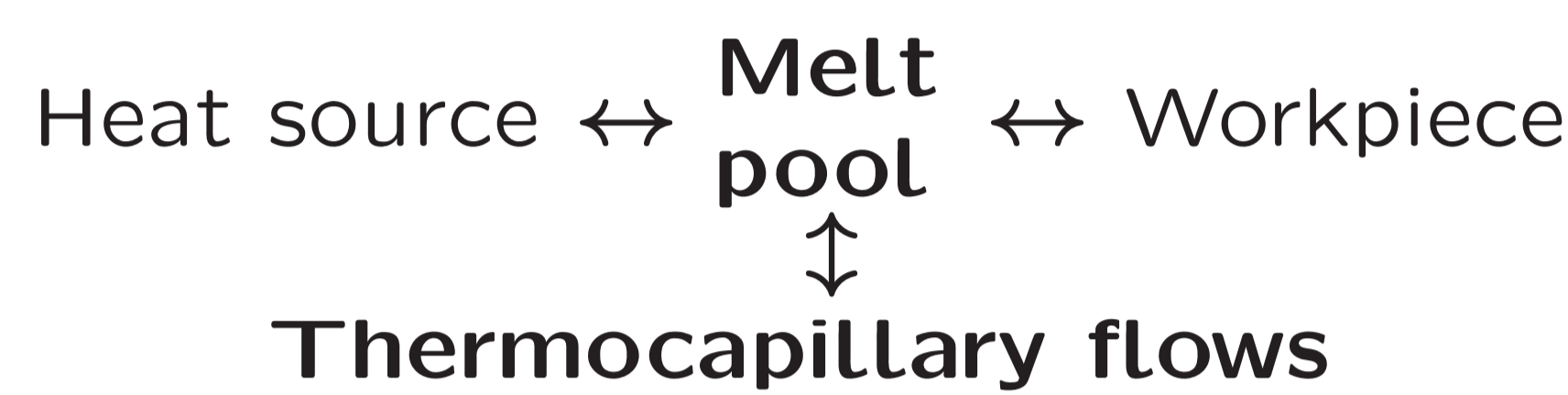


3D metal printing. Laser-Powder Bed Fusion (L-PBF) process [1]

## Liquid melt pool

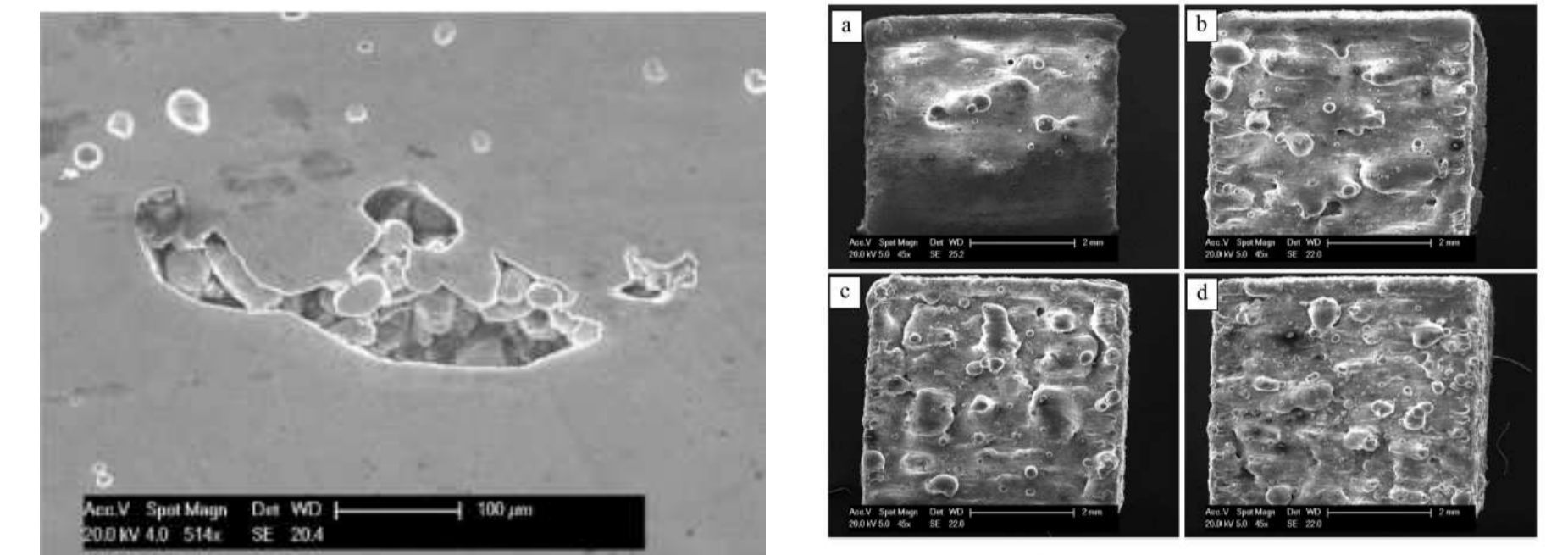


Melt pool physical phenomena [1]



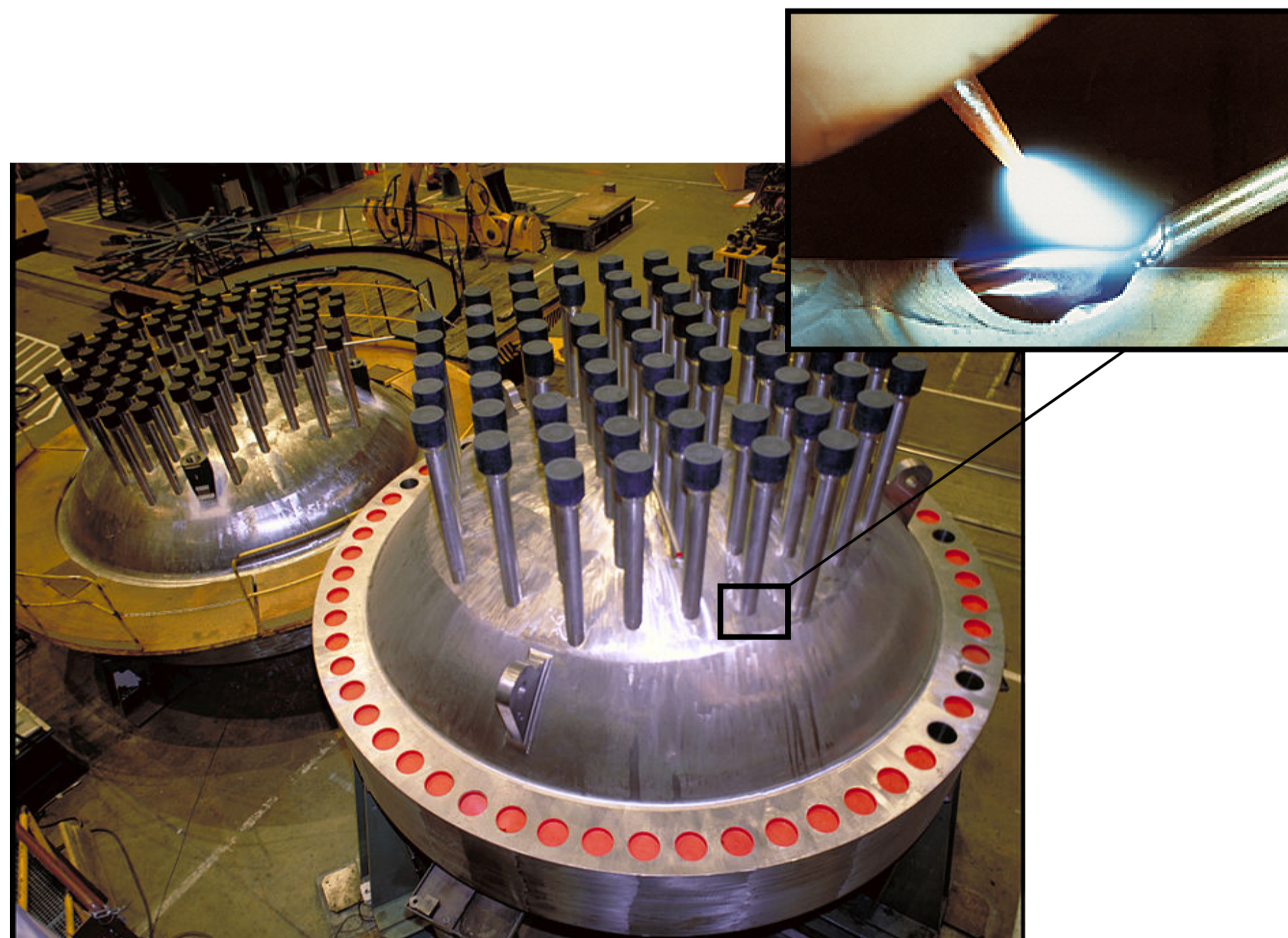
## Simulation goals ?

- Physical insights;
- Defect control: cracks, porosity, ejecta, bead stability. . .
- Process optimization: quality, speed. . .

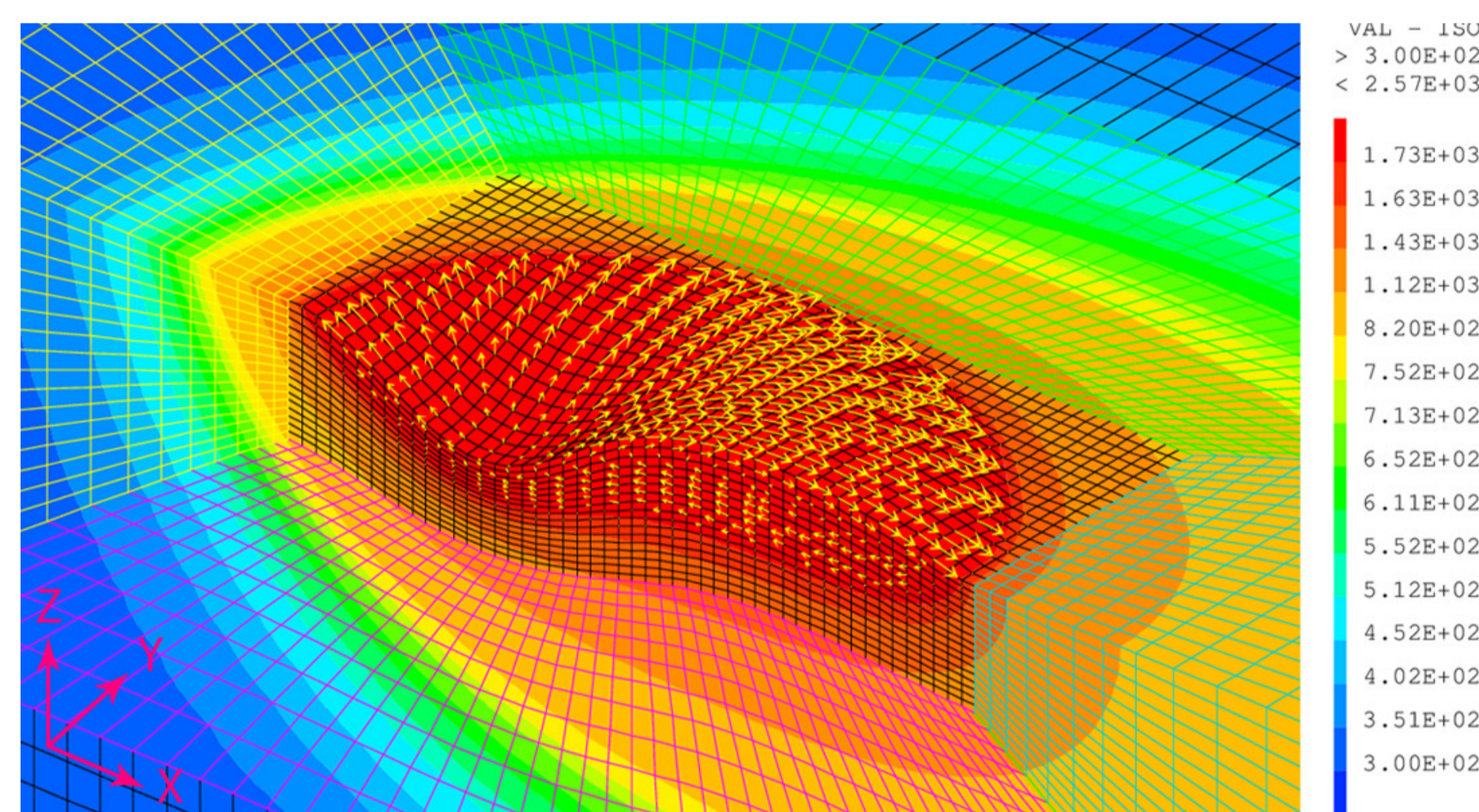


Porosity and projections

## From multi-physics welding simulation. . .



PWR vessel head ©NRC



Melt pool velocity and temperature [2]

Finite Element toolbox Cast3M [3]

$$\rho_0 \frac{\partial \mathbf{u}}{\partial t} + \rho_0 (\nabla \mathbf{u}) \cdot \mathbf{u} \stackrel{\Omega}{=} -\nabla p^* + \nabla \cdot \boldsymbol{\tau} + \mathbf{f}_{\text{Bou}} + \mathbf{f}_{\text{Ext}}$$

$$\nabla \cdot \mathbf{u} \stackrel{\Omega}{=} 0$$

$$\mathbf{u} \stackrel{\partial \Omega \setminus \Gamma}{=} \mathbf{u}_0$$

$$\mathbf{u} \cdot \mathbf{n} \stackrel{\Gamma}{=} \frac{\partial \mathbf{x}_r}{\partial t} \cdot \mathbf{n} - \frac{\dot{m}}{\rho_0}$$

$$-p^* + (\boldsymbol{\tau} \cdot \mathbf{n}) \cdot \mathbf{n} + \rho_0 g z \stackrel{\Gamma}{=} \gamma \left( \frac{1}{R_1} + \frac{1}{R_2} \right) + s$$

$$(\boldsymbol{\tau} \cdot \mathbf{n}) \cdot \mathbf{t} \stackrel{\Gamma}{=} \frac{\partial \gamma}{\partial T} \nabla_s \gamma + s$$

$$\theta \stackrel{\partial \Gamma}{=} \theta_0 \text{ ou } \mathbf{x}_r \stackrel{\partial \Gamma}{=} \mathbf{x}_0$$

$$\rho_0 \frac{\partial h}{\partial t} + \rho_0 \mathbf{u} \cdot \nabla h \stackrel{\Omega}{=} \nabla \cdot \lambda \nabla T + s$$

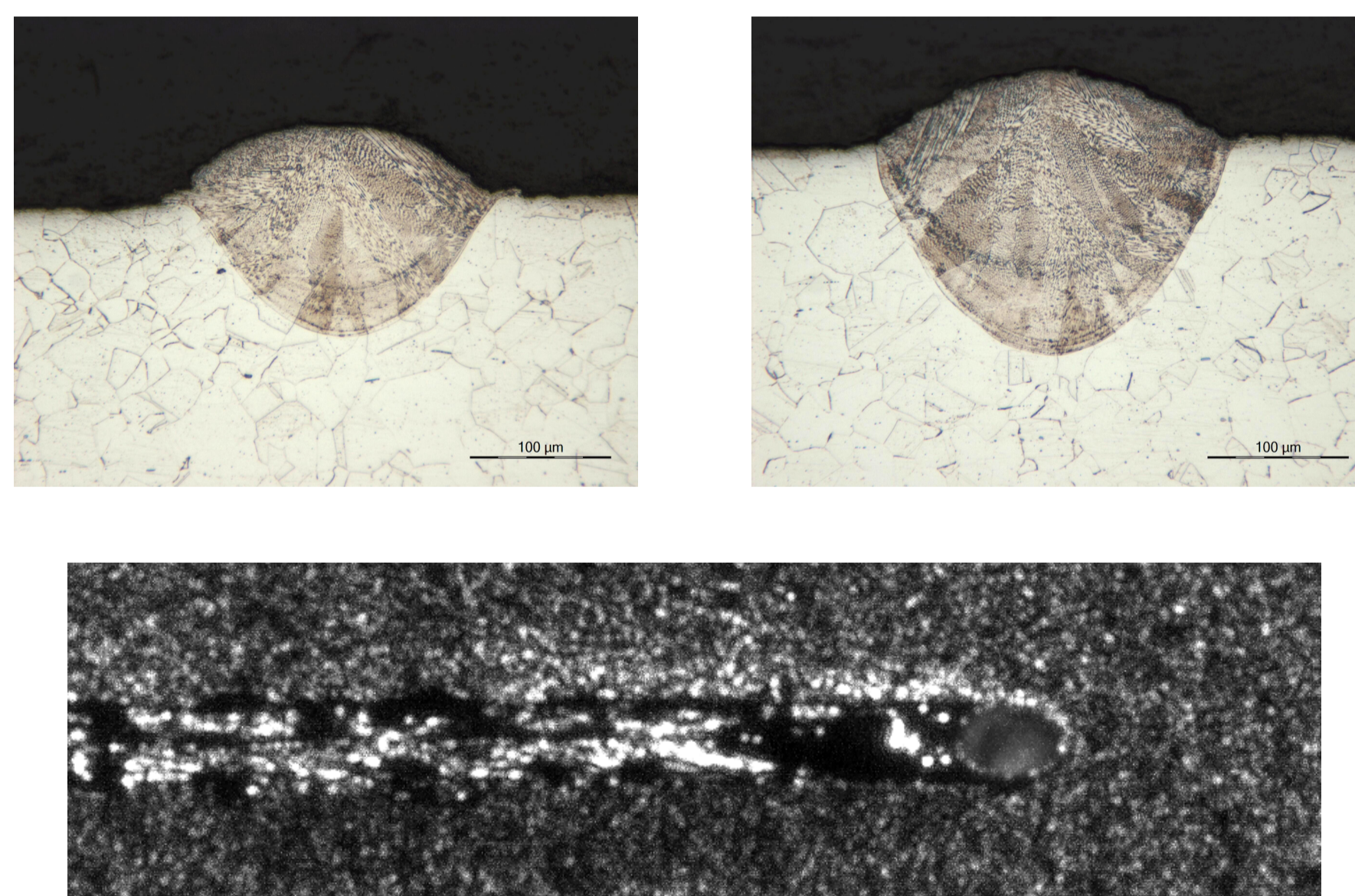
Steady free-surface laminar Navier-Stokes

## . . . to multi-physics additive manufacturing simulation (AM)

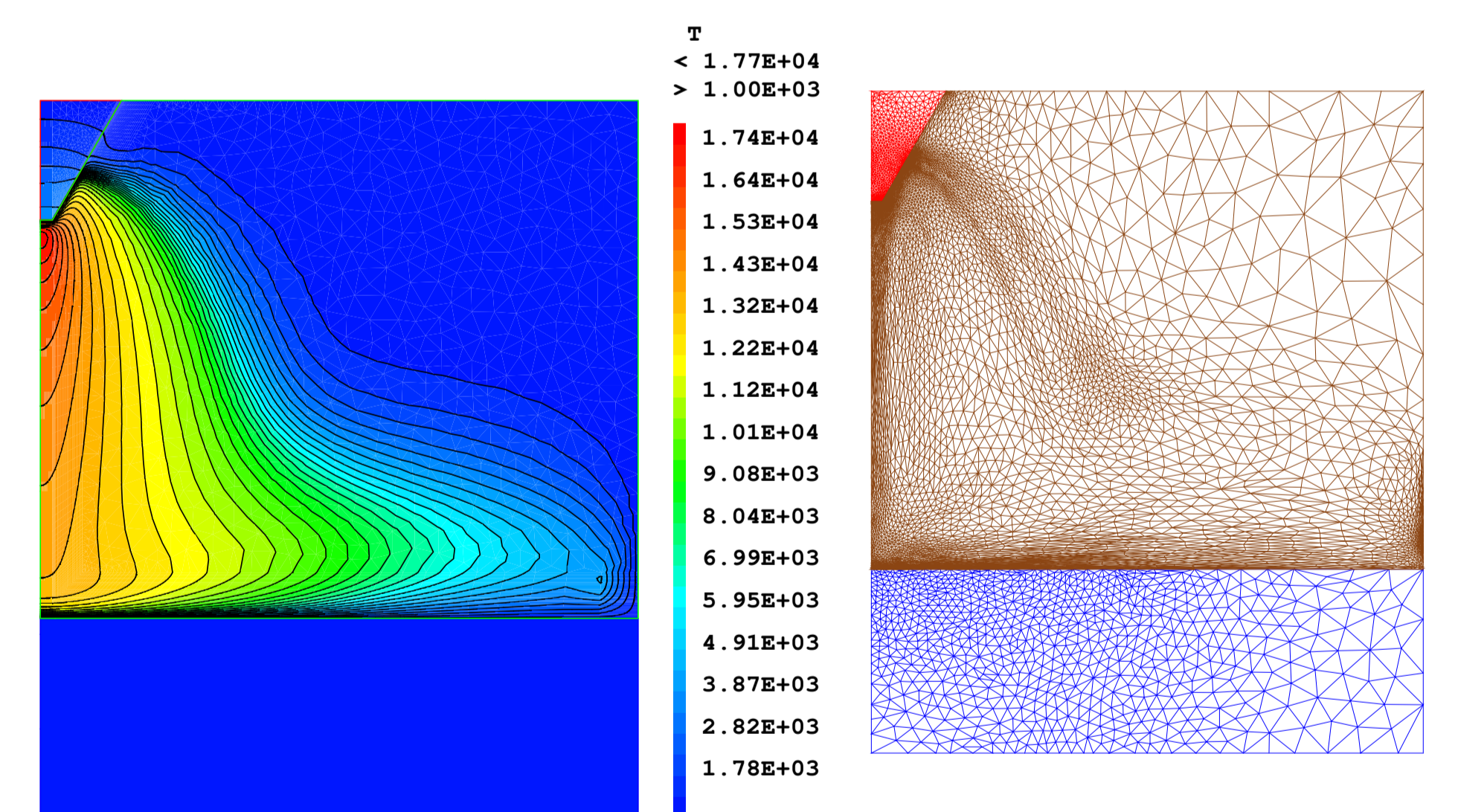
### Characteristic values

	Welding	AM
$P_{\text{source}}$ (W)	$1.10^3$	$1.10^2$
$r_{\text{source}}$ (m)	$5.0.10^{-3}$	$5.0.10^{-5}$
$\mathbf{u}_{\text{source}}$ ( $\text{m} \cdot \text{s}^{-1}$ )	$1.0.10^{-3}$	1,0
Mass addition	Wire	Powder

Process parameters



Single-pass validation experiments [4]



Multiscale numerical methods

## Post-doctoral work, 2022-2023 (Dihya Mezi)

- Up-to-date bibliography;
- Implementation of laser-matter interaction: evaporation and recoil pressure models;
- Comparison: numerical simulation vs Baumard's experiments [4].

## Bibliographie

- [1] T. DebRoy et al. Additive manufacturing of metallic components – process, structure and properties. **Progress in Materials Science**, 92: 112 – 224, 2018.
- [2] Minh Chien Nguyen, Marc Medale, Olivier Asserin, Stéphane Gounand, and Philippe Gilles. Sensivity to welding positions in GTA welding with a 3D multiphysics numerical model. **Numerical Heat Transfer, Part A: Applications**, 71(3):233–249, 2017. URL <https://dx.doi.org/10.1080/10407782.2016.1264747>.
- [3] Cast3m. Cast3m Web site. <http://www-cast3m.cea.fr/>.
- [4] Anaïs Baumard, Danièle Ayrault, Olivier Fandeur, Cyril Bordreuil, Frédéric Deschaux-Beaume, and Anne-Laure Vetele. Numerical prediction of grain structures formation during Laser Beam Melting of Single-Track 316L Stainless Steel. **Computational Materials Science**, 2020. URL <https://www.sciencedirect.com/science/article/pii/S0264127520309709>.