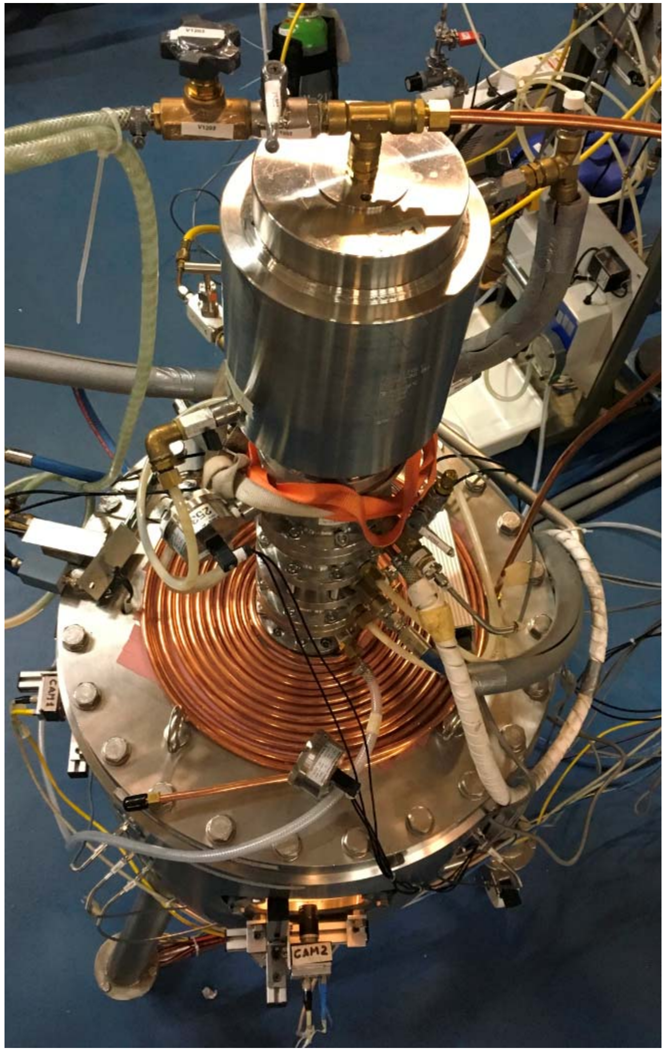
MOSCAB Collaboration for Dark Matter Search

MOSCAB is a geyser-concept bubble chamber sensitive to nuclear recoils in which the achievement/retention of the superheated state of the target liquid is obtained thermally, by heat transfer, instead of mechanically, by the action of a piston.



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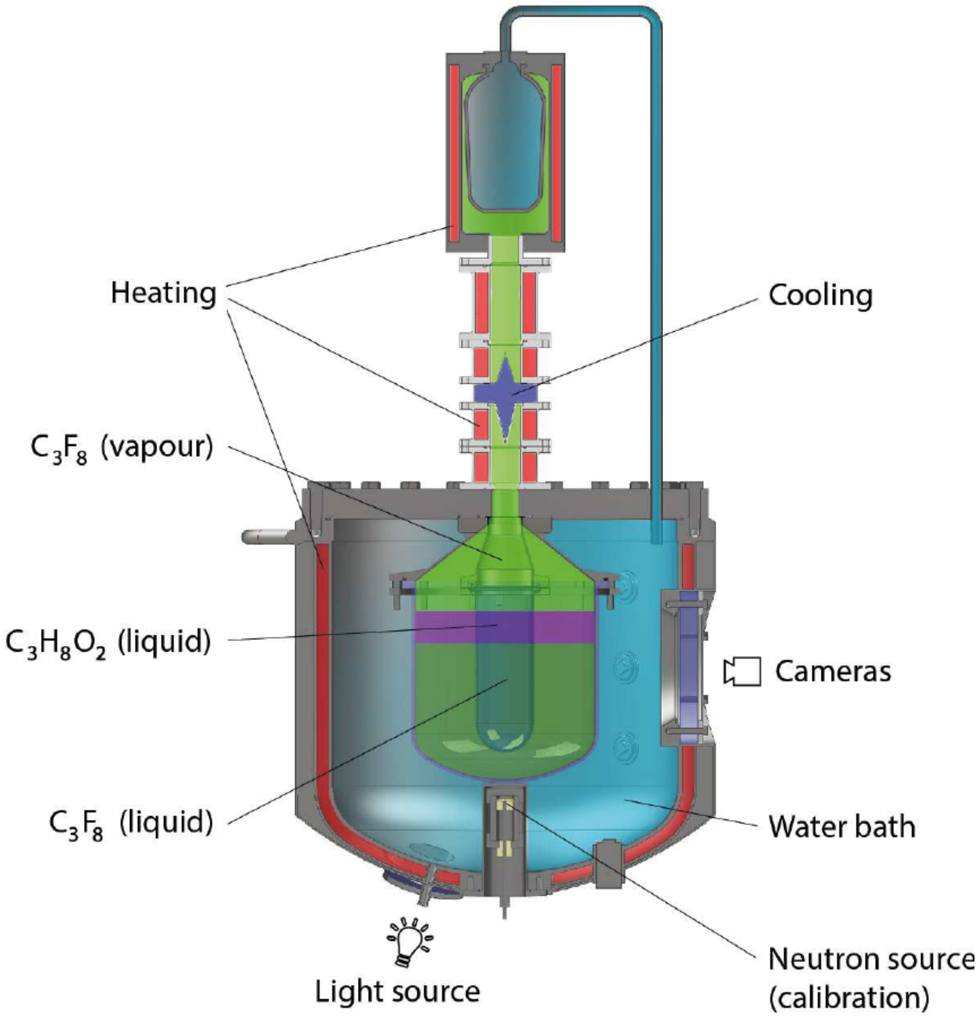

In the MOSCAB bubble chamber the metastability is gained by filling the chamber with the target liquid (C_3F_8) in equilibrium with its vapour at a given temperature, and subsequently cooling the top portion of the chamber, while the liquid is still kept at the original temperature.

As a consequence, a partial condensation of the vapour occurs and the operating pressure decreases to the saturation value at the cooling temperature of the top, which allows the target liquid to enter into a superheated state.

A buffer layer of propylene glycol ($C_3H_8O_2$) is inserted between the target liquid and its saturated vapour to contain surface evaporation and provide for thermal insulation.

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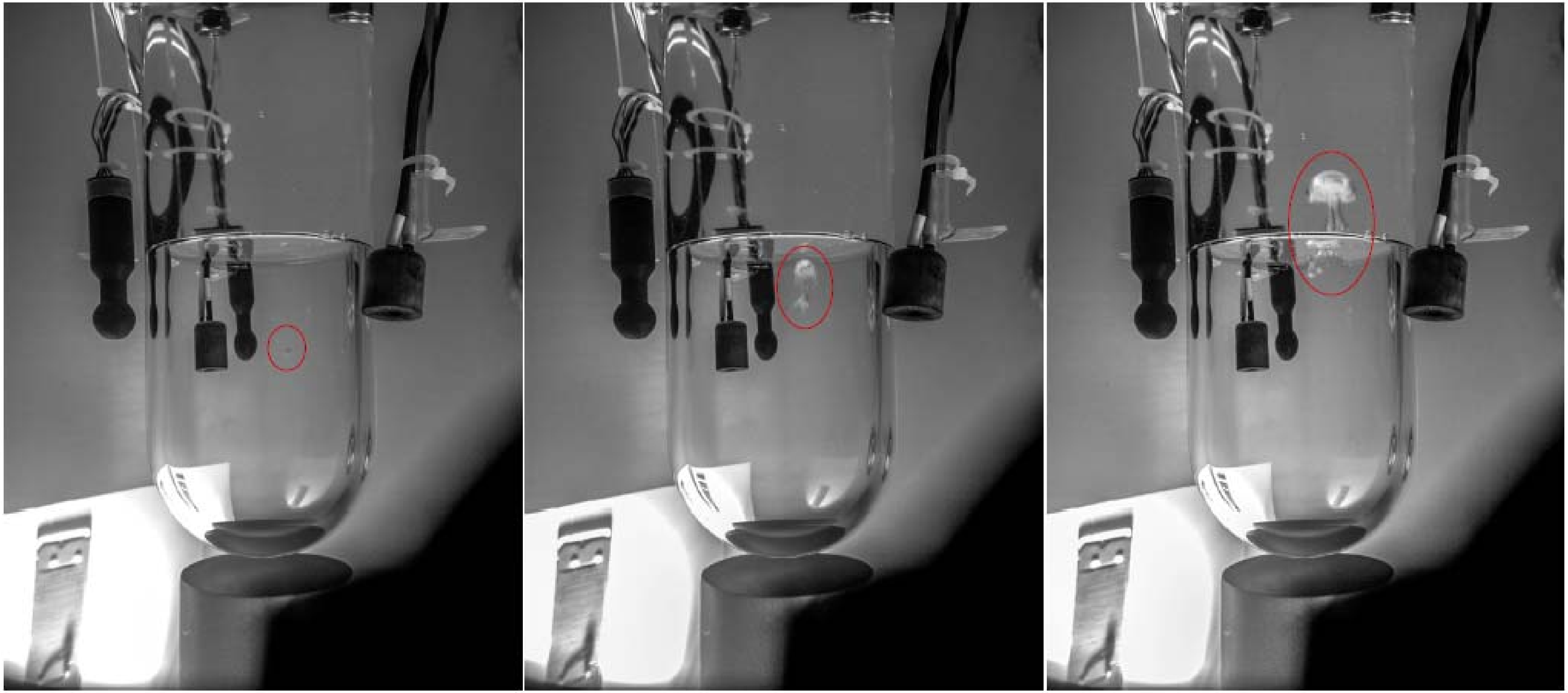
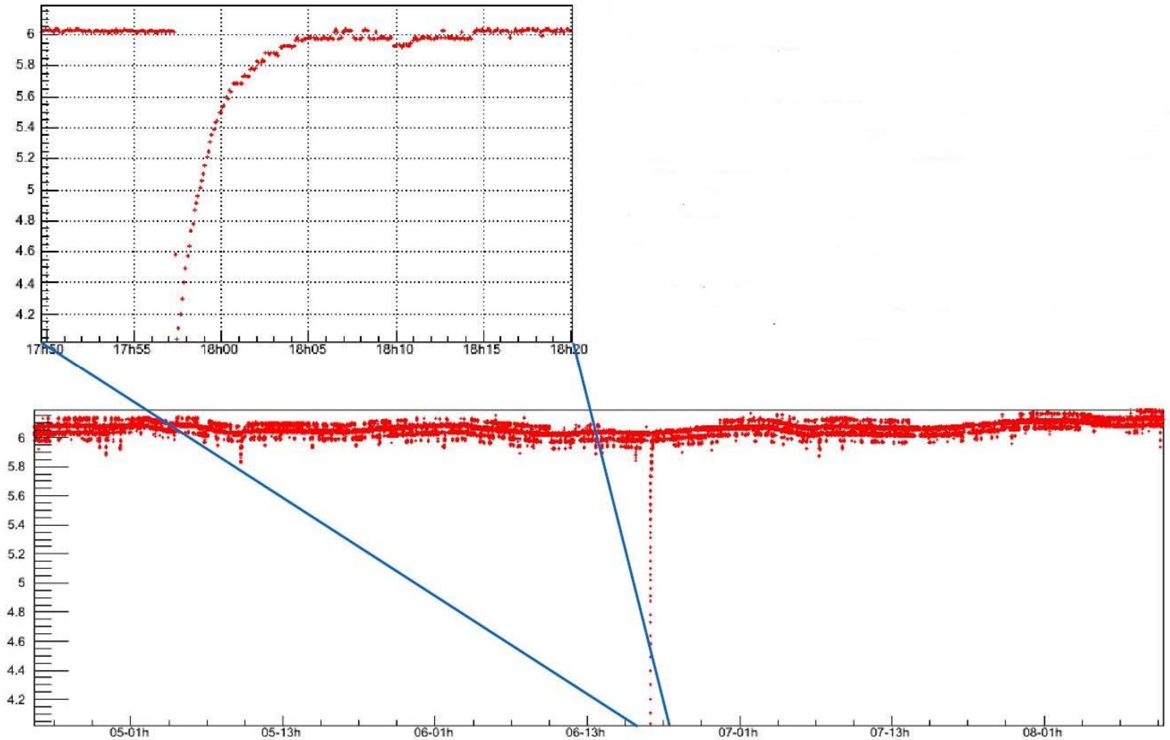
In the MOSCAB bubble chamber, once a vapour bubble nucleates due to a nuclear recoil, it rises through the superheated liquid generating a small geyser when crossing the interface with the overlying buffer layer, which is the reason for the name GEYSER.



In the MOSCAB bubble chamber, after the condensation of the excess vapour occurs at the top, the drops of condensate fall back into the target liquid, which recovers its original superheated state, as displayed by a typical time distribution of the superheat degree during a run.



Notice the peak of ~2°C of amplitude, due to a sudden and strong evaporation occurred at the jar wall. The close-up shows the recovery of the original superheat degree. In fact, owing to the reduced superheat, the bubble nucleation decreases drastically, whereas the subsequent vapour condensation at the top reduces the total pressure inside the vessel, which demonstrates the intrinsic self-regulatory aptitude of the detector to spontaneously regain the imposed metastability degree.

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The role played by ROMA1 research unit within the MOSCAB Collaboration

ROMA1 research unit is committed to:

- **the study of the thermodynamics behind the MOSCAB detector**
- **the development of a new model of radiation-induced bubble birth and growth in a superheated liquid**
- **the execution of CFD simulations of the thermo-fluid-dynamic behavior of the MOSCAB detector, mainly with the scope to determine the optimal thickness of the buffer layer to minimize the heat and momentum transfer inside the target liquid and the pressure changes consequent to high evaporation rates at the jar wall**
- **the execution of MC simulations for the underground calibration of the MOSCAB detector using different neutron sources**
- **the execution of CFD and MC simulations aimed at the thermo-mechanical design of a new configuration of the MOSCAB detector**
- **the development of a software code to track, count and locate the vapour bubbles which nucleate inside the MOSCAB detector.**

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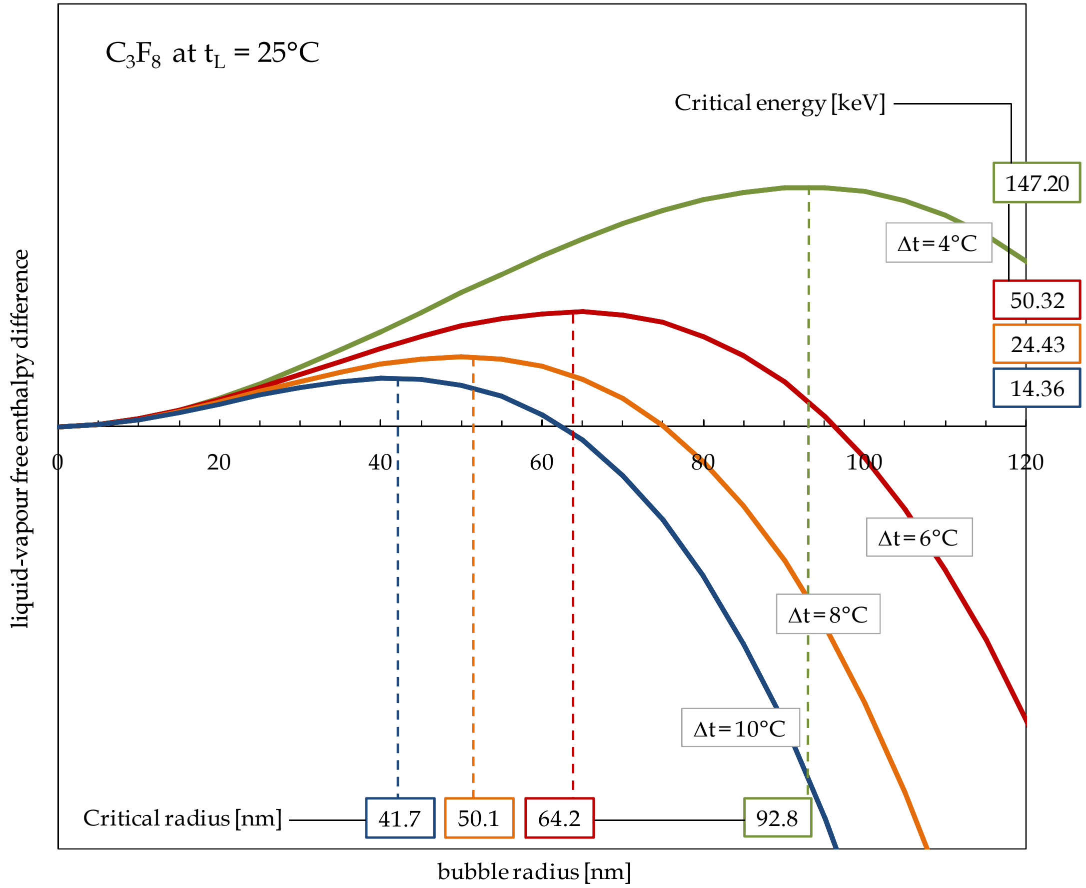
Thermodynamics: a couple of new equations are proposed to determine the critical energy and bubble radius

$$E_c = \frac{4}{3}\pi R_c^3 \rho_V \lambda + 4\pi R_c^2 \left(\sigma - T_L \frac{d\sigma}{dT}\right) \qquad R_c = \frac{2\sigma}{\rho_V \lambda \frac{T_L - T_V}{T_V}}$$



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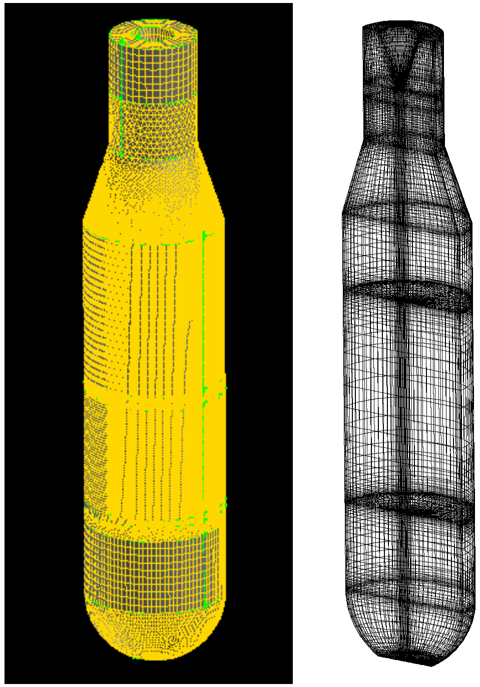
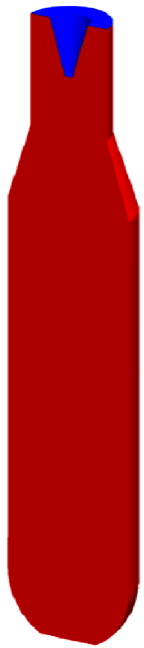
Thermo-fluid-dynamics: CFD is applied to determine the effects of the motion intensity of the buffer liquid on the uprising velocity of the target liquid in the vicinity of the jar wall (1/4)

The system of the governing equations of continuity, momentum and energy is solved using a FV code based on the SIMPLE-C algorithm for the pressure-velocity coupling



Discretization grid of the 2L-jar



Boundary conditions

T and UY fields for the base case

Solutions are investigated to limit the motion of the target liquid either by suspending a hexagonal honeycomb inside the propylene-glycol buffer or by changing the amount of propylene-glycol

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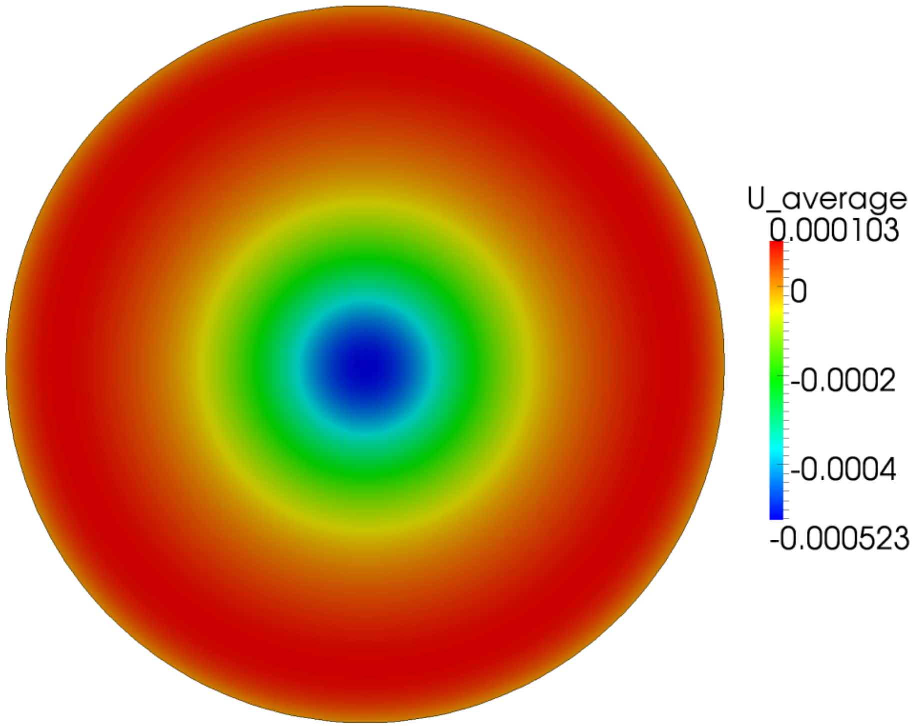
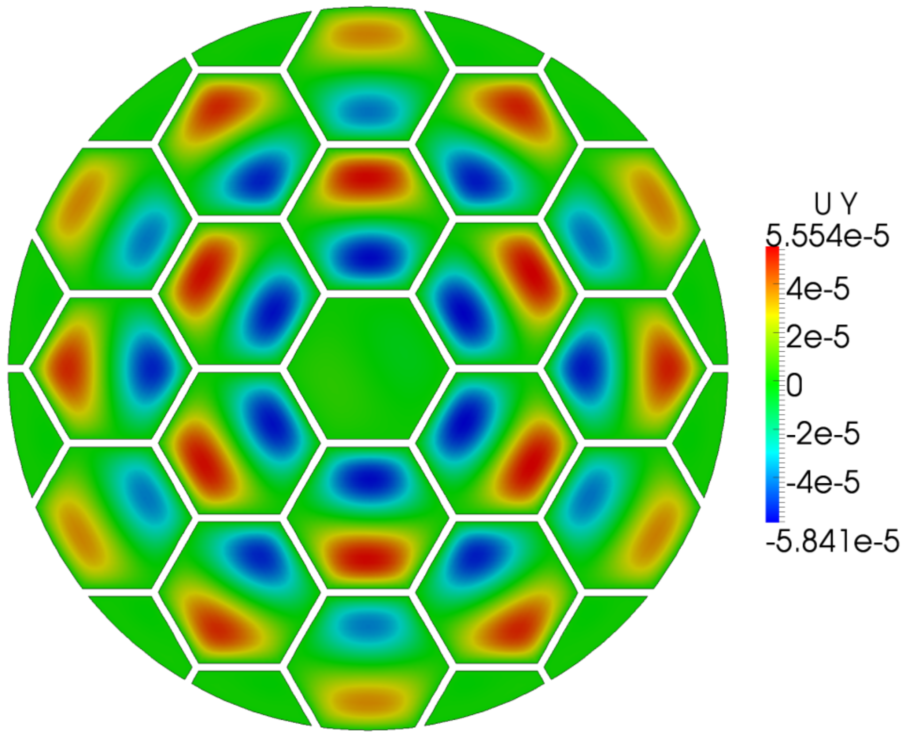
Thermo-fluid-dynamics: CFD is applied to determine the effects of the motion intensity of the buffer liquid on the uprising velocity of the target liquid in the vicinity of the jar wall (2/4)

Suspension of a hexagonal honeycomb inside the buffer liquid below the steel flange:
distributions of the vertical velocity component across the horizontal mid-plane of the buffer liquid



Base case



With the suspended hexagonal honeycomb

The suspension of the hexagonal honeycomb inside the buffer liquid results in a limitation of the momentum transfer to the underlying target liquid

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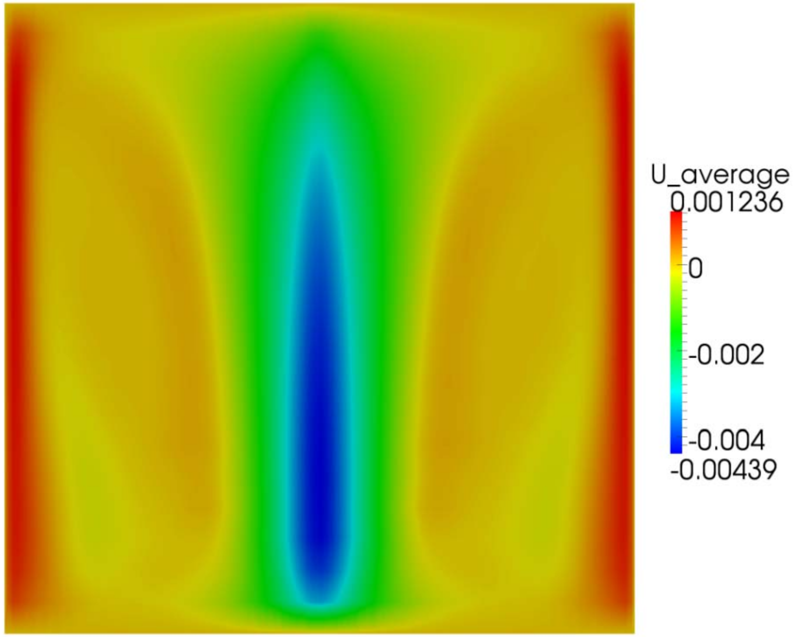
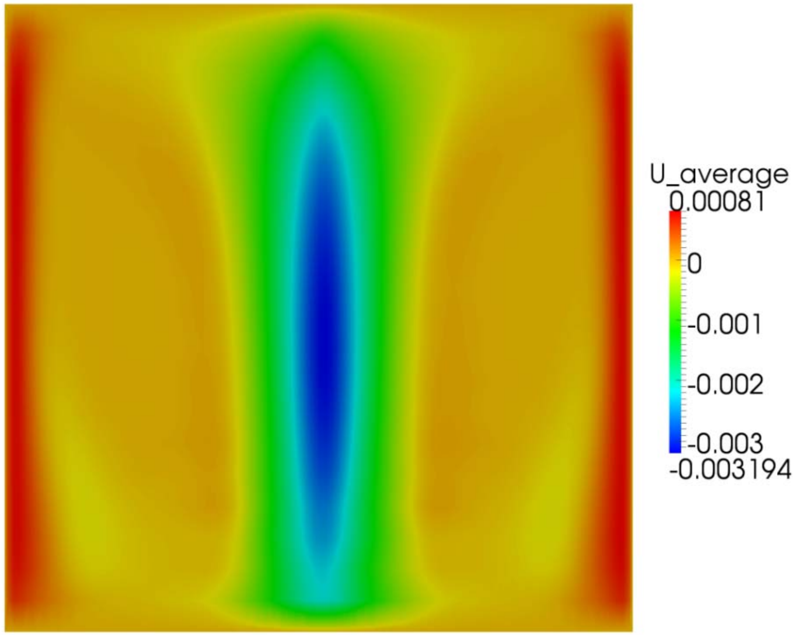
Thermo-fluid-dynamics: CFD is applied to determine the effects of the motion intensity of the buffer liquid on the uprising velocity of the target liquid in the vicinity of the jar wall (3/4)

Suspension of a hexagonal honeycomb inside the buffer liquid below the steel flange:

distributions of the vertical velocity component across the vertical mid-plane of the target liquid



Base case



With the suspended hexagonal honeycomb

The decreased momentum transfer from the overlying buffer liquid results in a reduced uprising velocity of the target liquid

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A shear velocity decrease means that the probability of development of fake bubbles/evaporation at the jar wall decreases

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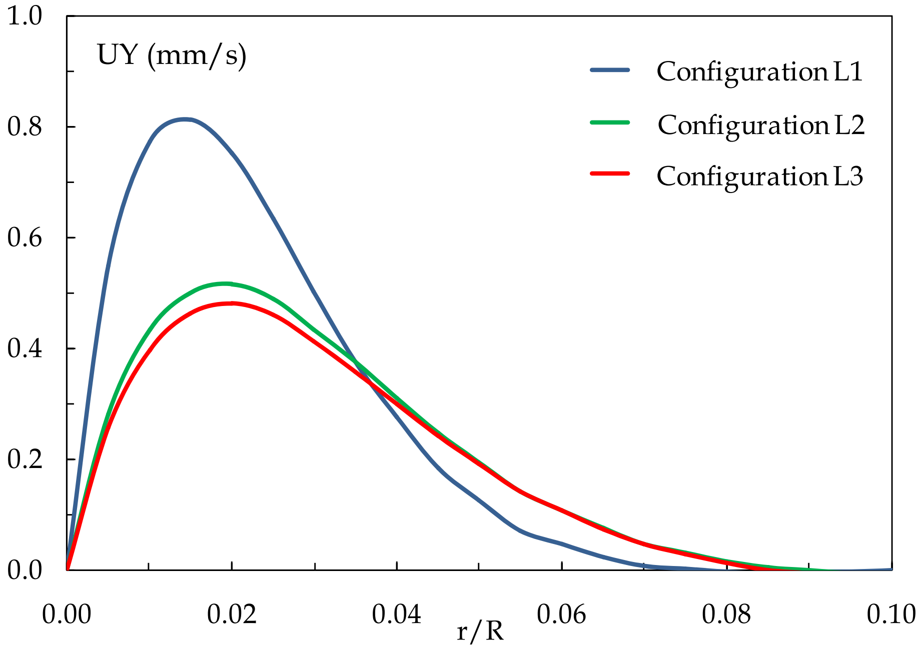
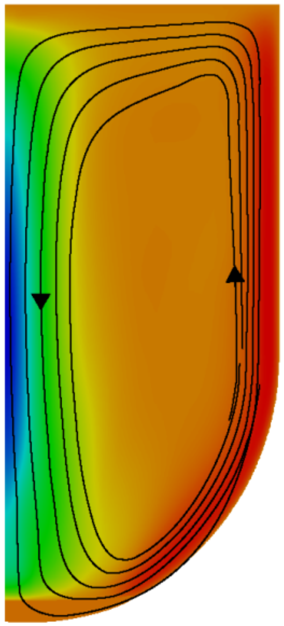
Thermo-fluid-dynamics: CFD is applied to determine the effects of the motion intensity of the buffer liquid on the uprising velocity of the target liquid in the vicinity of the jar wall (4/4)

Change of the amount of the buffer liquid inside the detector:
distributions of the vertical velocity component within the target liquid





The penetration of the buffer liquid into the neck of the detector results in a significantly reduced uprising velocity of the target liquid and shear stress at the wall, which implies a decrease of the probability of development of fake bubbles

No meaningful advantage derives from the increase of the charge level of the buffer liquid above level L2 that can thus be used as charge level to avoid excessive pressure fluctuations when strong evaporations occur

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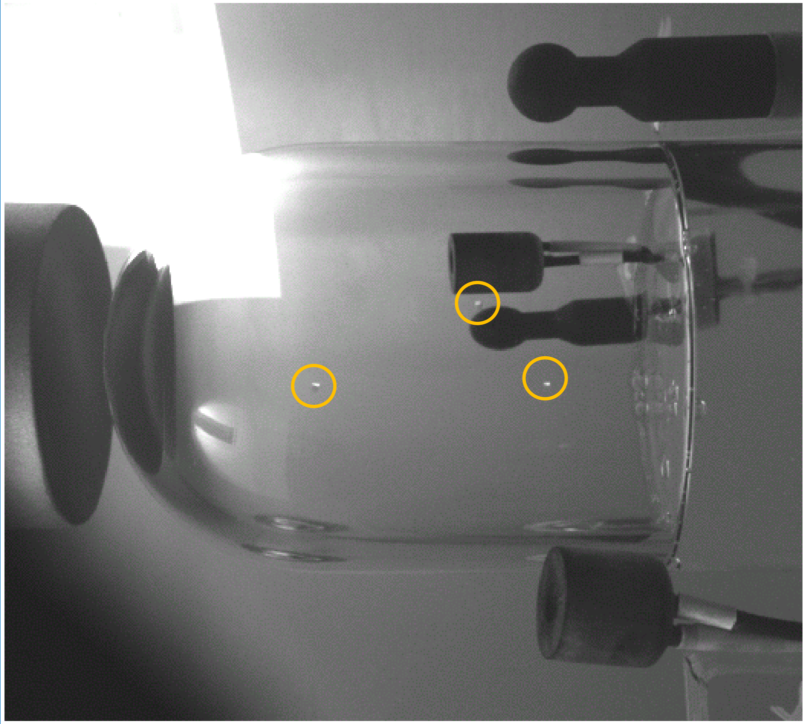
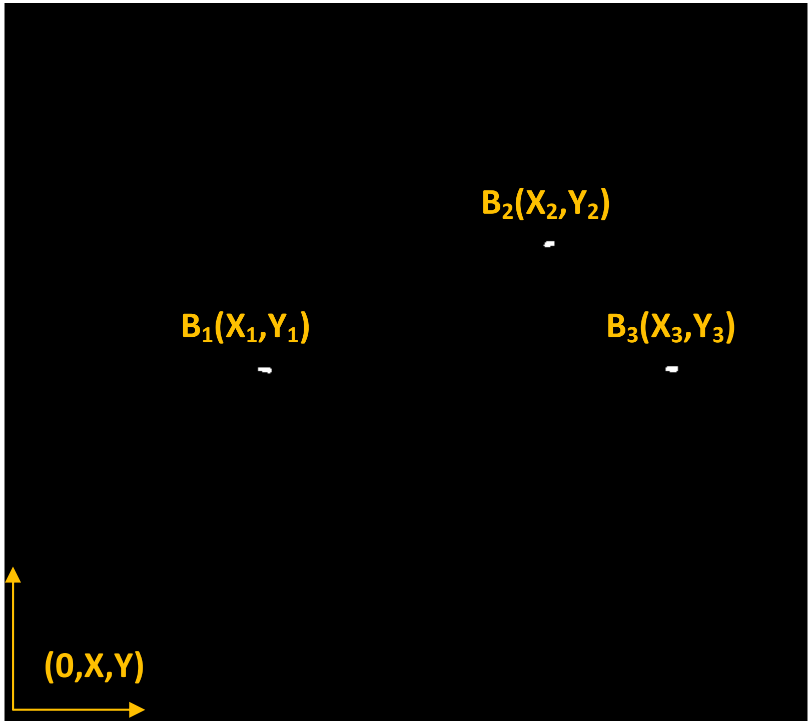
Bubble tracking and counting: main steps of the bubble count procedure

1 - Subtraction of the background image (void of bubbles)
2 - Enhancement of the contrast
3 - Conversion of the grey-scale image to a binary file image





4 - Detection of the number and position of the candidate bubbles within the frame
5 - Repetition of steps (1-4) for any subsequent image of the event taken by Camera1
6 - Tracking of the paths and count of the bubbles
7 - Repetition of steps (1-6) for the images of the same event taken by Camera2

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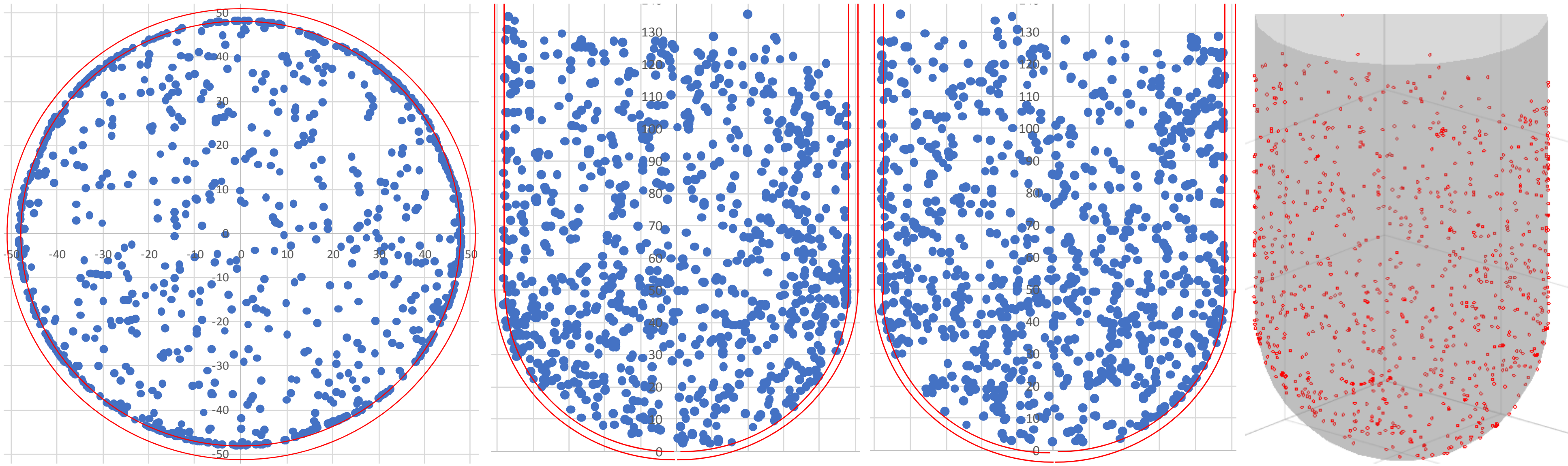
Bubble location: the birth location of any detected bubble is placed inside the volume of the target liquid by a specifically-developed reconstruction code of the light paths from the bubble to the cameras.

Here are some of the graphical outputs.

(run #2069)



Horizontal projection | **Vertical projections seen from Camera1 and Camera 2** | **3D reconstruction**

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THANK YOU FOR YOUR ATTENTION