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BIOMASS DEGRADATION UNDER A CONTROLLED HEAT FLUX

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BIOMASS DEGRADATION UNDER A CONTROLLED HEAT FLUX

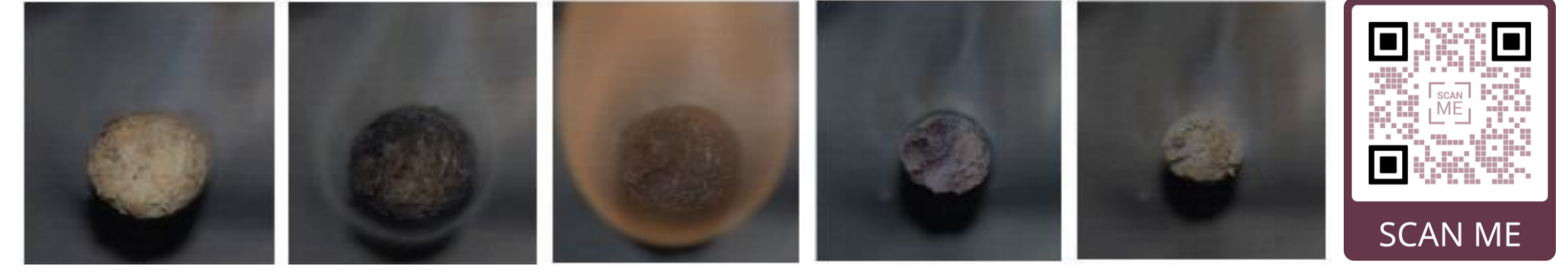
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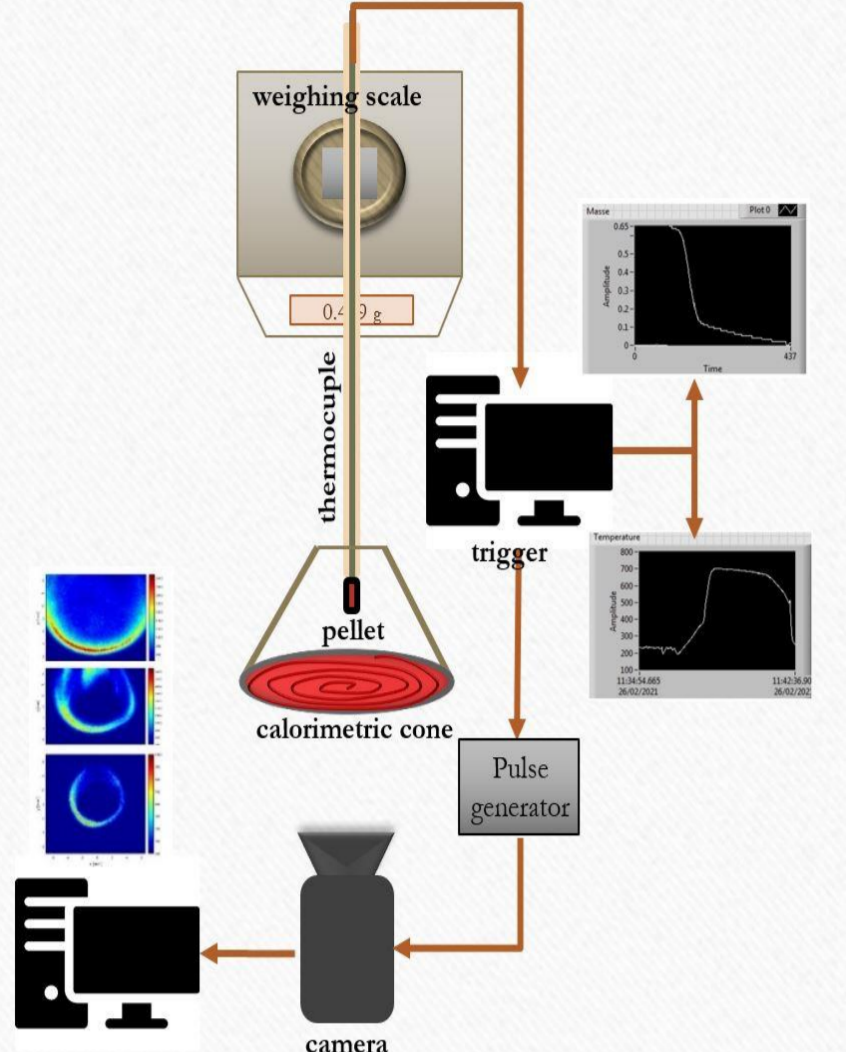


Context

- Biomass → wide variety of sources : composition & properties affect the degradation sequence during combustion
- still require fundamental knowledge to overcome efficiency, pollutant emissions, and ash-related issues
- This work : combustion of single pellets of biomass in a free-ventilated cone calorimeter



Experimental setup



Set up

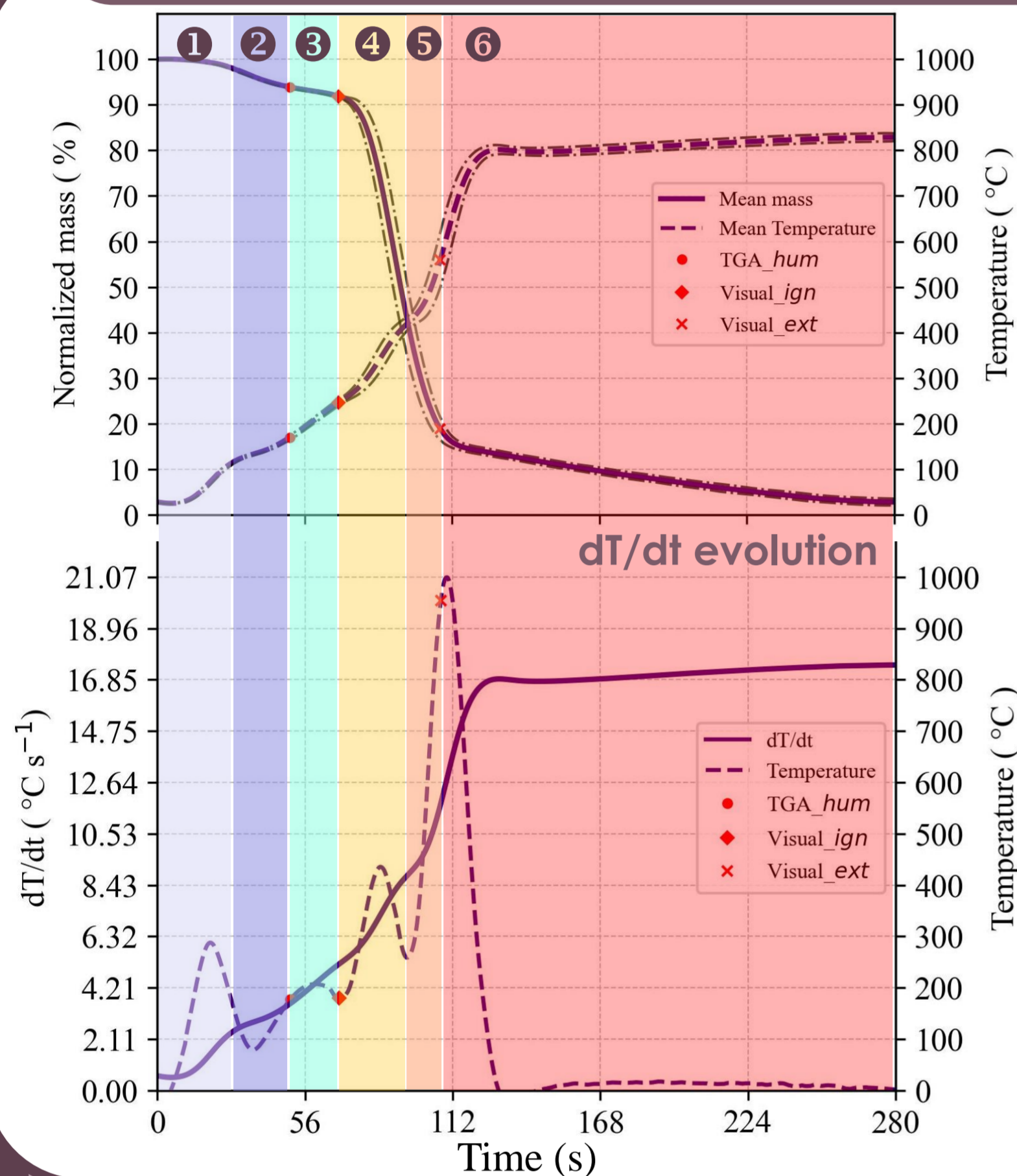
- Cone calorimeter: constant & controlled radiative heat flux
- Measure of M & T at the pellet center
- LabVIEW data synchronisation
- Samples prepared for reproducibility: pellets 6mm dia.

Operating conditions

- Woody pellets = reference biomass
- Miscanthus, herbaceous biomass
- Straw = agricultural waste
- differences in VM, density, porosity affects HRR, modifies thermal properties oxygen supply, ignition time

	WOOD	MISCANTHUS	STRAW		
Elemental	%C	46,08	44,12	41,88	ICP-AES
	%H	6,42	6,02	6,02	
	%O	46,3	49,1	50,74	
Proximate comp.	Humidity (%)	6,21	6,17	6,27	TGA
	Volatile Matter VM (%)	75,43	77,66	70,43	
	Char (%)	18,36	16,16	23,29	
	Ash (%)	0,1	1,9	4,4	
Physical	Fixed Carbon FC (%)	18,26	14,26	18,89	measures
	Volumic mass (kg/m ³)	1250	1150	950-1000	
	Porosity	46%	43%	63%	
	Thermal cond (W K ⁻¹ m ⁻¹)	0,187	0,175	0,157	

Mass degradation of wood pellets at 34kW.m⁻²



Degradation sequential steps

- 1 Pure heating of the sample by thermal conduction,
 - 2 Drying of the sample (6.2% mass loss ATG)
 - 3 Heating & start of devolatilization,
 - 4 Devolatilization & flame → rapid mass loss, intense heating
 - 5 Devolatilization, flame & char oxidation → (dT/dt) increase
 - 6 Pure char oxidation (flame extinction / end of VM)
- lower mass loss, cont. heating up: exothermicity & char thermal diffusivity
 - char oxidation T_c=800°C: balance char oxidation HR & loss by conduction + mass transfer
 - ashes Cooling down: sharp drop of temperature

Maximum of mass degradation during devolatilization / gas combustion phase
Maximum heating during char oxidation phase

Heat flux effect on the degradation process

Flux 21kW.m⁻² : below flame ignition threshold
→ devolatilization & char oxidation

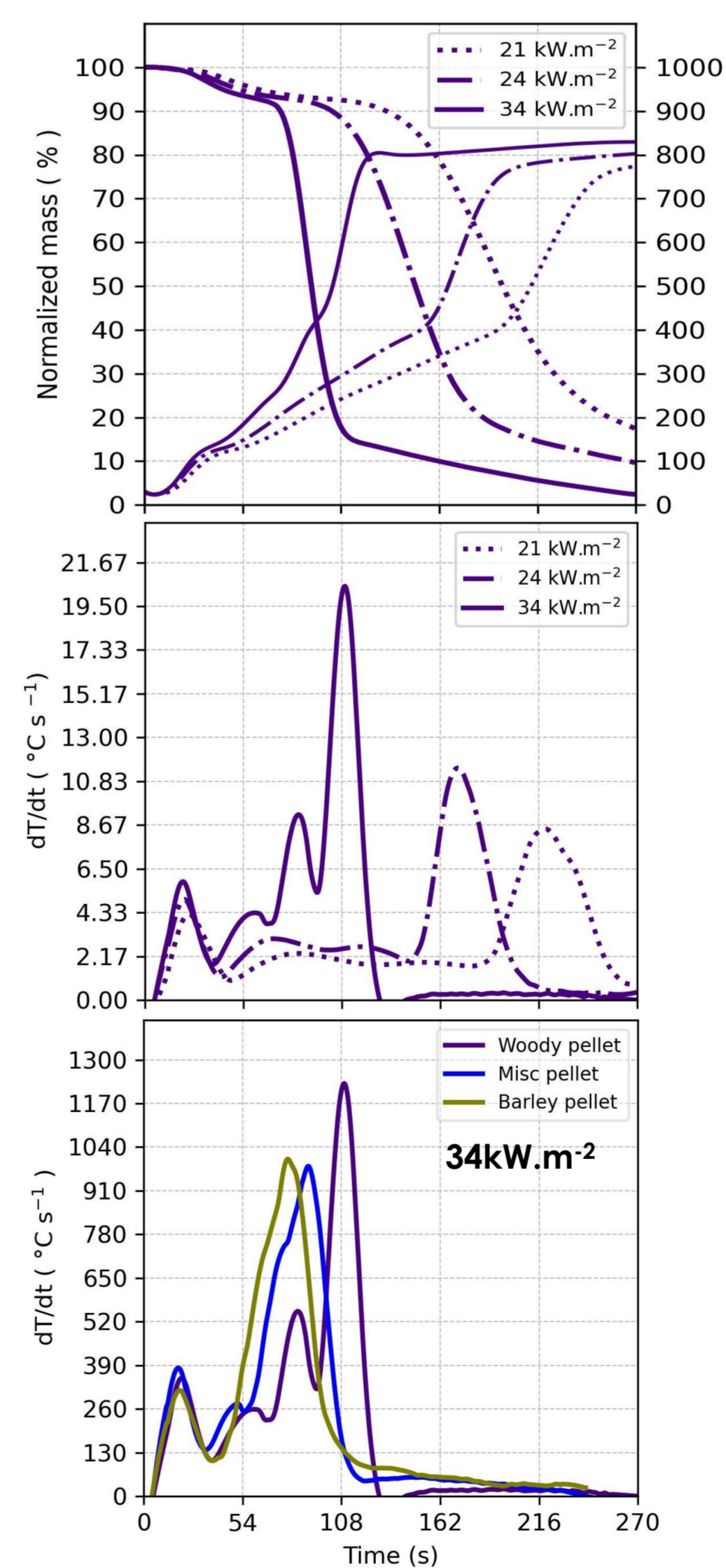
Flux 24kW.m⁻² : limit for flame ignition
→ devolatilization, combustion gas phase & char oxidation

Wood pellets:

- Low fluxes: drying, devolatilization, & char oxidation, last longer, spaced out over time.
- High flux: shorter & superimposed steps
- Mass degradation & heating sped up with heat flux
- Independent of flux :
Change of slope @ 450°C → char oxidation start
Plateau at 800° C → char oxidation period
- 34 kWm⁻²: change of slope @300° C → additional heat flux due to flame ignition

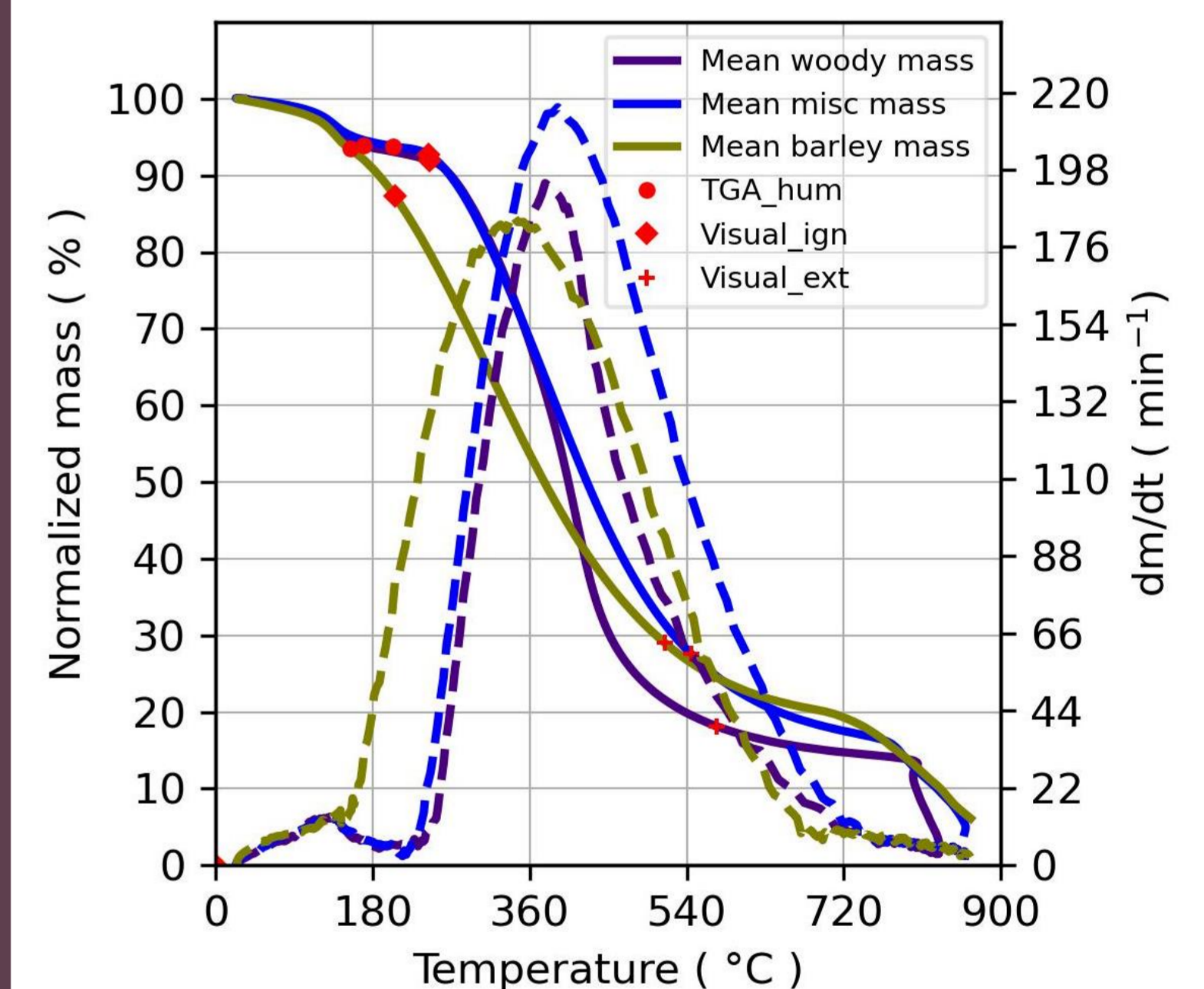
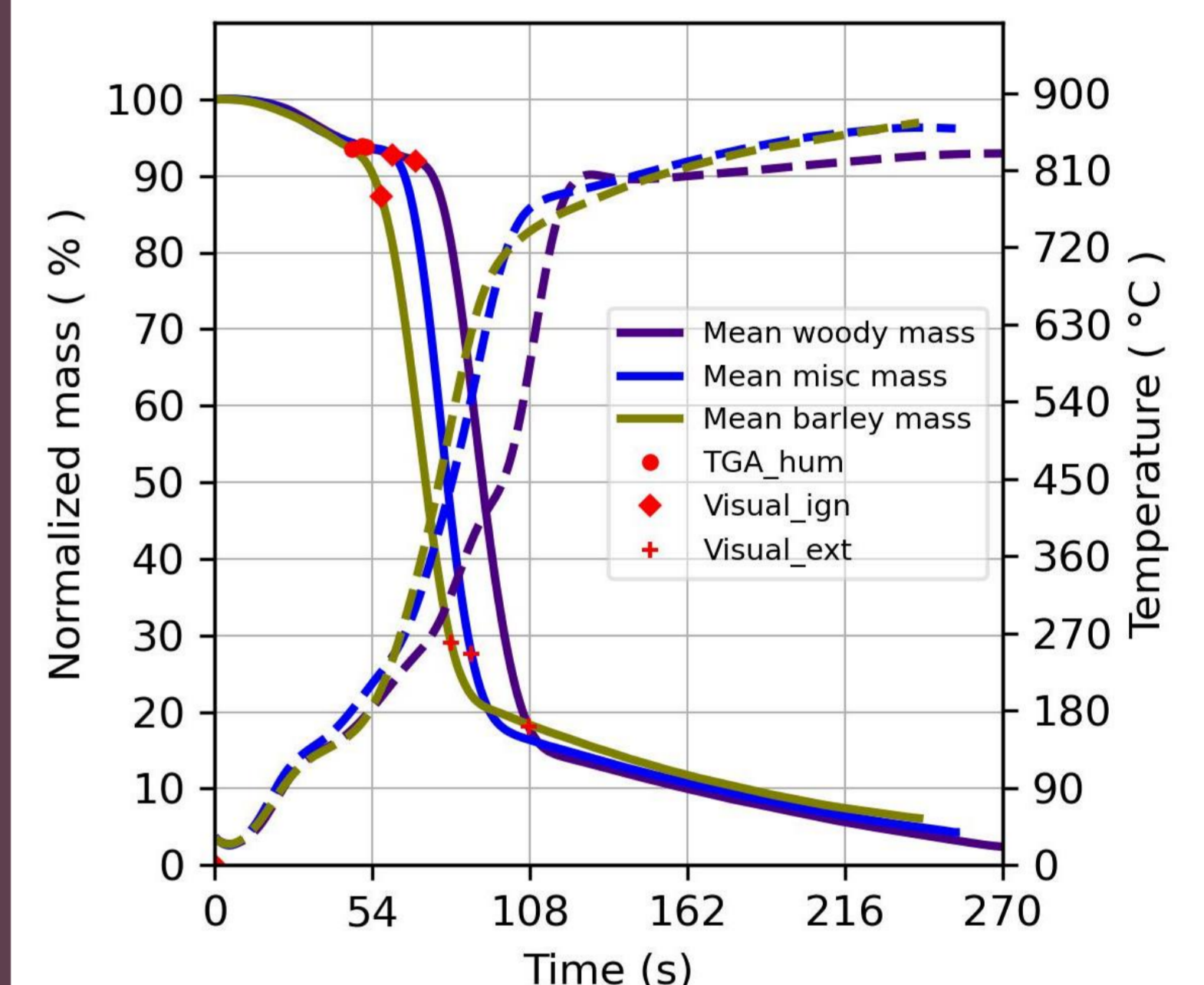
Wood, miscanthus, straw @ 34kWm⁻²

- Steps occur in a shorter time and are overlapped
- Wood : devolatilization rapidly followed by gas phase combustion before char oxidation
- Miscanthus & straw : overlap of devolatilization, flame & char oxidation
- density effect
- high amount of inorganic catalyst (alkaline)



Degradation dynamics

Comparison of degradation of wood, miscanthus & straw @ 34kW.m⁻²



- Similar Humidity loss
- Straw degrades first then miscanthus finally wood
- **Wood:** heats up slowly compared to miscanthus and straw → density effect
- **Straw:** flame duration shorter → effect of low VM content
- Higher density**
→ slow material degradation
- Low density, high porosity**
→ lower T for devolatilization & ignition

Conclusions

- Detailed description of sequential process of solid fuel degradation under combustion
- characteristics time scales and orders of magnitude:
 - duration of the gas flame very short (50s) compared to char oxidation (150s)
 - (dm/dt) max at the end of the devolatilization step
 - particle heating max during char oxidation

Influence of biomass origin: low VM → flame duration shorter
low density / high porosity → low devolatilization T & ign T

Overlap of flame and char oxidation stages important for straw and miscanthus
→ density effect, higher content of inorganics (Na, K) = degradation process catalysts

Perspectives

OH* Chemiluminescence flame imaging → more insight flame stage / degradation process
[Na], [Ca] [K] measured by CF-LIBS → influence on the degradation process & residual ashes.

Acknowledgement

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