Lateral flame spread on PMMA in vertical orientation

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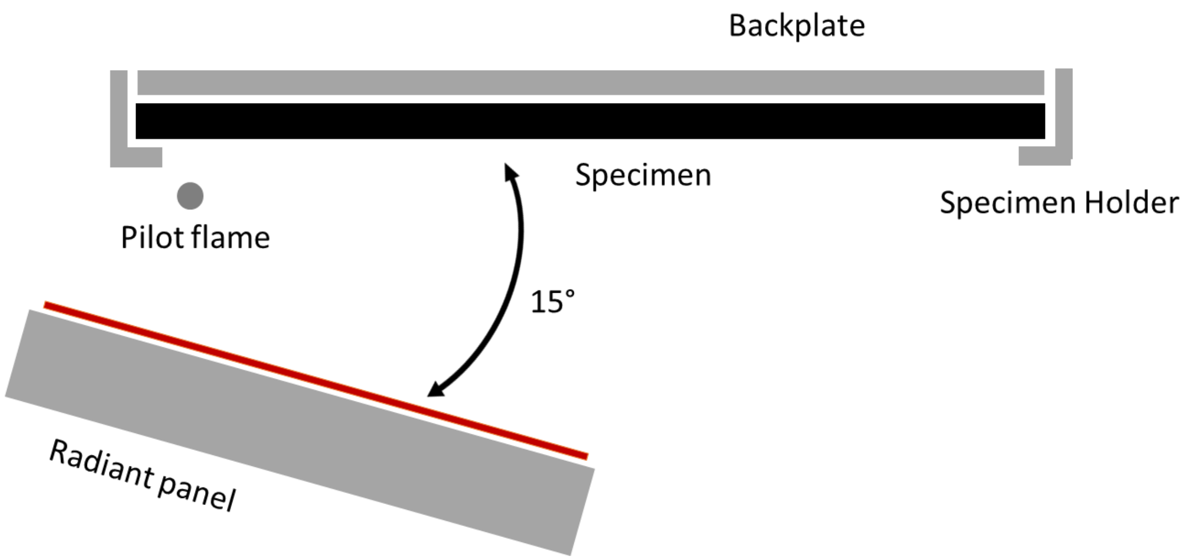
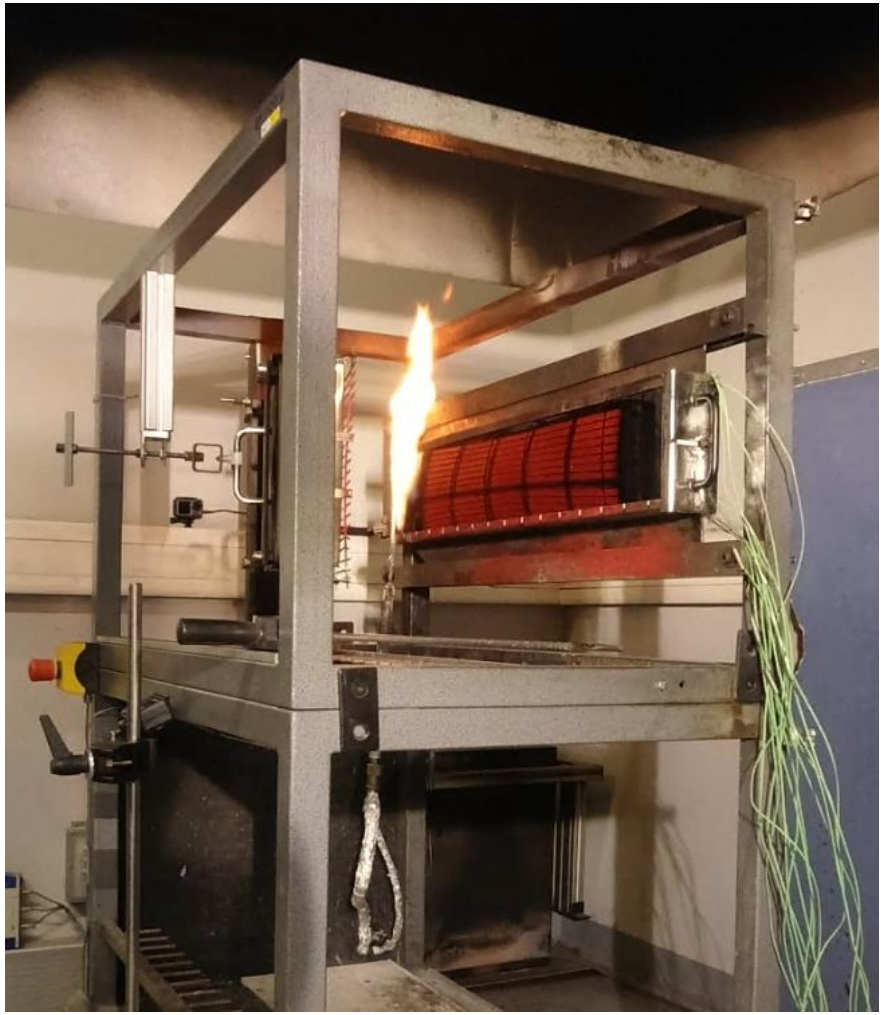
Standardised Experiment

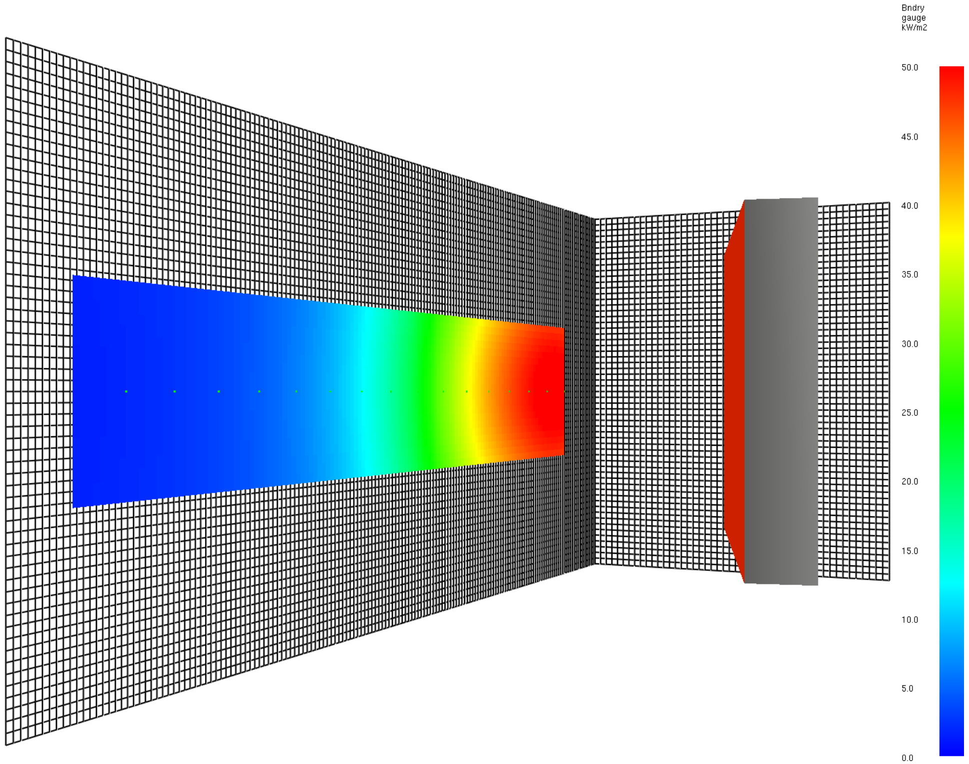
- Lateral flame spread in vertical orientation from ISO 5658-2 [1]
- Radiant panel in an angle of 15°

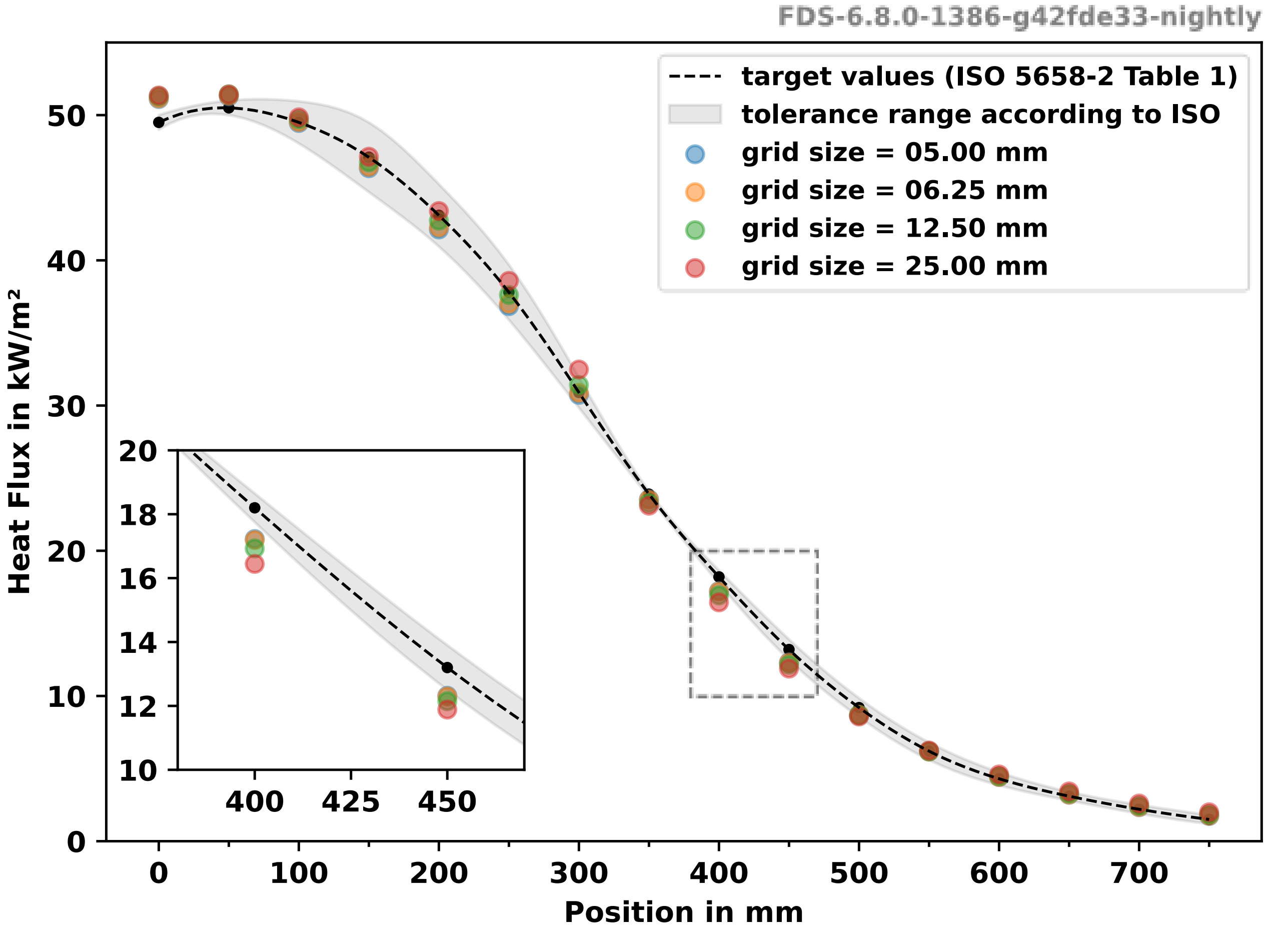




FDS Validation Case

- with &GEOM tilted obstruction
- determination of radiator temperature with inverse modeling process PROPTI [2]





FDS Pyrolysis Models

Material: black, casted PMMA, 6 mm

Simple Pyrolysis	Complex Pyrolysis
– Simplified fire spread based on ignition temperature – SPyro: scaled burning rate dependant on heat feedback and thickness of material	– Fire spread based on fundamental principles (Arrhenius equation)
– Parameters from Cone Calorimeter experiments	– Parameters from experiments on multiple scales (TGA, MCC, Cone Calorimeter etc.)

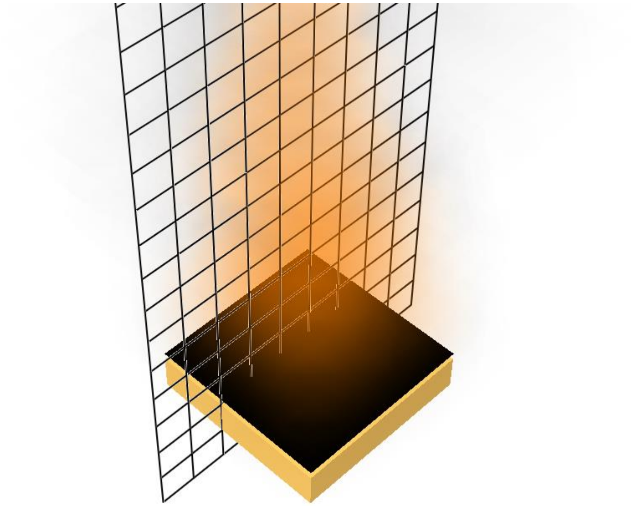
1. Optimization for Input parameters with PROPTI

2. Comparison: Parameters estimated by Hehnen [3] from MaCFP Database

Parameter Optimization SPyro

Relations	Heat fluxes
Heat Release Rate	25,50,75
Ignition times	25,50,75
Front temperatures during flaming [4]	25,50,75
Backside temperatures	50

Optimization parameters
Ignition temperature
Heat of vaporization
Conductivity
Heat capacity
Emissivity

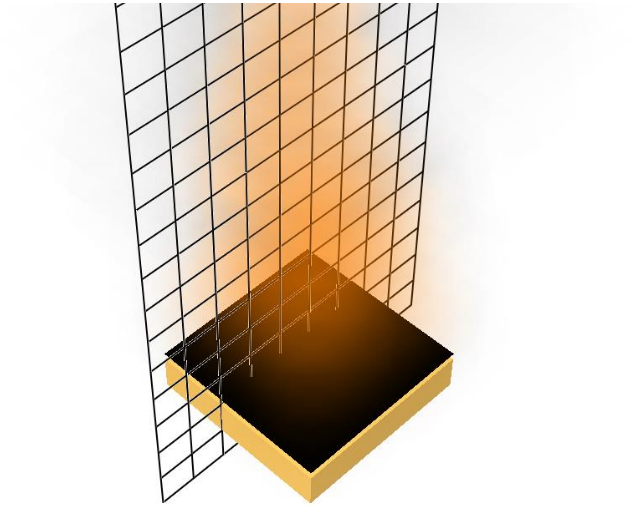


Cell sizes of cone geometries
C3
C5

Parameter Optimization SPyro

Relations	Heat fluxes
Heat Release Rate	**25,50,75**
Ignition times	**25,50,75**
Front temperatures during flaming [4]	**25,50,75**
Backside temperatures	50

Optimization parameters	
Ignition temperature	
Heat of vaporization	
Conductivity	**taken from literature [5]**
Heat capacity	
Emissivity	

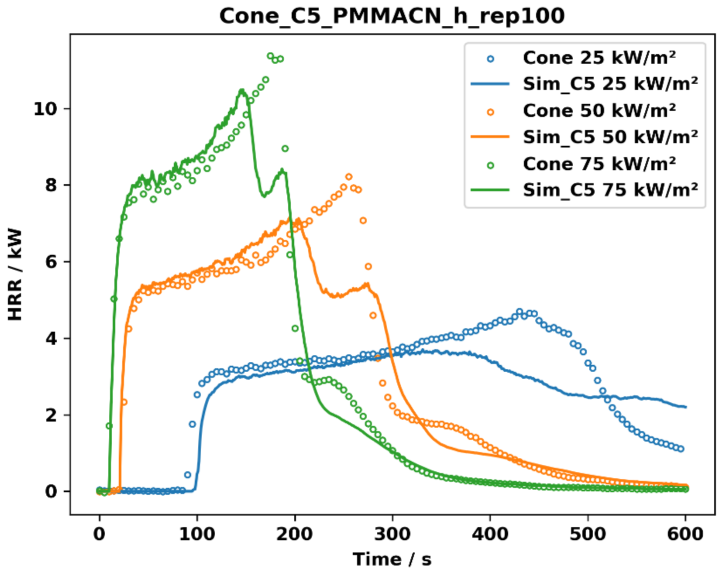


Cell sizes of cone geometries
C3
C5

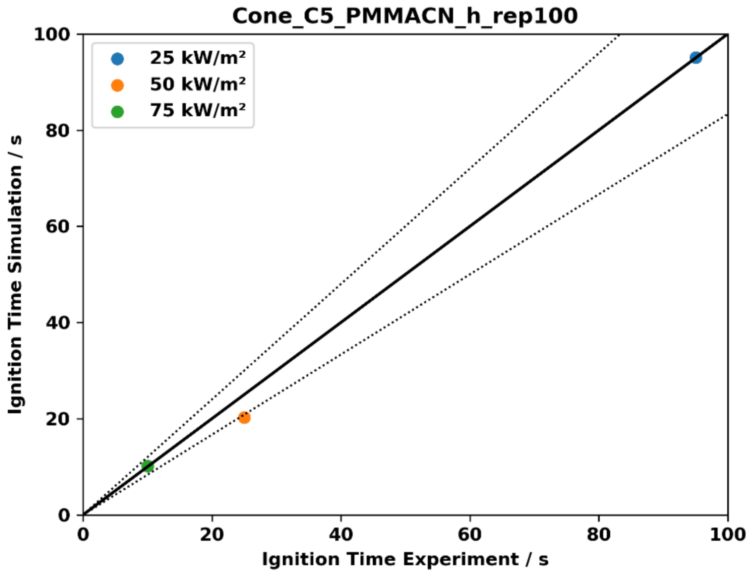
Optimisation Results

Number of iterations: 120
Parameters with best fit: Ignition temperature 341°C
Heat of vaporization 2038 kJ/kg

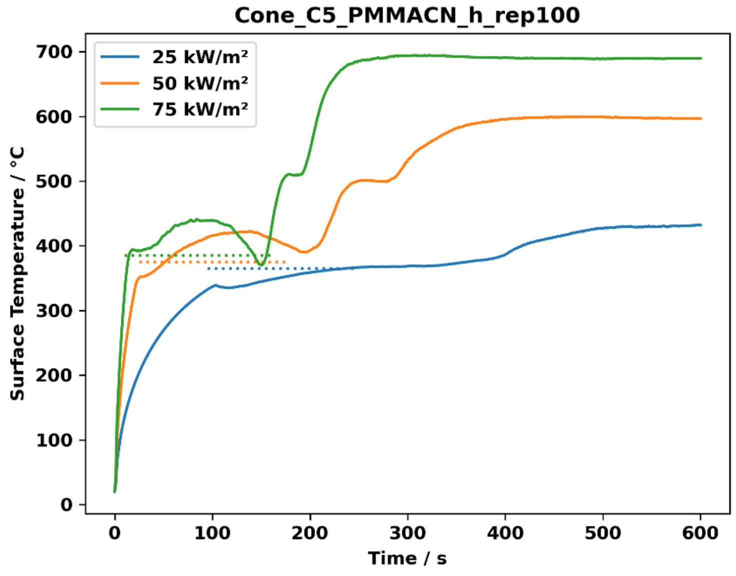
Heat Release Rate



Ignition time

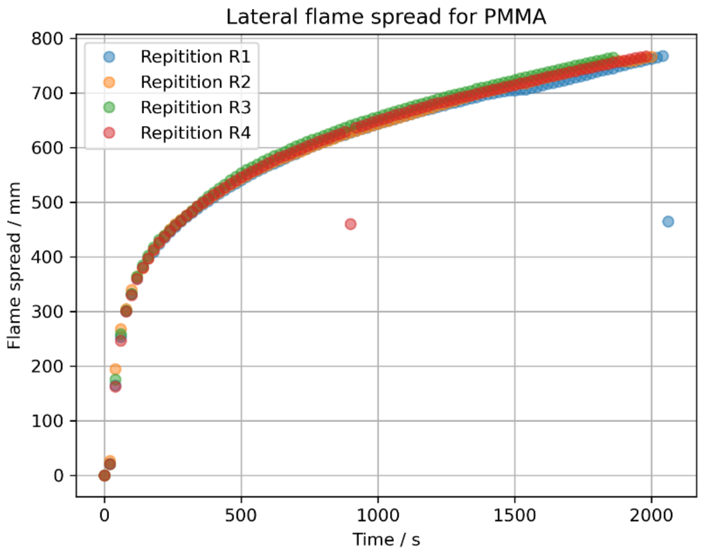


Front temperature during flaming



Experiments Lateral Flame Spread

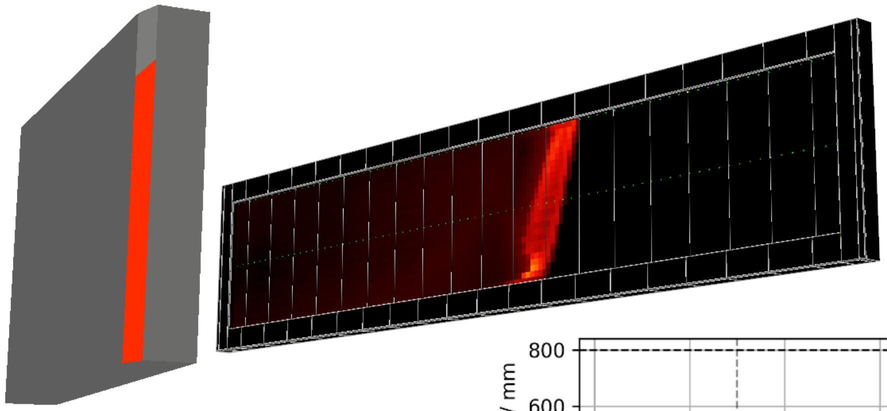
- ISO 5658-2 experiments in April 2024 with black, casted PMMA, 6 mm thickness
- Position of flame front extracted from thermography data by Forschungszentrum Jülich
- Flame spread over entire samplewidth

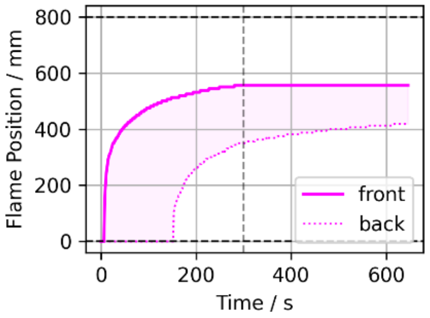


Simplification of Geometry

Validation Geometry:

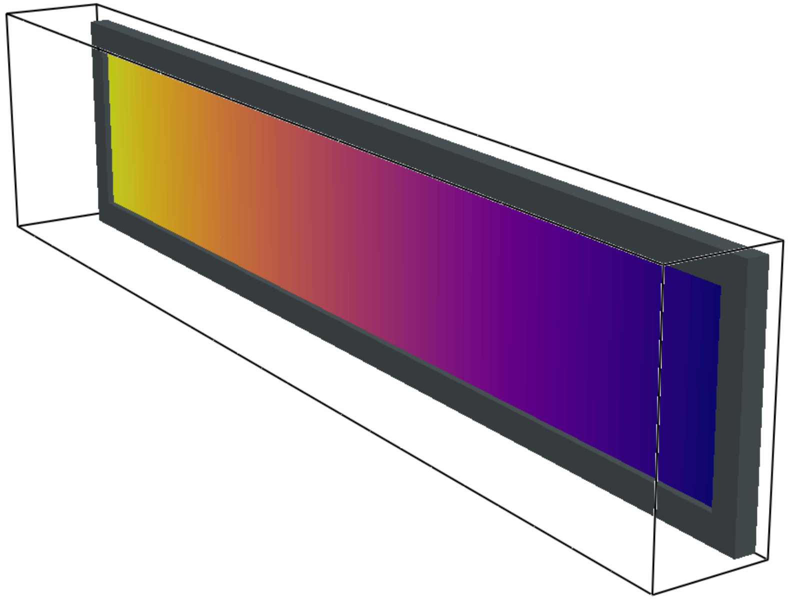
- cell sizes ≥ 5 mm no self sustained burning
- smaller cell sizes not feasable with available computing capacity





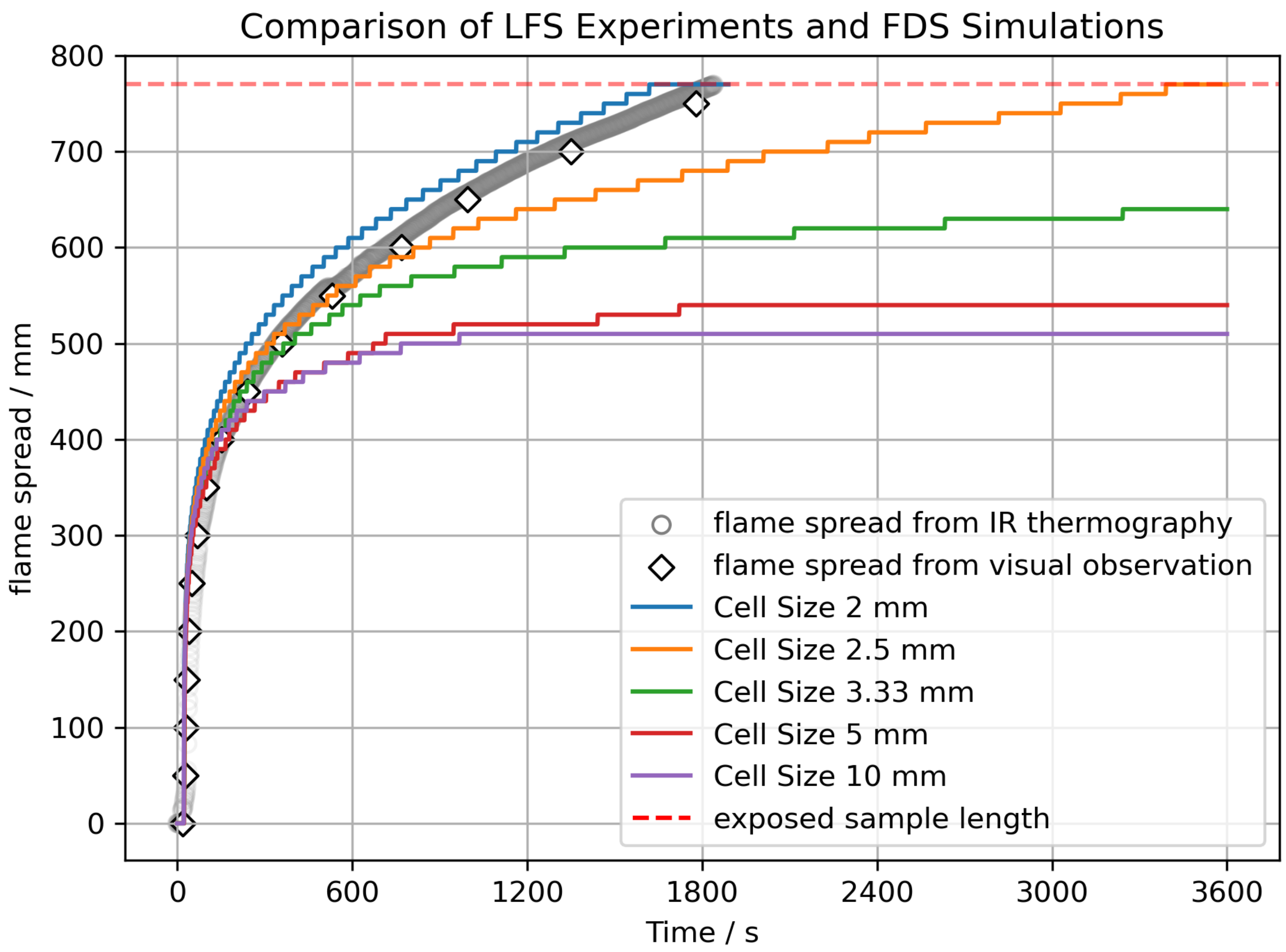
Simplified Geometry:

- direkt application of external heat flux on surface section
- reduction of the domain and computing costs
- self sustained burning ≤ 2.5 mm cell size



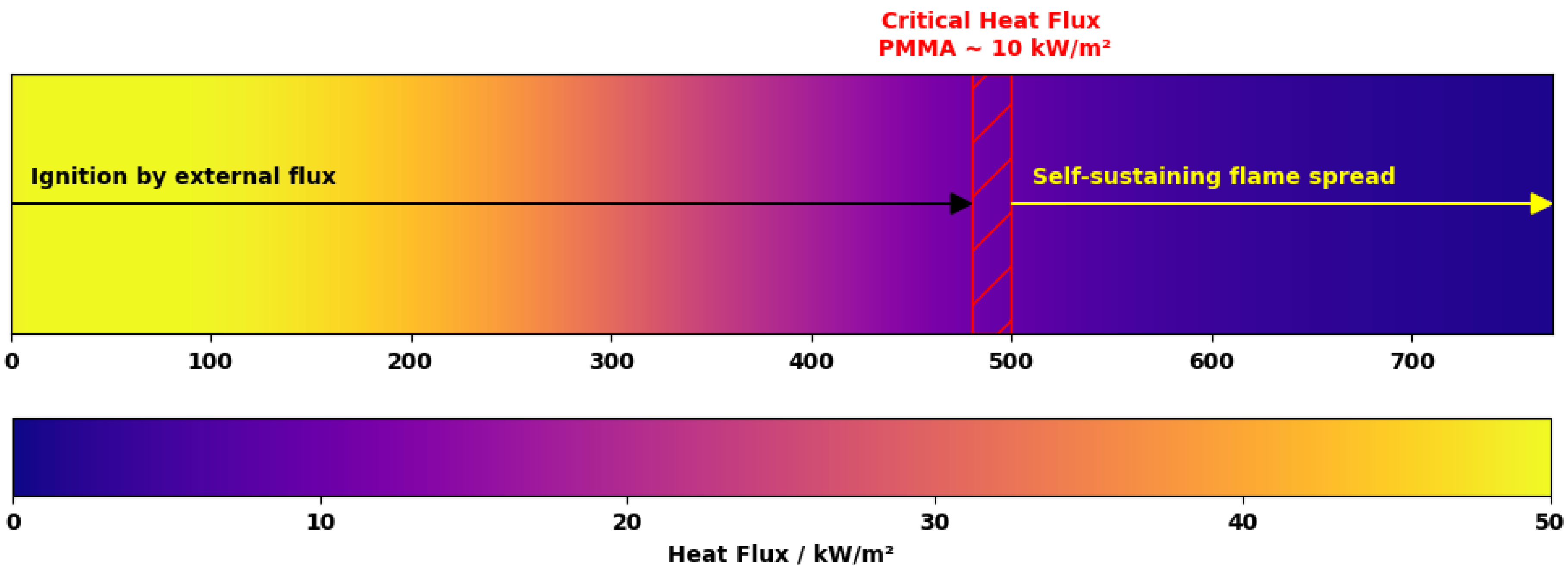
Comparison with experimental flame spread

- flame spreads further with lower cell size
- with cell size ≤ 2.5 mm flame spreads until end of sample
- results of cell size 2.0 mm comparable with experiment



Conclusion

- In this setup the cell size has a significant impact on the simulated flame spread.
- With a cell size of 2.0 mm and the simple pyrolysis approach, the flame spread between experiment and simulation is comparable.



Outlook

- Comparison between validation geometry and simplified geometry
- Comparison between simple pyrolysis and complex pyrolysis (with parameters from [3])
- Parameter optimisation for all 5 (temperature-dependent) parameters in simple pyrolysis
- Sensitivity analysis of input parameters
- Comparison of effective parameters with literature values
- Experiments and simulations for further materials

Sources and Supporters

[1] ISO 5658-2 – 2006-09: Reaction to fire tests – Spread of flame – Part 2: Lateral spread on building and transport products in vertical configuration.

[2] L. Arnold; T. Hehnen; P. Lauer; C. Trettin; A. Vinayak (2019): Application cases of inverse modelling with the PROPTI framework. Fire Safety Journal. 108. 102835. 10.1016/j.firesaf.2019.102835.

[3] T. Hehnen; L. Arnold (2023): PMMA pyrolysis simulation – from micro- to real-scale. Fire Safety Journal. 141. 103926. 10.1016/j.firesaf.2023.103926.

[4] Rhodes, B. T., & Quintiere, J. G. (1996). Burning rate and flame heat flux for PMMA in a cone calorimeter. Fire Safety Journal, 26(3), 221-240.

[5] FDS Validation Case: NIST_NRC_Parallel_Panels. https://github.com/firemodels/fds/blob/master/Validation/NIST_NRC_Parallel_Panels/FDS_Input_Files/PMMA_60_kW_1_cm.fds (last checked: 13.06.2024)

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