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# Experimental and numerical study of fire spread on a wooden façade

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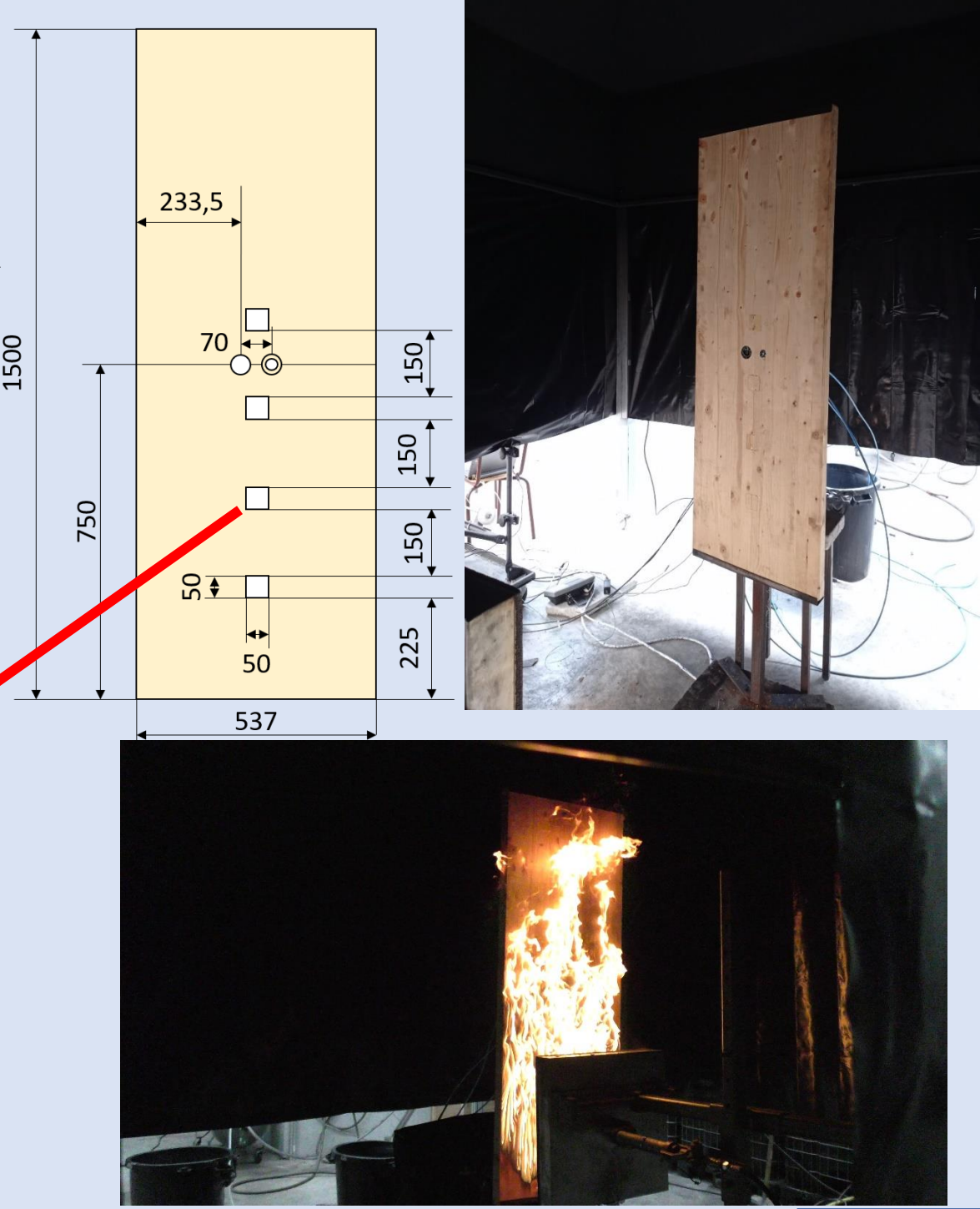
## Context and Objectives

Wood has become one of the key elements of modern construction. However, wood remains a very reactive material, which implies a higher risk in terms of fire safety. To understand the different aspects of façade fires, a national project called FIREWALL+ has been launched in France. The main objectives of the FIREWALL+ project are to answer some fundamental questions about the main mechanisms that control fire propagation, the interaction between the flow and the façade, etc. In order to answer these questions, medium and large-scale experiments have been conducted, establishing a detailed database. These experiments will then be used to validate existing numerical codes, in the present work FireFOAM<sup>1</sup> was used. Afterwards, these numerical tools will be used to study more complex phenomena that cannot be addressed experimentally.

## Experimental study

### A. Experimental configuration

- **Material:** Spruce
- **Dimensions:** 150 x 53 x 5 cm<sup>3</sup>
- **Fire source:** Radiant panel 50 x 50 cm located 20 cm from the wood panel with a 50 kW heat release rate.
- **Instrumentation:**
  - Weighing scale
  - Two heat flux meters (total and radiative)
  - Oxygen consumption hood
  - Infrared camera
  - In-depth temperature measurement<sup>2</sup> (20 thermocouples)



### B. Results

#### • Heat release rate (HRR)

- Good agreement between HRR measured by oxygen consumption and HRR calculated based on mass loss rate.
- Heat of combustion ranges from 13 MJ/kg to 18 MJ/kg

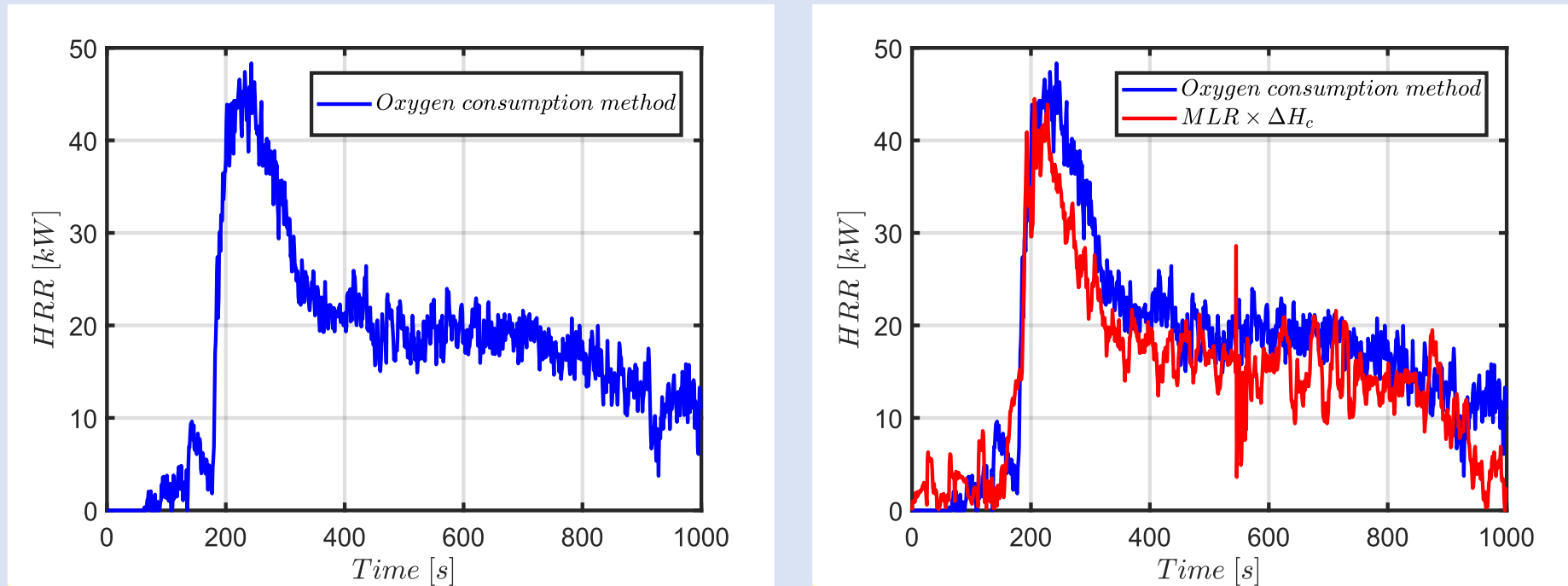


Fig.1. Evolution of the HRR

#### • Heat flux at the panel surface

- The convective heat flux is determined from the differences between total and radiative heat flux.
- In the early stages, heat transfer is dominated by convection.
- The radiative heat flux is practically constant, while the convective heat flux decreases.

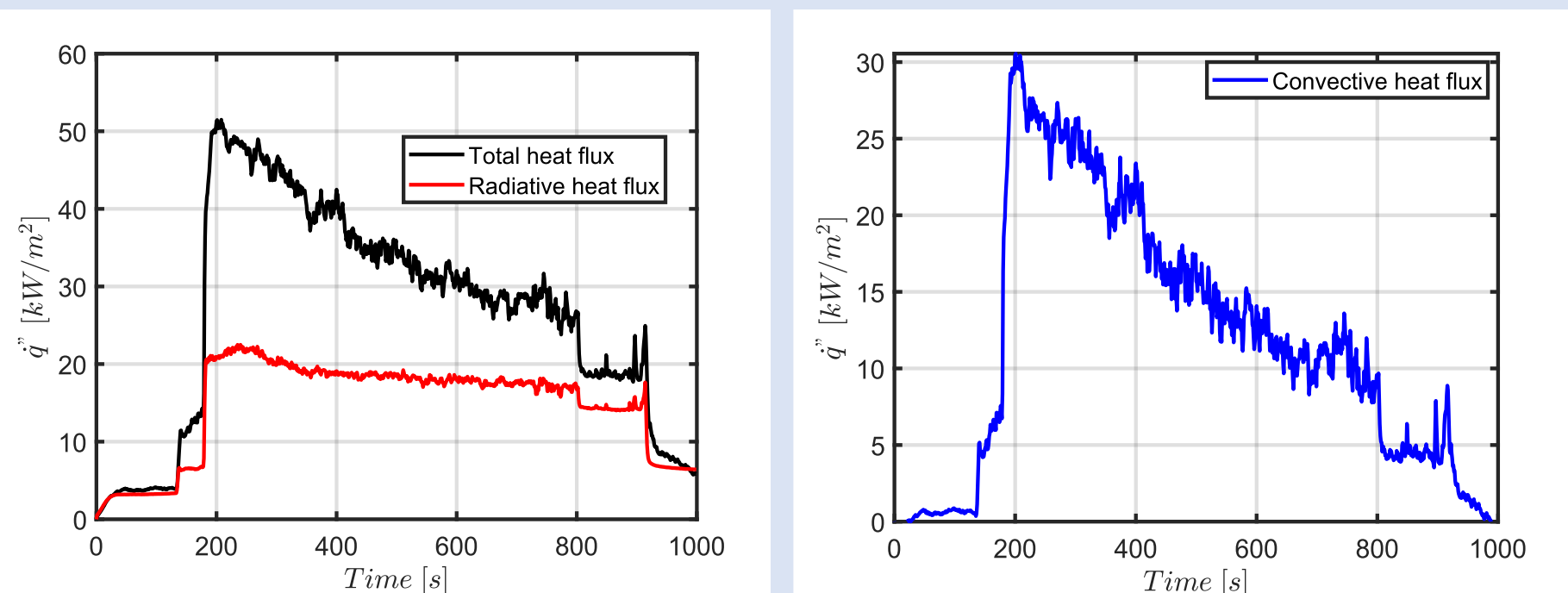


Fig.2. Variation of the total, radiative and convective heat flux

#### • In-depth temperature

- In-depth temperature profiles were provided by thermocouples embedded within the sample. Here, the 300 °C isotherm is presented, which is known to correspond to the char front position.
- At the end of the test, the panel had lost 1.4198 kg of its initial mass (the degraded surface is 70 cm high and 53 cm wide), i.e. an average char front thickness of 8.5 mm. A similar value is found based on the temperature measurements (slightly more than 10 mm).

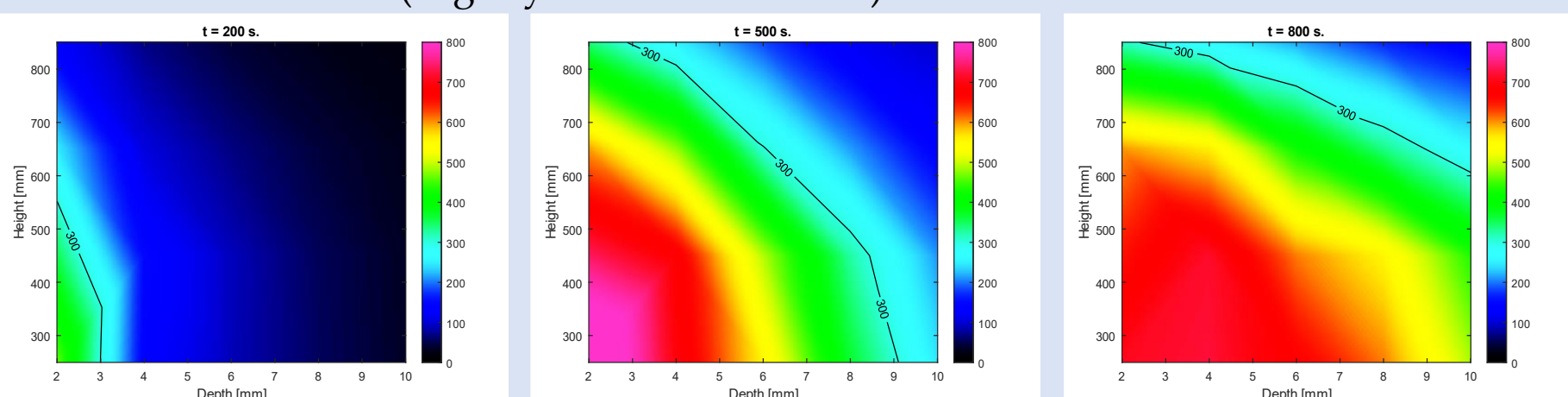
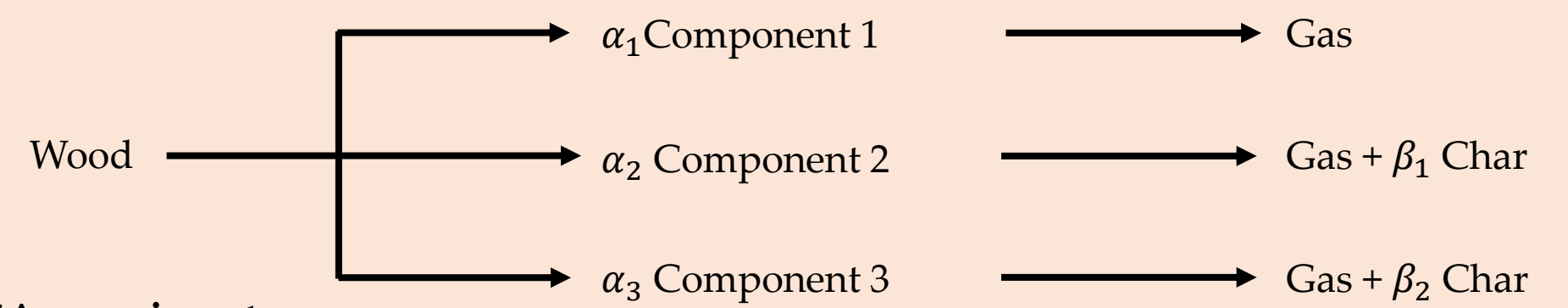


Fig.3. Variation of the in-depth temperature [°C]

## Numerical study

### A. Degradation model<sup>3</sup>



#### • TGA experiments

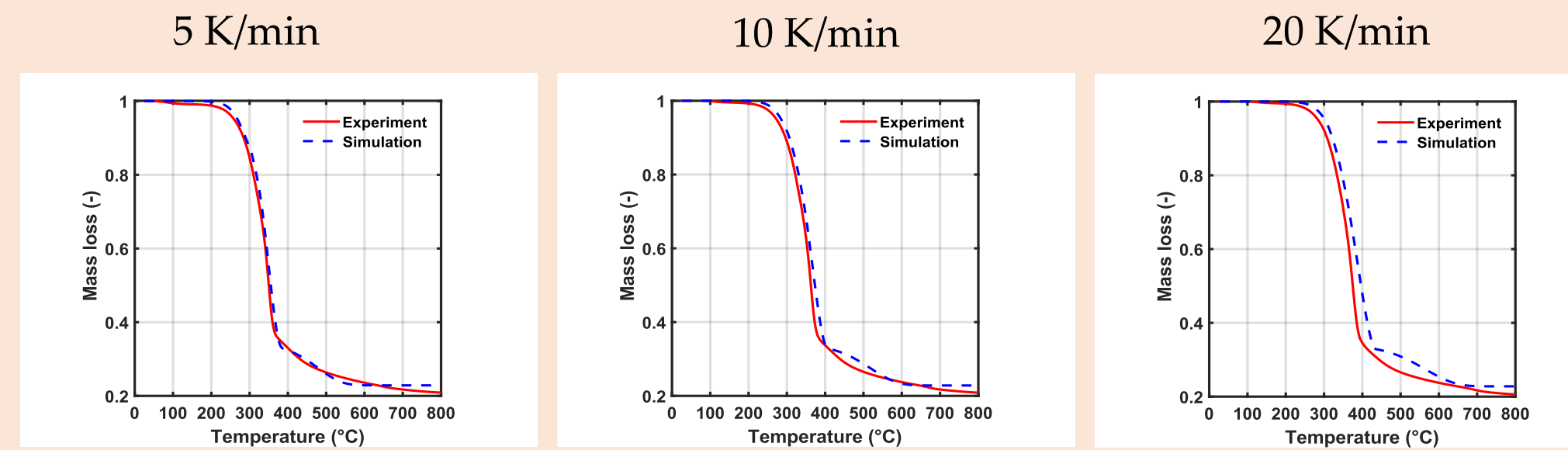


Fig.4. Normalized mass loss versus temperature for different heating rates

#### • Cone calorimeter experiments in inert atmosphere

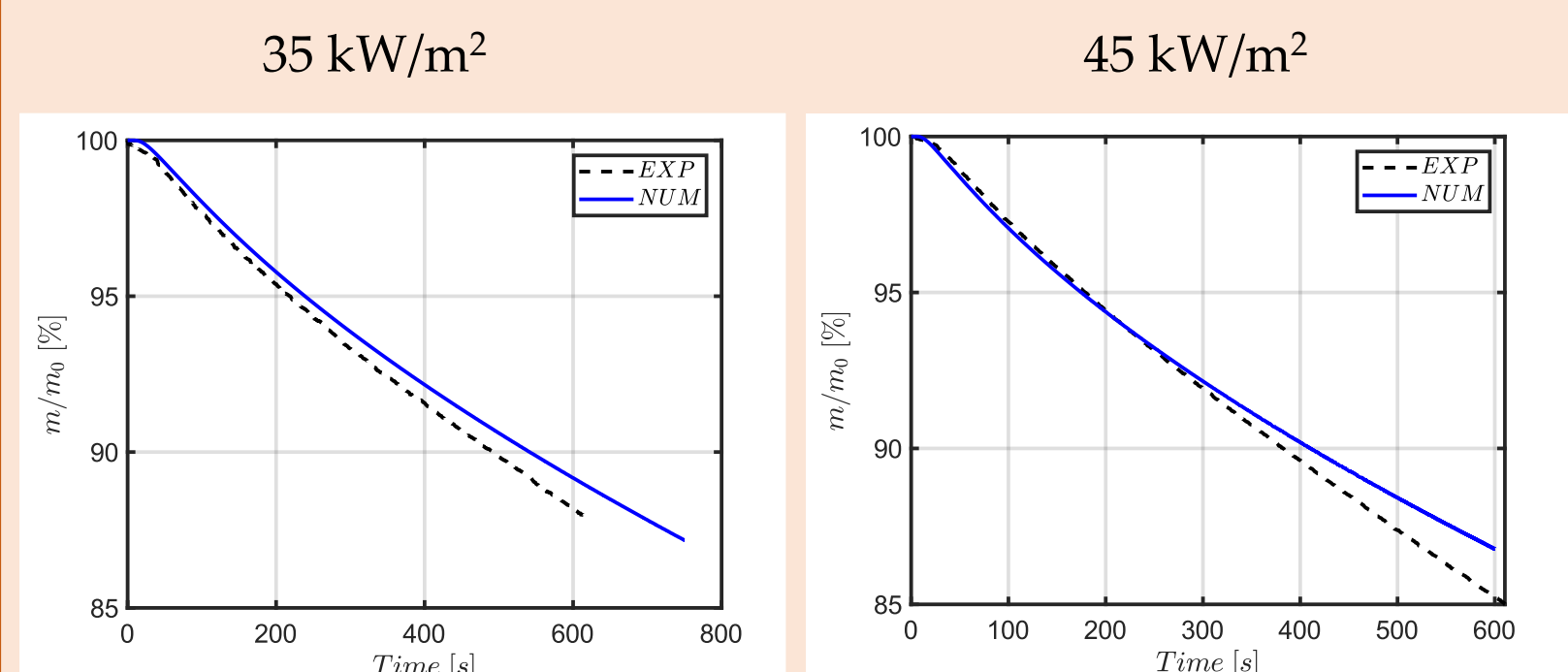


Fig.5. Normalized mass loss for cone calorimeter tests under inert atmosphere

Good agreement between the measured and the predicted mass loss

### B. Full scale

#### • Model parameters

- Combustion > EDC
- Radiation > FVDM with 100 solid angles
- Turbulence > LES with WALE (Wall-Adapting Local Eddy-Viscosity)
- Grid size > 2 cm for the fluid region, 1 cm for panel region

#### • HRR & MLR

- The agreement between measured and predicted HRR and MLR is satisfying. Both quantities are presented since their independent measurements, as described in the previous section, provide additional validation of the results.

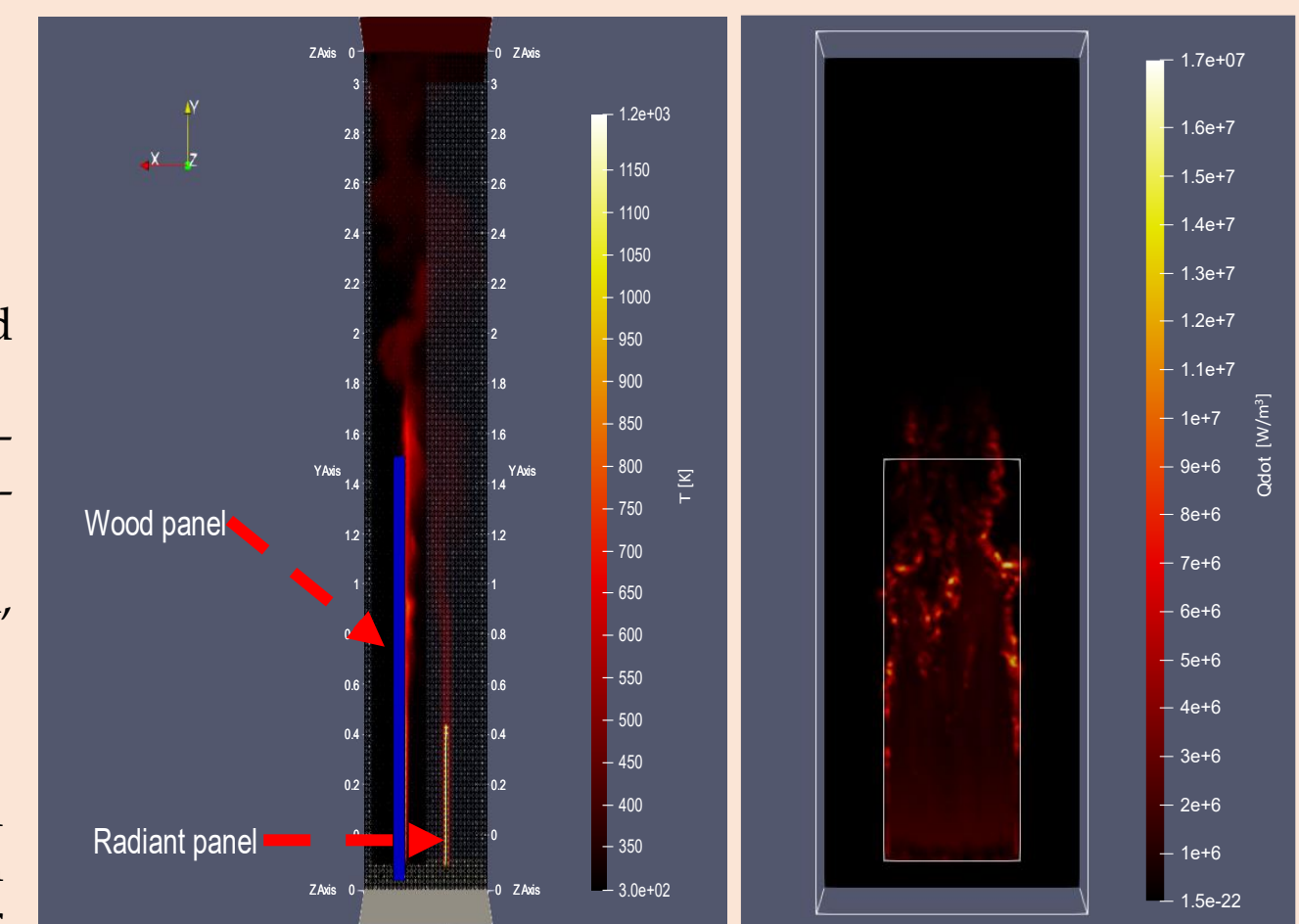


Fig.6. Numerical set-up (right) and an illustration of the reaction

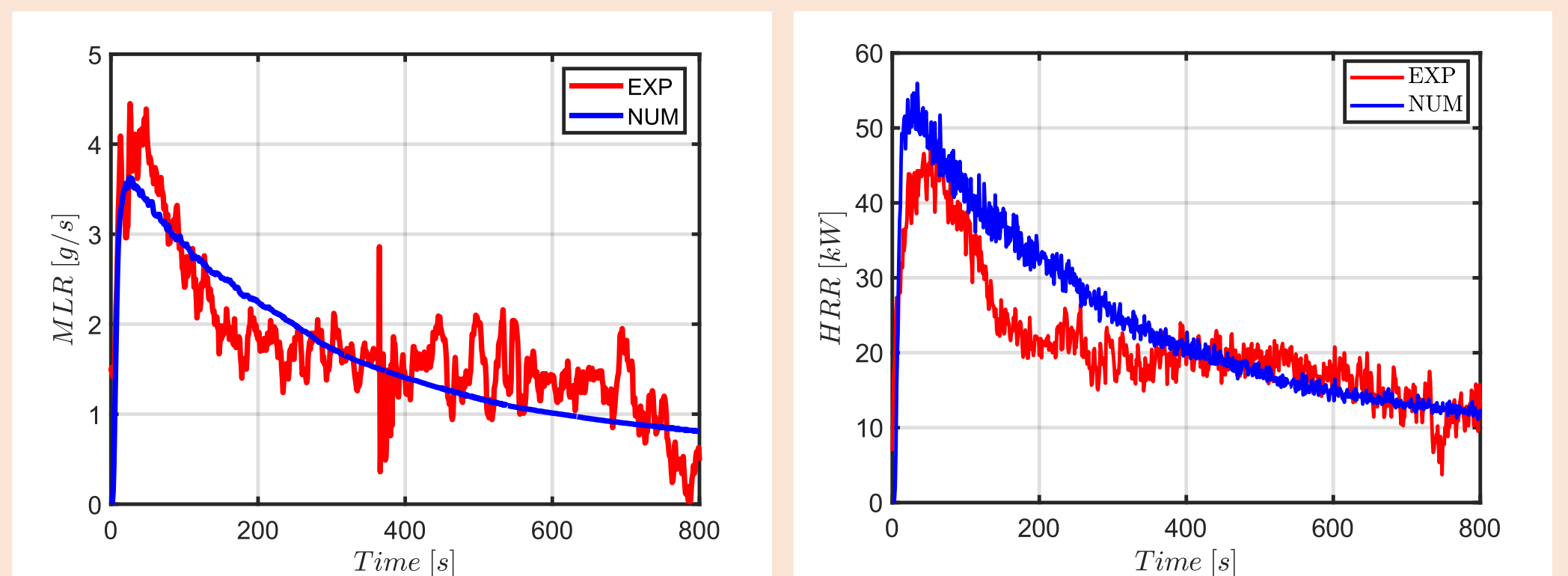


Fig.7. Comparison between the experimental and predicted mass loss rate (left) and the heat release rate

- This work was conducted as part of the FIREWALL+ project
- High Performance Computing resources were partially provided by the EXPLOR center hosted by the University de Lorraine

<sup>1</sup> <https://github.com/fireFoam-dev/fireFoam-v1912>

<sup>2</sup> Terrei Lucas, Zoubir Acem, Véronique Marchetti, Paul Lardet, Pascal Boulet, et Gilles Parent. « In-Depth Wood Temperature Measurement Using Embedded Thin Wire Thermocouples in Cone Calorimeter Tests ». International Journal of Thermal Sciences 162 (avril 2021): 106686. <https://doi.org/10.1016/j.ijthermalsci.2020.106686>.

<sup>3</sup> Hassan Flity, Mariam Abdo, Lucas Terrei, Zoubir Acem, Rabah Mehaddi, Paul Lardet, Gilles Parent « 3D-Modeling of thermal degradation of spruce wood under inert atmosphere » Fire Safety Journal 141 (2023) 103979

