Etude de la micro-explosion de combustibles liquides

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INTRODUCTION: APPLICATION (W/O)

- The field of application is very extensive:

Food

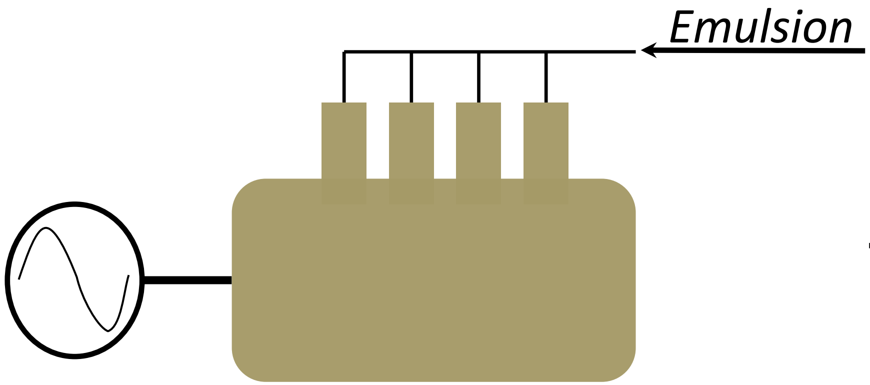
Pharmaceutical

<u>*Energy*</u> → <u>Bring out of waste</u>:

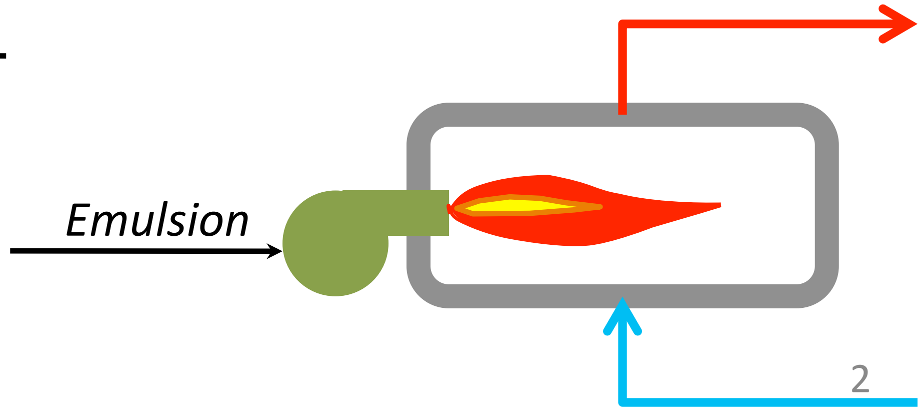
- Food industry: *Animal fat, Vegetables oils etc.*
  LHV≈38MJ/kg
- Oil Industry: *Heavy oils*
  LHV≈40MJ/kg

- Production of electricity and heat

Internal combustion engines

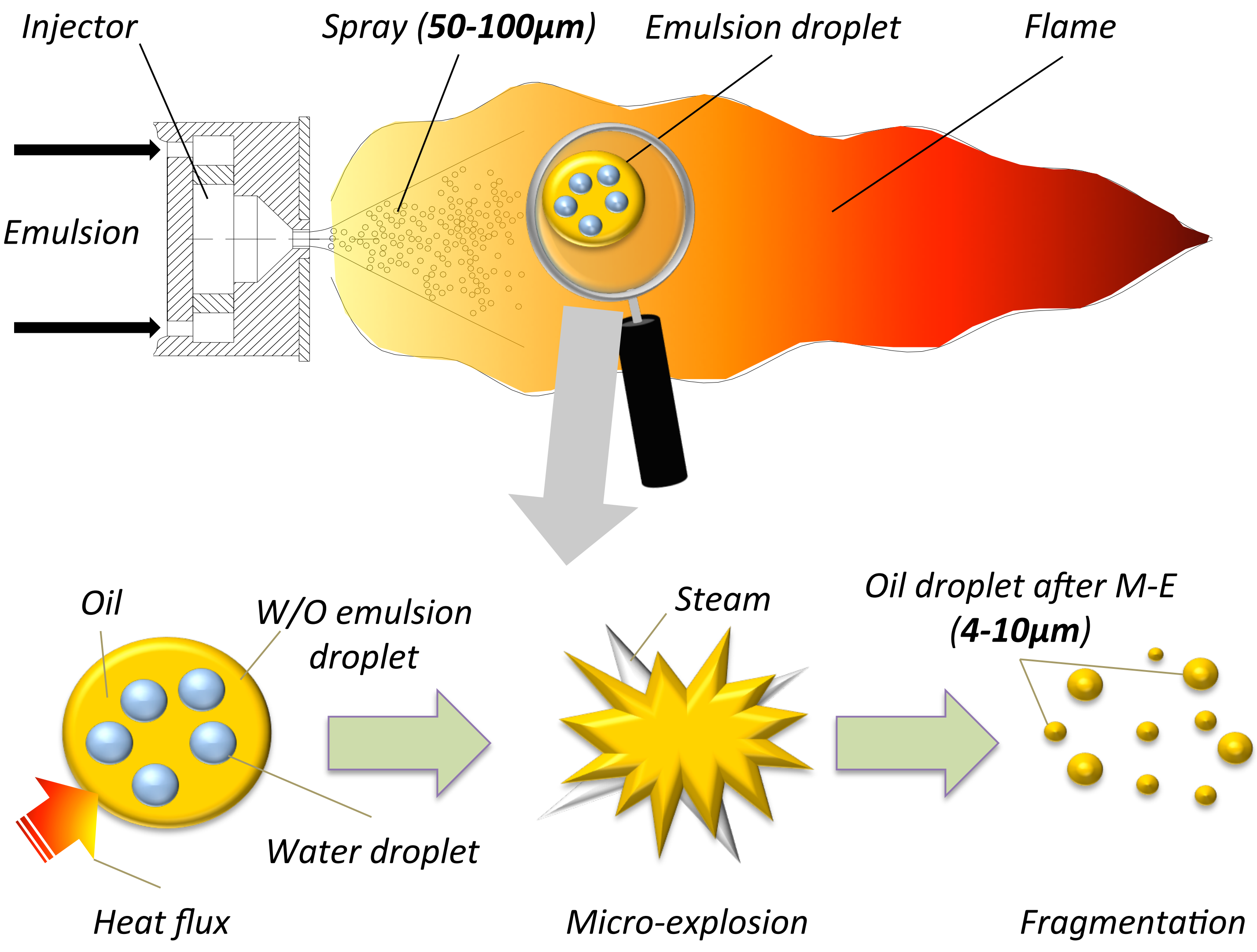


Boilers



W/O EMULSION IN A FLAME

- Spray
- Vigorous expansion of water.
- Second atomization ↑ *S/V*.



PLAN

- The detailed M-E investigation (Mura et al.)
- The Mechanical & Thermal Energy Balance (Tarlet et al.)
- Conclusions and Perspectives

Part. 1

ATOMISATION OF A EMULFIED FUEL DROP: EFFECT OF THE DISPERSED WATER GRANULOMETRY

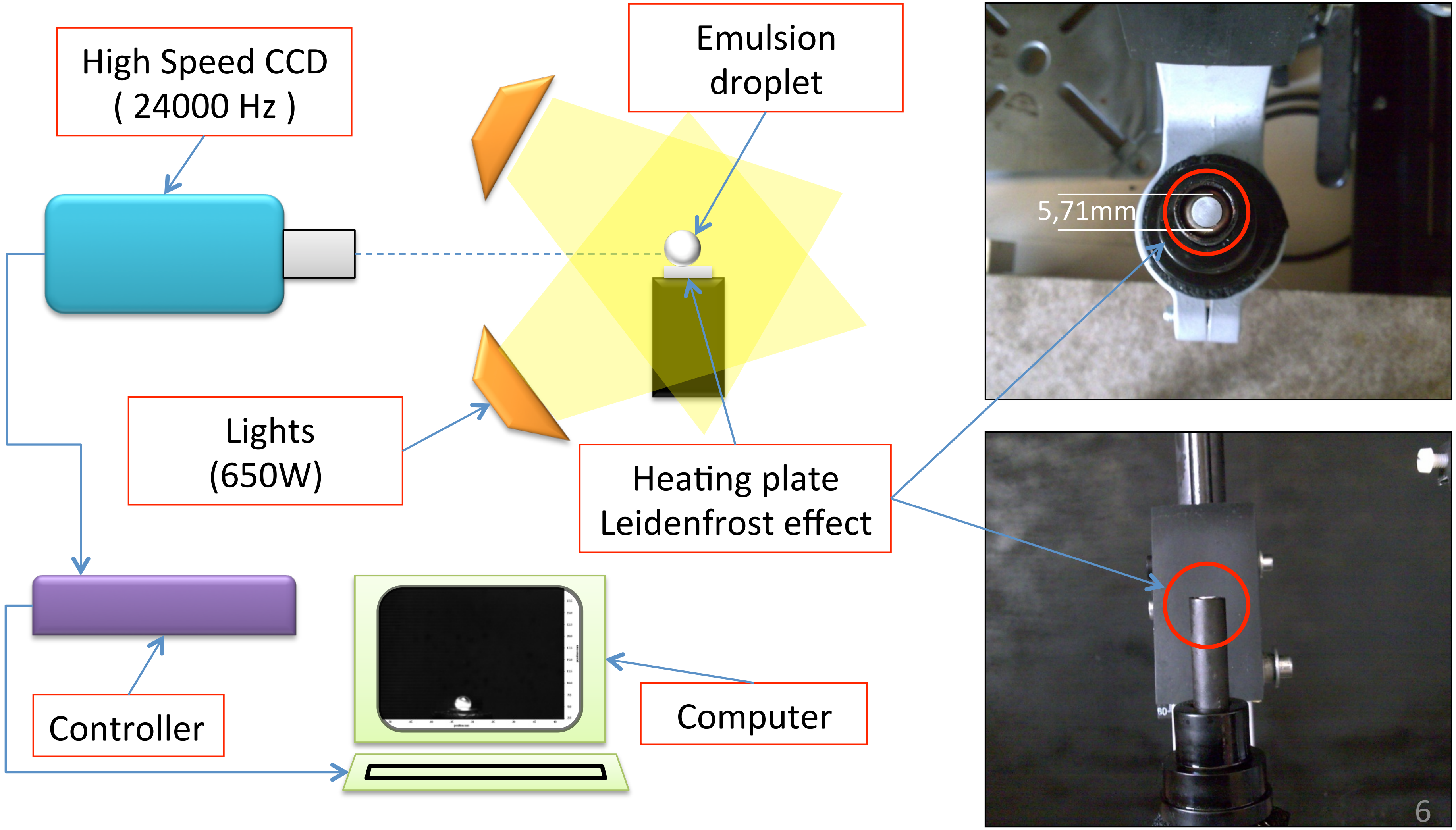
Ernesto Mura, Christophe Josset, Khaled Loubar, Valeria Califano, Raphaella Calabria, Jérôme Bellettre, Patrizio Massoli

(2008 – 2013)

Experimental set up

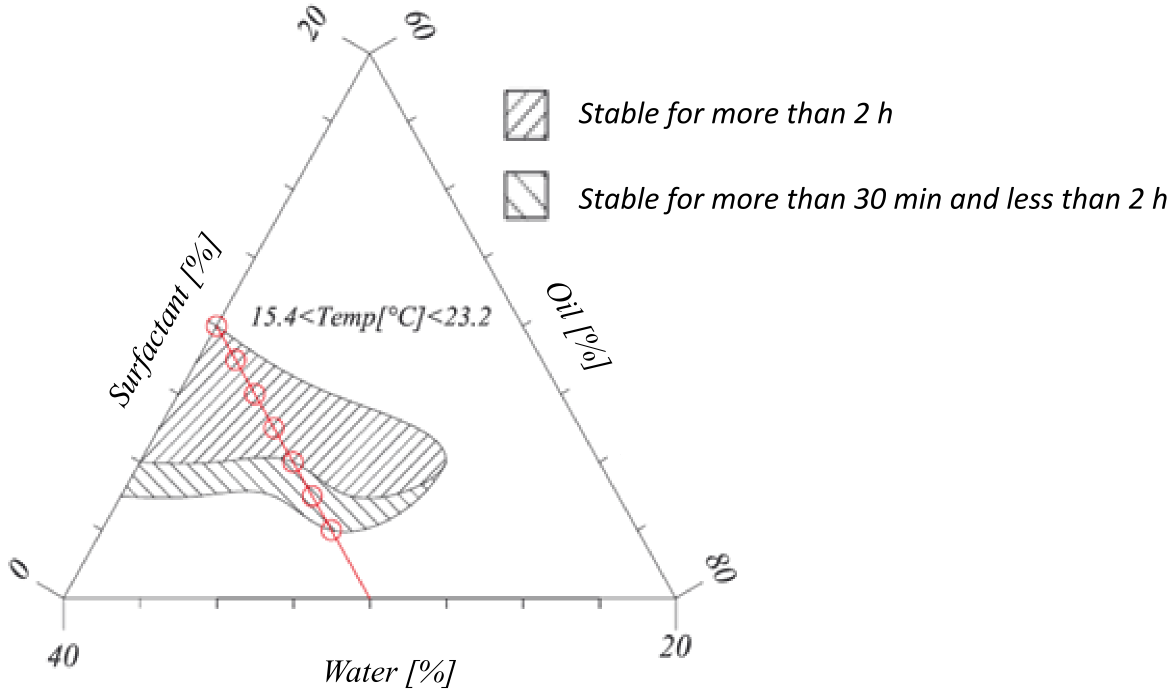
General sketch

Microplaque views



EMULSION CLASSIFICATION

- Emulsions prepared by stirrer working at 400 *rpm* for 60 *min* using Sunflower oil, distilled not-degassed water and a surfactant.
- The stability of the emulsions evaluated and then seven different **"Iso-water" emulsions** were selected.

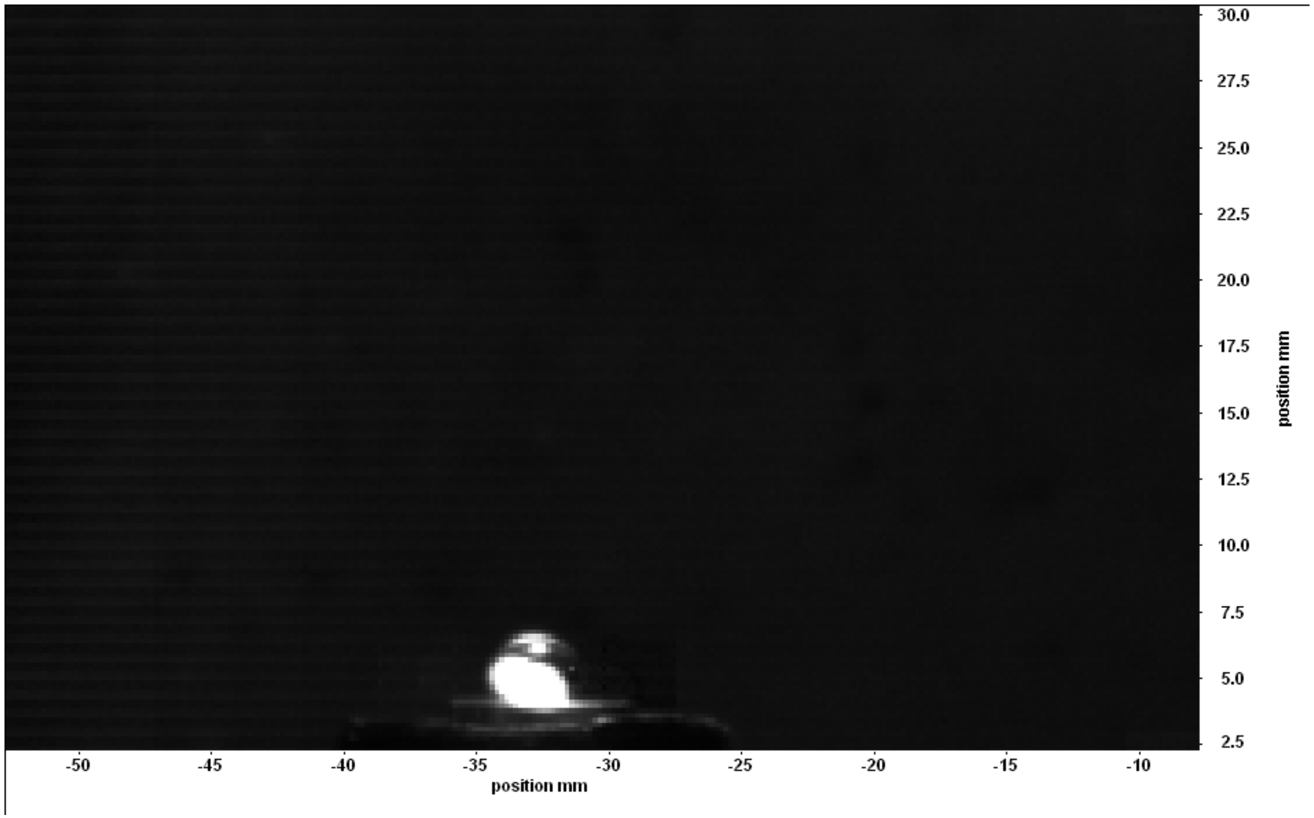


- Size of the drops estimated by a microscope and its image treatment software

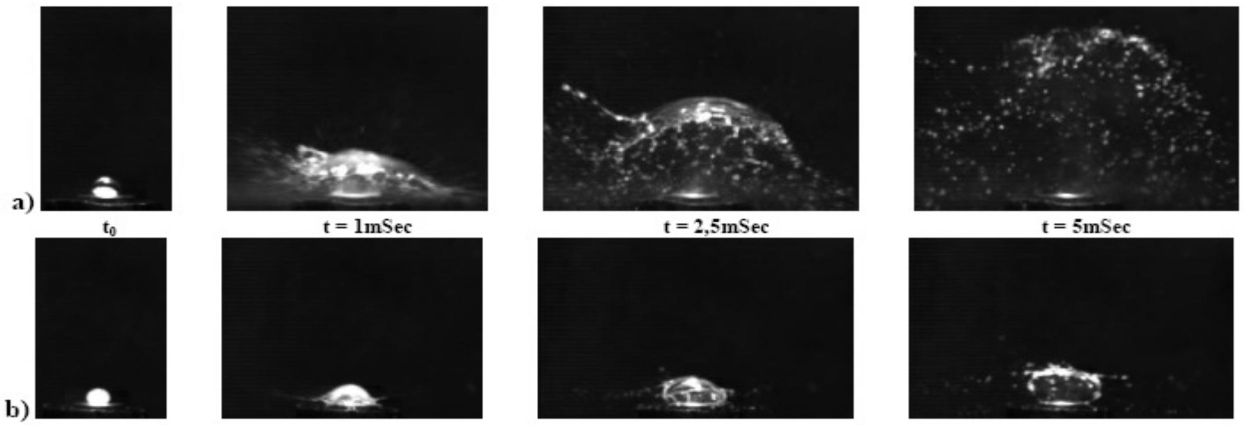
Micro-Explosion Images

Video of one experiment

Acquisition frame : 10kHz



Video frames



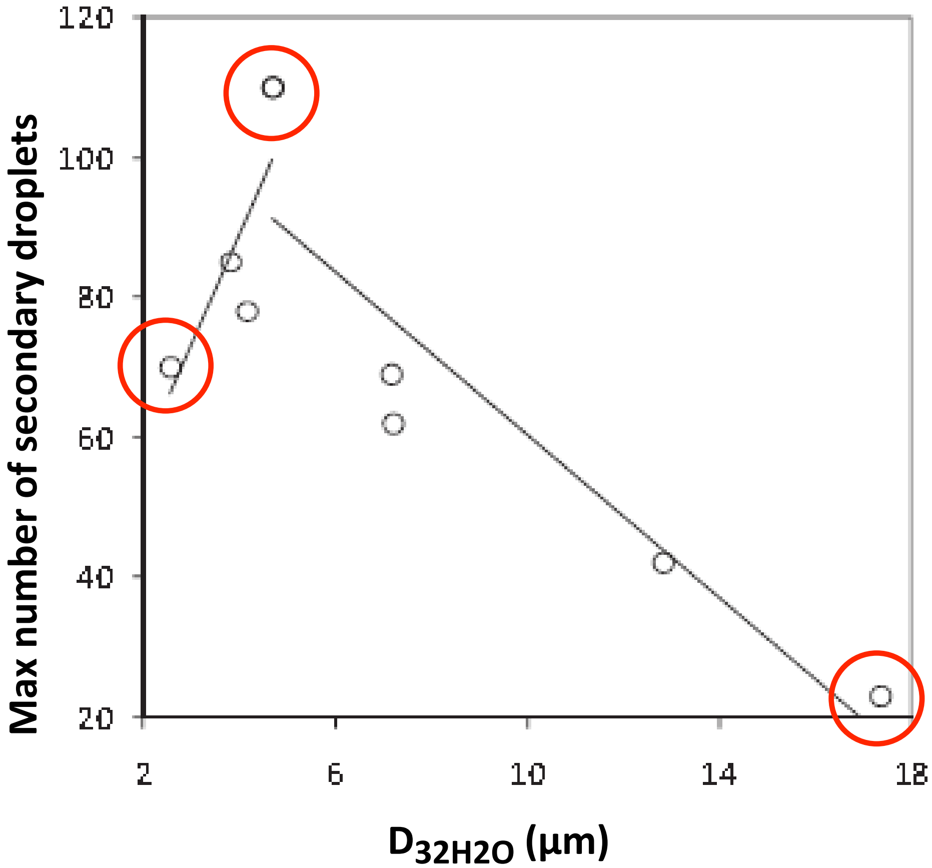
Two ISO-Water emulsions (30%)

- D_{32}= 4,7µm
- D_{32}= 17,4µm

MICRO-EXPLOSION: PREVIOUS RESULTS

Experimental results show the influence of the size of the dispersed water droplets in the micro-explosion phenomenon, in terms of fragmentation efficiency

The minimum numbers of secondary droplets are found for the highest D_{32H2O} and it increases in reducing D_{32H2O} until a maximum matching to D_{32H2O} = 4.7 µm



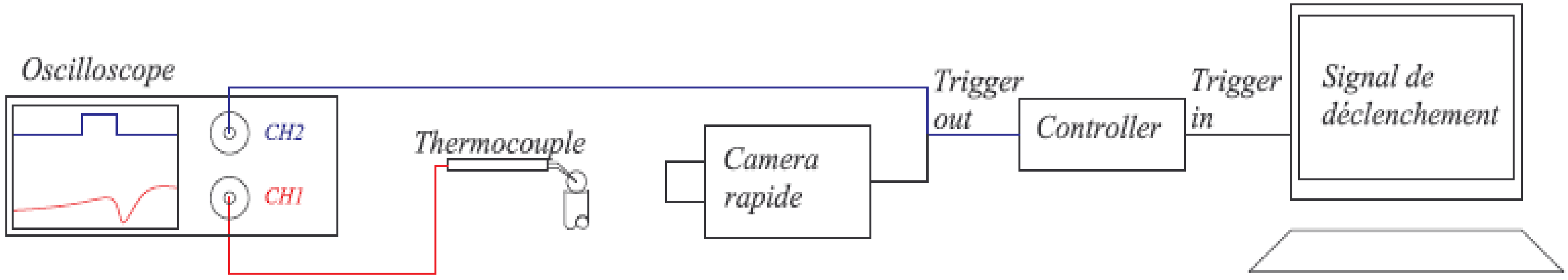
The same trend:

- Numbers of detected droplets
- Size of fragmented droplets
- Velocity of ejected oil front

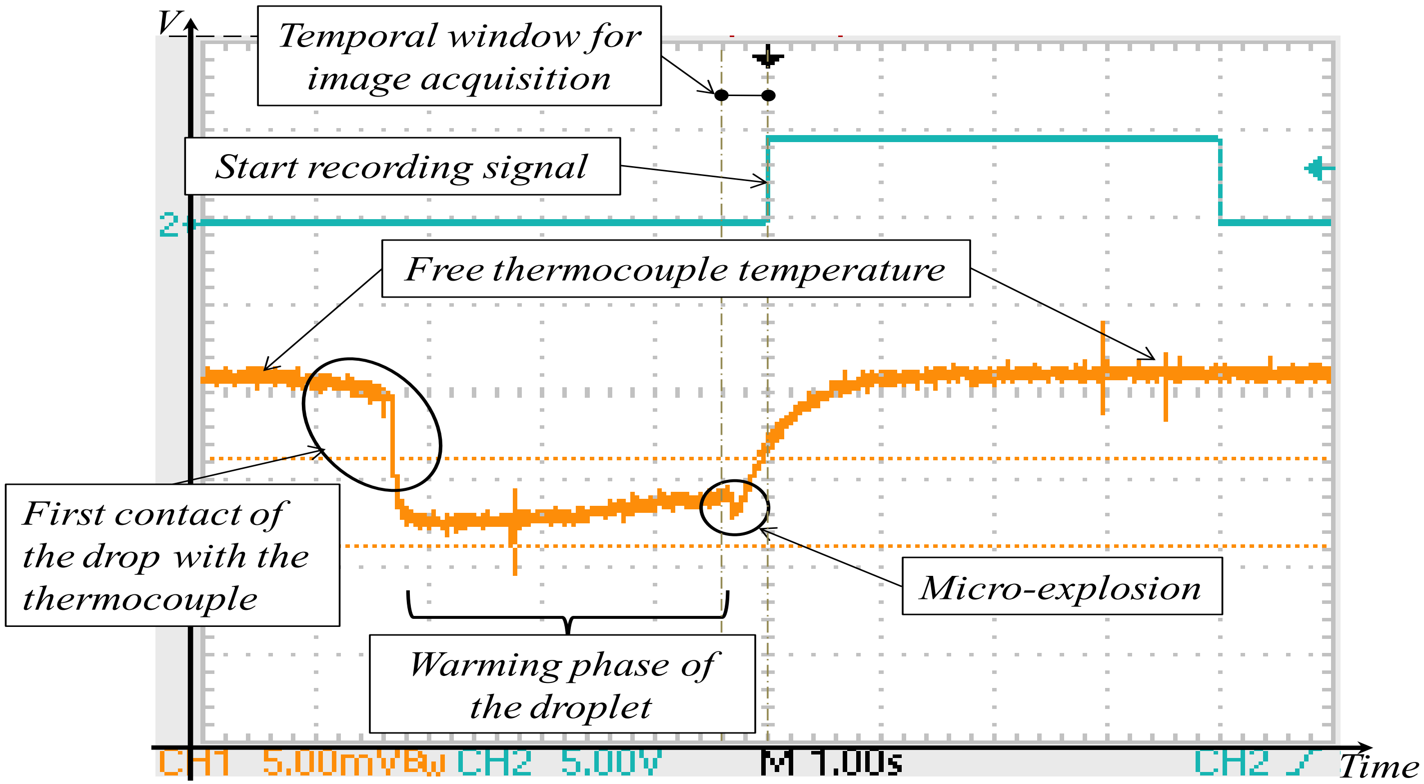
(Mura et al. Atomization and sprays, 20(9): 791-799, 2010)

TRIGGER AND SIGNAL

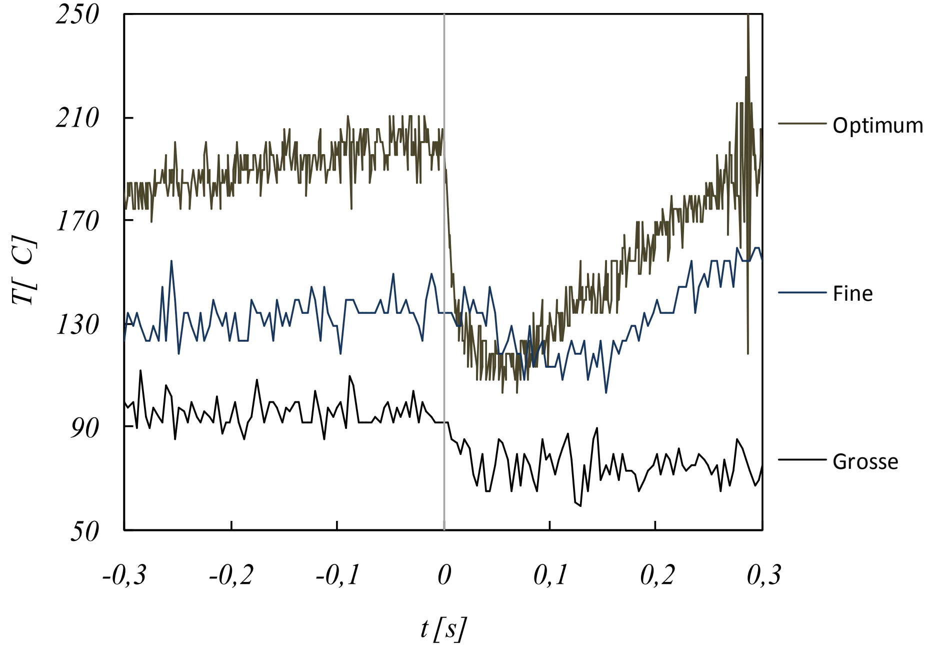
- Trigger

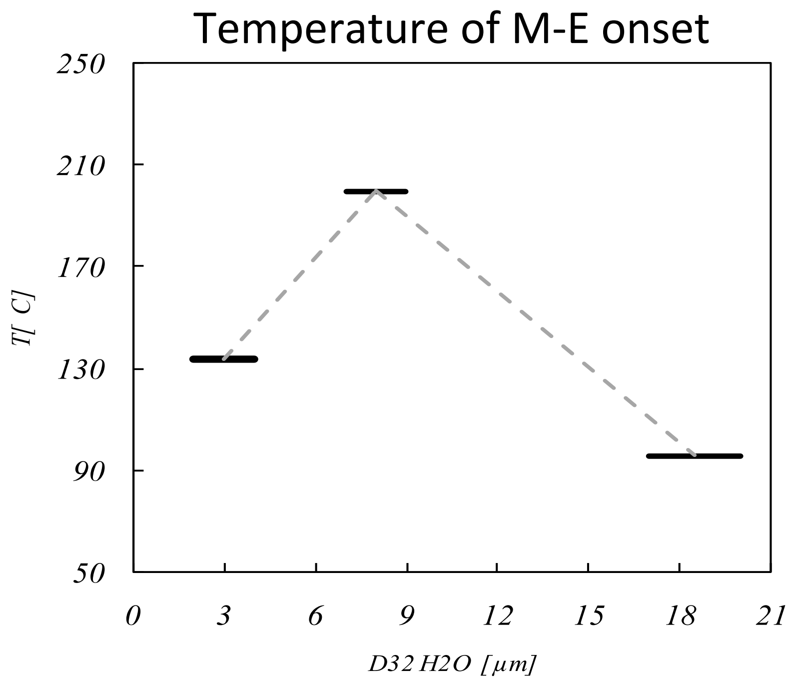


- Signal of the thermocouple

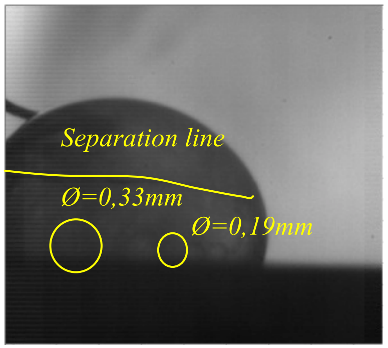


RESULTS

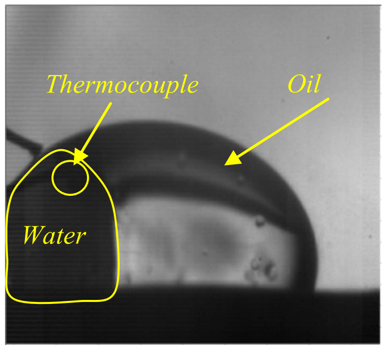




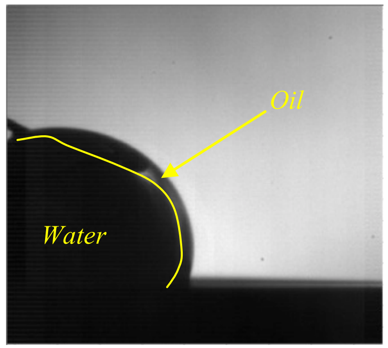
	Temperature drop
Fine	*20,3°C*
Medium	*81,4 °C*
Thick	*30,6°C*



Thick



Medium



Fine

Film 2

CONCLUSION

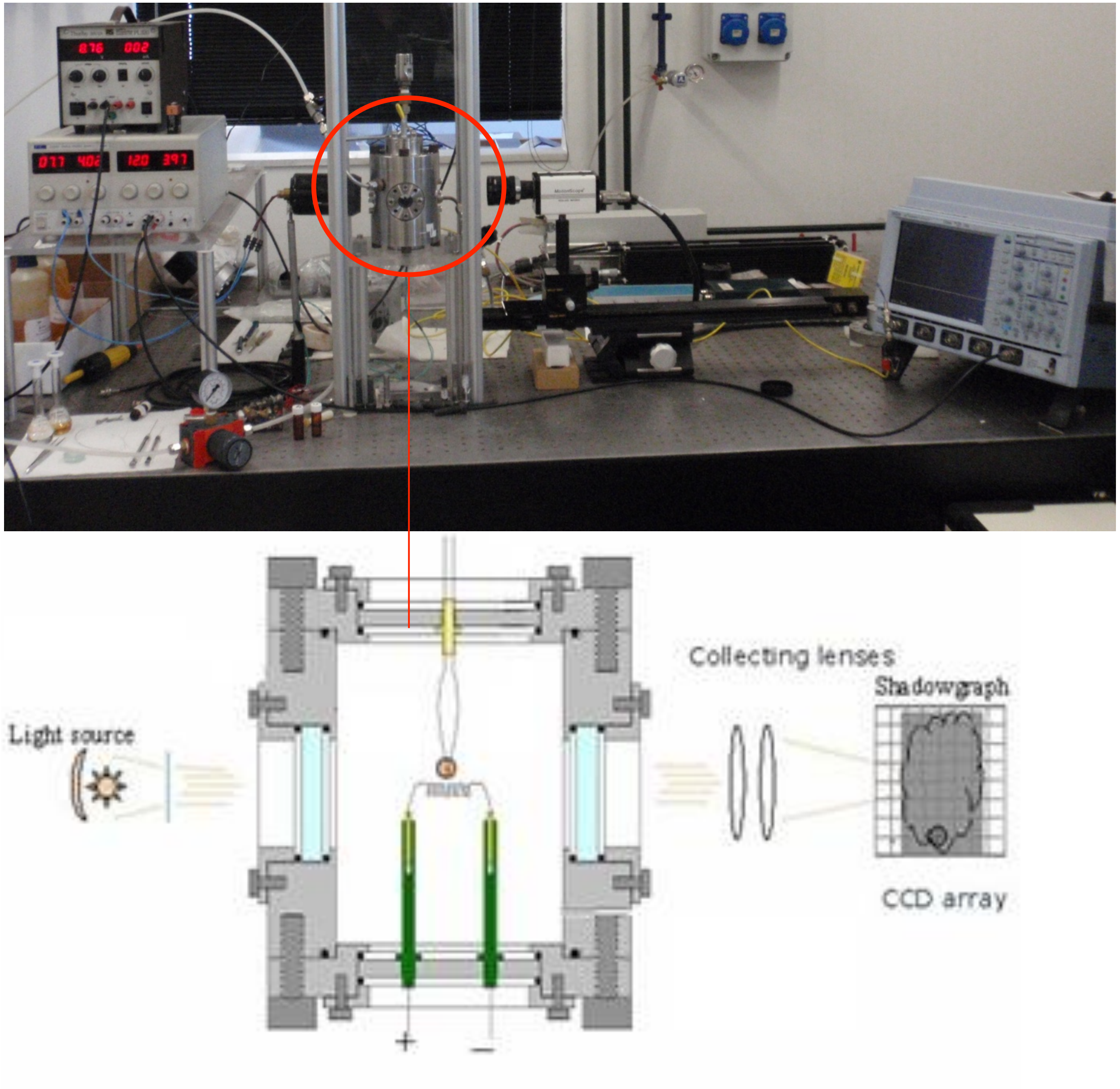
➢ **Experimental technique**: hot surface (Leidenfrost) + thermocouple.

➢ **The goal** is to simultaneously observe the evolution of temperatures and images of the phenomenon of micro-explosion.

➢ **The results**:

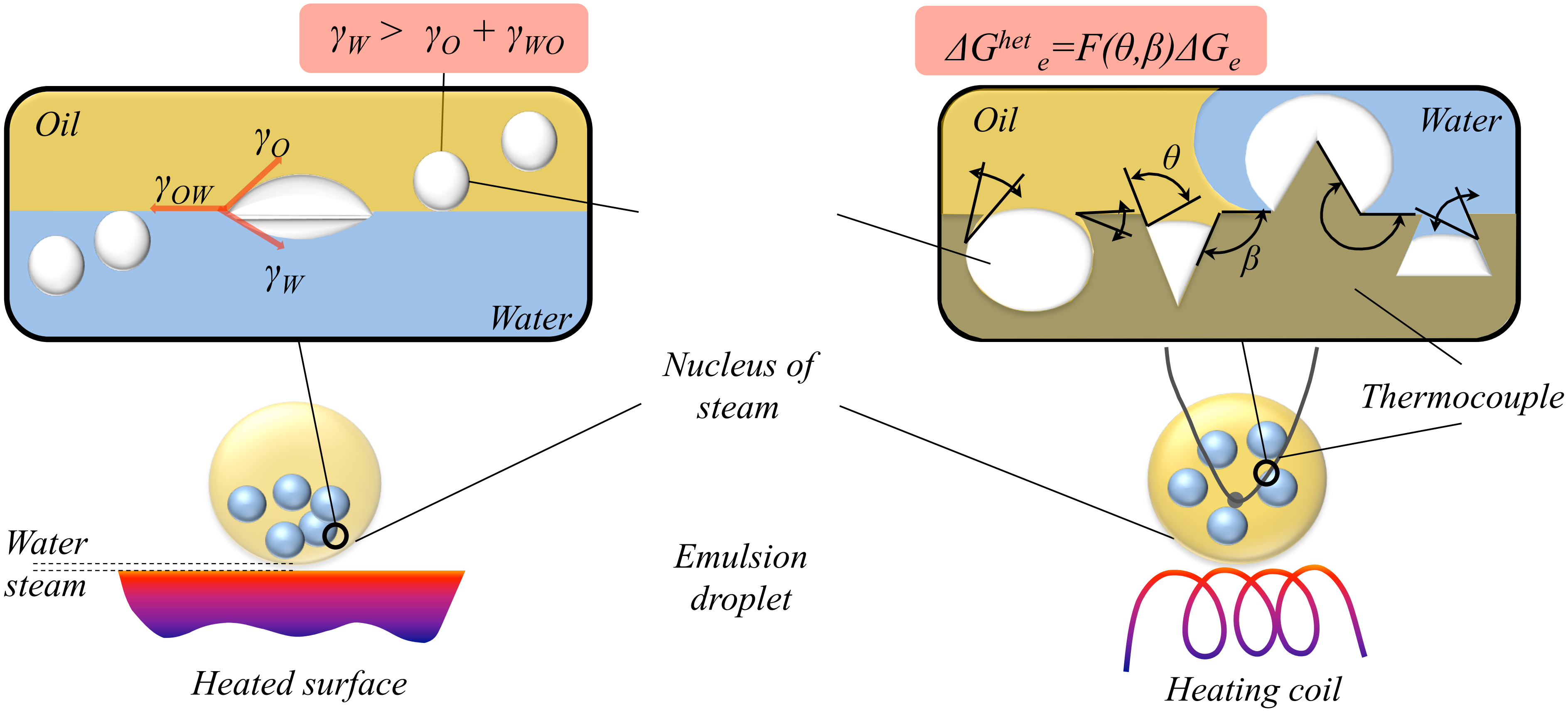
- the non-monotonic trend highlighted in previous results was confirmed with this new approach. The Optimum coincides with that previously observed.
- The phenomenon of separation is important: competition between coalescence (D_{32H2O} ↑) and creaming (D_{32H2O} ↓).
- A high degree of metastability was observed: $T_{M\text{-}E} = 200\ °C$.

Experimental setup: Single Droplet Combustion Chamber



- Cromel/allumel coil for heating
- Thermocouple K as support
- High speed camera CMOS Photron SA5 (*10KHz*) with *90mm* macro lens.
- Trigger heater/camera/Th
- Shadowgraphy configuration
- Semple droplets $\varnothing_D \approx 1mm$
- *P=atmospheric pressure*

The main differences: heterogeneity



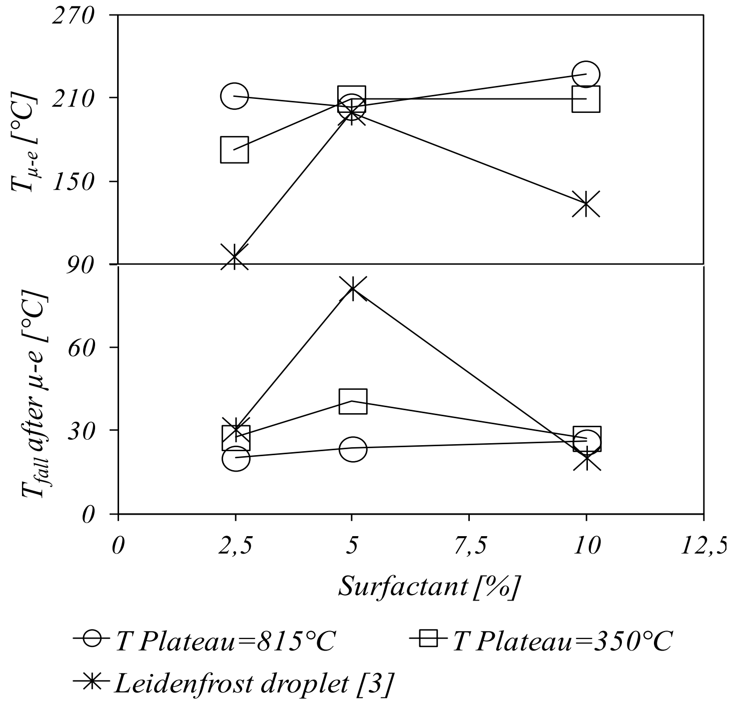
Nucleation in the fluid with lower γ:

- $\gamma_W > 2\gamma_O$
- Surfactant $\downarrow \gamma_O$

Nucleation favored by surface roughness Film 3

Heating rates and temperature levels are also very different

Results: μ-explosion temperature and temperature fall



Temperature of *μ-e* ($T_{\mu\text{-}e}$ upon); Fall temperature after *μ-e* (T_{fall} *after μ-e* down) in function of the mass fraction of surfactant

The effects of separation seem heavily influence the phenomenology:
it promotes and reduces the micro-explosion efficiency respectively in both the Leidenfrost and Suspended droplet approaches.

Part. 2

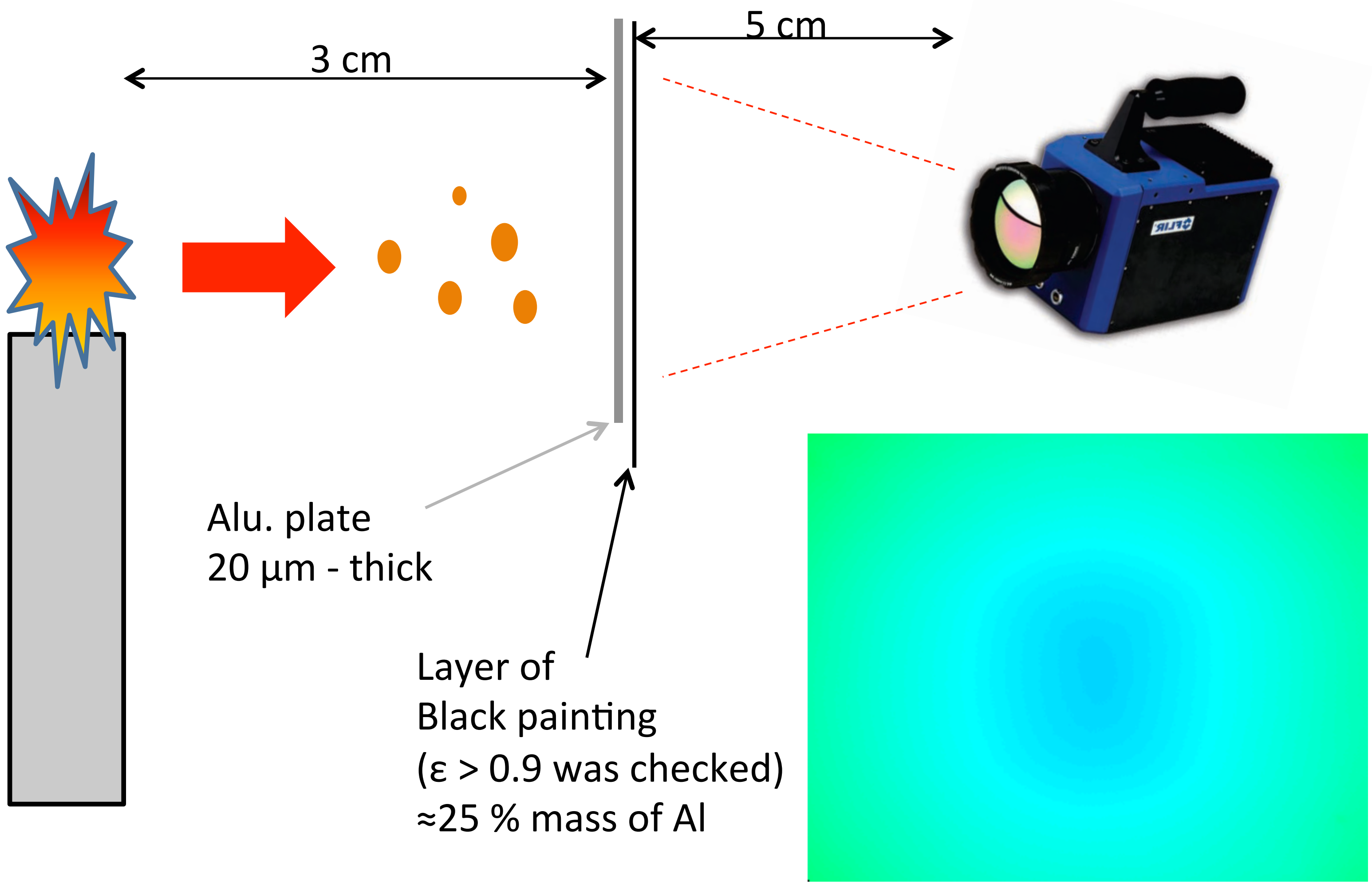
ATOMISATION OF A EMULFIED FUEL DROP: MECHANICAL AND THERMAL ENERGY BALANCE

Dominique Tarlet, Ernesto Mura, Christophe Josset, Christophe Allouis, Jérôme Bellettre, Patrizio Massoli

(from 2012)

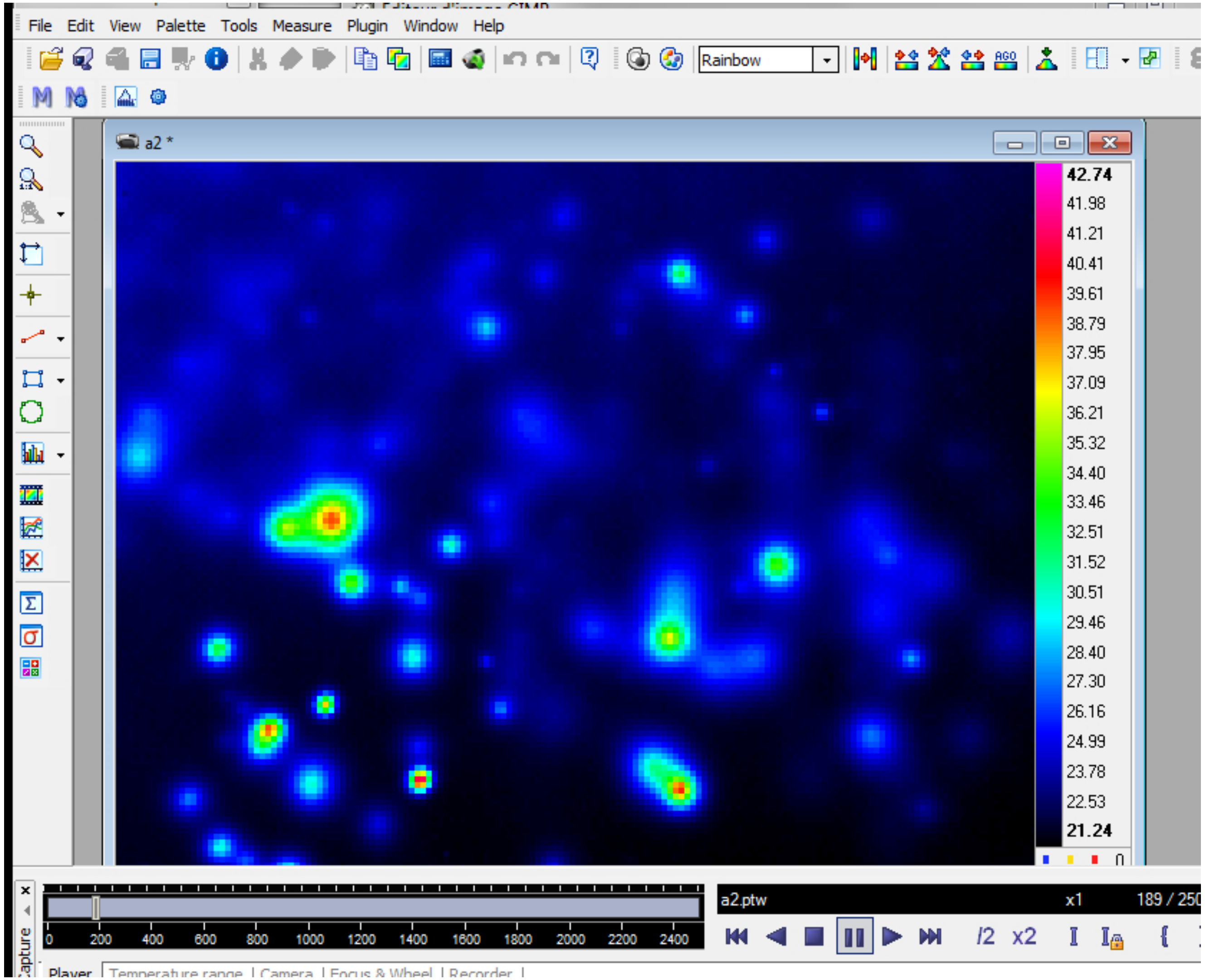
Thermal energy of child droplets?

➢ Effect on a plate *impact.*



Local transient temperature

- <u>Exemple:</u> Bigger case, 18/10/12



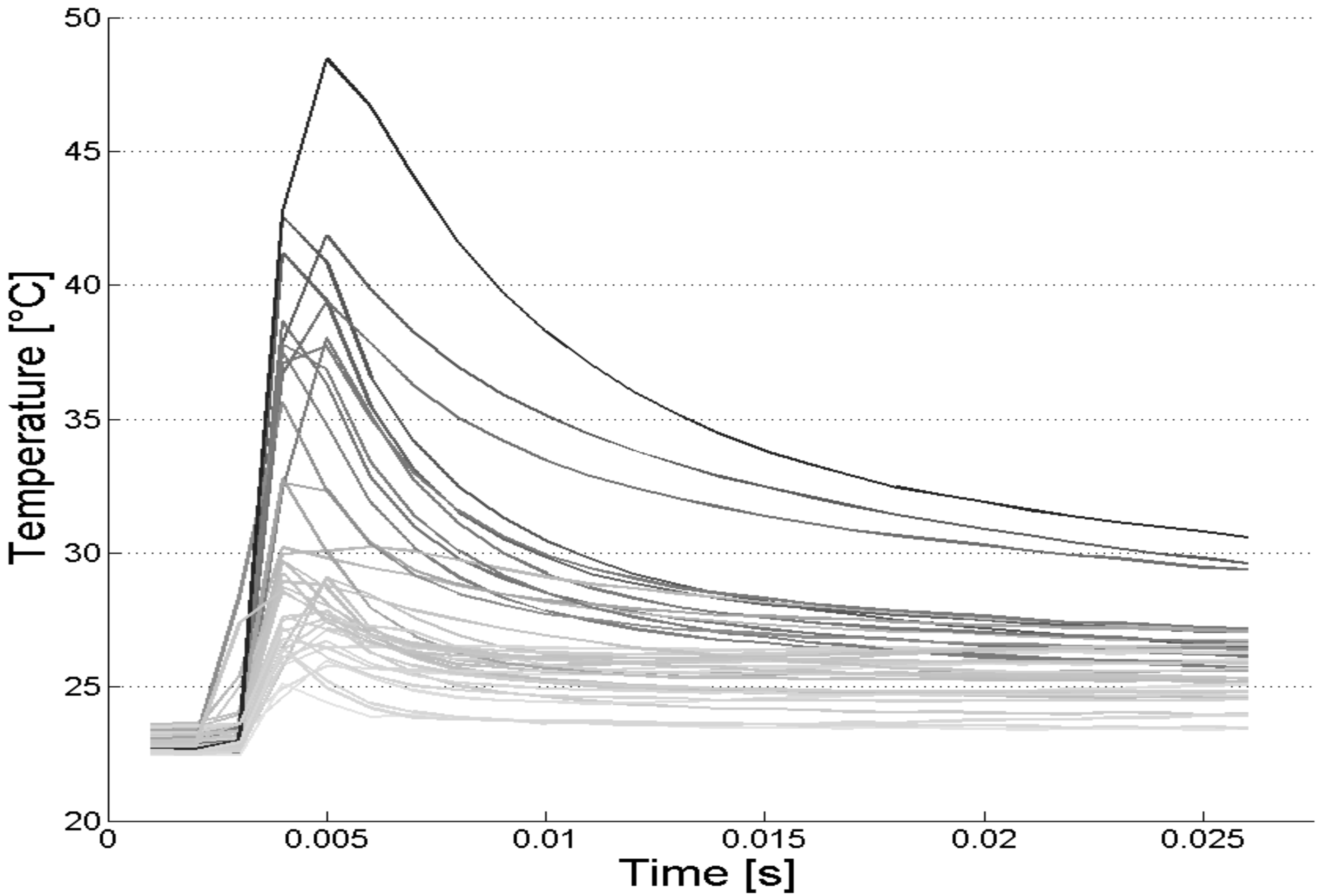
1 succeeded micro-explosion
= 1 video

1 video generally shows 5 to 30 impacts of DDs

10 to 15 videos enable to sample the needed 200 impacts of DDs for post treatment

Local transient temperature

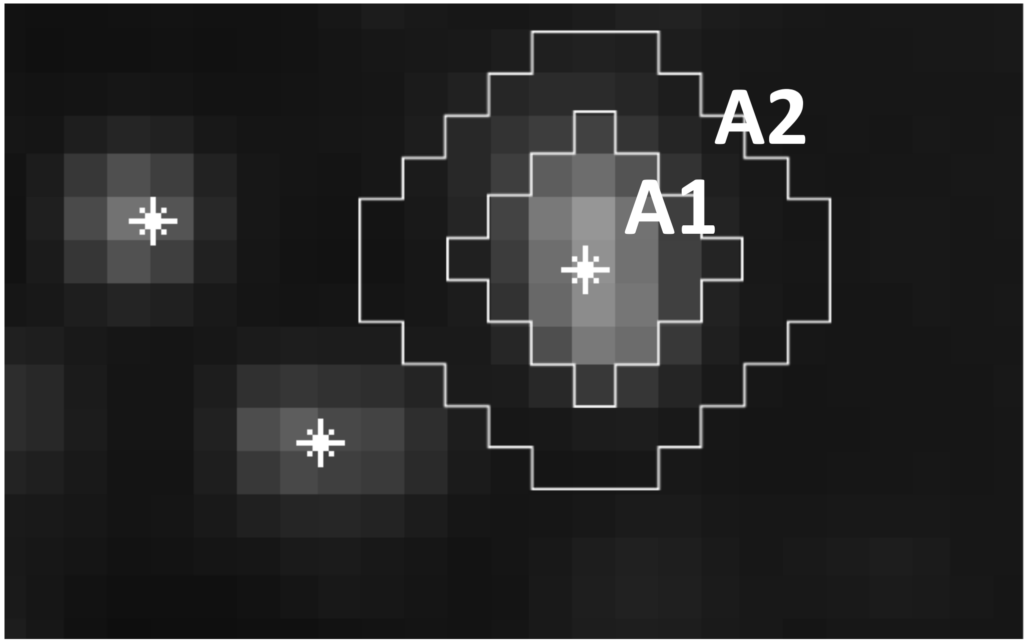
- <u>Exemple:</u> Bigger case, 18/10/12



Thermal energy calculation

$$\Delta_{xy}(T) = \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}$$

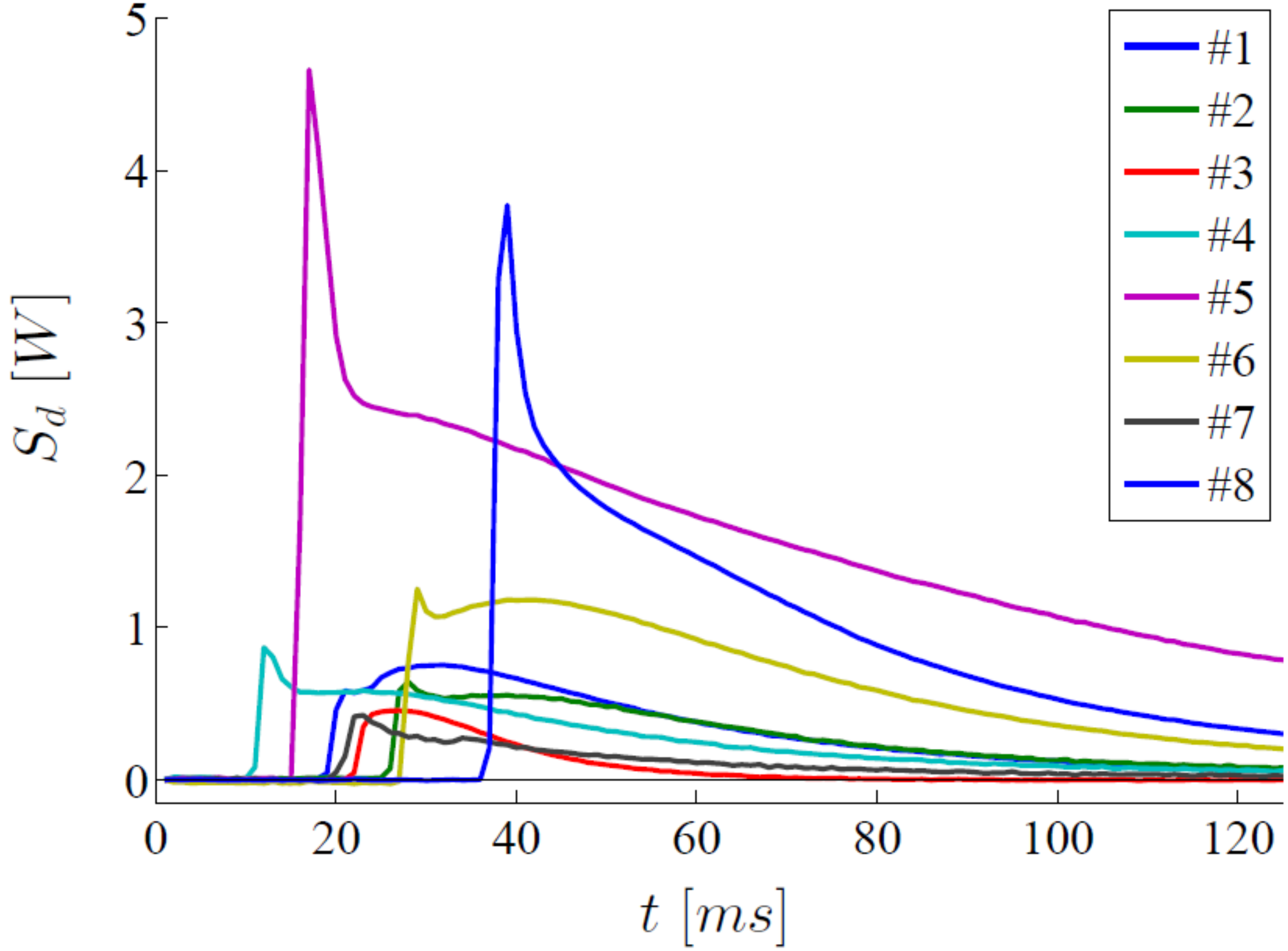
$$\rho C_P \frac{\partial T}{\partial t} = \lambda \Delta_{xy}(T) + \frac{h}{e}\left(T_a - T\right) + \frac{\varepsilon\sigma}{e}\left(T_a^4 - T^4\right) + S_d \rightarrow \left[W.m^{-3}\right]$$



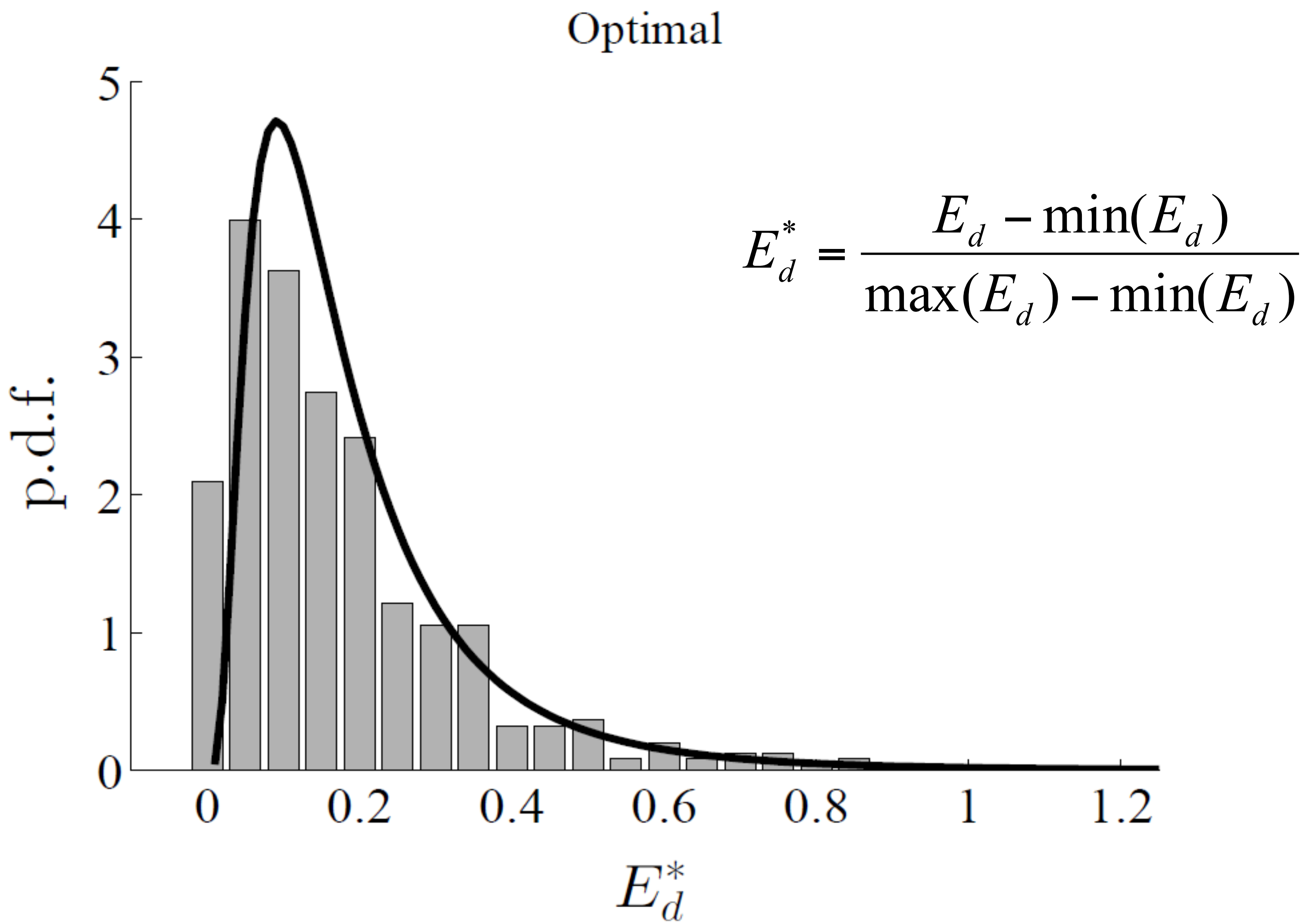
$$E_d(A) = m_d C_P\left(T_d - T_a\right)$$

$$E_d(A) = \int\left[\iint_A S_d e\, dA\right] dt$$

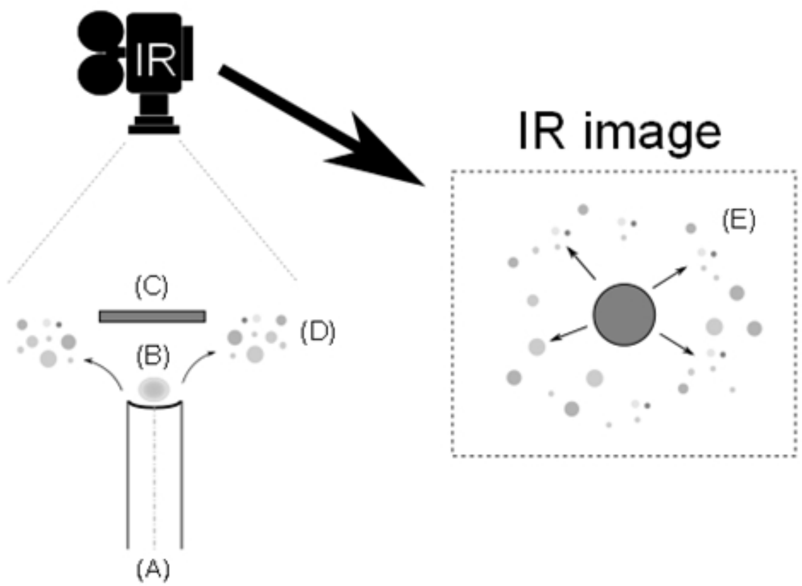
Result example

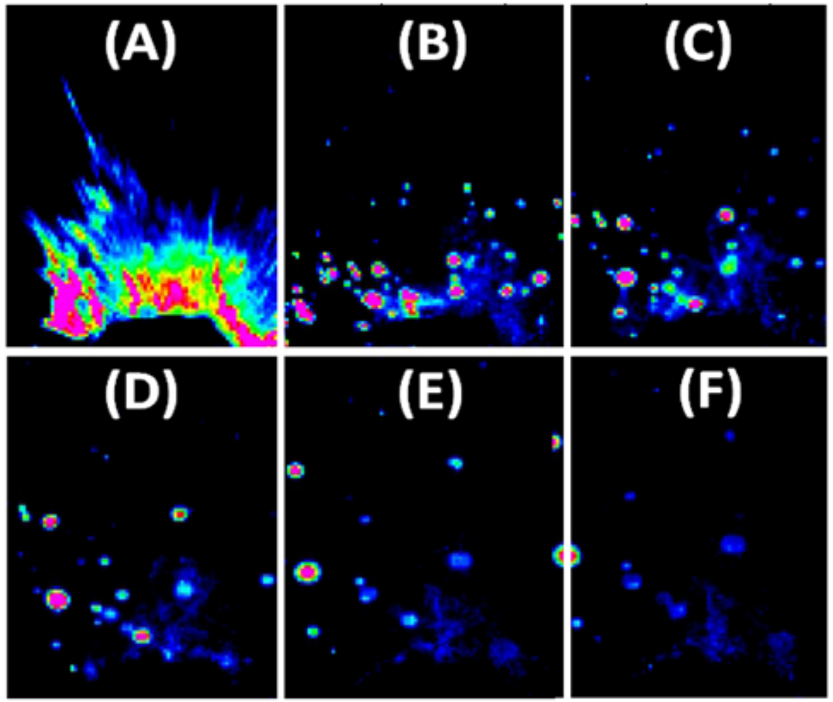


Les résultats statistiques [2/2]

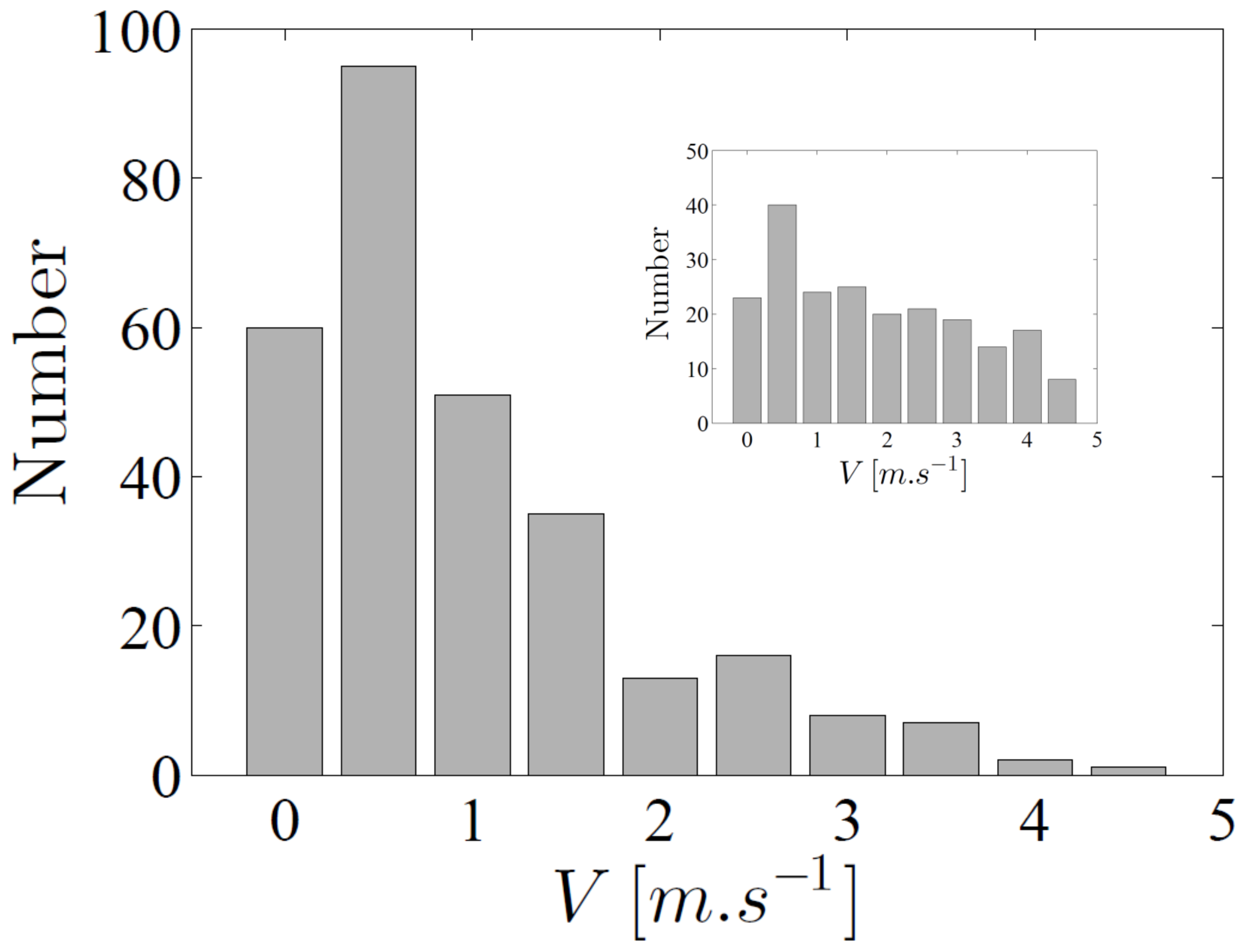


Child-Drop kinetic energy

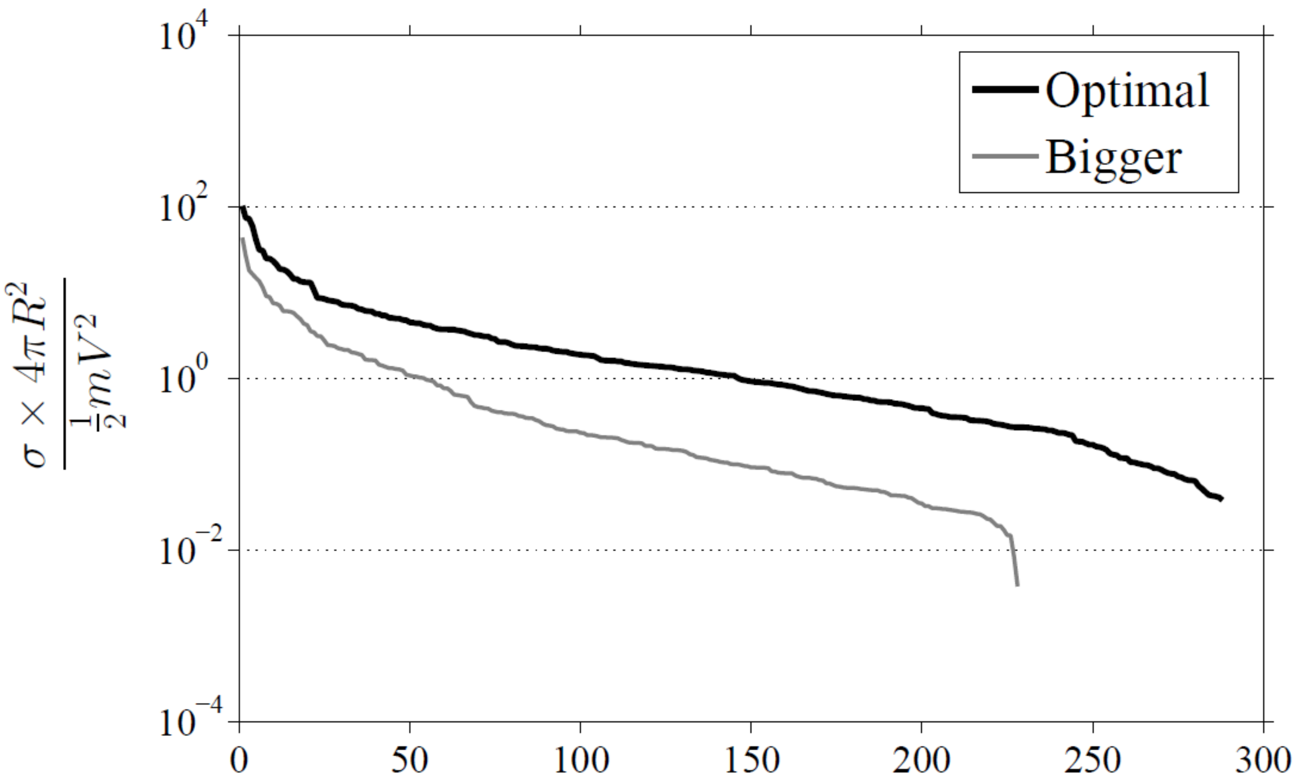




(A) Heated plate, (B) Emulsion drop undergoing micro-explosion, (C) Infra-red opaque covering of the heated plate, (D) Launched child-droplets in the field of view
(E) watched by the FLIR SC-7500 infra-red camera.
Six images (159×455) of optimal micro-explosion (1-6) with resolution of 210 μm per pixel were recorded at **1500Hz acquisition frequency**, with 140 μs integration time.



Average velocities over the identified trajectories in the optimal case (main figure - and in the bigger, non-optimal case (corner figure).



identified trajectories

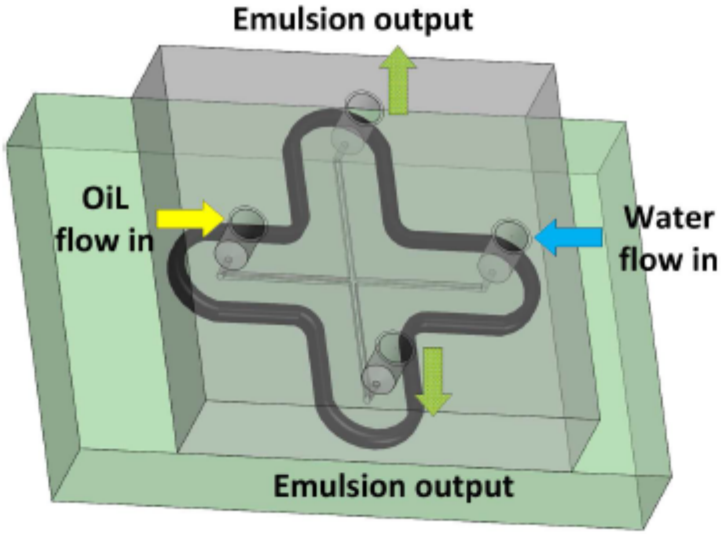
Optimal M-E generates more surface energy than kinetic one

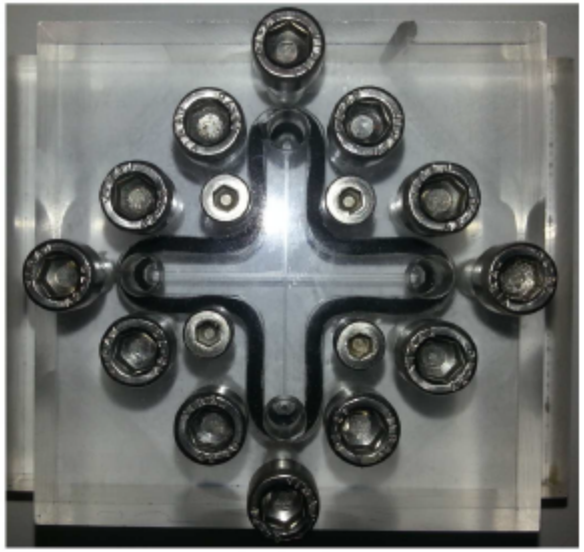
ATOMISATION OF A EMULFIED FUEL DROP: CONCLUSIONS

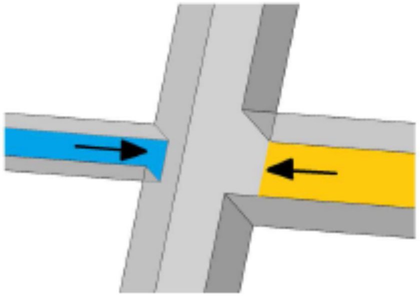
- ✓ Micro Explosion of emulsified drops has been intensely studied
- ✓ Homogeneous and Heterogeneous nucleation investigated
- ✓ Water droplet size has a high impact on the M-E quality
- ✓ Non monotone effects both in mechanical and thermal point of views
- ✓ Water history before M.E. (coalescence) is of first importance

Emulsion quality production has to be under controle

PERSPECTIVES: EFFICIENT EMULSION PRODUCTION
(Belkadi et al.)

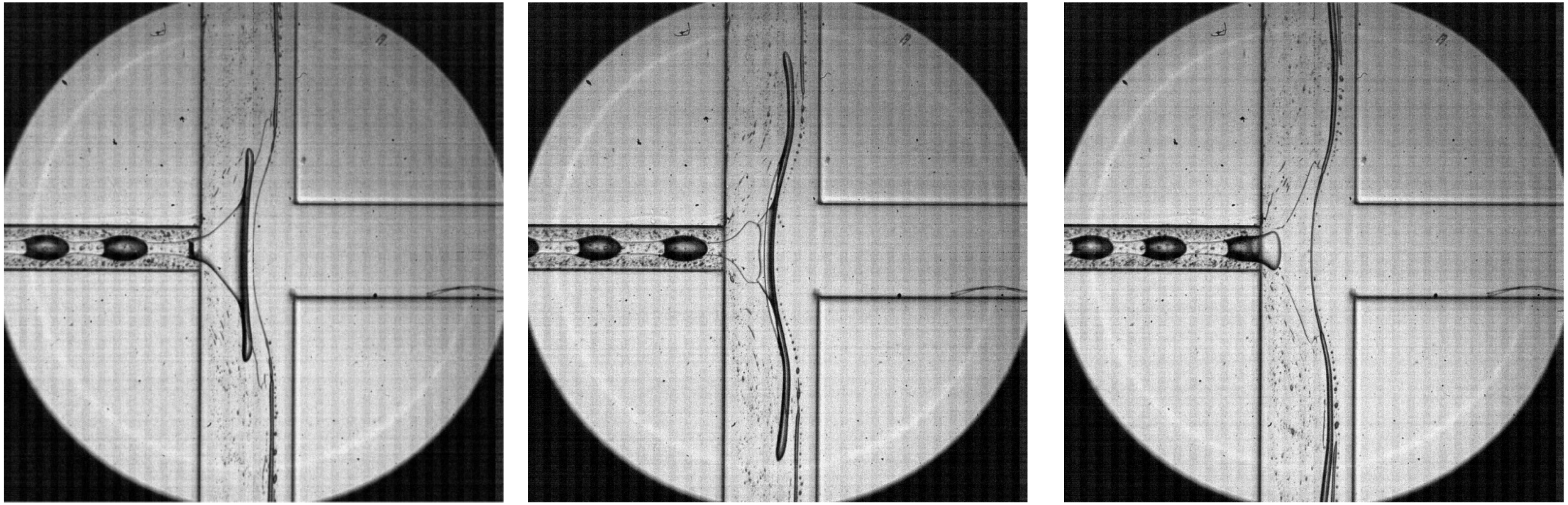






Investigations inside two-phase flows by High speed CCD & Laser extinction

Two devices in serie: Images inside the second mini channel



300 × 600 µm mini channel: inter-frame 1 ms, exposition duration1 µs

THANK YOU FOR YOUR ATTENTION