Cone calorimeter: color and geometry effect for PMMA

25/11/2021 I Karen De Lannoye

Overview

- Introduction
- Results
  - Black vs transparent PMMA
  - Rods vs plates
- Balance for the tube furnace
- Conclusion and outlook

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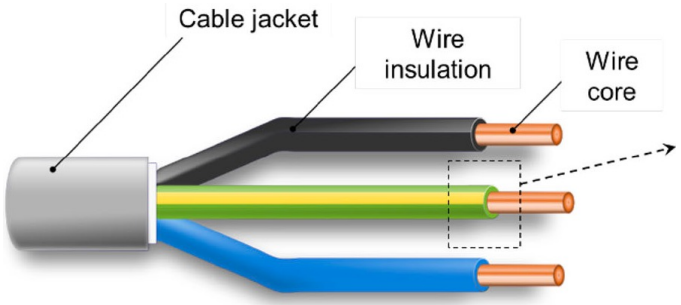
Introduction

Motivation



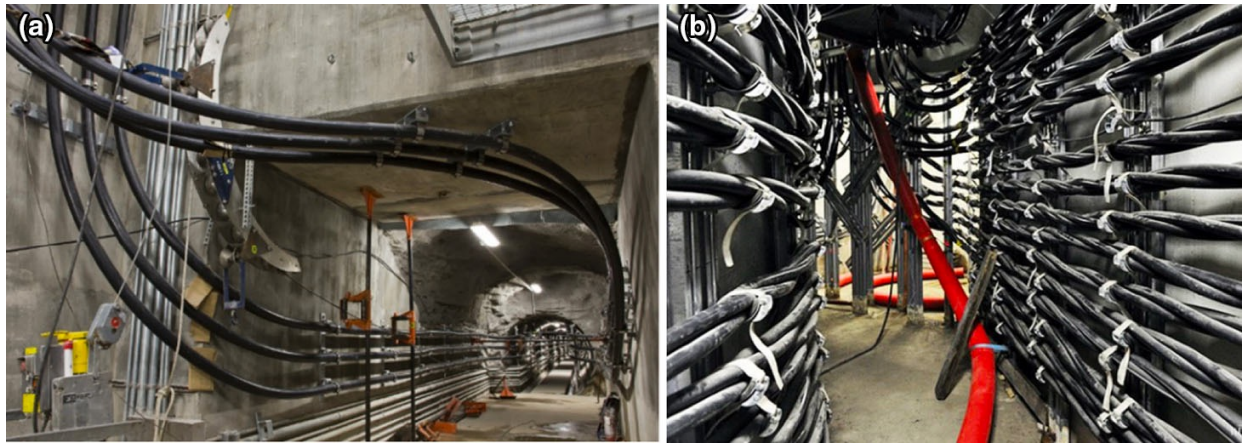
➢ Objective of thesis: Study the pyrolysis of cable fires

- Potential source of fire: residential buildings, nuclear power plants, aircrafts, spacecrafts,…
- Challenging combined system of metal core and insulation

- Gap between experimental data and modeling
  - Different boundary conditions

➢ Experiments with spatial and time resolved information to improve modelling

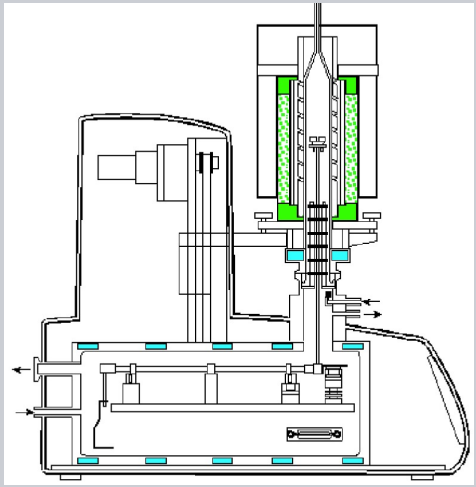
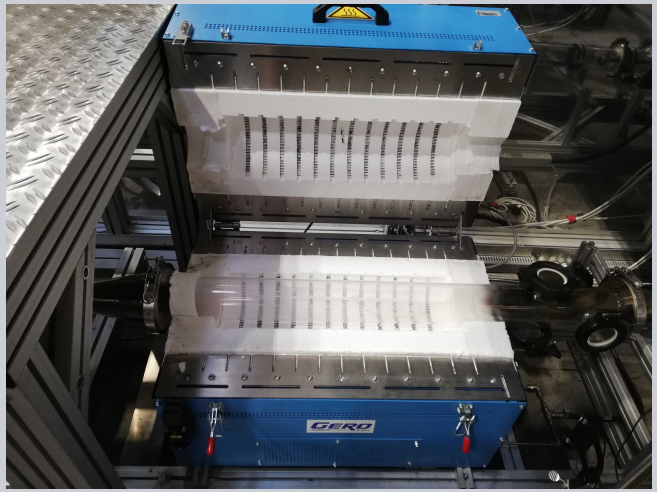
➢ New experimental device



Ref. fig: [1]

Introduction

Experimental overview

Thermogravimetric analyser	Tube furnace	Cone calorimeter
Sample size: mg  Ref. fig: [3]	Sample size: 60 cm 	Sample size: 10 cm x 10 cm 
• Mass loss • Temperature difference Amount of material Lack of heat feedback	• CO, CO_2, O_2 (and H_2) • Sample temperature • Outside temperature • Massloss	• Mass loss • CO, CO_2, O_2 → heat release rate Open → boundary conditions not controlled

Introduction

Sample material

Part 1: Compare different devices

Cables are to complex for comparison

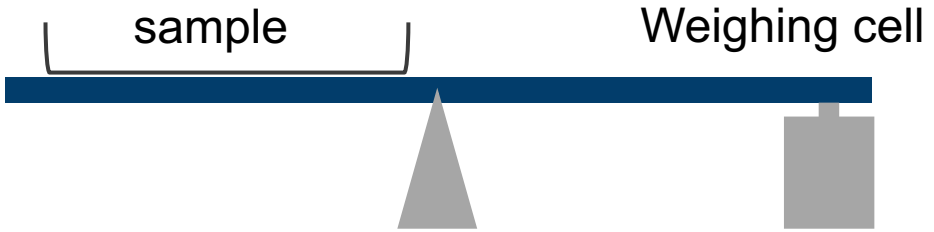
- ➢ Use PMMA (polymethylmethacrylate)
  - • Well known and studied
  - • Easy burning behaviour
  - ➢ Reproduce literature studies

Quantity to compare: mass loss rate

- • Measured both in TGA and cone experiments
- • Important output parameter of the simulations
- ➢ Need for balance in REKO-Fire

Part 2: Conduct cable fire experiments

Ref fig: [2]



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Introduction

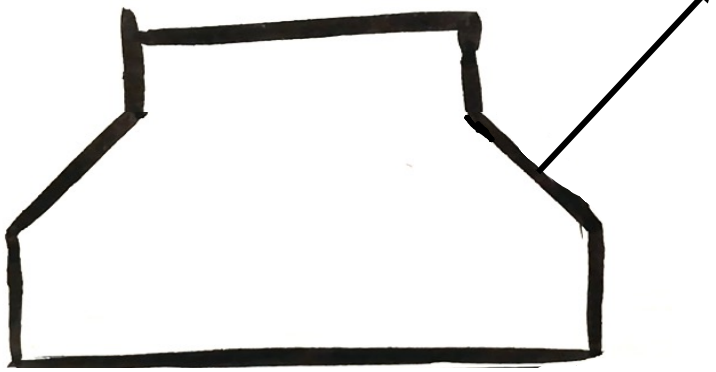
Experimental Matrix

Black vs Transparent	Plates vs Rods
	
Cable: different colour of mantel material	Cable: does the geometry of the sample influence the results?

- Heating rates: 25 kW/m^2, 35 kW/m^2, 50 kW/m^2, 75 kW/m^2
- 3 repetitions/ experiment

Introduction

Cone calorimeter

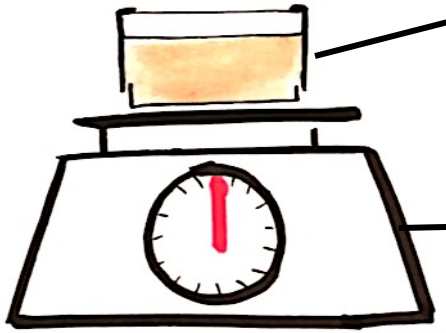


Exhaust hood

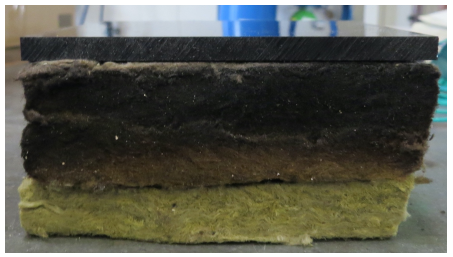
- Gasanalyzer: CO, CO_2, O_2
- Heat release rate

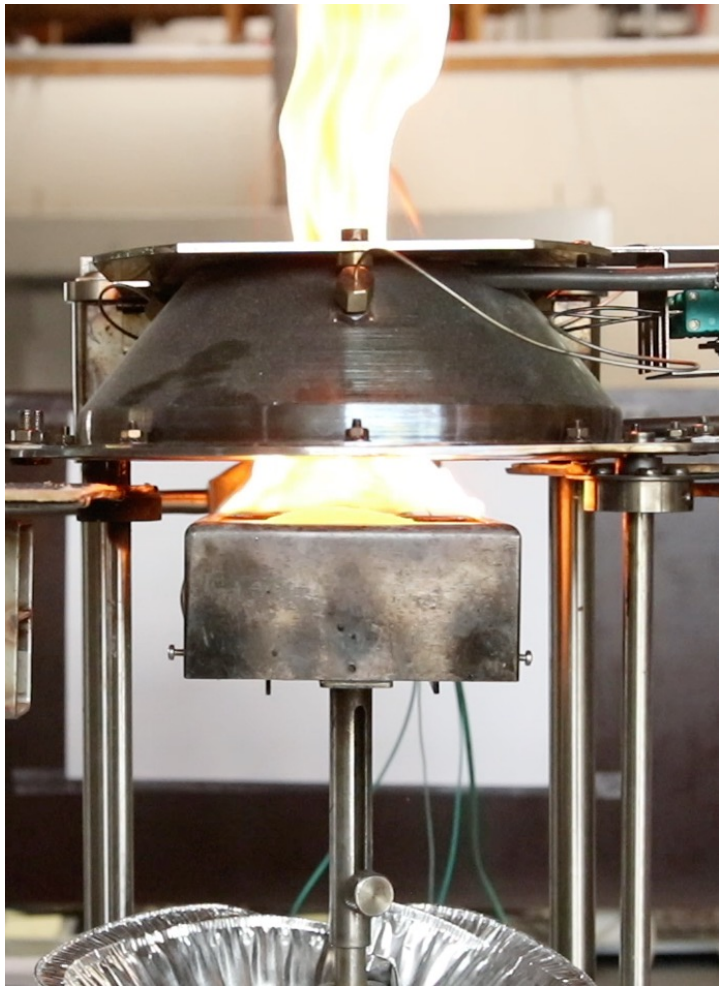
Heater

Sample holder



Balance





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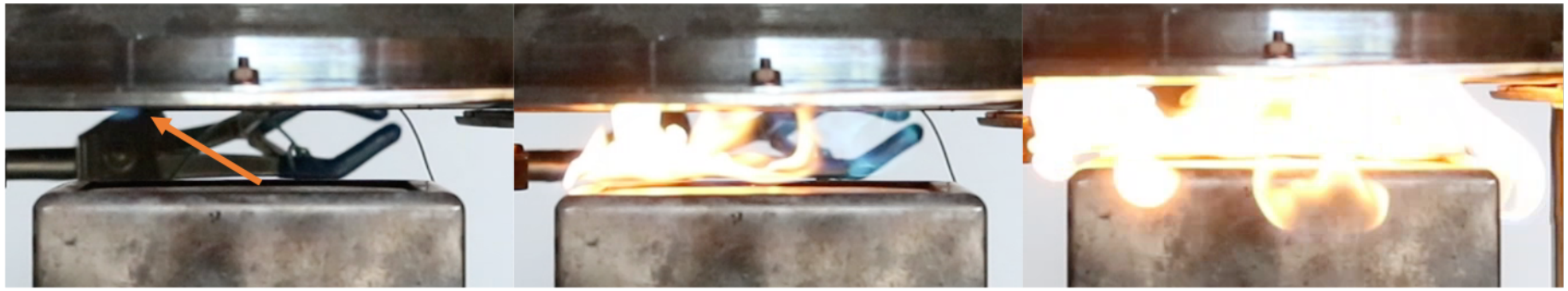
Results

Black vs Transparent

- Ignition time:
  - Higher heat flux → lower ignition time
  - No significant difference between black and transparent
- Ignition at cone heater
- Deformation of the sample surface

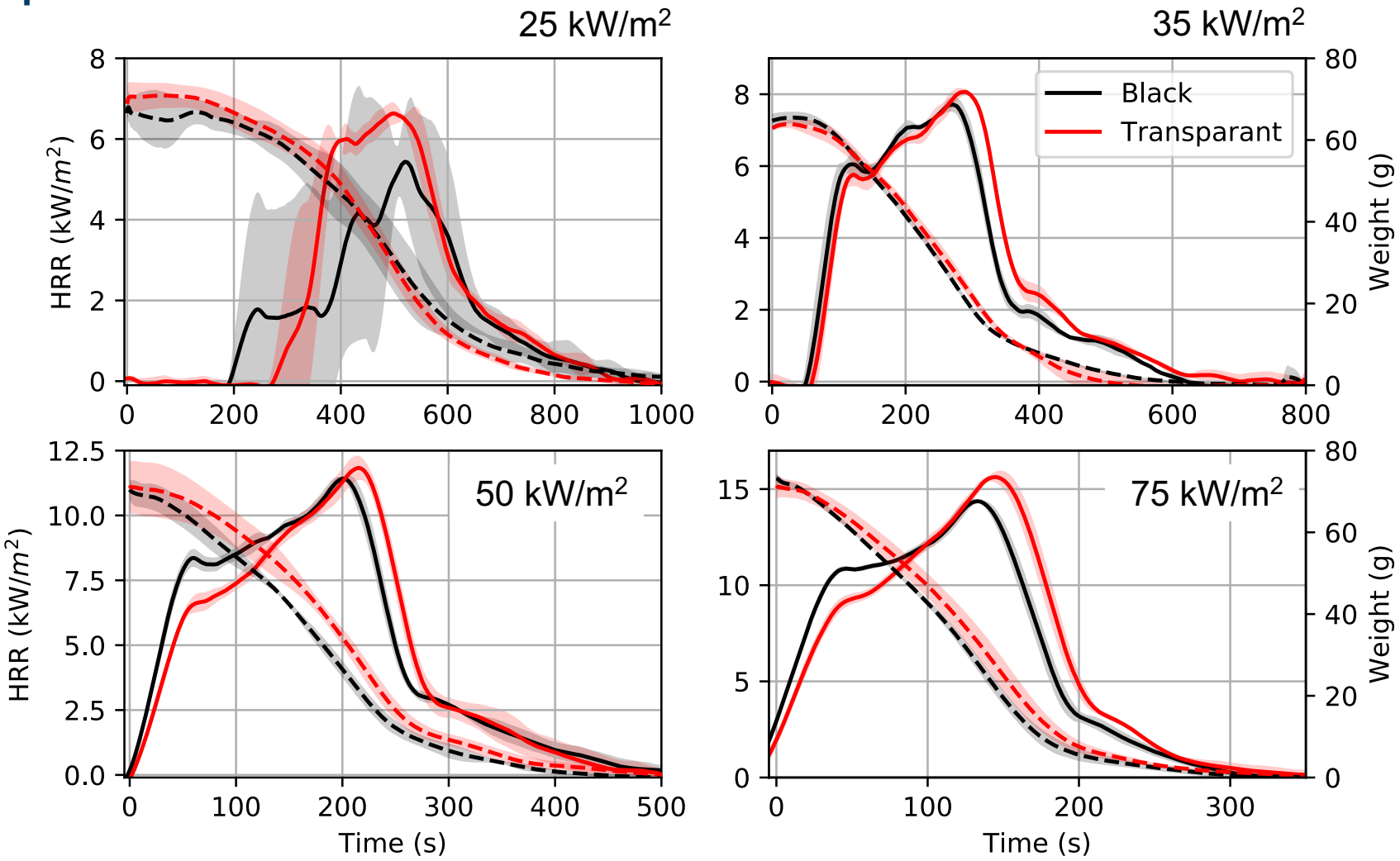
	Black	Transparent
C (wt%)	59.7 ± 0.1	59.8 ± 0.5
H (wt%)	7.83 ± 0.01	7.75 ± 0.09
O (wt%)	32.4 ± 0.01	32.4 ± 0.01

	Black	Transparent
25 kW/m^2	461 ± 154 s	350 ± 29 s
35 kW/m^2	82 ± 10 s	90 ± 6 s
50 kW/m^2	31 ± 2 s	25 ± 4 s
75 kW/m^2	13 ± 3 s	14 ± 1 s



Results

Black vs Transparent



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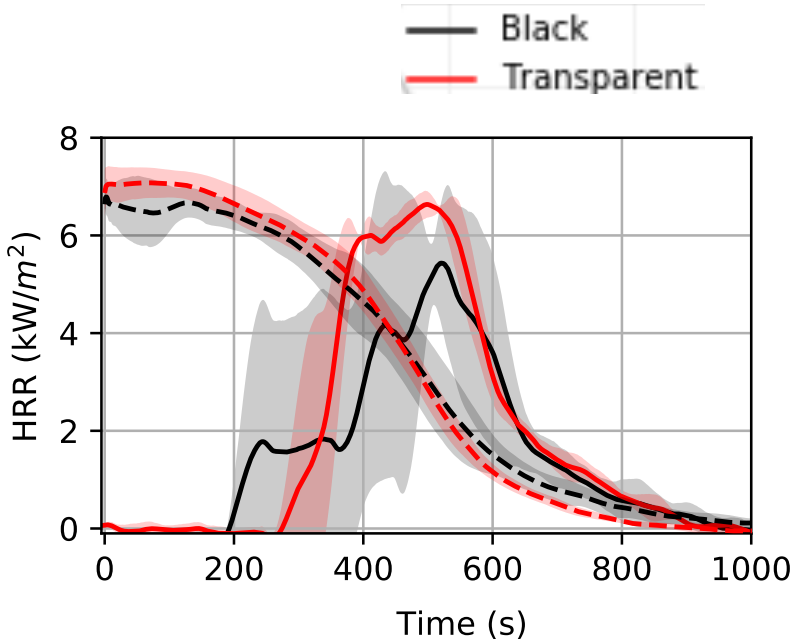
Results

Black vs Transparent

- Large uncertainty
- Large spread in ignition time
- Influence from external factors

➢ Inconclusive

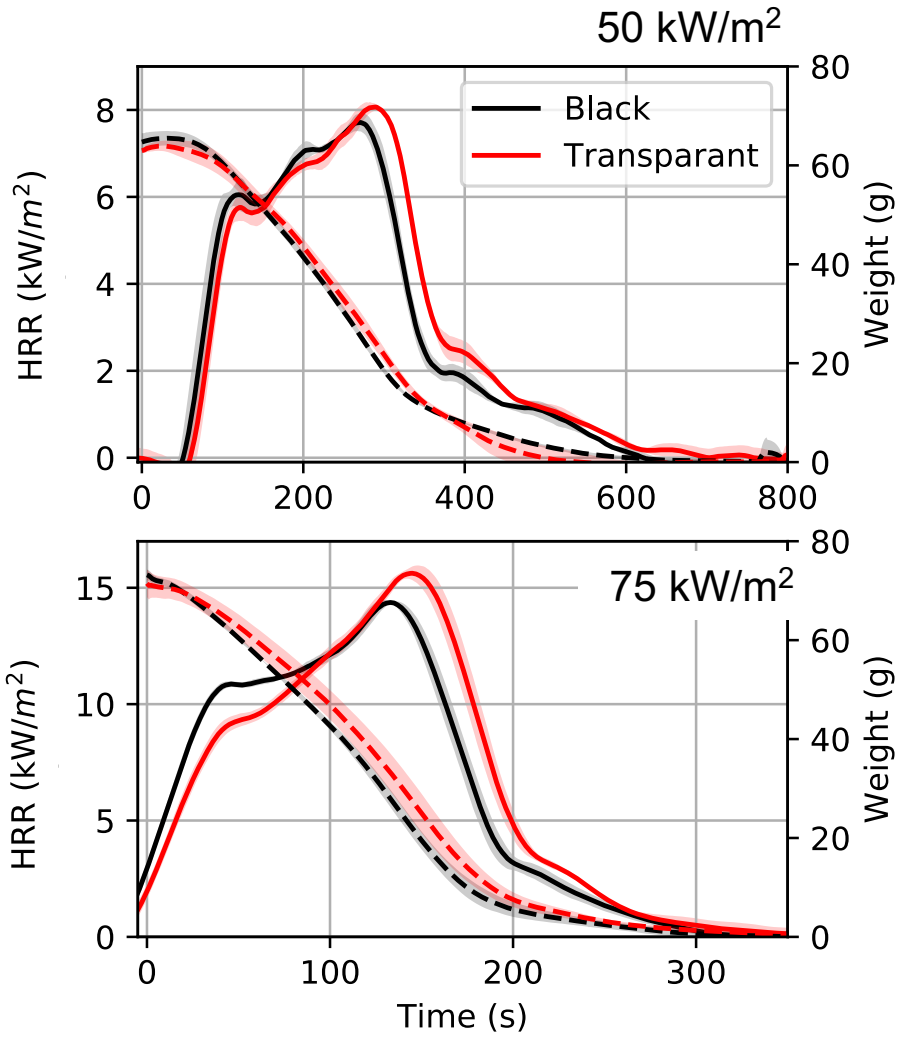


Results

Black vs Transparent

- 25 kW/m^2: inconclusive
- 35, 50 and 75 kW/m^2
  - Black: faster mass loss rate
  - Black: initially, stronger increase in HRR
  - Transparent: higher peak HRR
  - Difference becomes larger for higher heating flux

➢ Difference caused by absorption coefficients?



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  - **Rods vs plates**
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Results

Plate vs rods

- Ignition time:
  - Higher heat flux → lower ignition time
  - Lower ignition time for plates?
- Ignition at cone heater
- Deformation of the sample surface

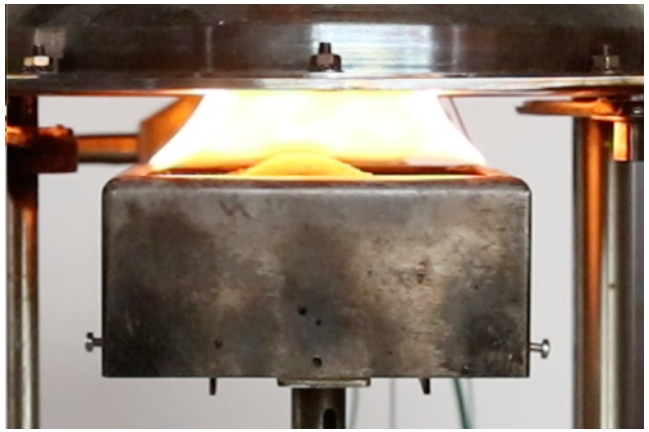
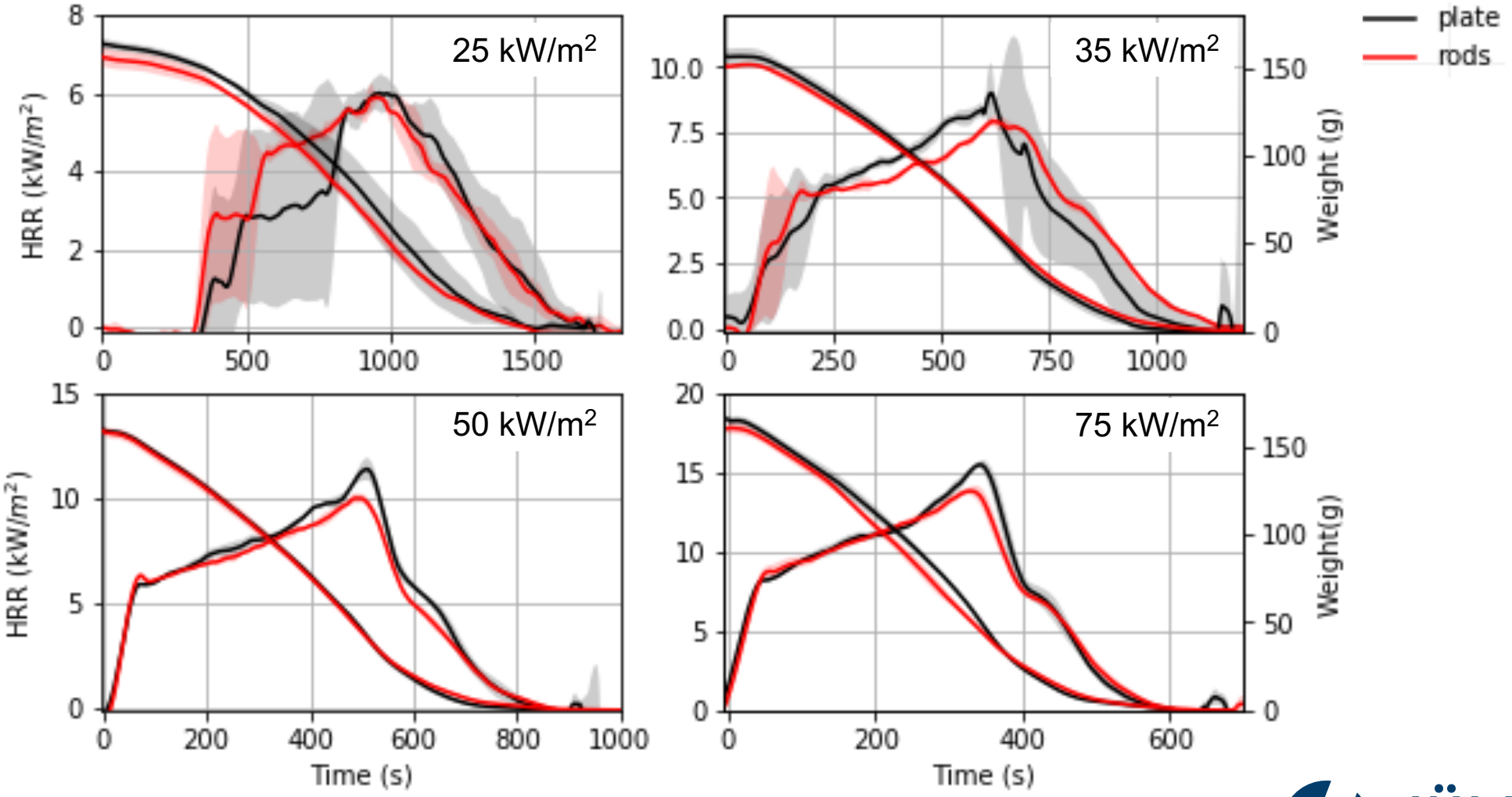


	Plate	Rods
25 kW/m²	553 ± 197 s	420 ± 89 s
35 kW/m²	130 ± 42 s	104 ± 2 s
50 kW/m²	35 ± 3 s	41 ± 2 s
75 kW/m²	14 ± 1 s	24 ± 3 s

Results

Plate vs rods



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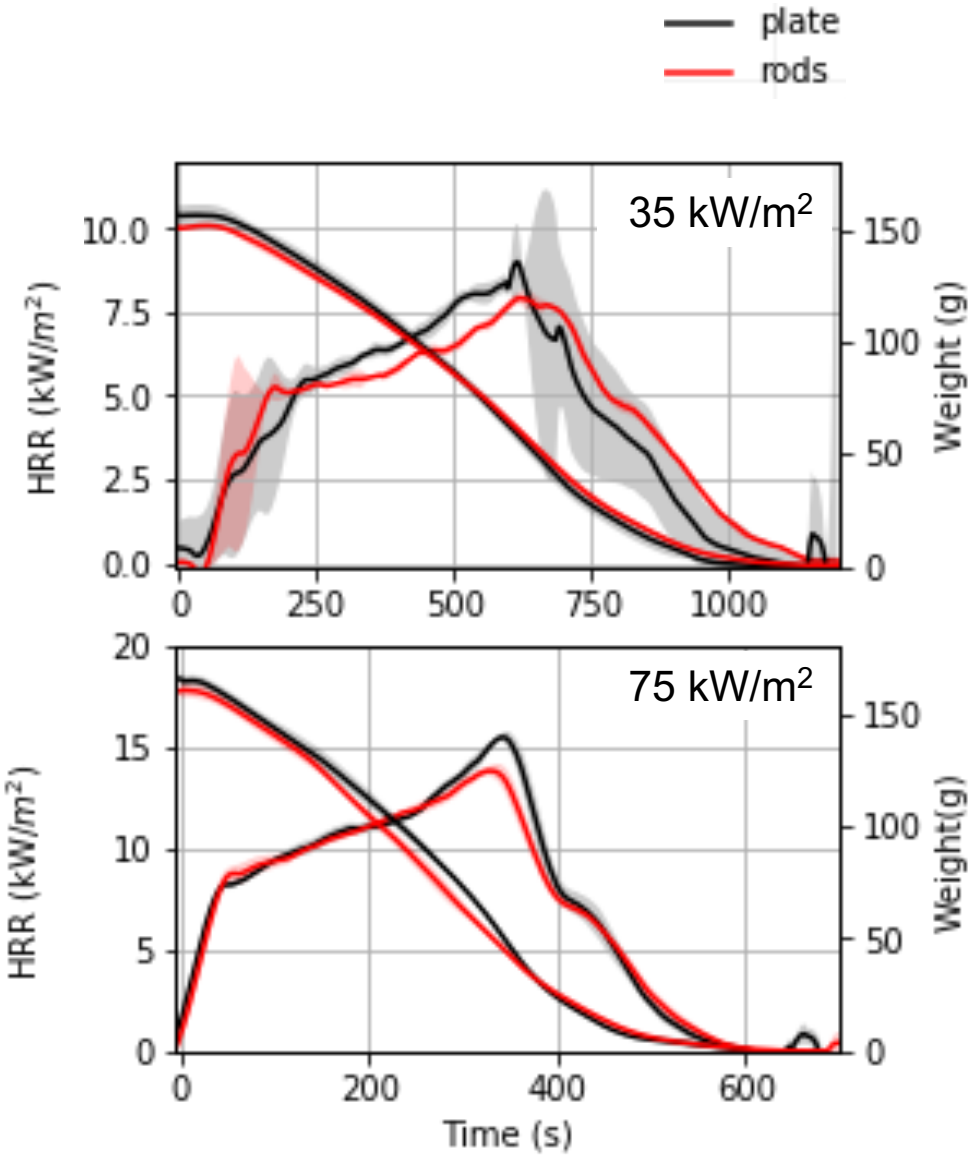
Results

Plate vs rods

- 25 kW/m^2: large uncertainty
- 35, 50 and 75 kW/m^2
  - Similar mass loss
  - Higher peak HRR for plates
    - Plates have slightly higher mass.



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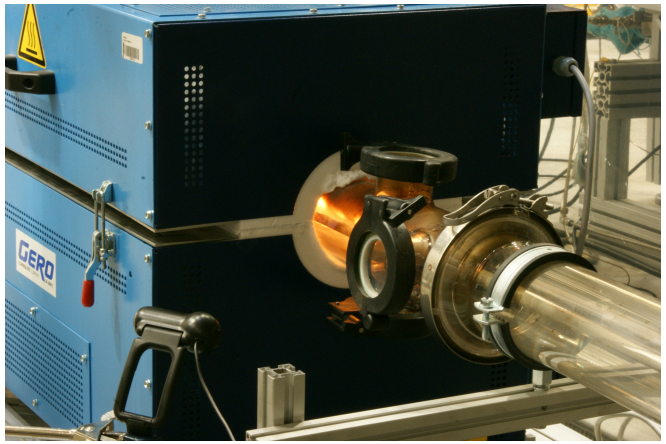
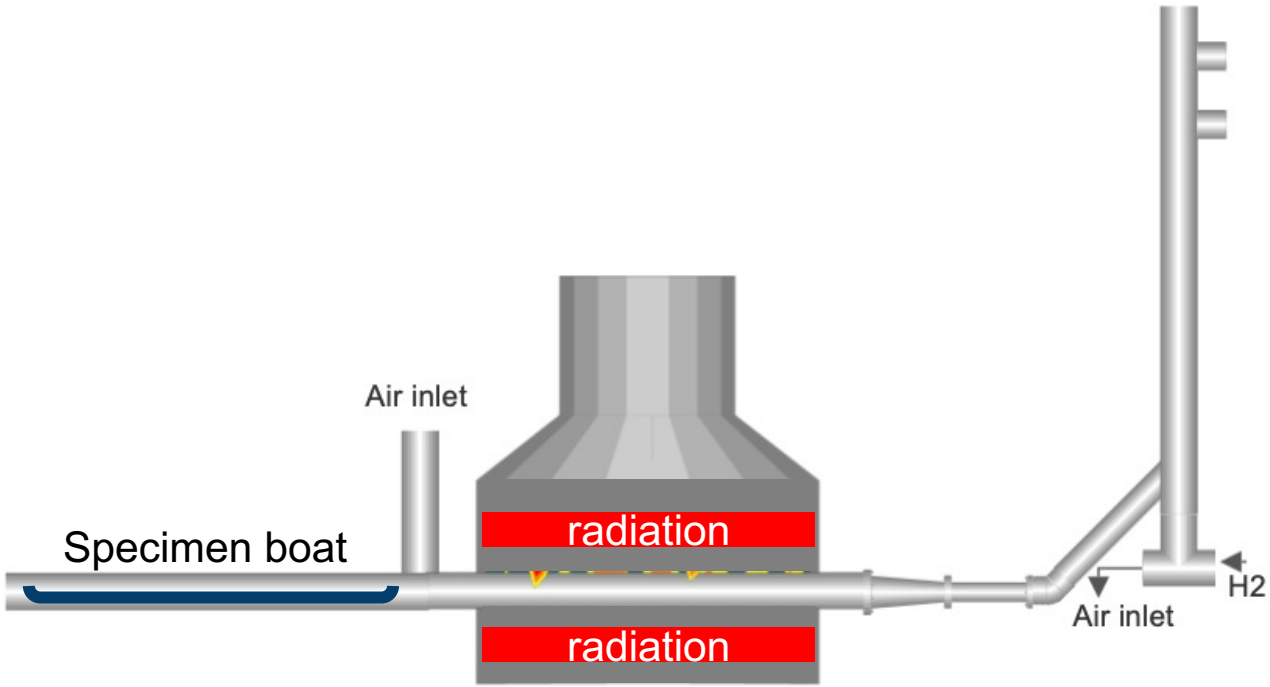
Tube furnace



- Specimen size: 60 to 80 cm
- Movable specimen boat
  - Experiments at specific temperature
  - Experiments with a certain heating rate
- Maximal temperature: 1000˚C
- Maximal heating rate: 300˚C/h
- Analytics: CO, CO_2,O_2
  → Heat release rate
- Controlled atmosphere



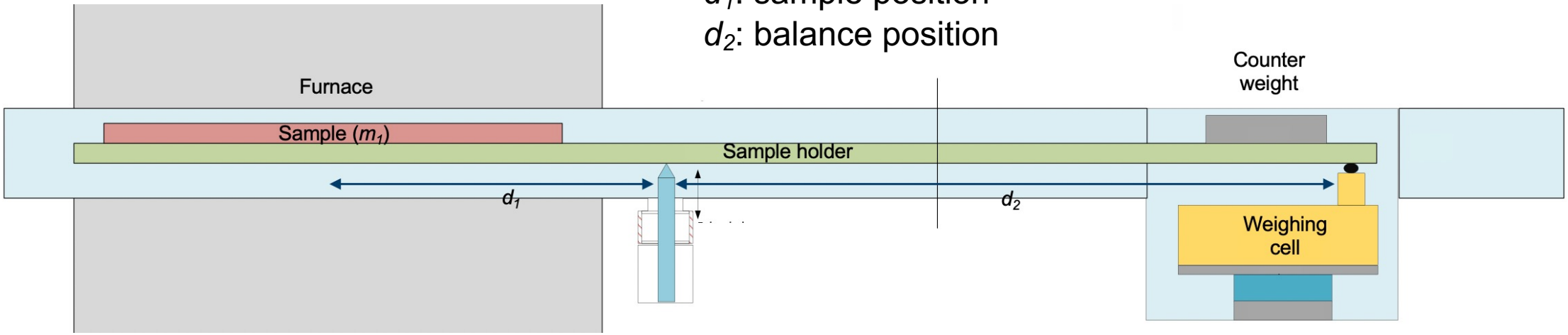
Tube furnace

Additional diagnostics: the balance

- Both for isothermal as for dynamic experiments
- Seesaw mechanism:
  sample on one side, weighing cell on the other side

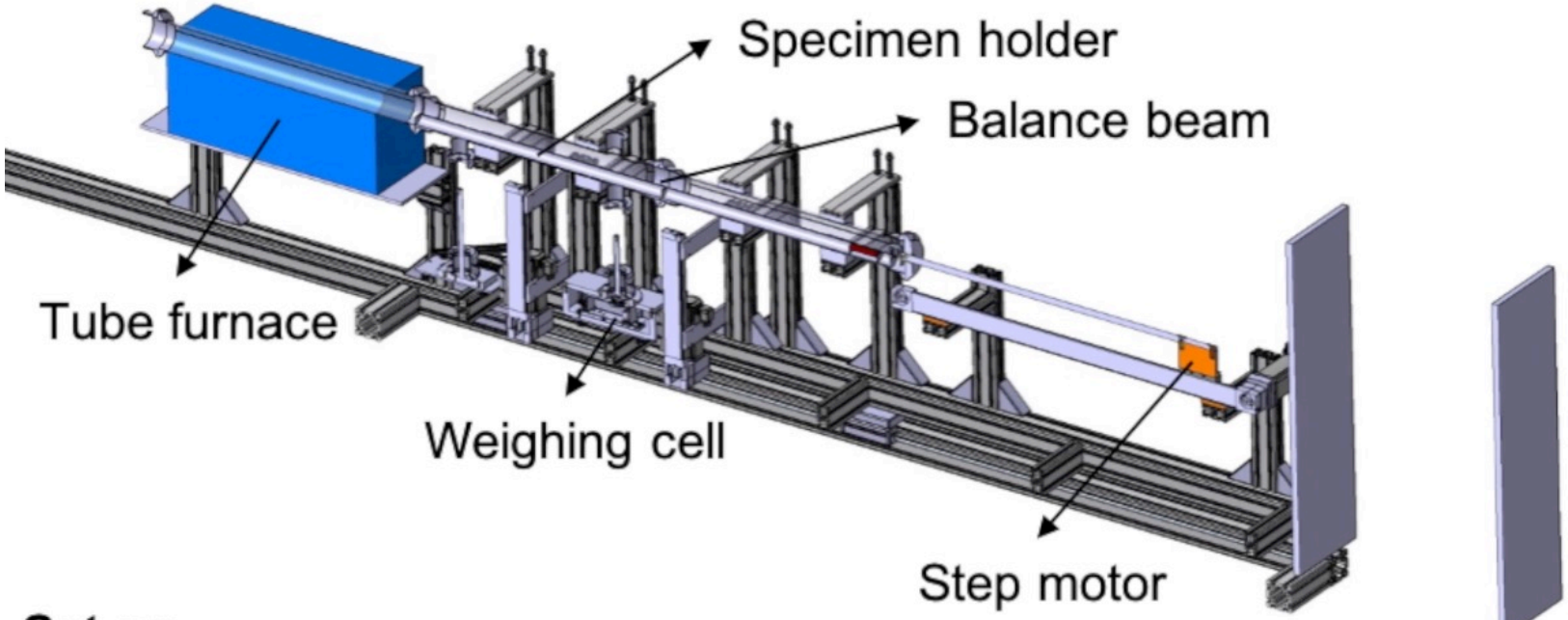
$$F_{balance} = \frac{m_1 g\, d_1}{d_2}$$

$F_{balance}$: force on the balance
g: gravitational constant
m_1: sample mass
d_1: sample position
d_2: balance position



Tube furnace

Additional diagnostics: the balance



Set-up

Overview

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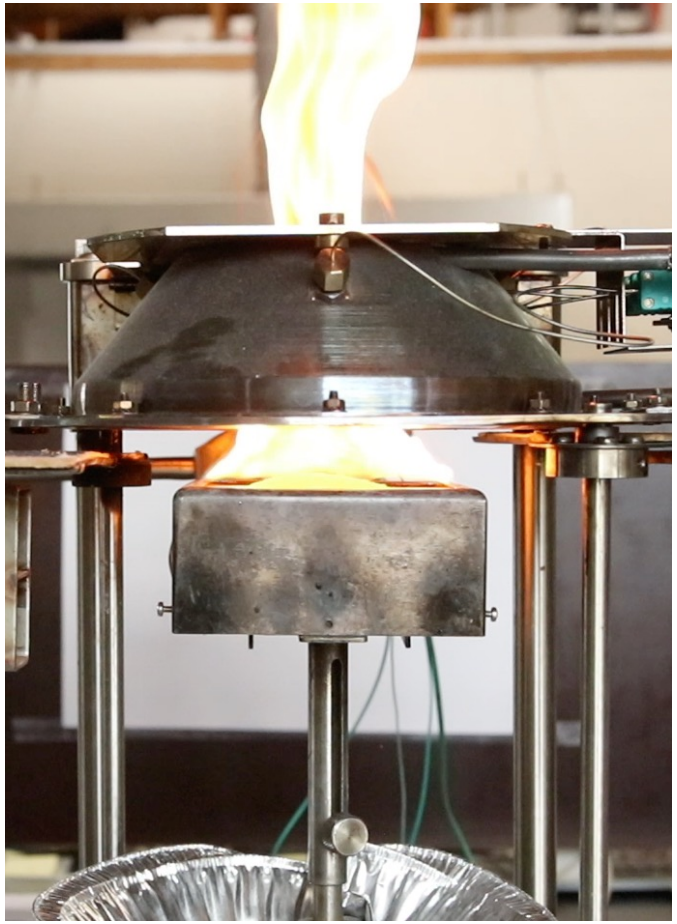
Conclusion & outlook

- Transparent vs. Black:
  - No difference in ignition time
  - Black: faster mass loss rate, stronger initial increase of HRR
  - Transparent: higher peak HRR
  - Difference becomes larger for higher heating flux

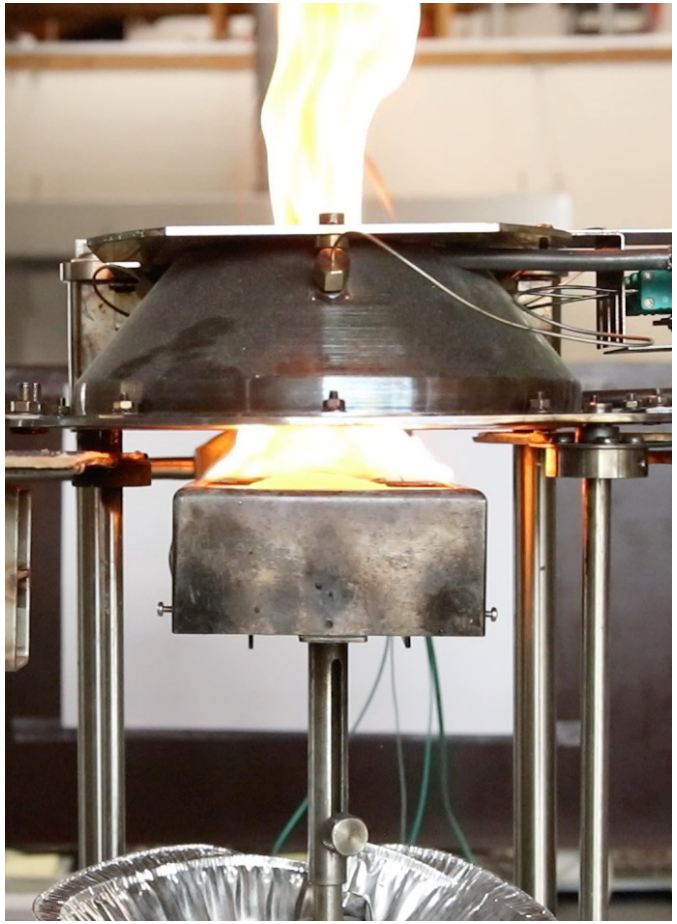
  → Difference in absorption coefficient?

- Plates vs Rods
  - Difference in peak HRR
  - To be further analysed



Conclusion & outlook

- Further analyse cone data
  - Repeat under inert atmosphere ?
- Start tube furnace experiments
  - PMMA experiments
    - ➢ Compare to TGA and cone
  - Cable experiments
    - ➢ TGA experiments have been started



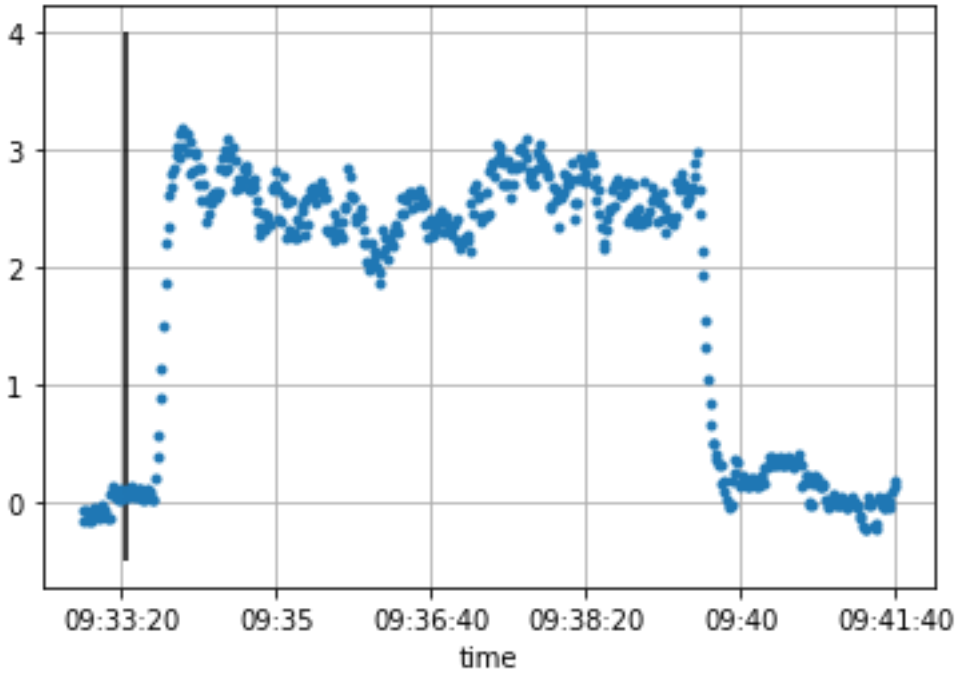
Reference

[1] Huang X, Nakamura Y (2020) *A review of fundamental combustion phenomena in wire fires*. Fire Technol 1–32. https://doi.org/10.1007/s10694-019-00918-5

[2] *Private communication with C. Tretin*

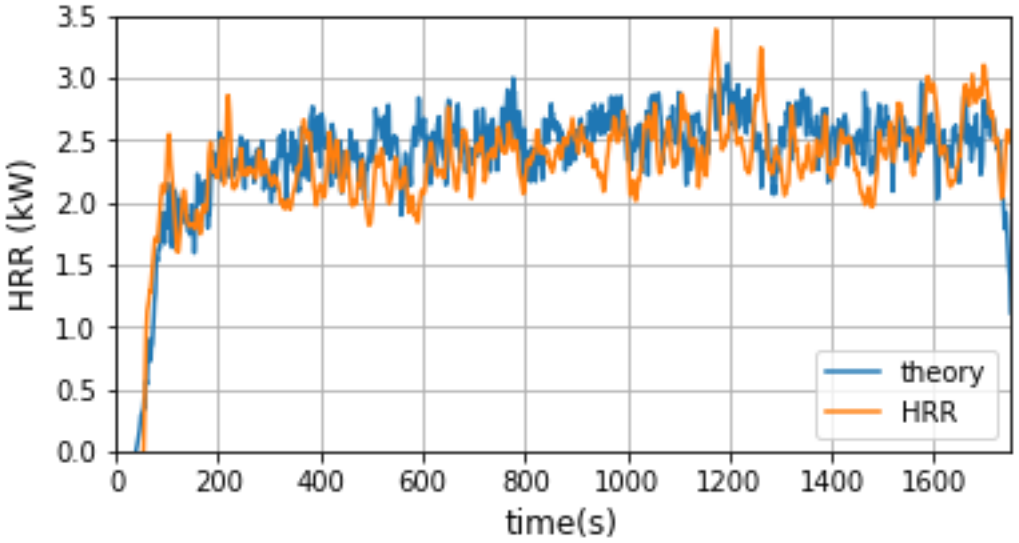
Delay time HRR

- Methanol tests
- 28 +/- 3 s



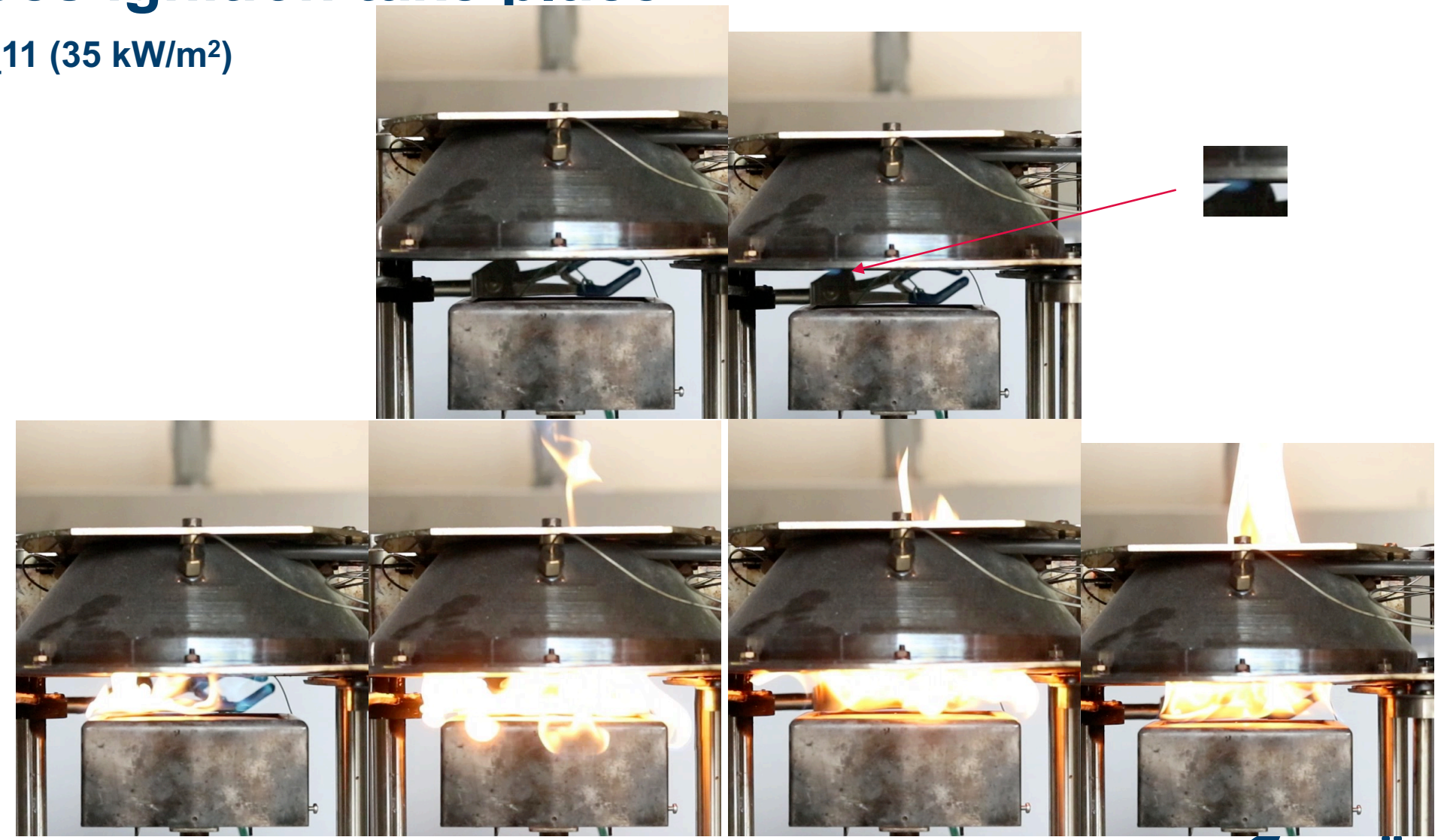
HRR calibration

- Methanol tests



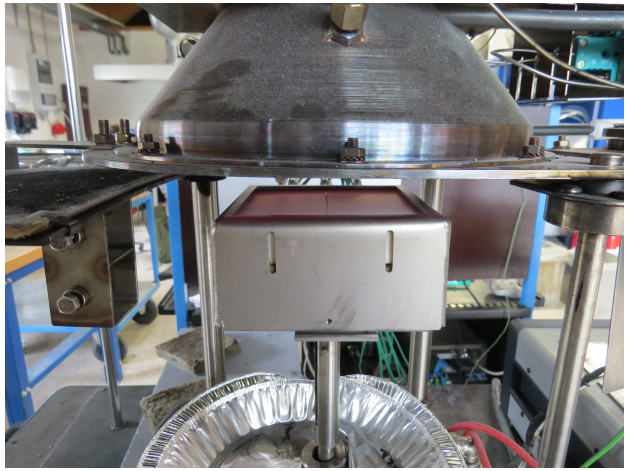
Where does ignition take place

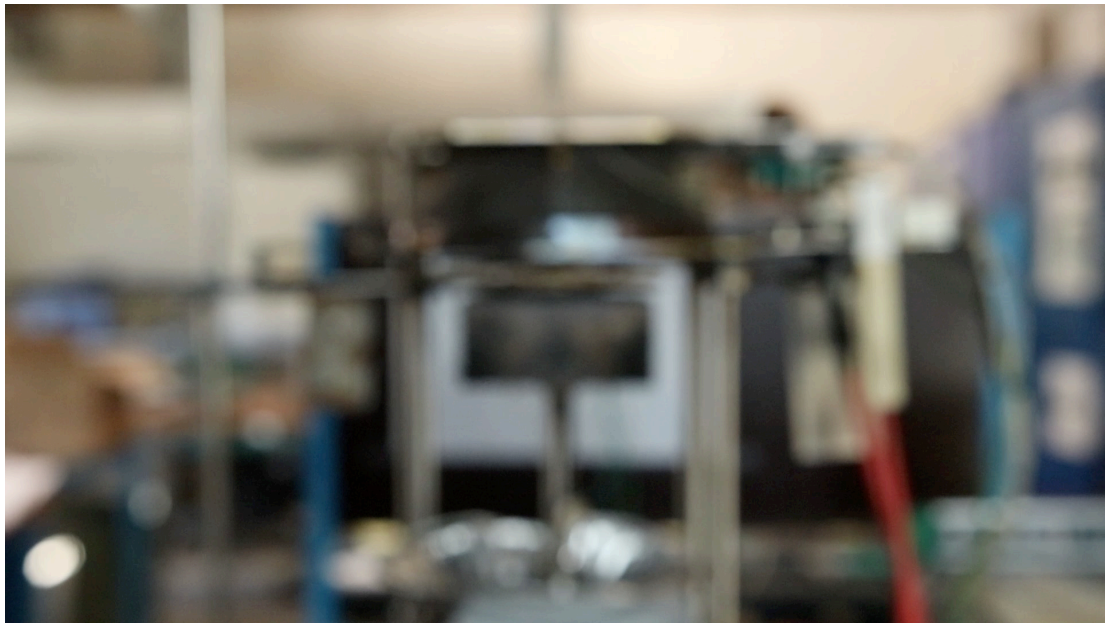
PMMA_T_cone_11 (35 kW/m²)



Cone calorimeter

- Auto-ignition tests
  → fds?



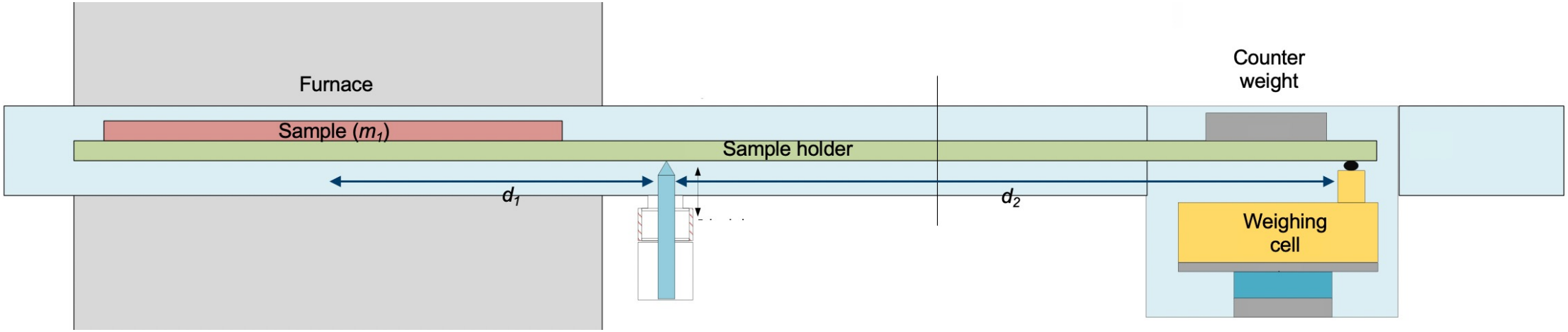


Tube furnace

Additional diagnostics: the balance

Remaining challenges:

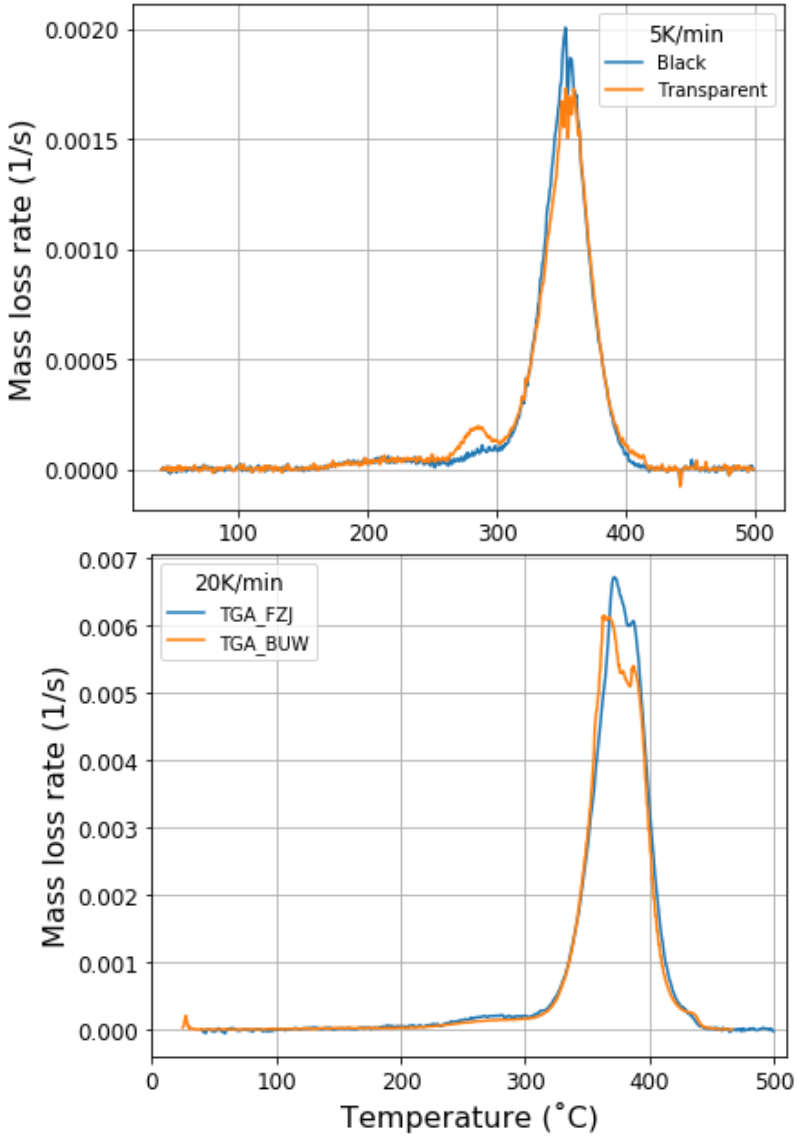
- Buoyancy effects: correct with zero curves (weight measurements without sample or with inert sample)
- Effect of thinning of the material
  → Changes the centre of mass
- Flow during the experiments
- Mass loss during moving in and out of the sample
  → Perform pre-experiment: moving in and out sample to estimate weight loss



Outlook & Conclusion

Thermogravimetric analyser

- Nitrogen atmosphere:
  - Slight differences between black and transparent PMMA
  - Difference between different devices: increasing with heating rate
  - ➢ Are these differences still important for large scale experiments
- Start air-atmosphere experiments with PMMA



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