Experimental study of the liquid jet-induced loads following a wave impact on MarkIII corrugations

by

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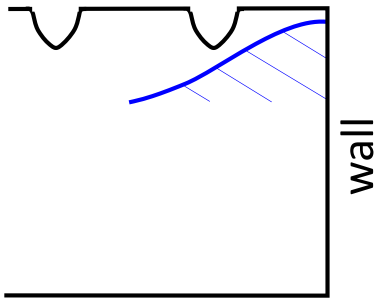
Overview

1. **First Campaign (2014)**
   a) Experimental setup
   b) How to generate experimentally waves to obtain significant pressures on ceiling
   c) The most interesting case of this campaign
2. **Second Campaign (2017)**
   a) The modified setup
   b) Strong impact – First case
   c) Strong impact – Second case
3. **Conclusions**

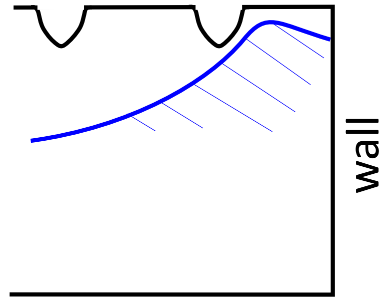
What we wanted to study?

Wave Impact on an instrumented corrugated ceiling

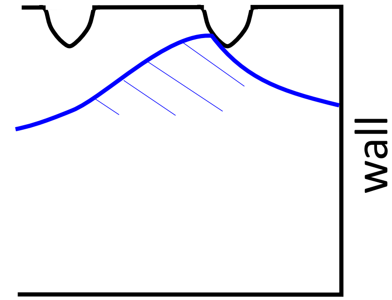
Impact on the corner



Impact at some distance from the wall with gas pocket

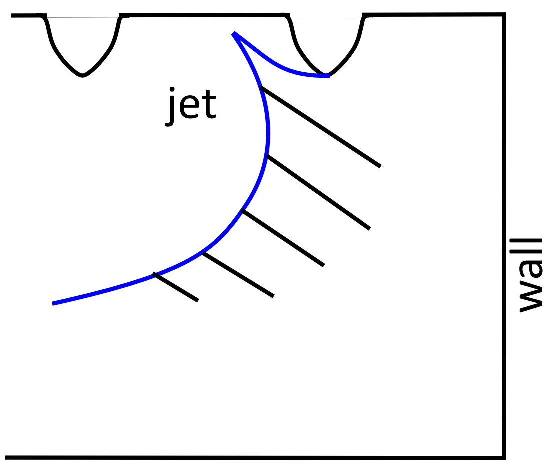


Small gas pocket

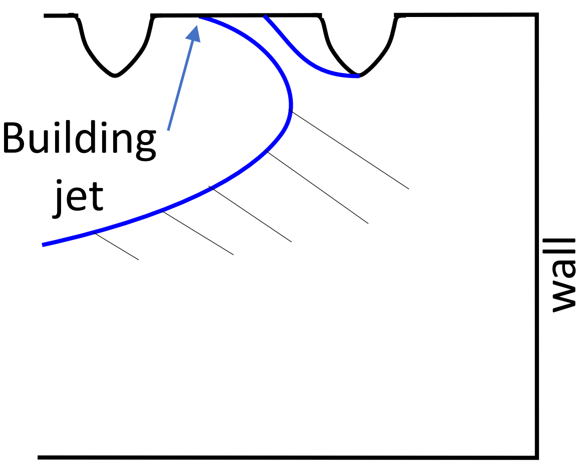


large gas pocket

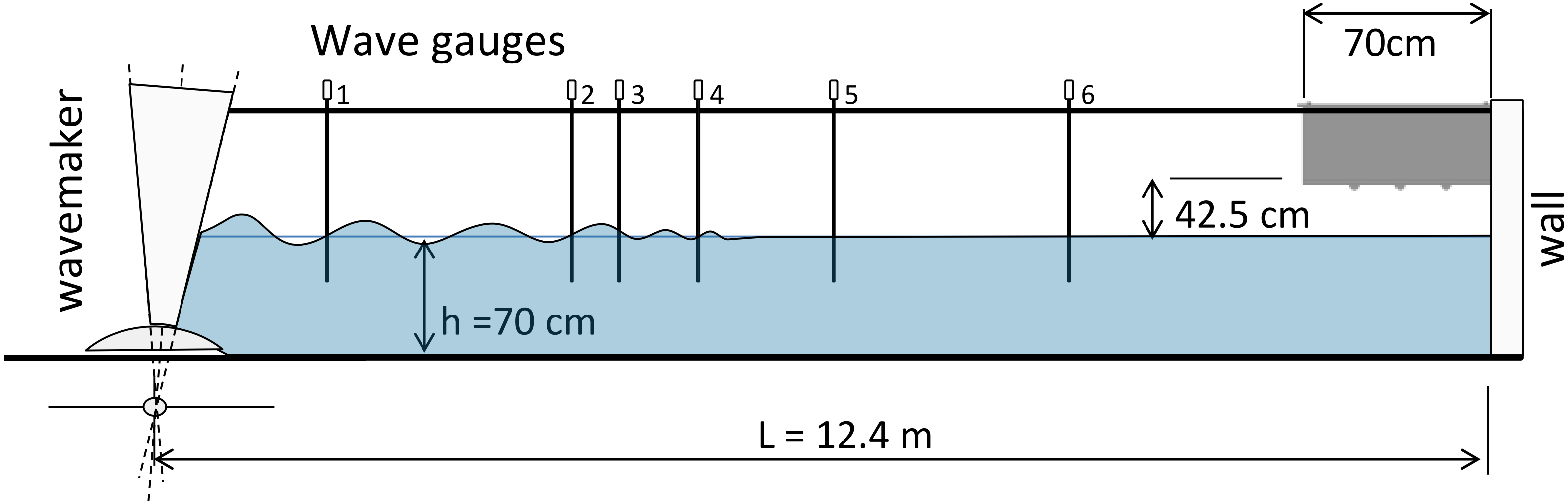
Separation of the flow at the top of the corrugation – creation of a jet

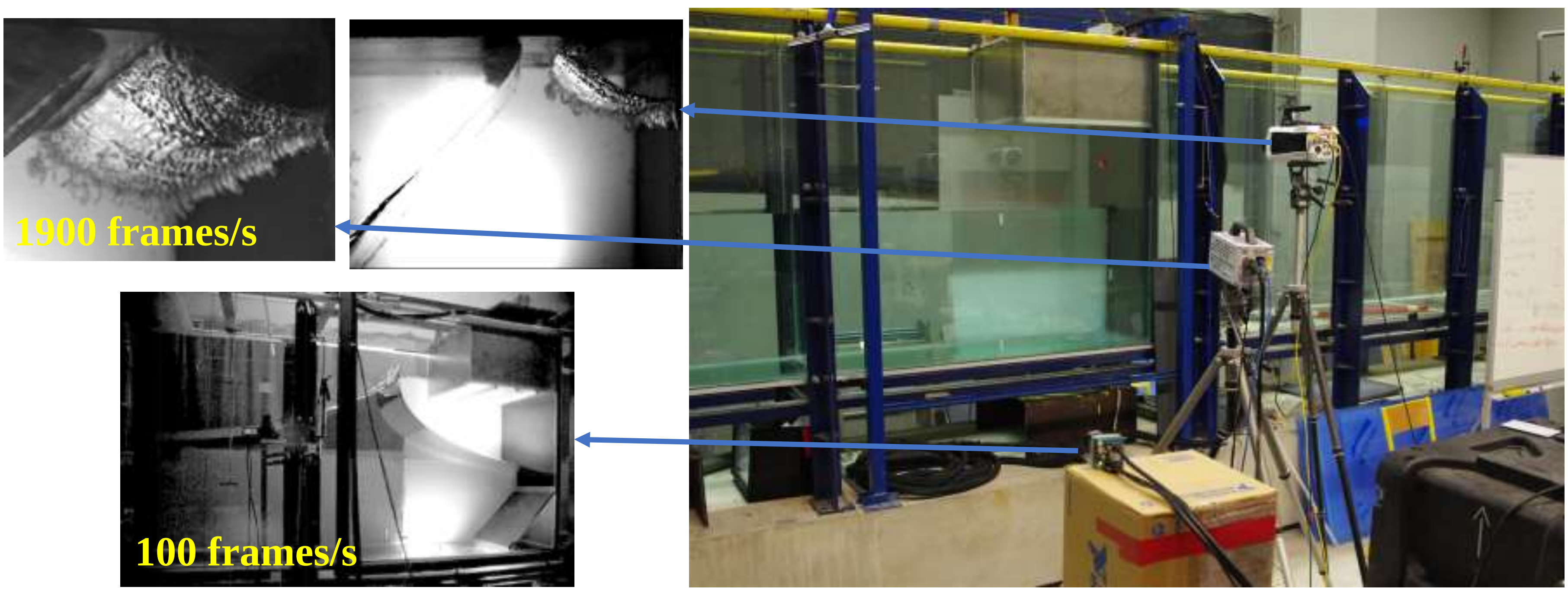


Reattachment of the jet on the ceiling – propagation of the building jet



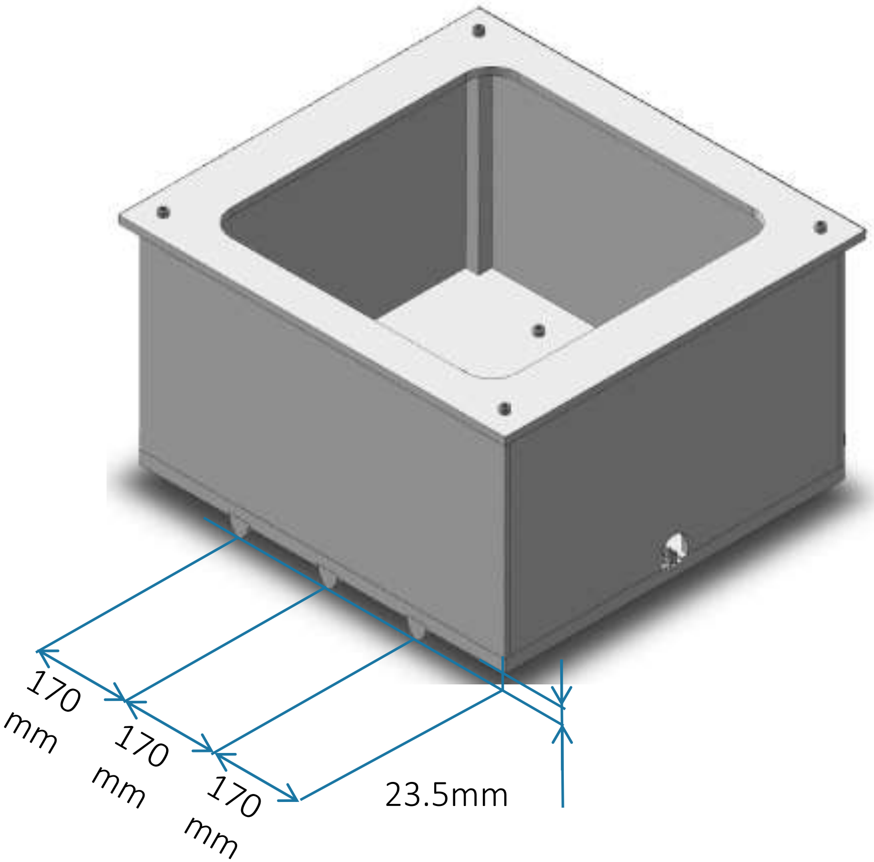
Experimental setup – 1st campaign

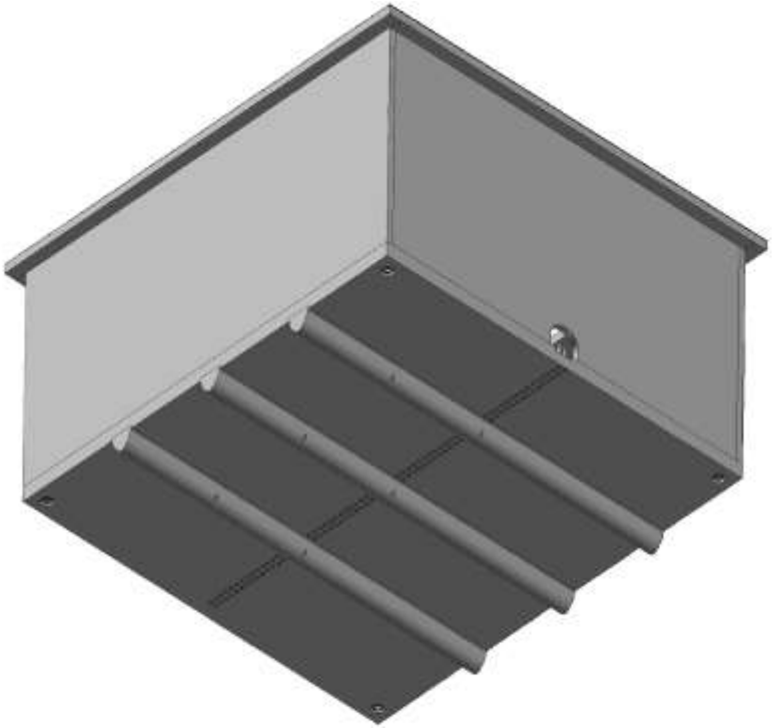




Experimental setup – 1st campaign

corrugated ceiling



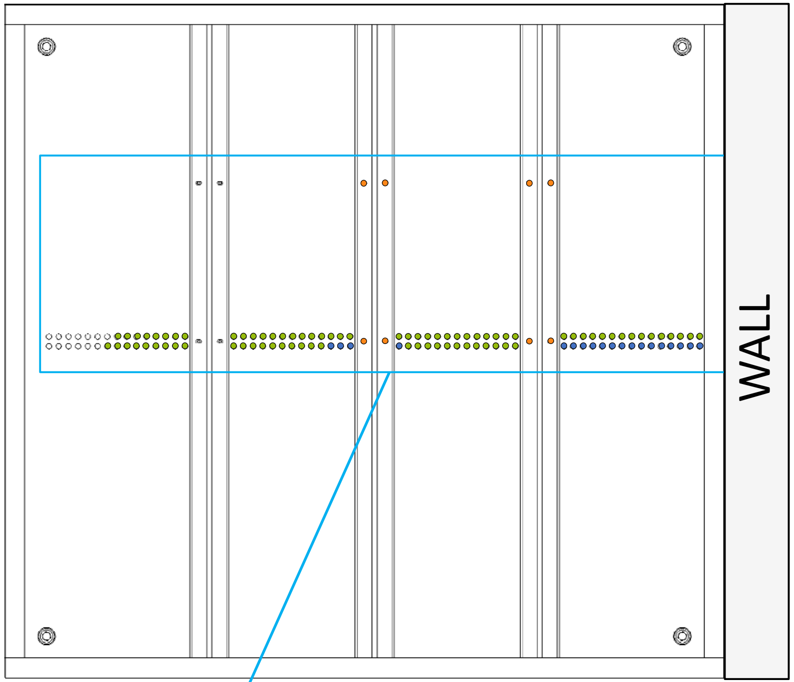


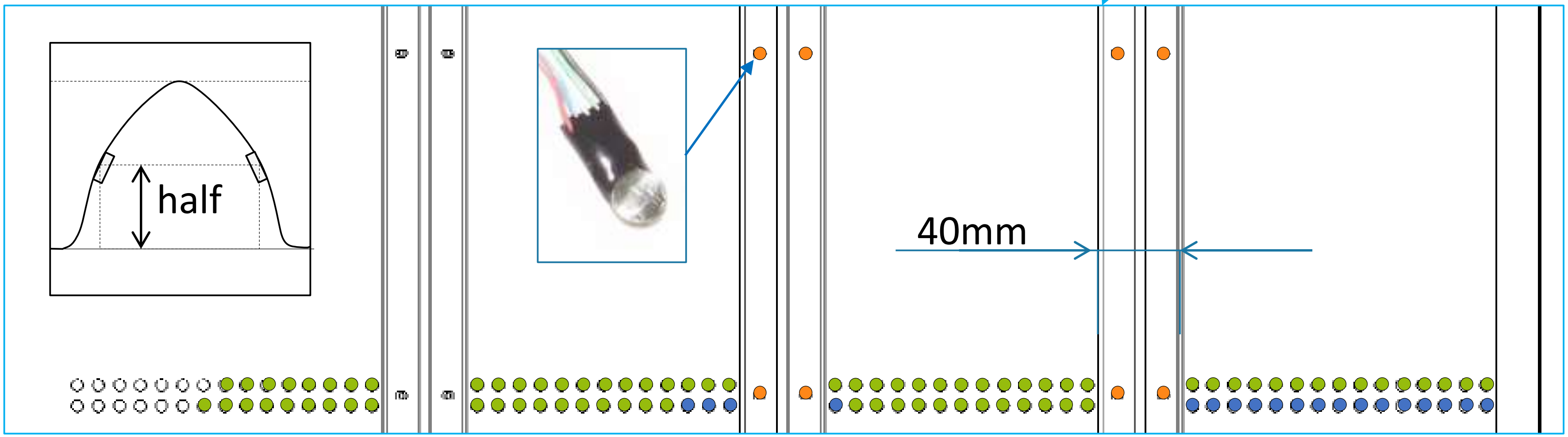
Design by Arnaud Landure – GTT

Experimental setup – 1st campaign. Corrugated ceiling

1. 99 Pressure sensors on the roof
   1. 19 PCB 112A21 (7 bars max)
   2. 80 PCB 113B24 (70 bars max)

1. **8 pressure sensors on the corrugations**
   1. **8 ENTRAN surface mount pressure sensors**

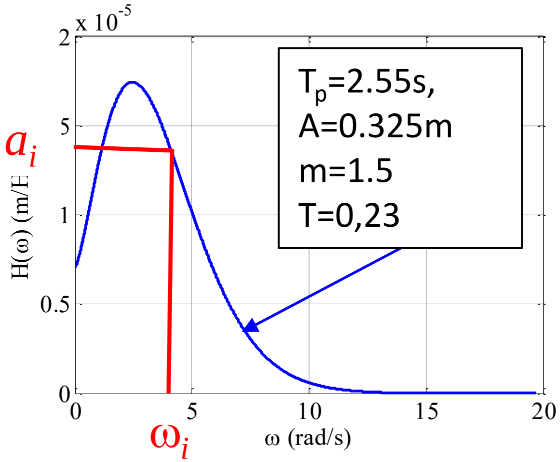




How to generate representative impact on the ceiling ?

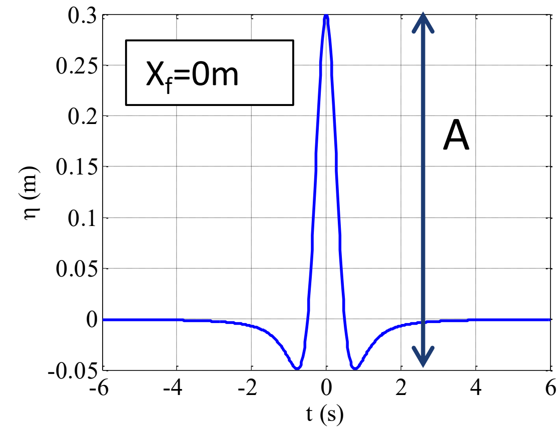
The classical space-time focusing technique

Starting from a given spectrum (RICKER)

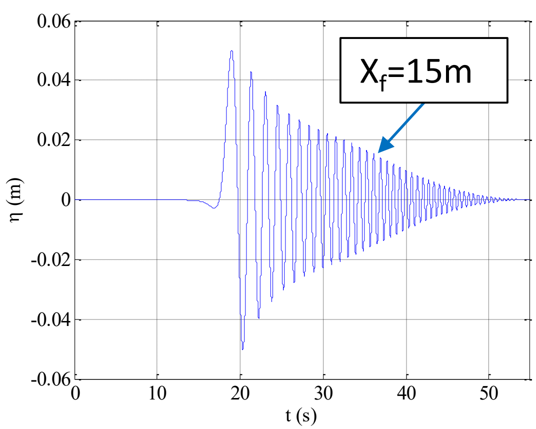


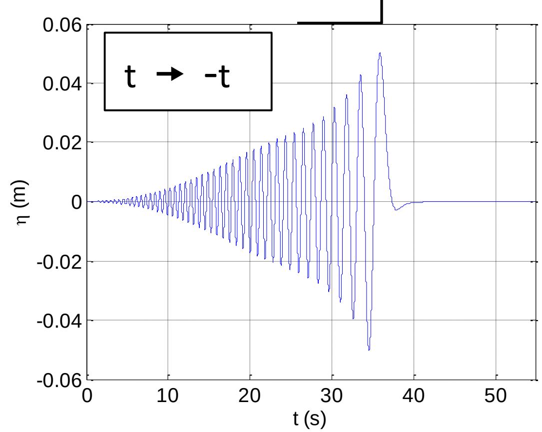
$$\sum_i a_i \cos(k_i x - \omega_i t + \varphi_i)$$

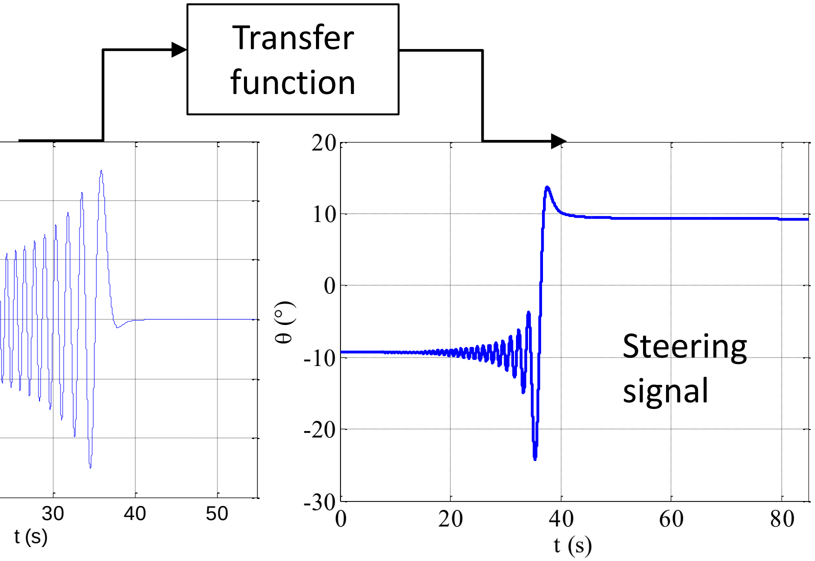
All the phases φ_i are determined to obtain a single wave at a given distance.



Due to dispersion, the single wave transforms into multiple waves







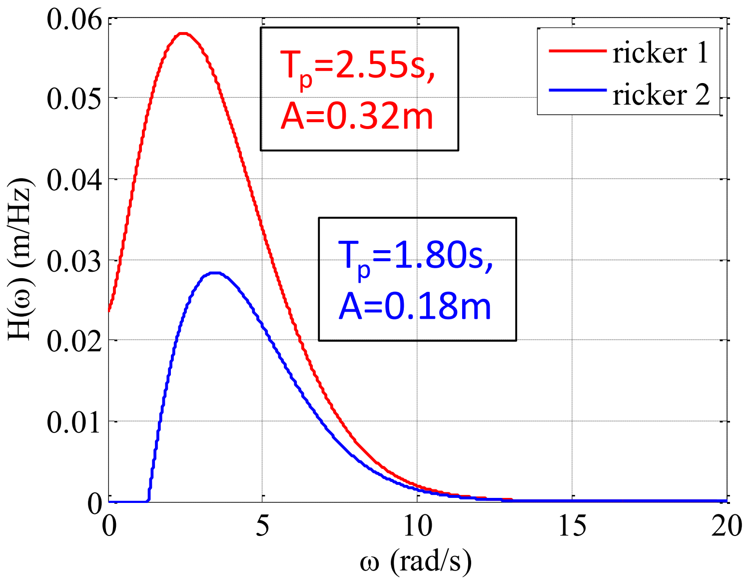
By reversing the time, this wave group leads to the single wave at the distance X_f=15m

How to generate representative impact on the ceiling ?

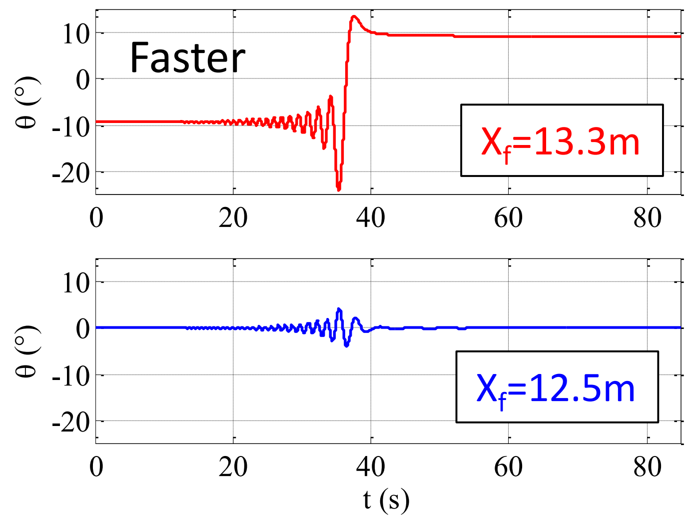
One focusing wave is not enough to obtain significant impact pressures

⇩

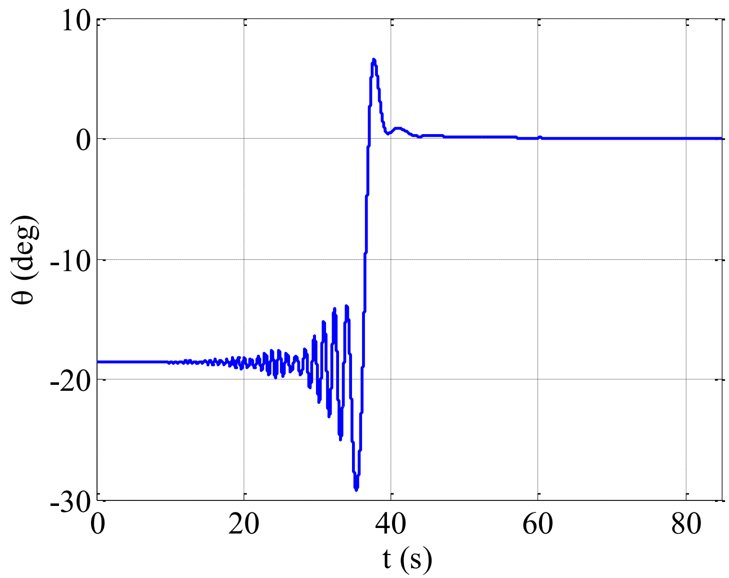
Superposition of 2 Ricker spectra



Steering signals



Sum of the 2 Steering signals



X_{wall}=12.55m

Behind the wall The focusing wave is reflected

+

In front of the wall

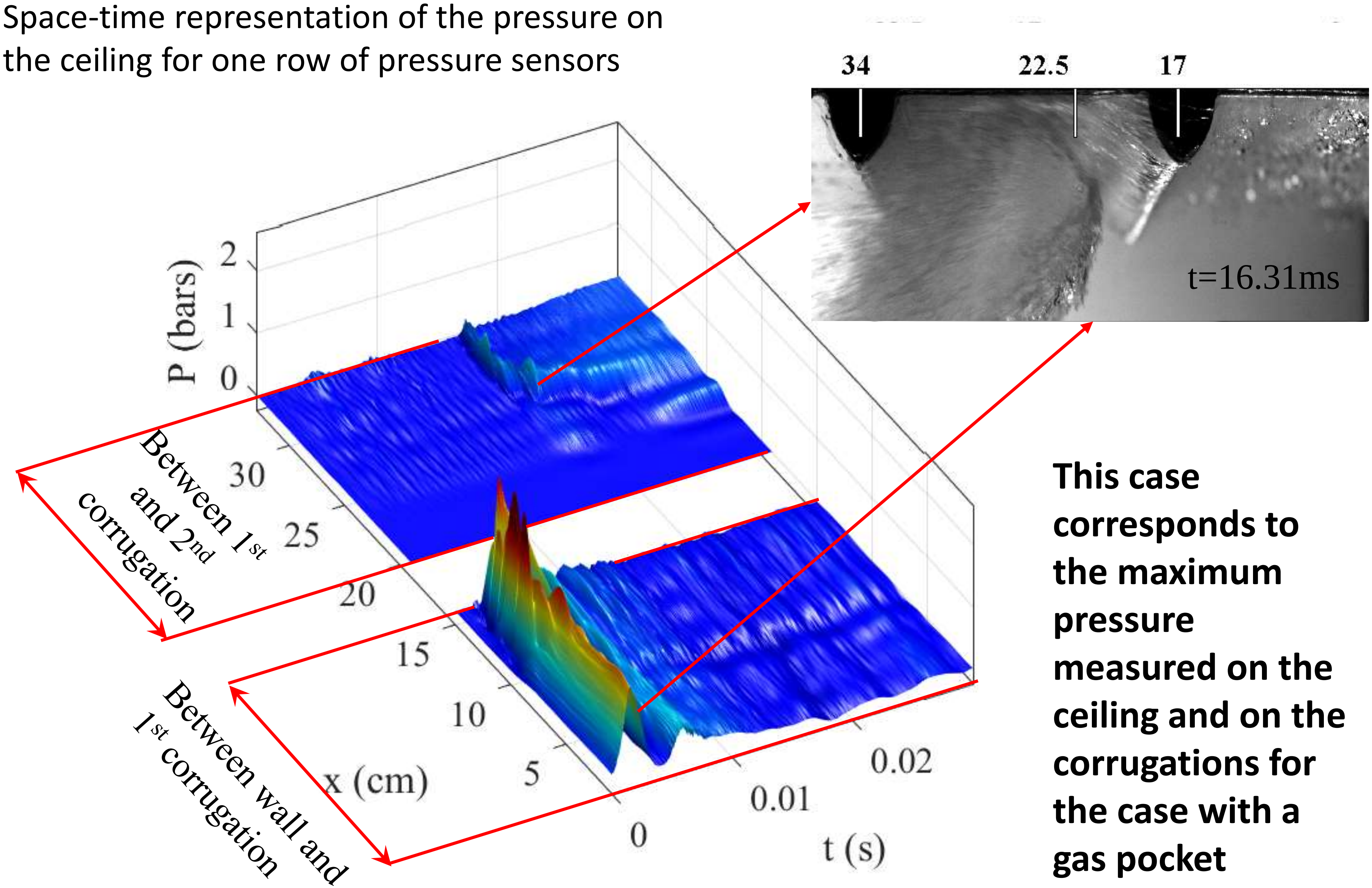
=

The two crests meet together at the same location

The most interesting case of this campaign

The most interesting case of this campaign

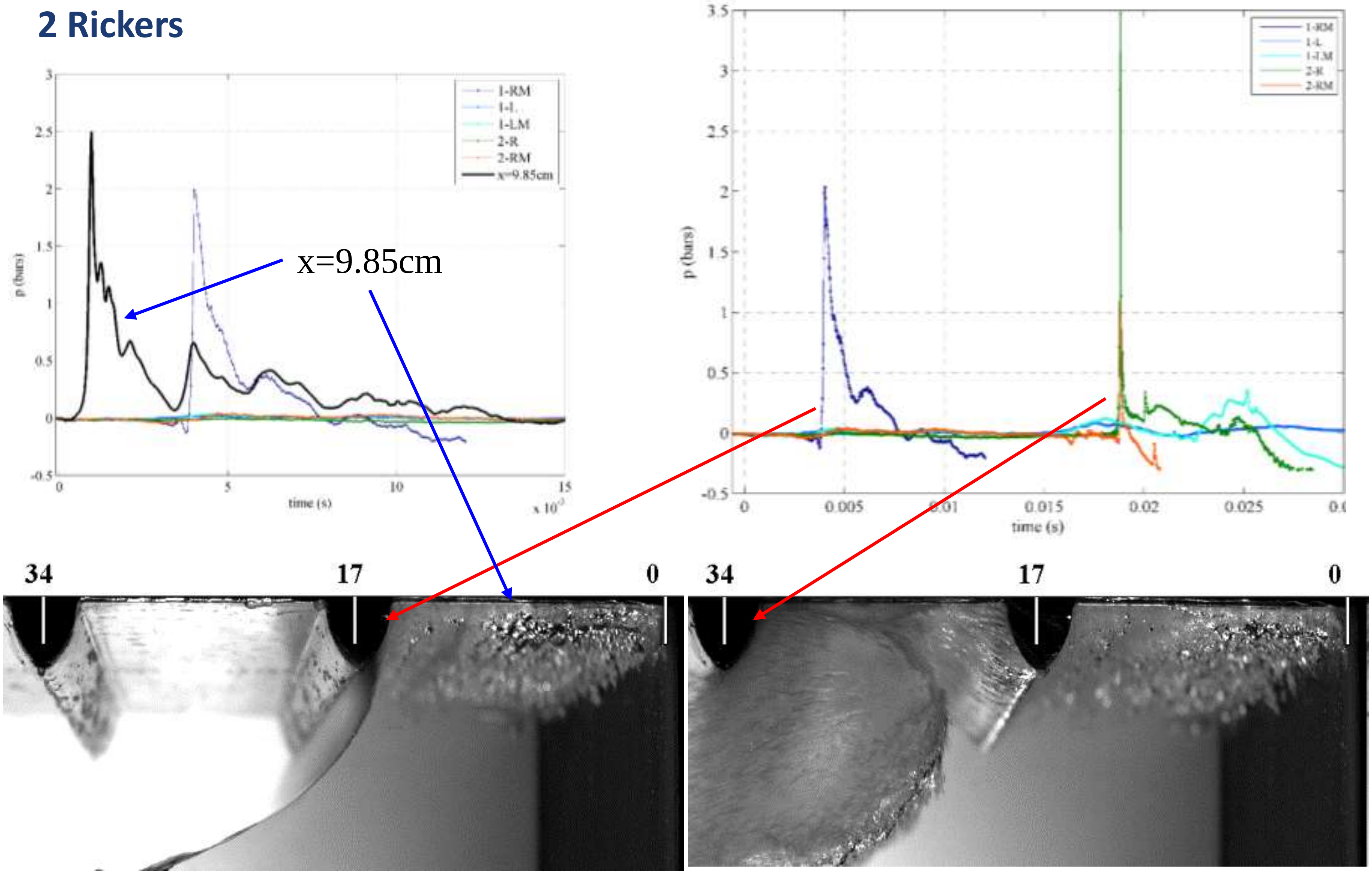
Space-time representation of the pressure on the ceiling for one row of pressure sensors



This case corresponds to the maximum pressure measured on the ceiling and on the corrugations for the case with a gas pocket

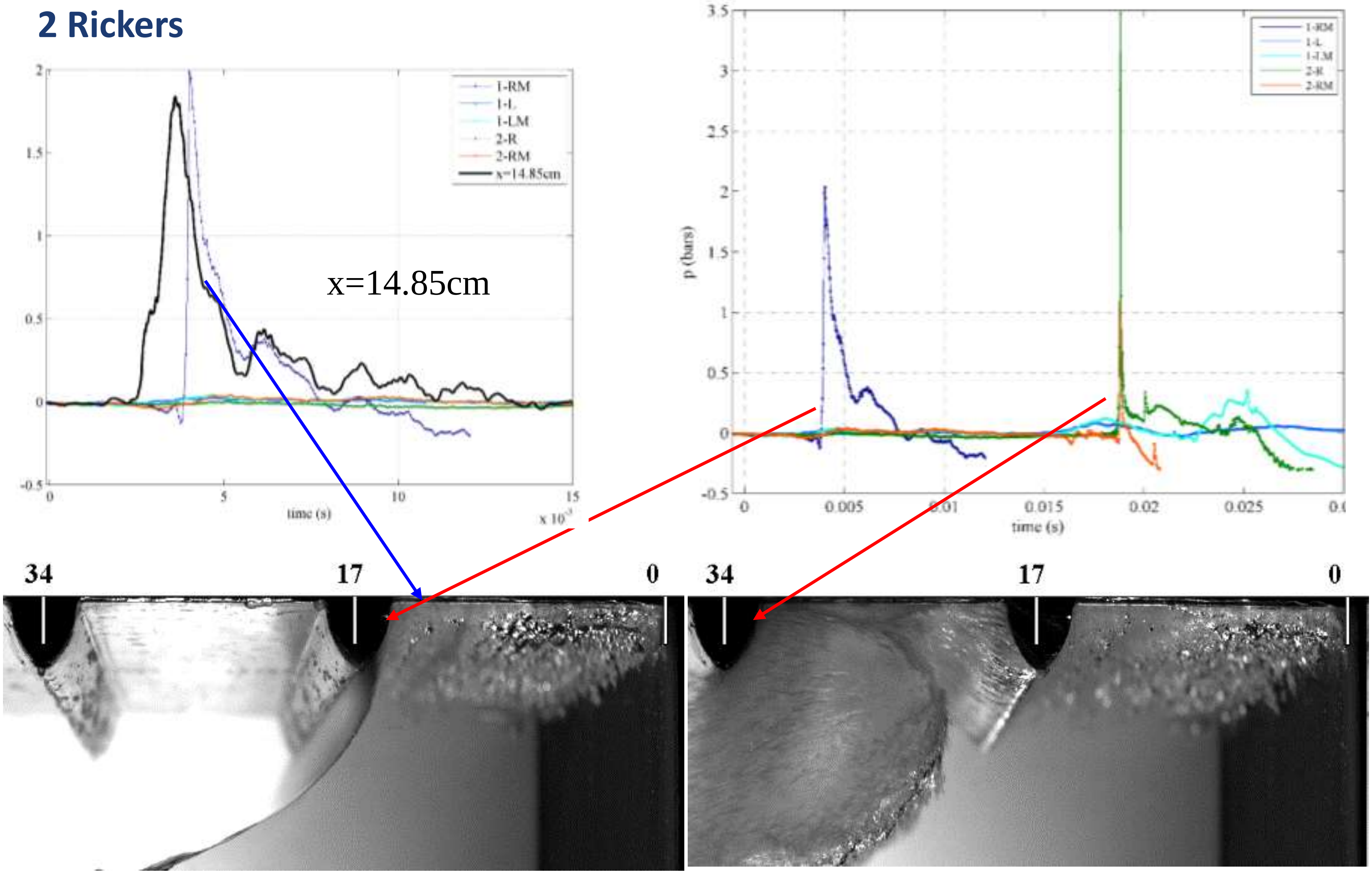
The most interesting case of this campaign

2 Rickers

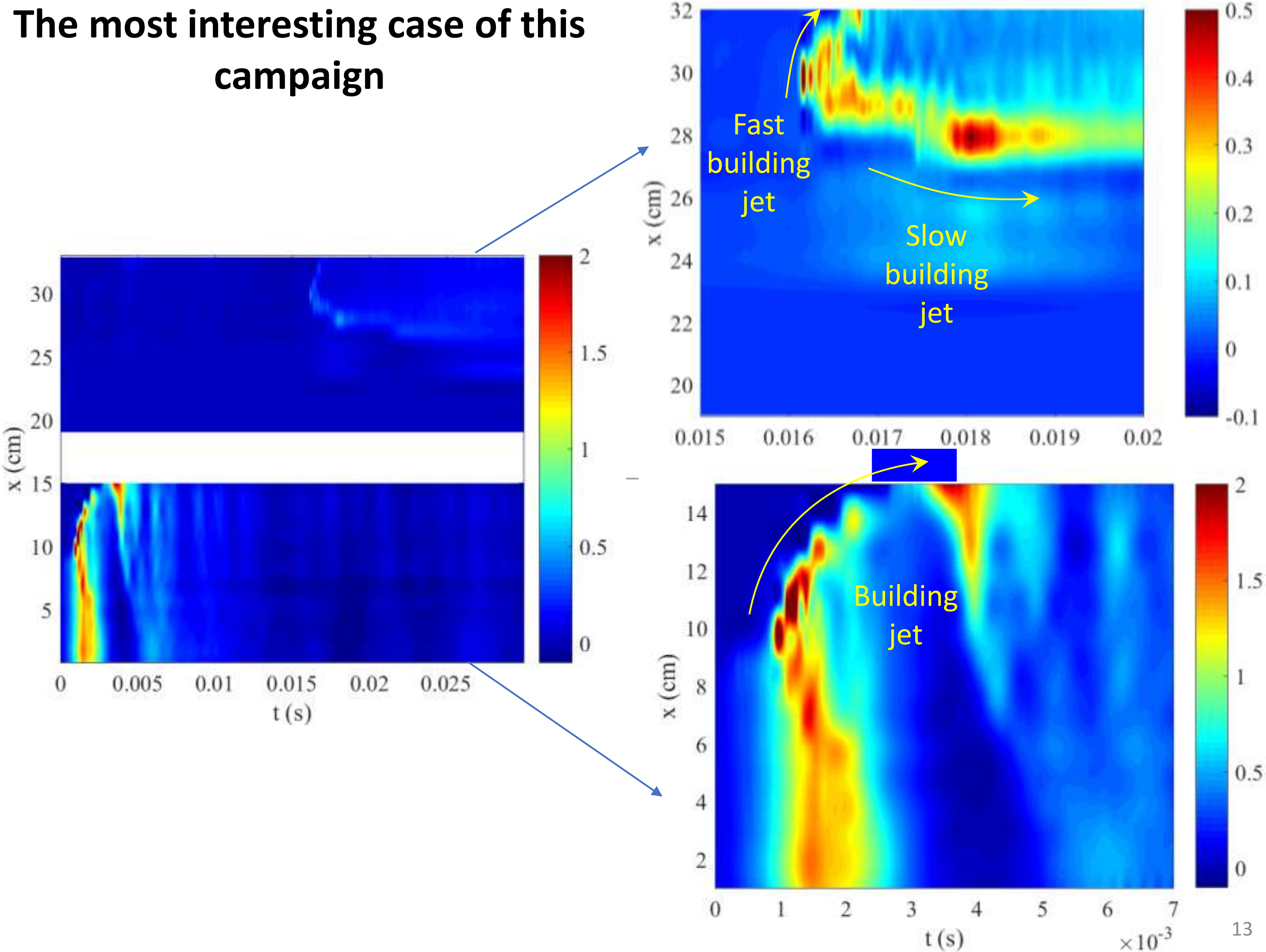


The most interesting case of this campaign

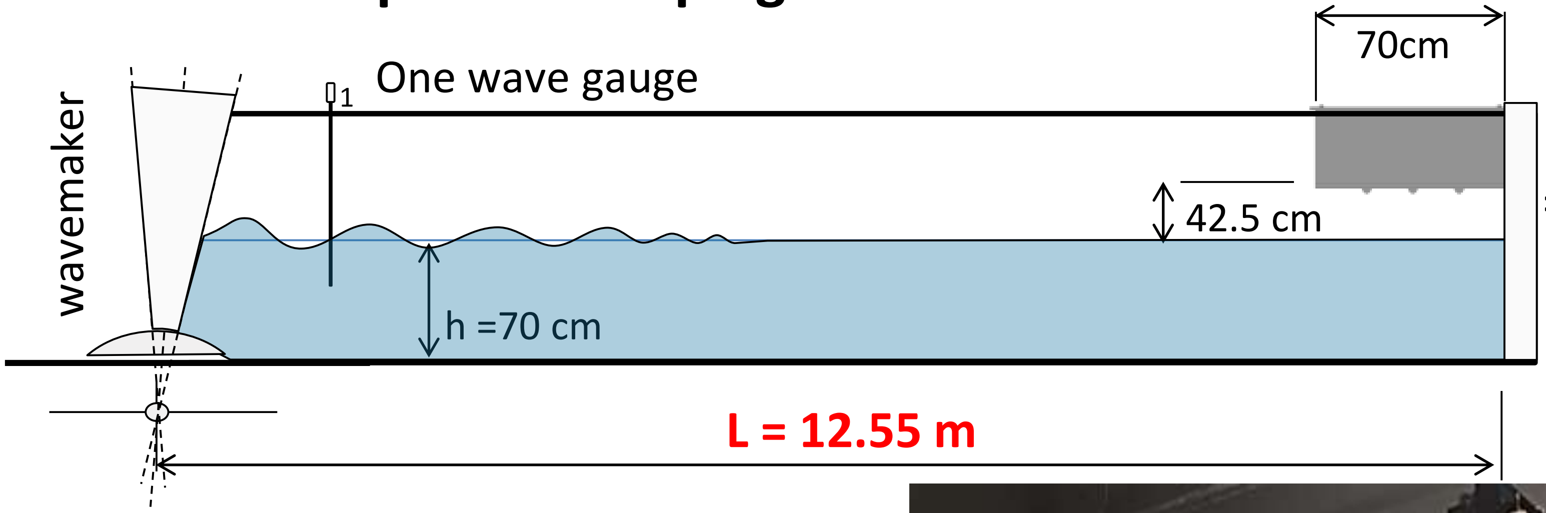
2 Rickers

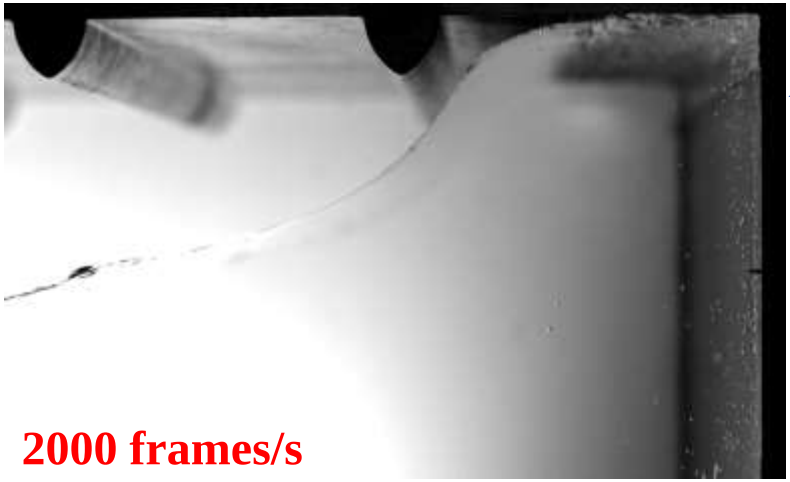


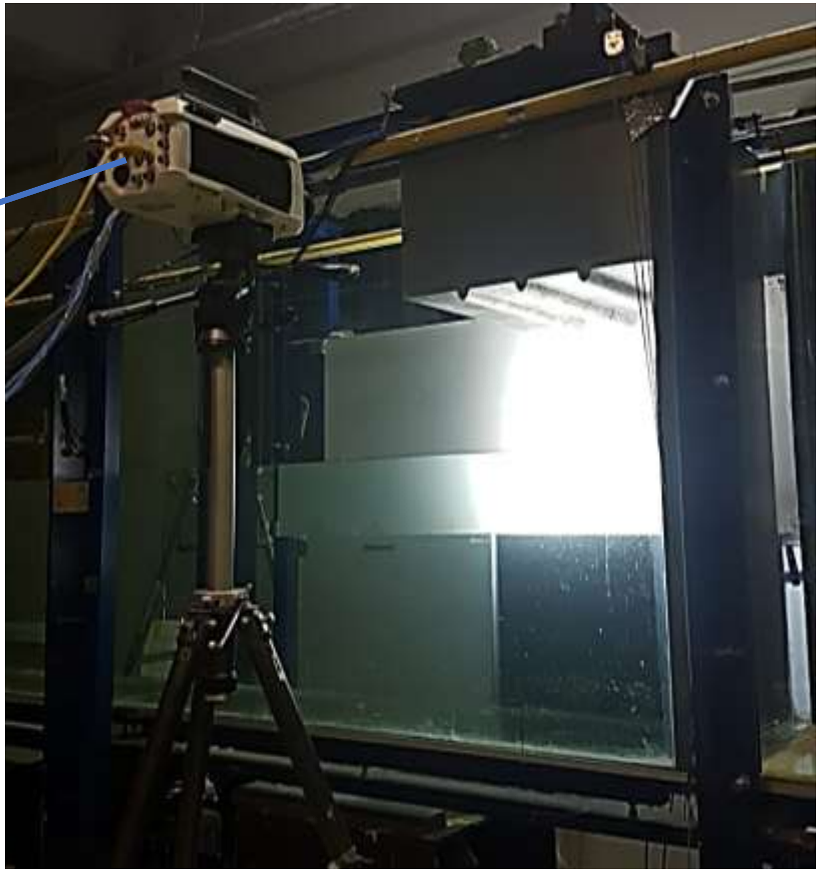
The most interesting case of this campaign



Experimental setup – 2nd campaign



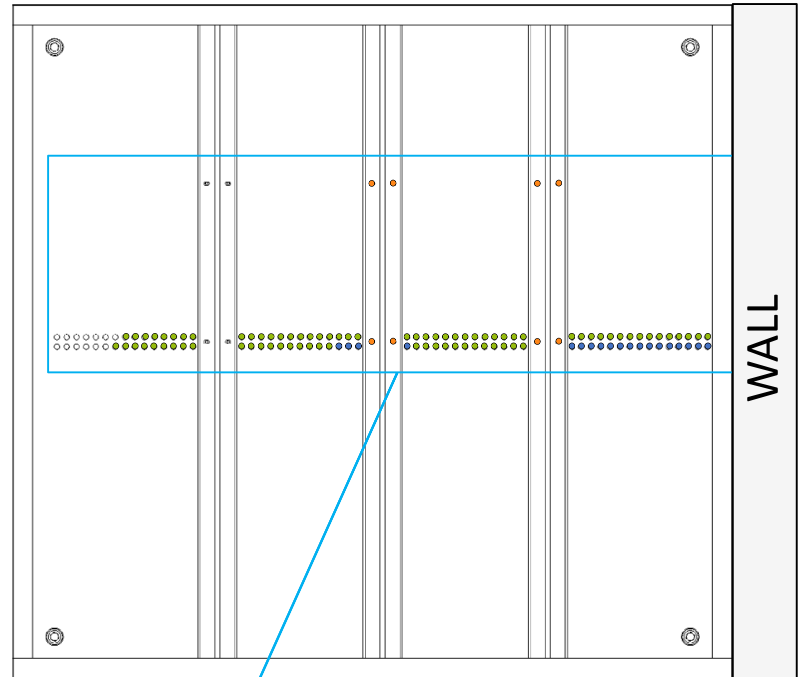




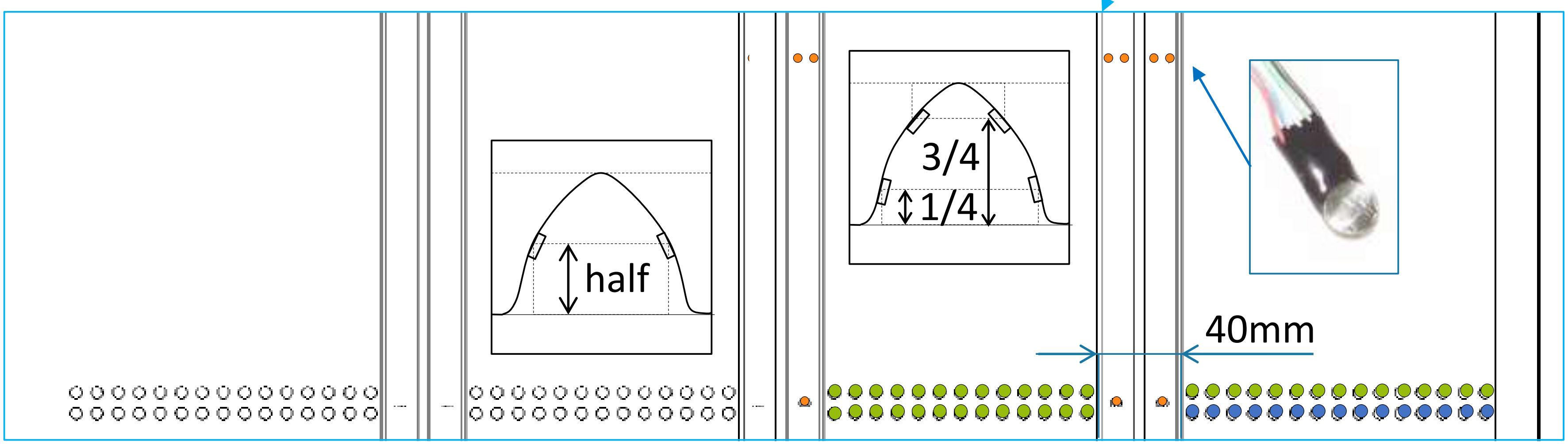
Corrugated Ceiling. 2nd campaign

1. **56 Pressure sensors on the ceiling**
   1. 🔵 15 PCB 112A21 (7 bars max)
   2. 🟢 42 PCB 113B24 (70 bars max)

1. **9 pressure sensors on the corrugations**
   1. 🟠 9 ENTRAN surface mount pressure sensors



Bottom view

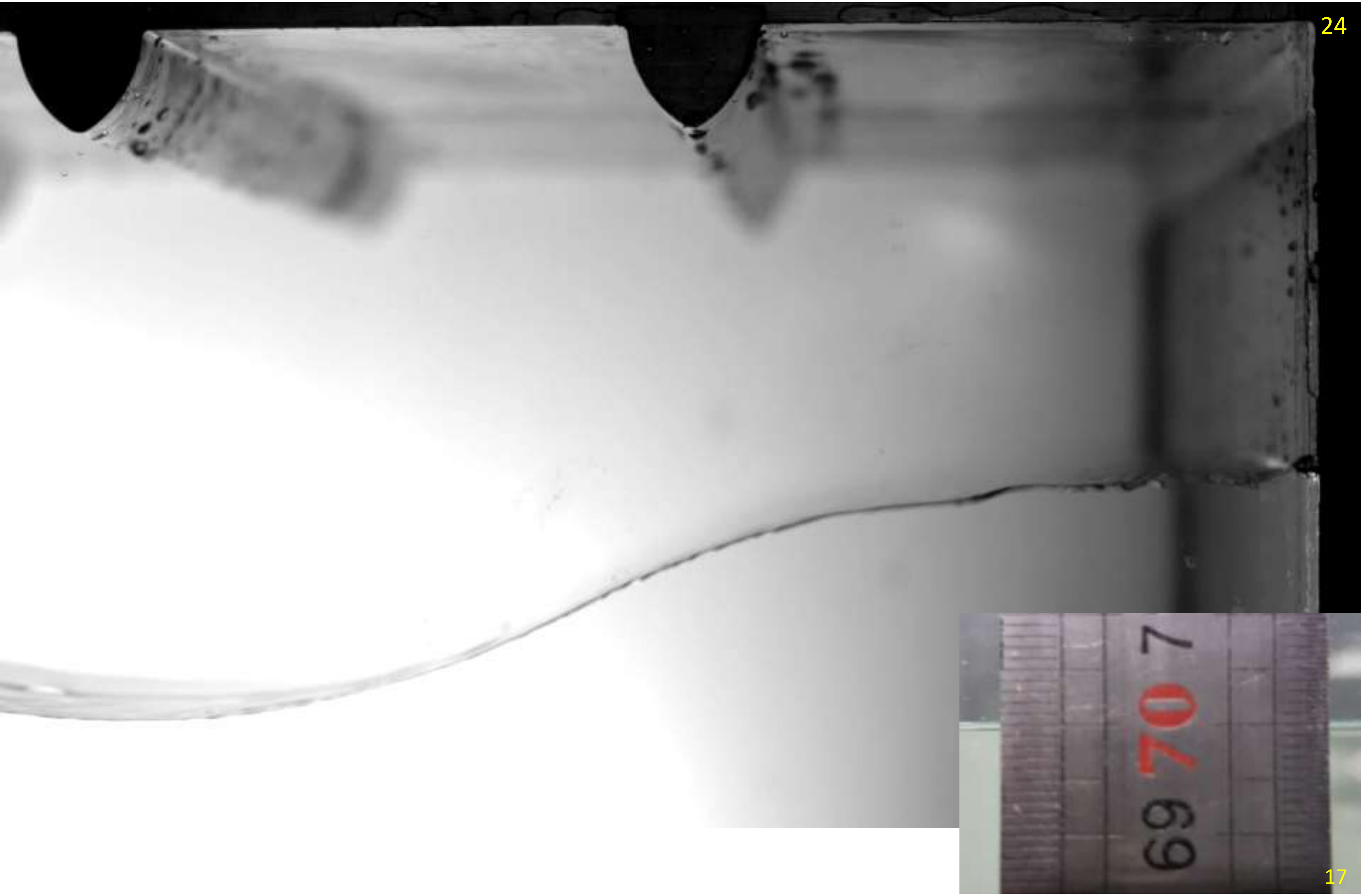


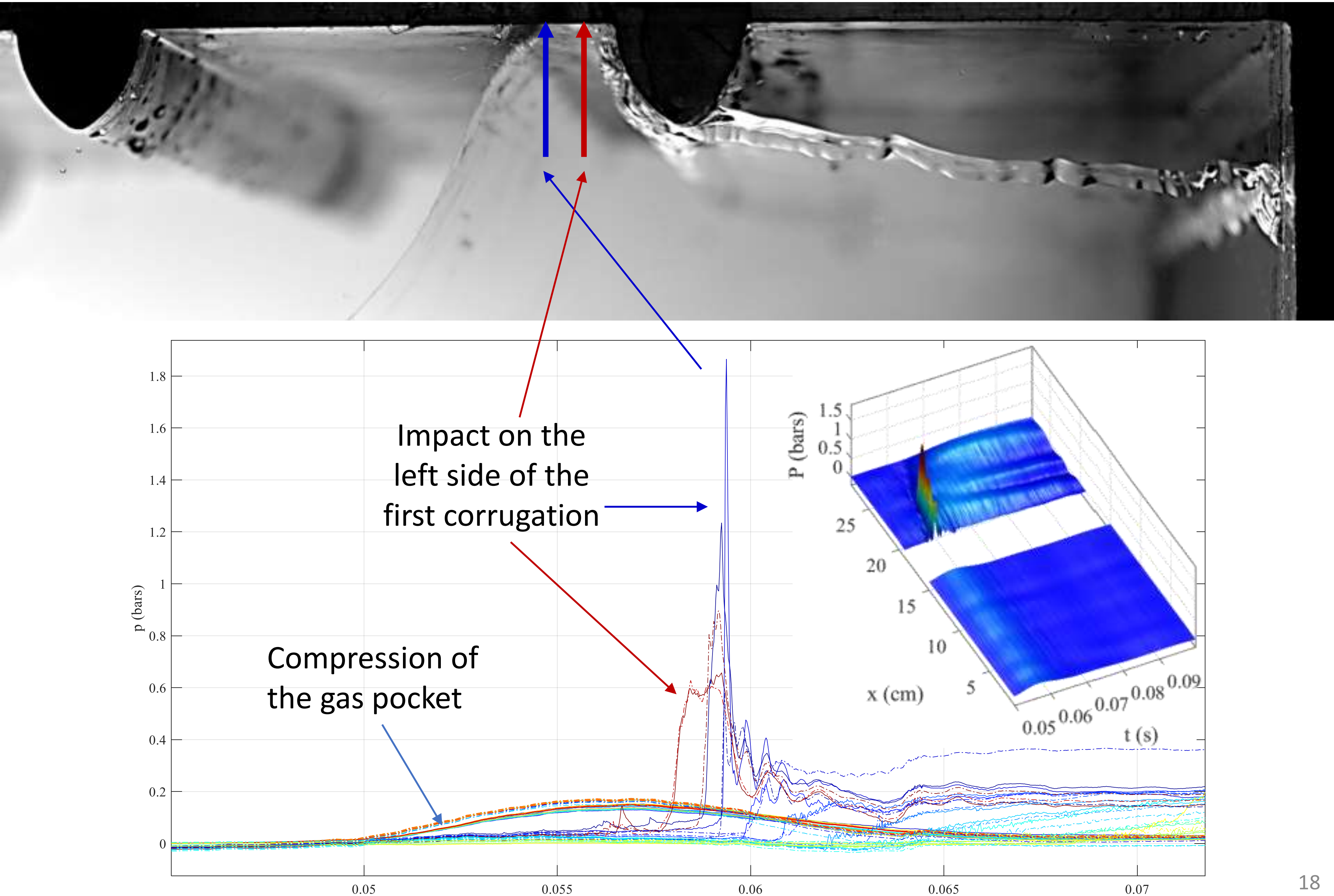
26 pressure sensors

30 pressure sensors

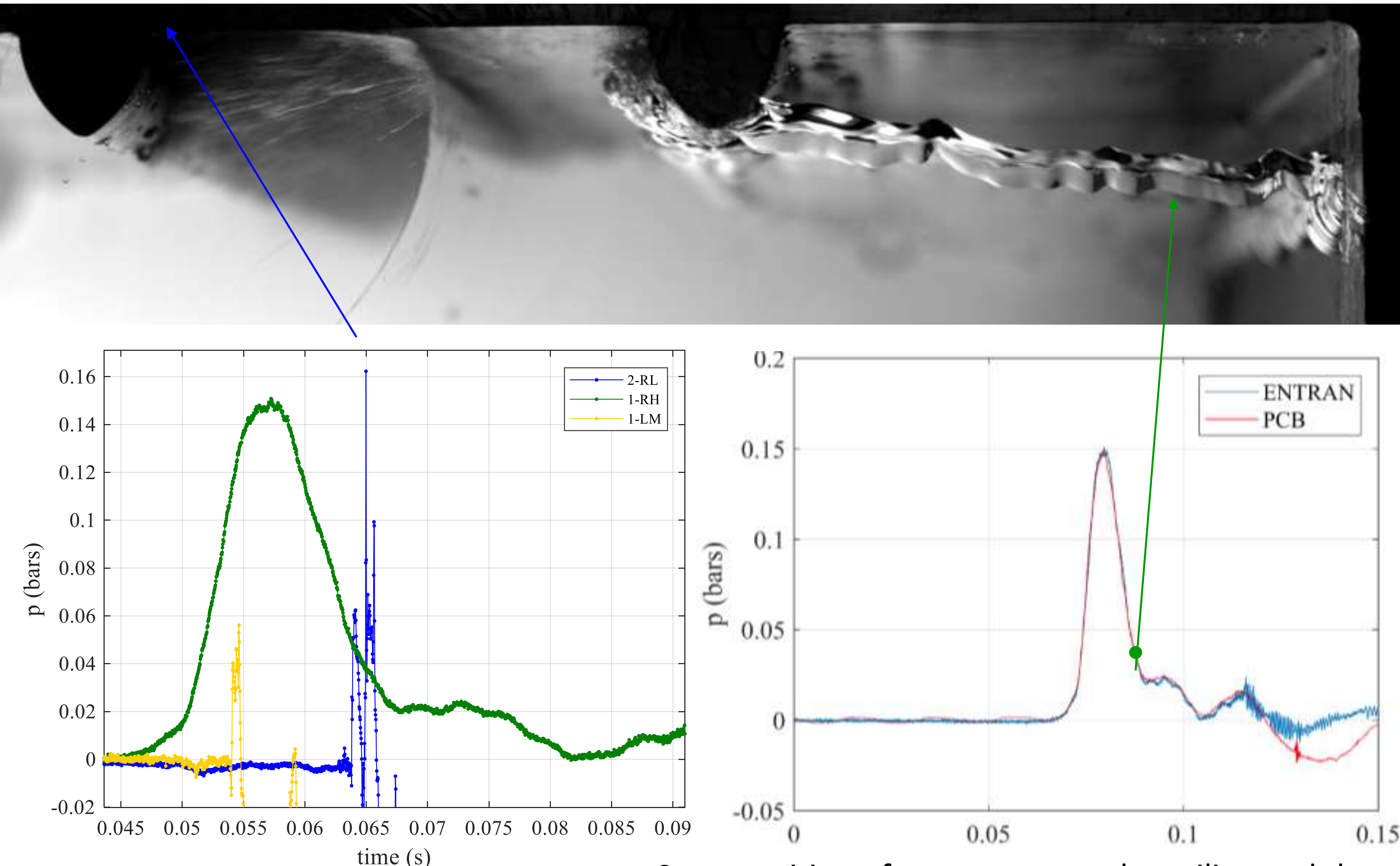
A test to calibrate the ENTRAN pressure sensors

Test n°24, T_1=2.617s, H_1=0.285m, x_1=x_{wall}+0.85m, T_2=1.825s, H_2=0.16m, x2=x_{wall}-0.1m





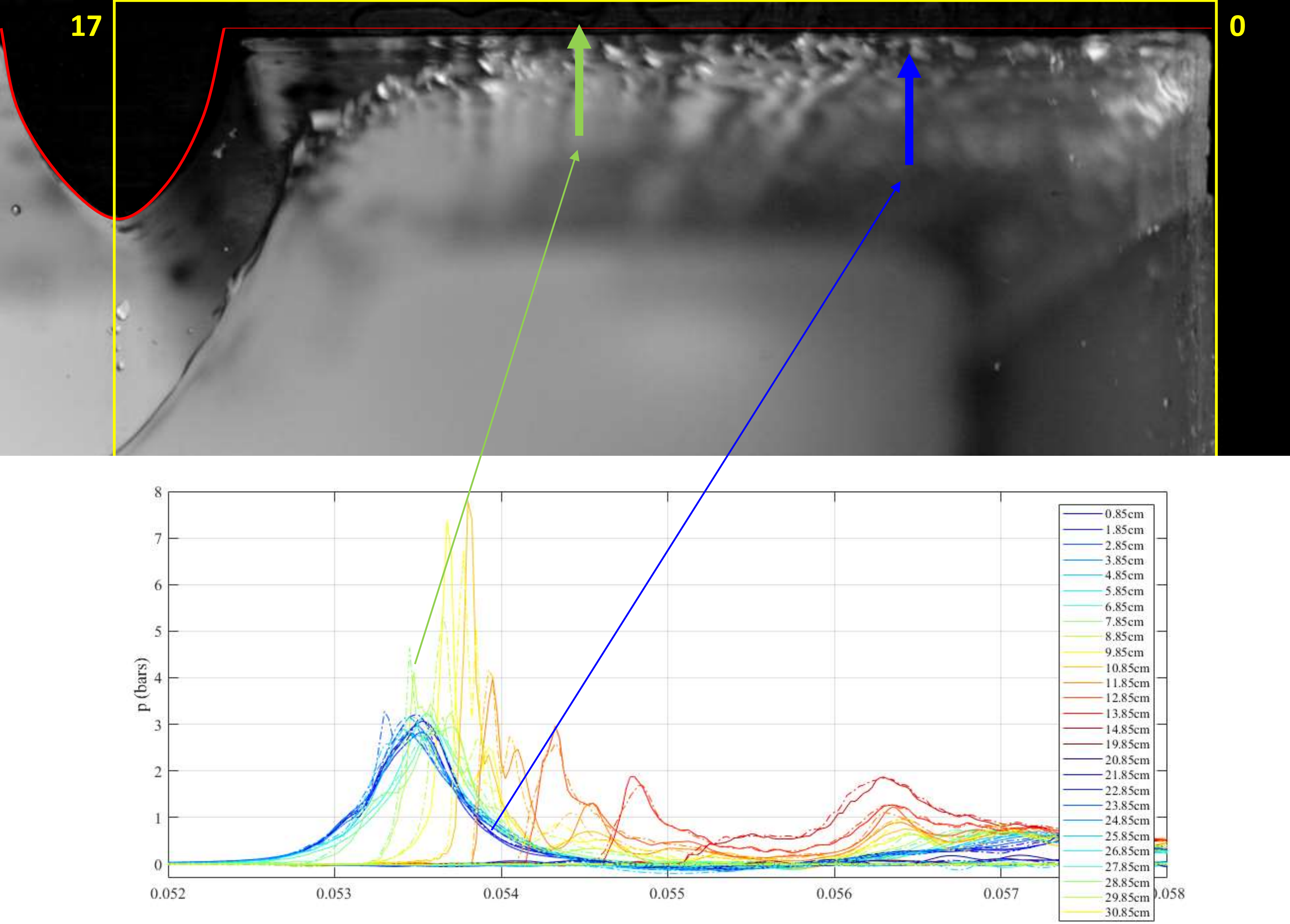
Impact on the left side of the first corrugation
Compression of the gas pocket
p (bars)
P (bars)
x (cm)
t (s)

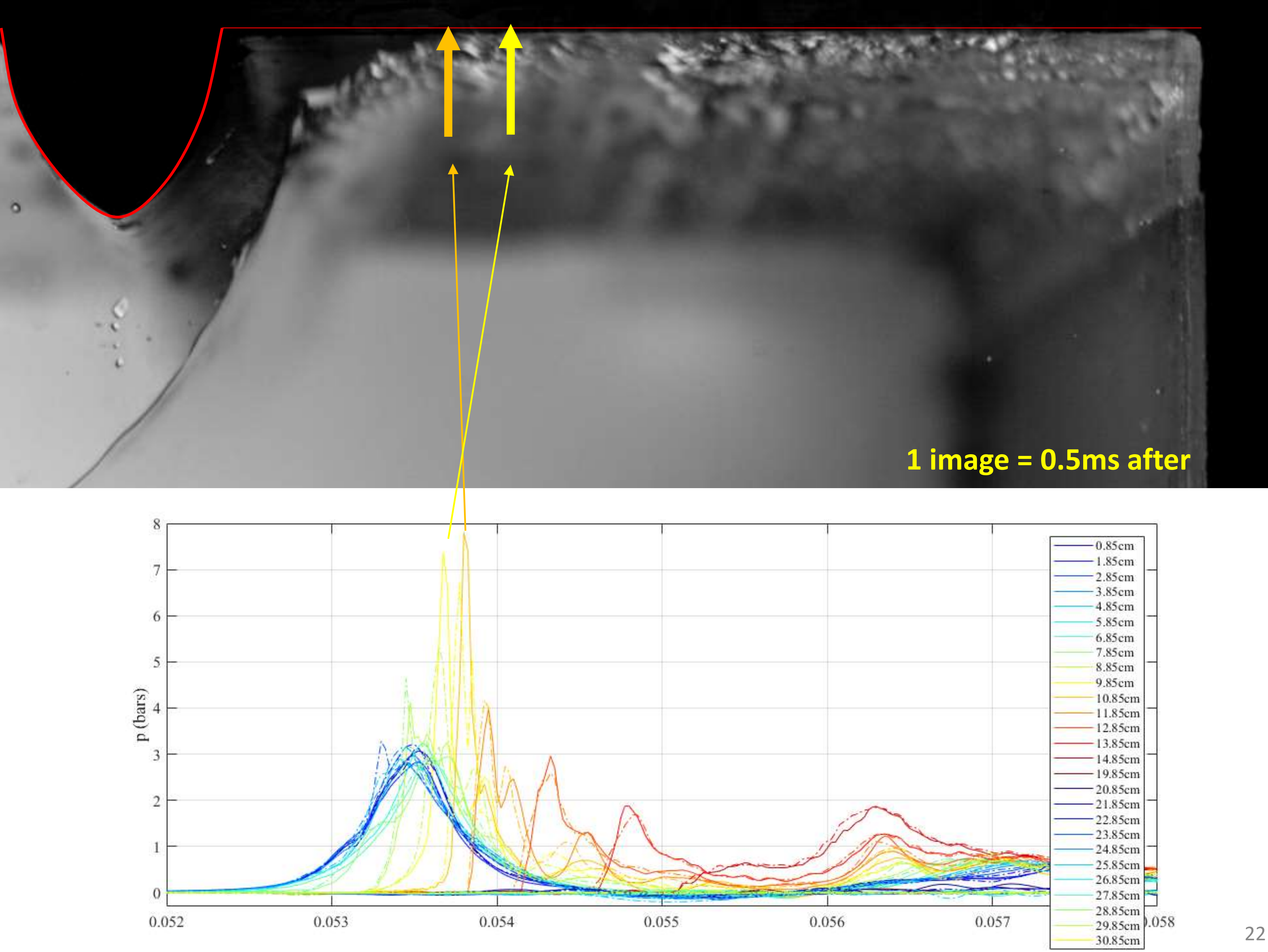


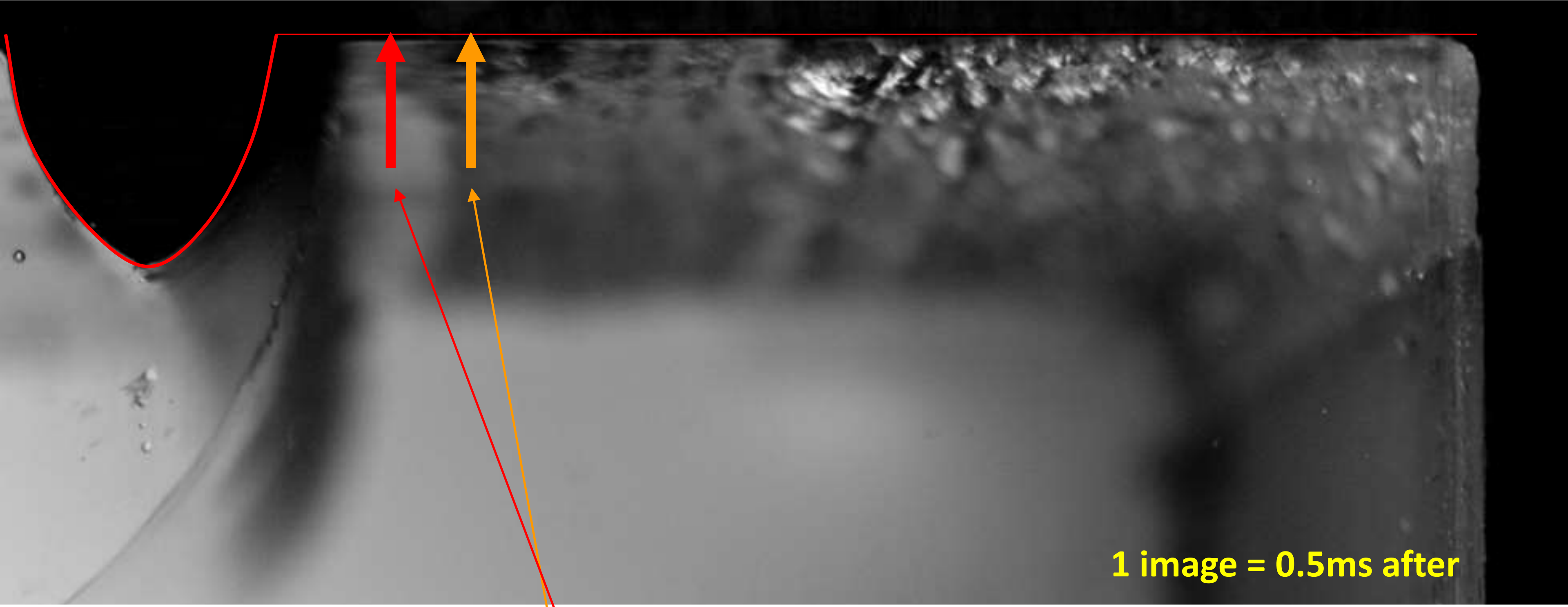
Superposition of one sensor on the ceiling and the sensor on the right side of the first corrugation

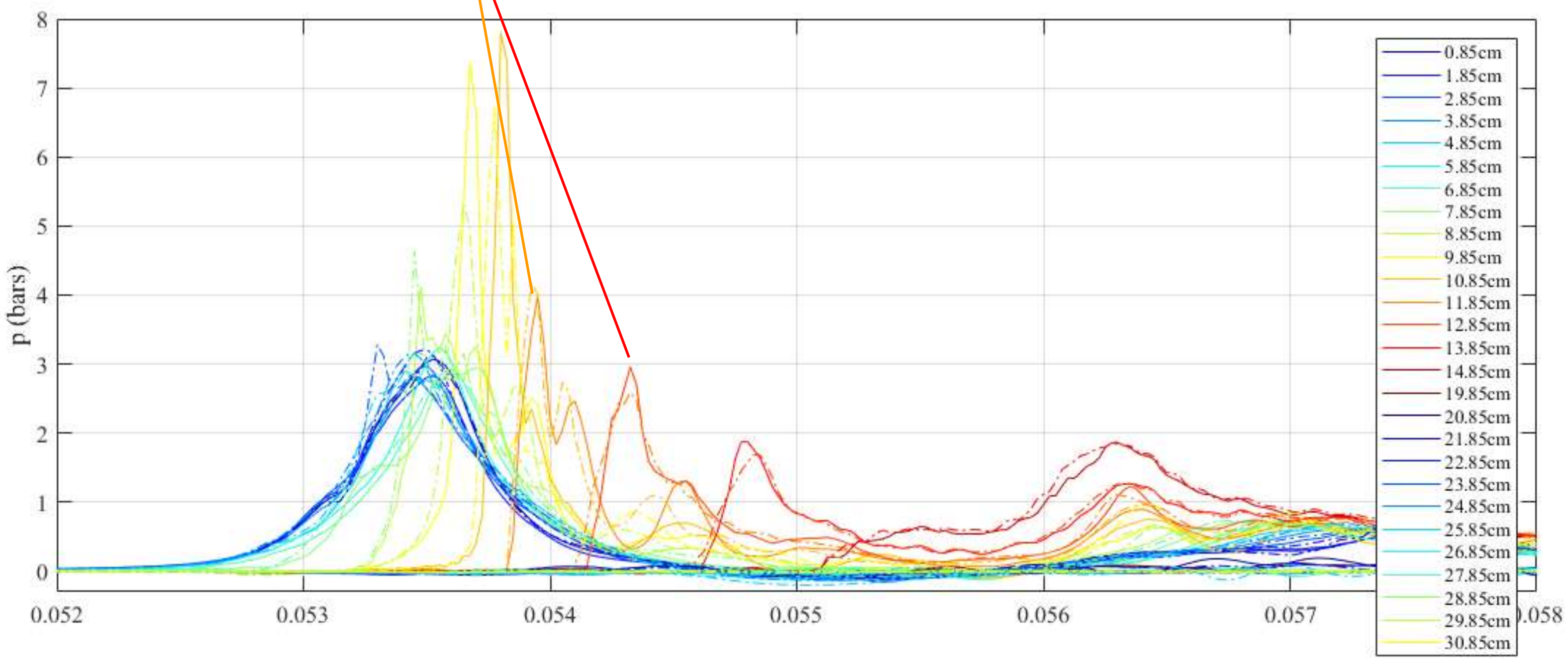
High pressures on the first part of the ceiling

Tests n°17 & 18, T_1=2.65s, H_1=0.300m, x_1=x_{wall}+0.75m, T_2=1.8s, H_2=0.115m, x2=x_{wall}-0.05m

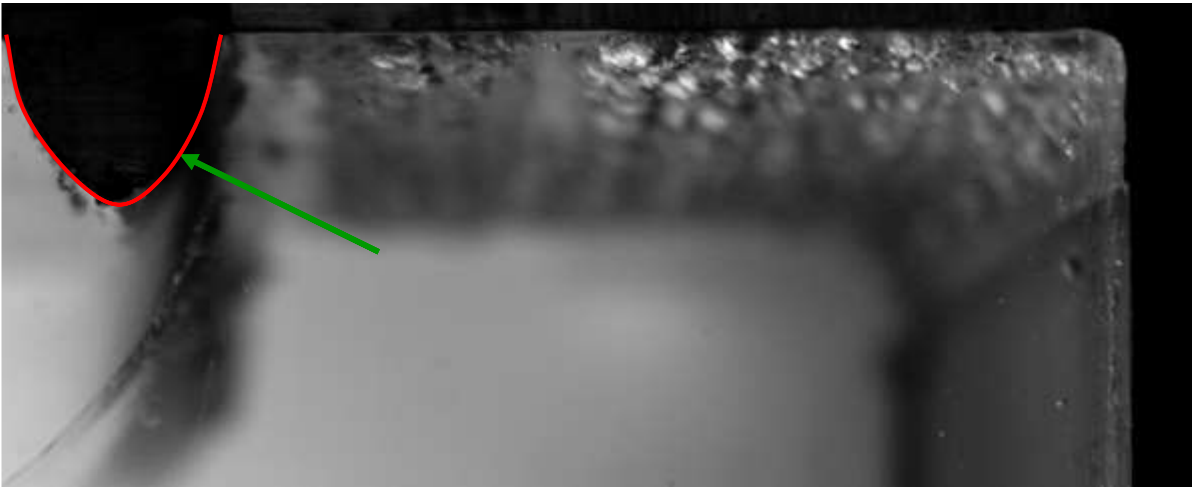

17
0
p (bars)
0.052
0.053
0.054
0.055
0.056
0.057
0.058
0.85cm
1.85cm
2.85cm
3.85cm
4.85cm
5.85cm
6.85cm
7.85cm
8.85cm
9.85cm
10.85cm
11.85cm
12.85cm
13.85cm
14.85cm
19.85cm
20.85cm
21.85cm
22.85cm
23.85cm
24.85cm
25.85cm
26.85cm
27.85cm
28.85cm
29.85cm
30.85cm

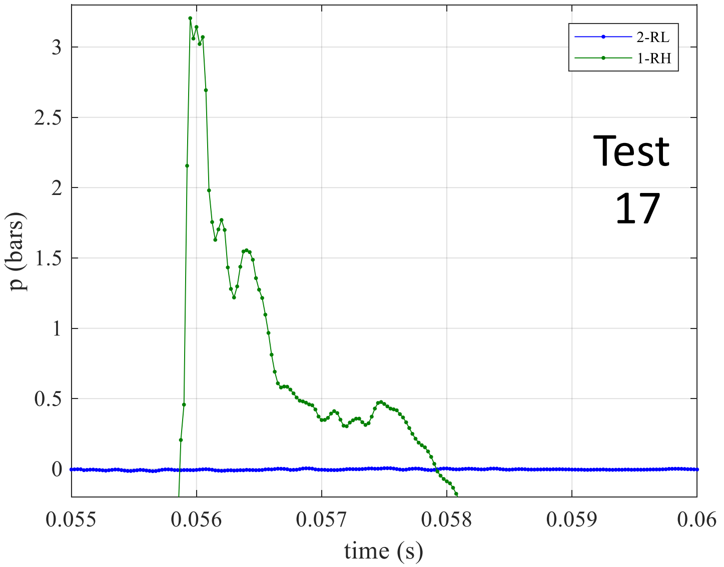

1 image = 0.5ms after
p (bars)
0.85cm
1.85cm
2.85cm
3.85cm
4.85cm
5.85cm
6.85cm
7.85cm
8.85cm
9.85cm
10.85cm
11.85cm
12.85cm
13.85cm
14.85cm
19.85cm
20.85cm
21.85cm
22.85cm
23.85cm
24.85cm
25.85cm
26.85cm
27.85cm
28.85cm
29.85cm
30.85cm


1 image = 0.5ms after

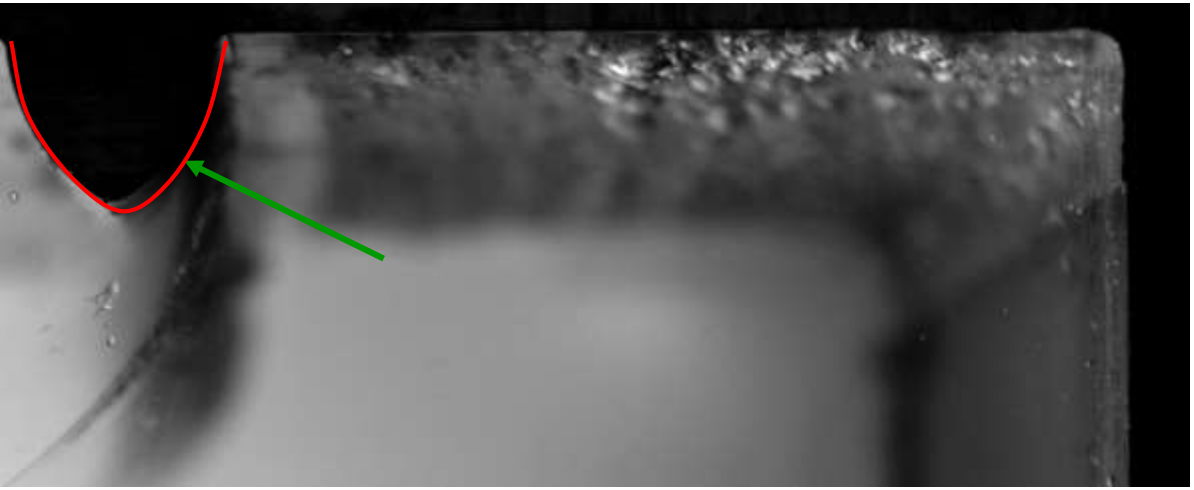

p (bars)
0
1
2
3
4
5
6
7
8
0.052
0.053
0.054
0.055
0.056
0.057
0.058
0.85cm
1.85cm
2.85cm
3.85cm
4.85cm
5.85cm
6.85cm
7.85cm
8.85cm
9.85cm
10.85cm
11.85cm
12.85cm
13.85cm
14.85cm
19.85cm
20.85cm
21.85cm
22.85cm
23.85cm
24.85cm
25.85cm
26.85cm
27.85cm
28.85cm
29.85cm
30.85cm

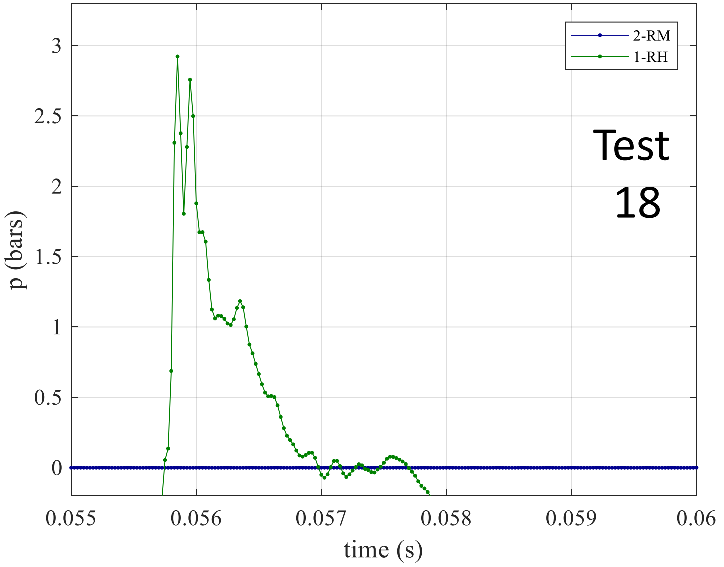
Impact on the corrugation





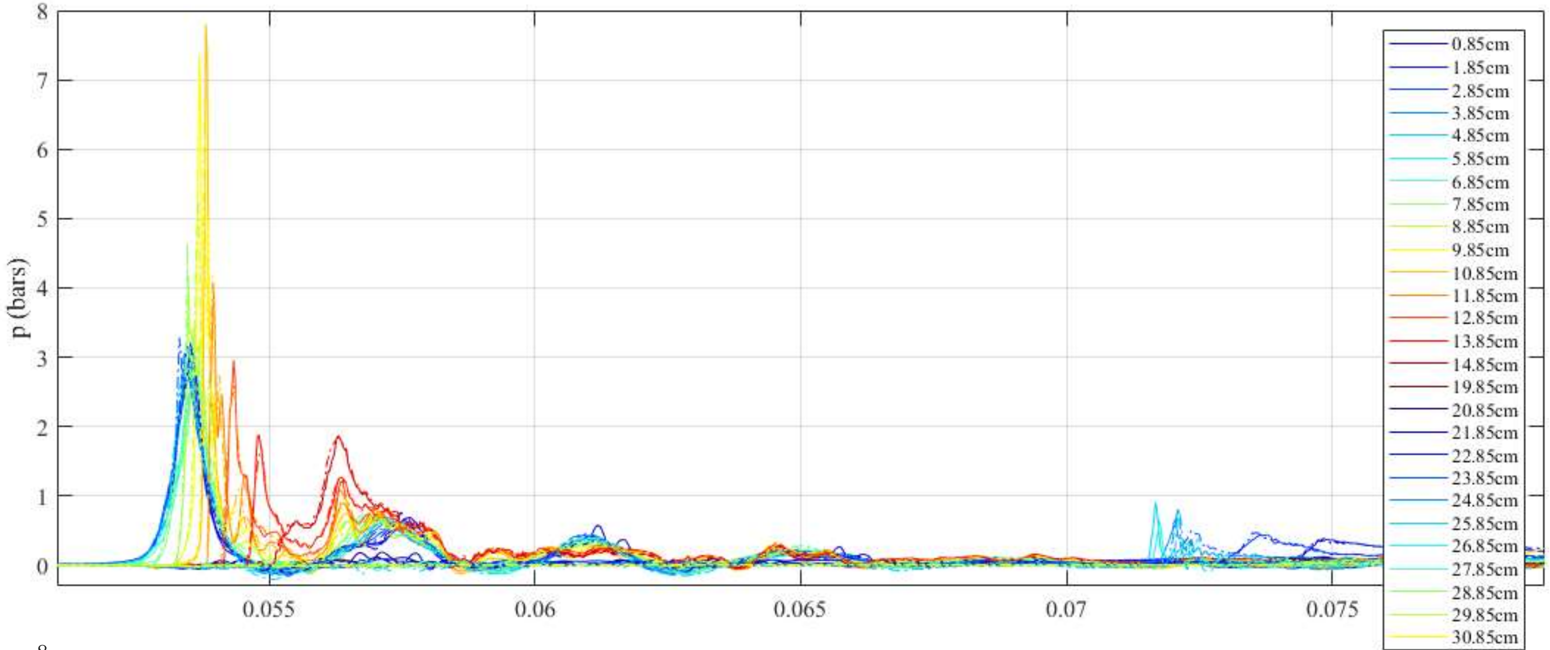
And repeatability



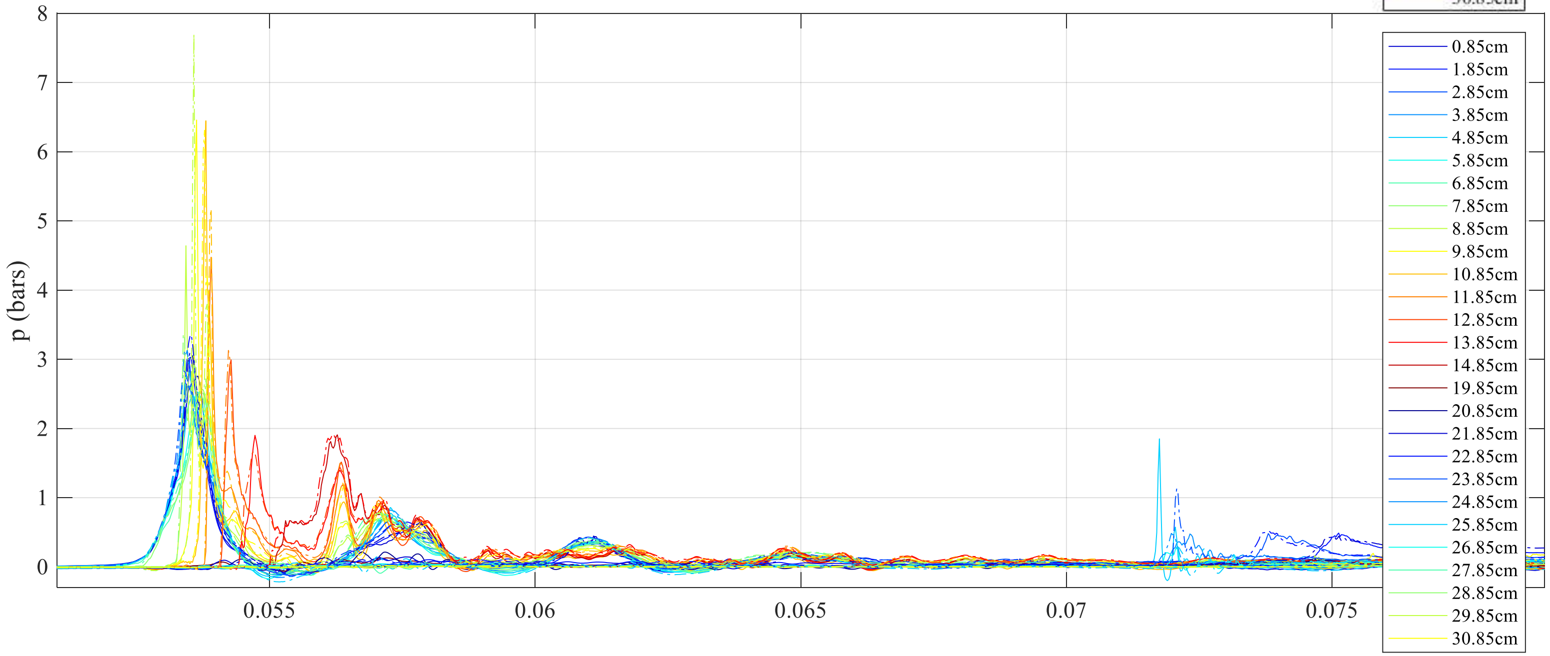


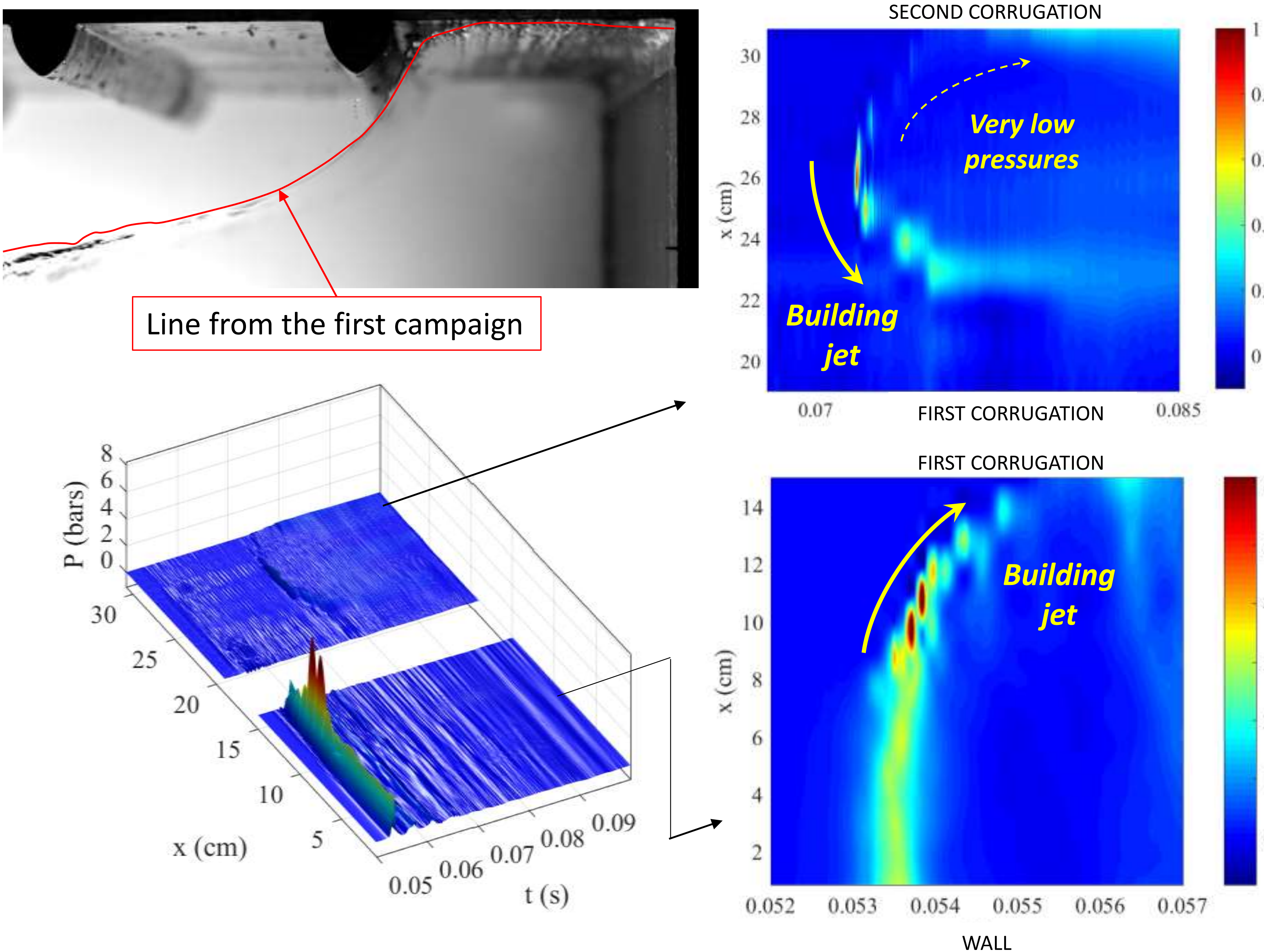
Repeatability

Test 17



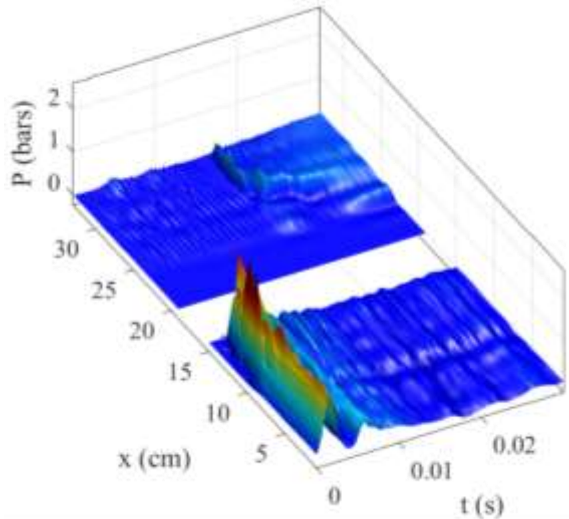
Test 18

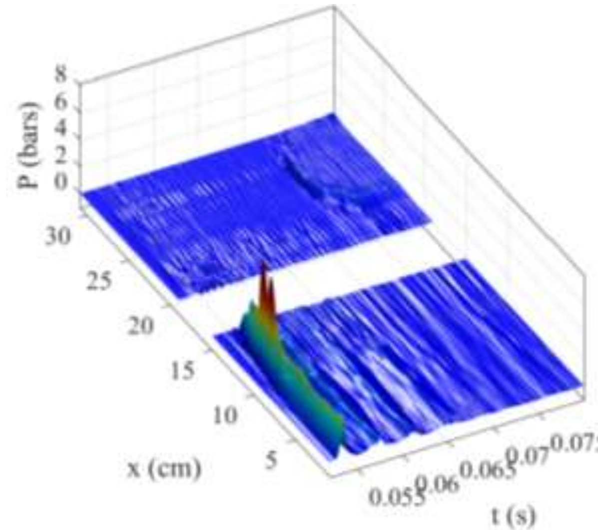


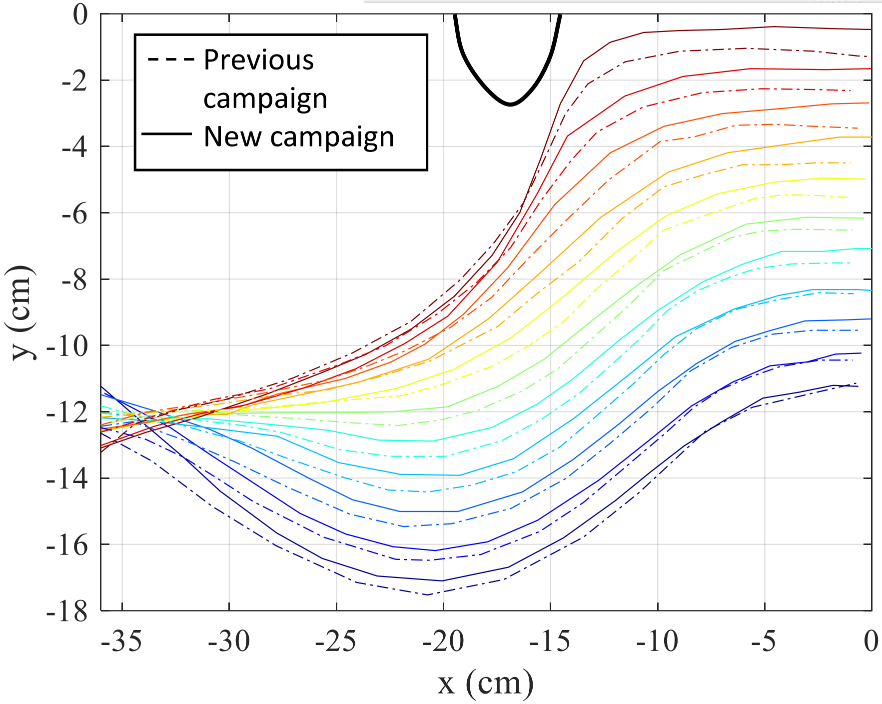


Line from the first campaign
SECOND CORRUGATION
Very low pressures
Building jet
x (cm)
30
28
26
24
22
20
0.07
FIRST CORRUGATION
0.085
1
0.8
0.6
0.4
0.2
0
FIRST CORRUGATION
Building jet
x (cm)
14
12
10
8
6
4
2
0.052
0.053
0.054
0.055
0.056
0.057
WALL
6
5
4
3
2
1
0
P (bars)
8
6
4
2
0
x (cm)
30
25
20
15
10
5
t (s)
0.05
0.06
0.07
0.08
0.09

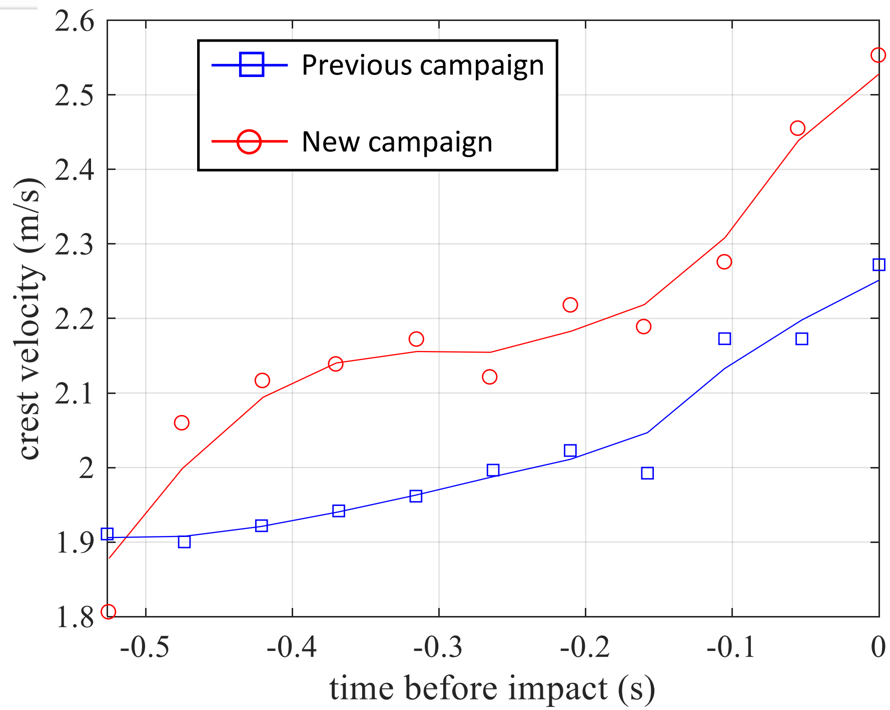
Comparisons with the previous campaign







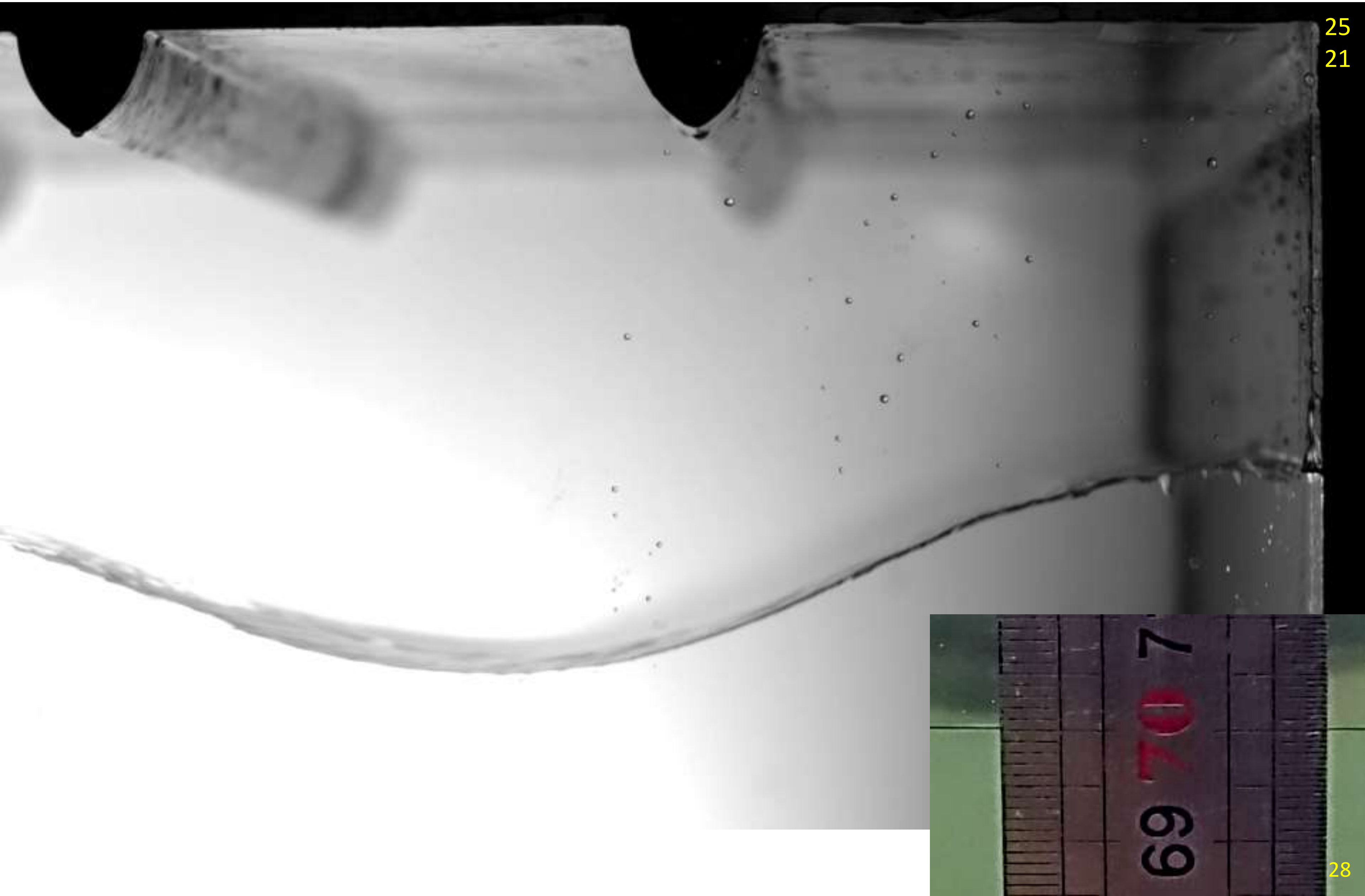
Evolution of the free surfaces before impact

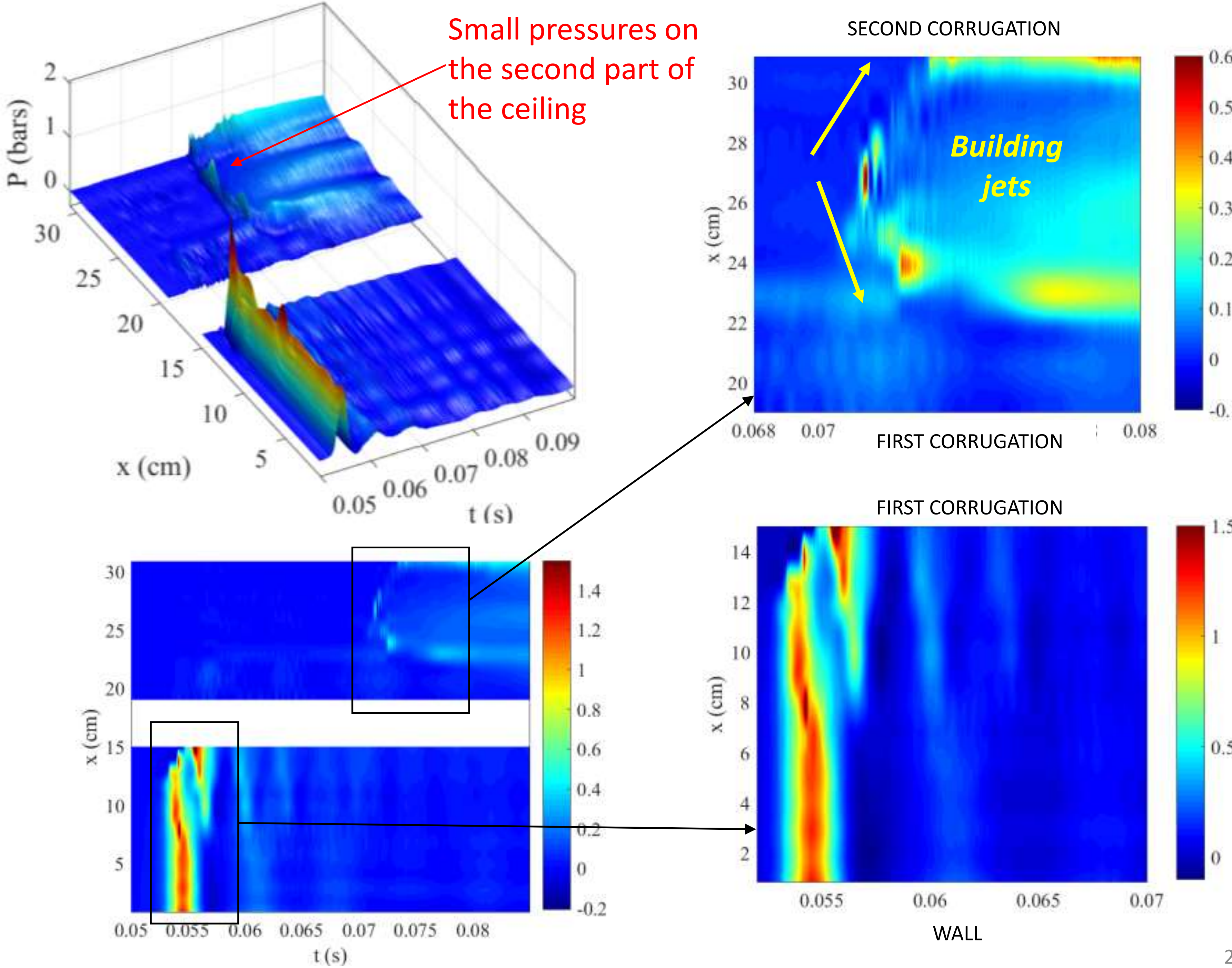


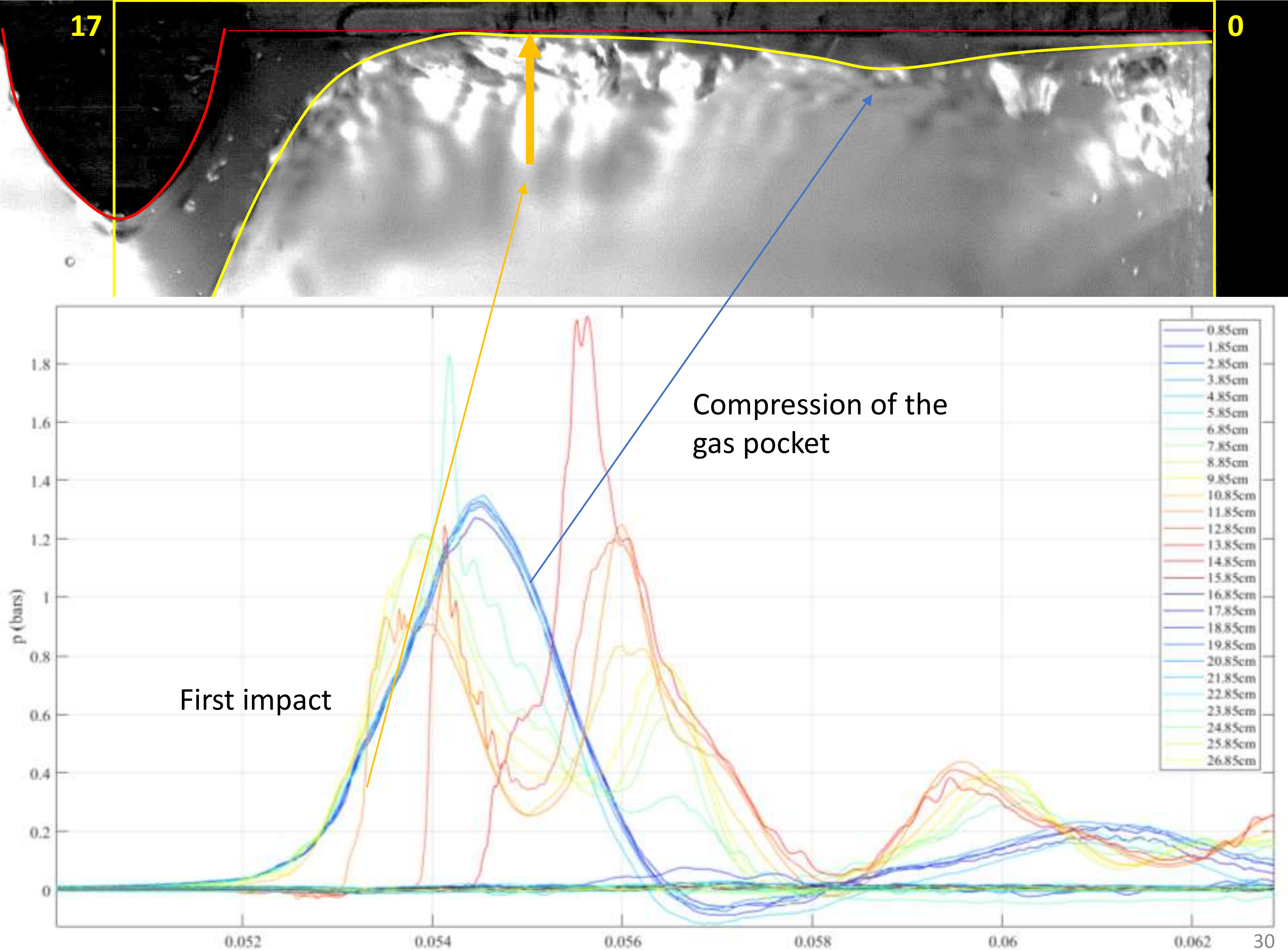
Velocity of the crest close to the wall

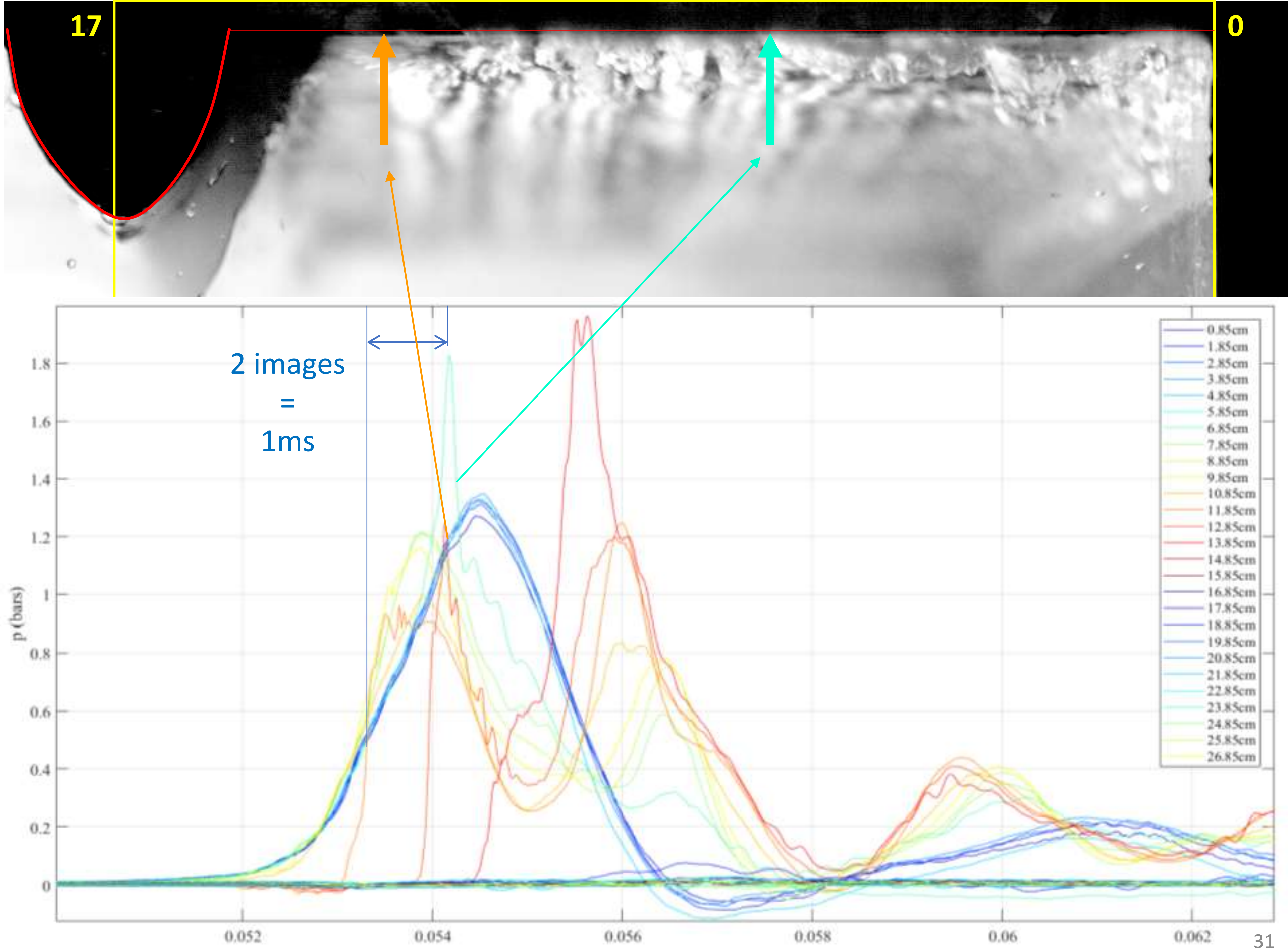
Impact close to the right side of the corrugation

Tests n°21 & 25, T_1=2.617s, H_1=0.300m, $x_1=x_{wall}$+0.75m, T_2=1.825s, H_2=0.11m, $x2=x_{wall}$-0.05m




Small pressures on the second part of the ceiling
P (bars)
x (cm)
t (s)
SECOND CORRUGATION
Building jets
x (cm)
FIRST CORRUGATION
FIRST CORRUGATION
x (cm)
WALL
x (cm)
t (s)
0.05
0.055
0.06
0.065
0.07
0.075
0.08
0.068
0.09
-0.1
0.6
1.5
1.4
-0.2


17
0
Compression of the gas pocket
First impact
p (bars)
0.85cm
1.85cm
2.85cm
3.85cm
4.85cm
5.85cm
6.85cm
7.85cm
8.85cm
9.85cm
10.85cm
11.85cm
12.85cm
13.85cm
14.85cm
15.85cm
16.85cm
17.85cm
18.85cm
19.85cm
20.85cm
21.85cm
22.85cm
23.85cm
24.85cm
25.85cm
26.85cm


17
0
2 images
=
1ms
p (bars)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.052
0.054
0.056
0.058
0.06
0.062
0.85cm
1.85cm
2.85cm
3.85cm
4.85cm
5.85cm
6.85cm
7.85cm
8.85cm
9.85cm
10.85cm
11.85cm
12.85cm
13.85cm
14.85cm
15.85cm
16.85cm
17.85cm
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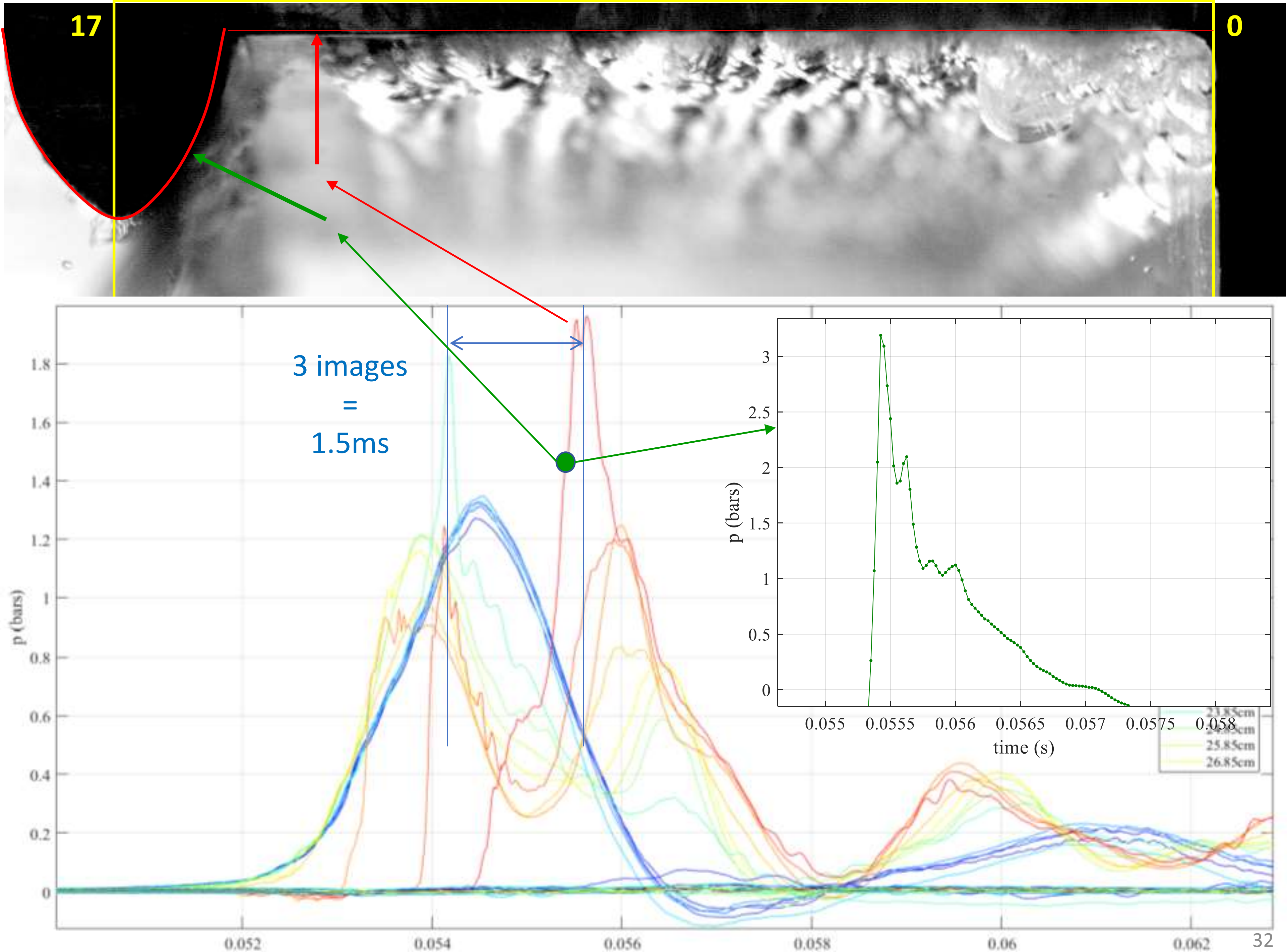
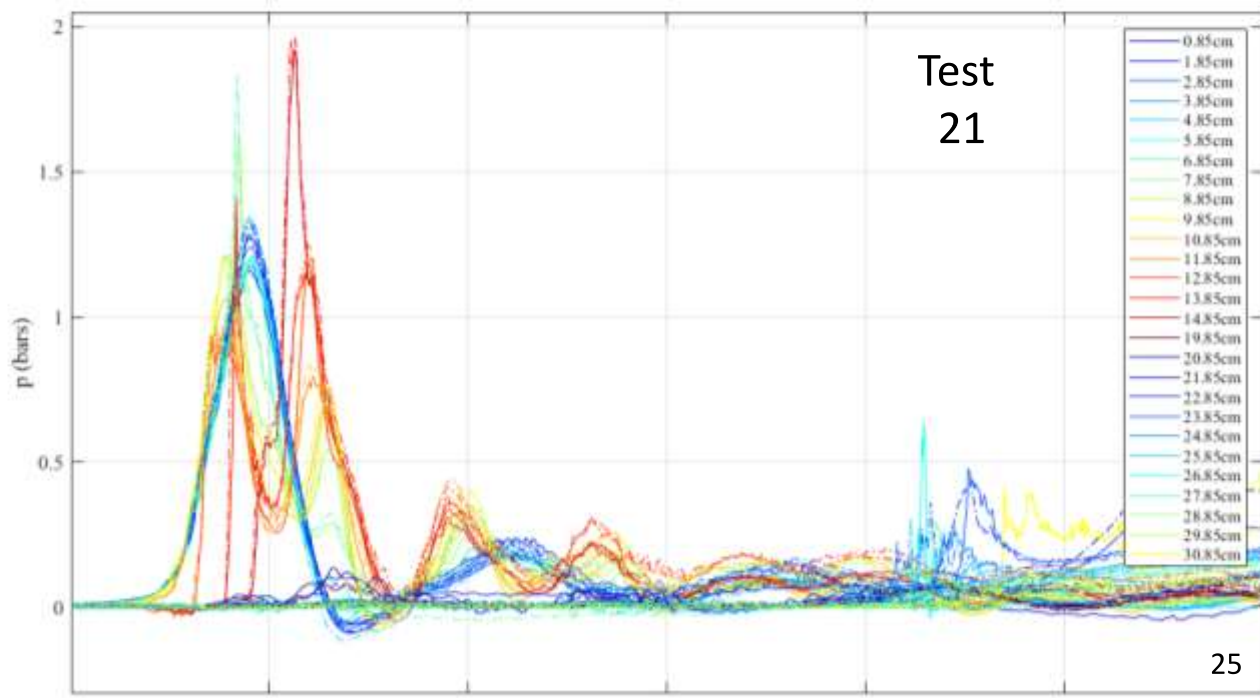
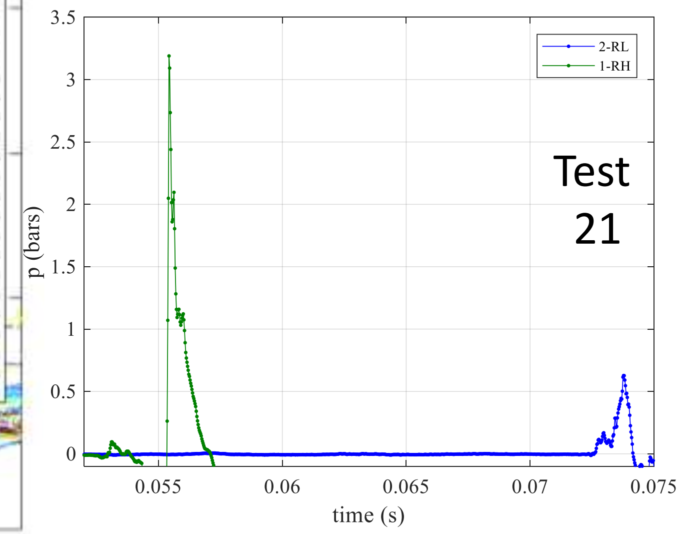
19.85cm
20.85cm
21.85cm
22.85cm
23.85cm
24.85cm
25.85cm
26.85cm

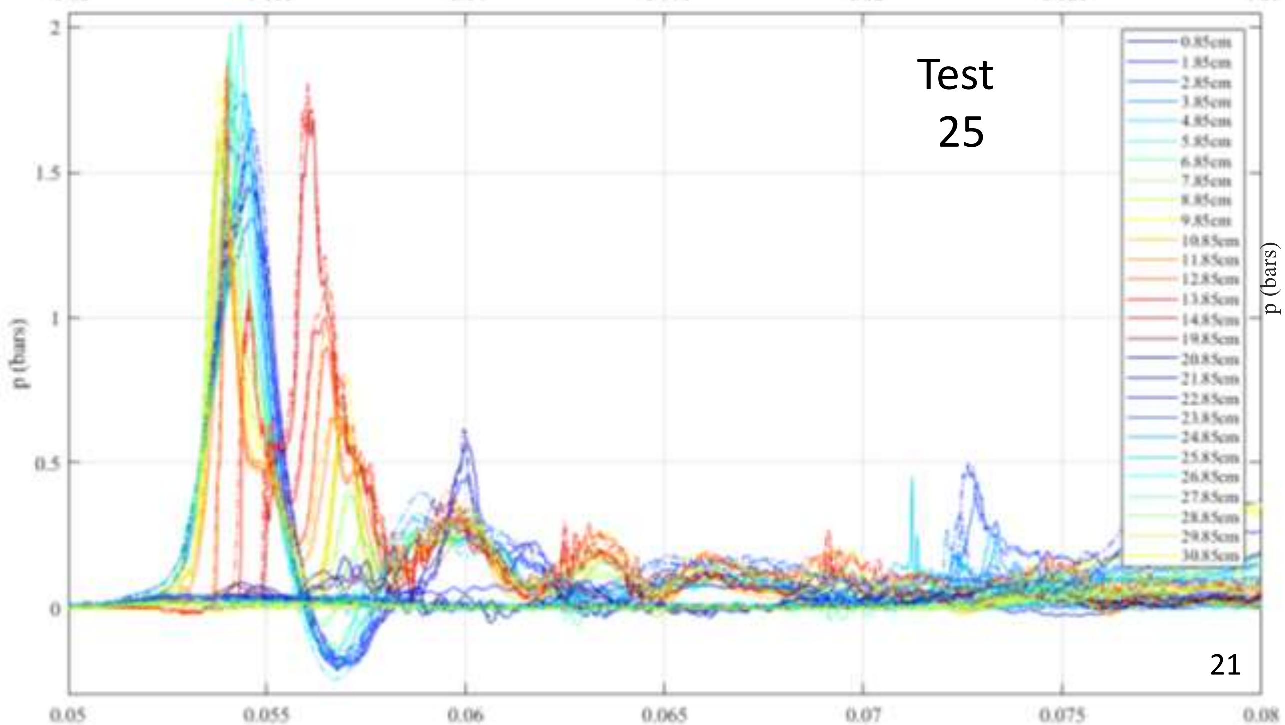


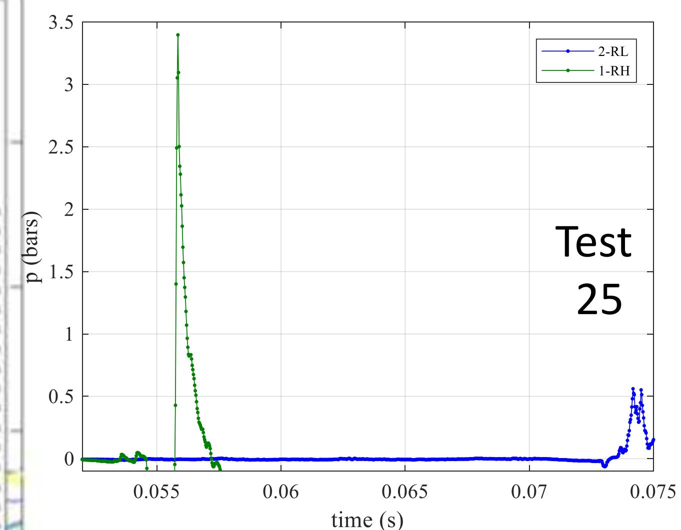
17
0
3 images
=
1.5ms
p (bars)
time (s)

Repeatability



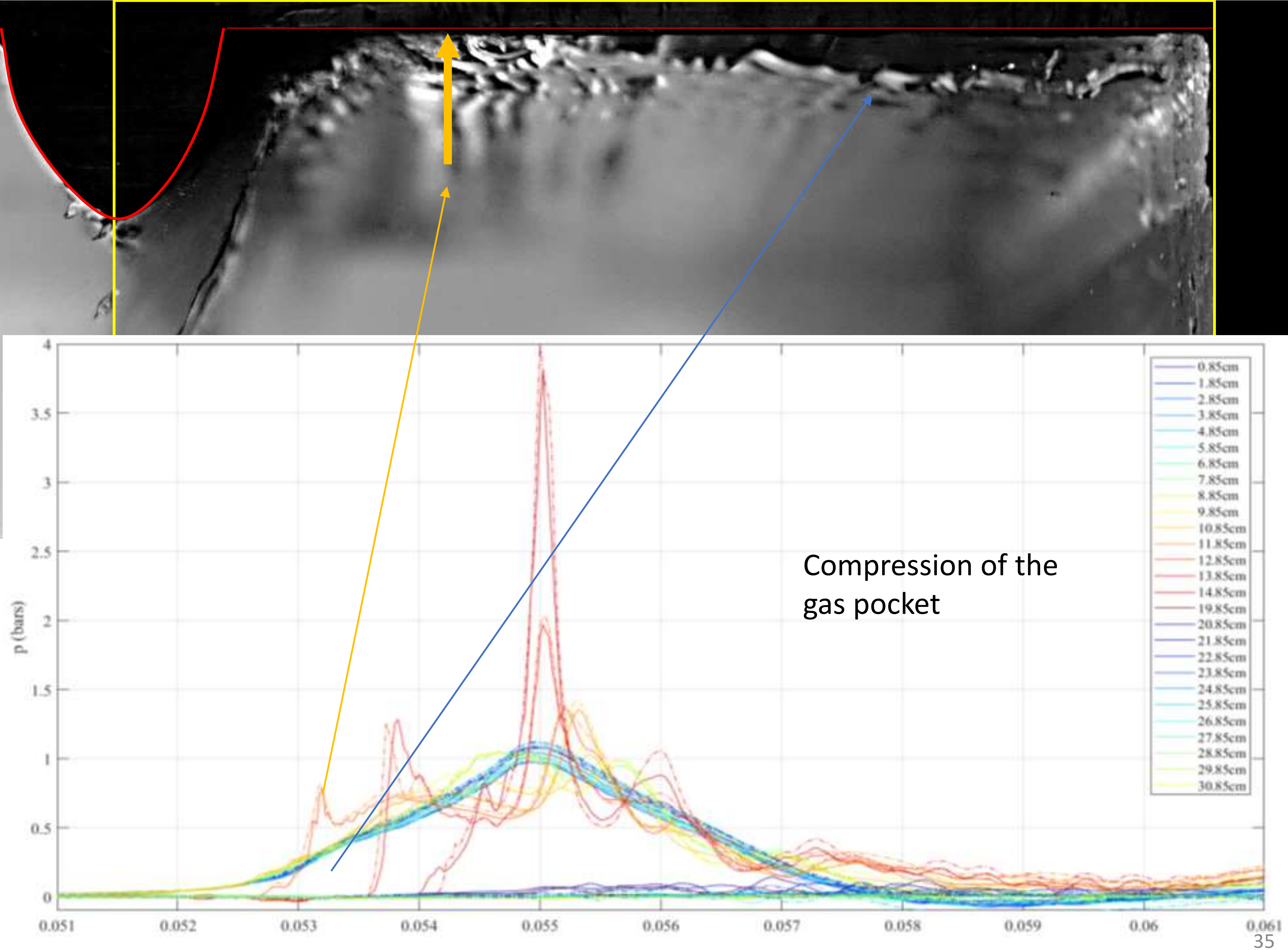


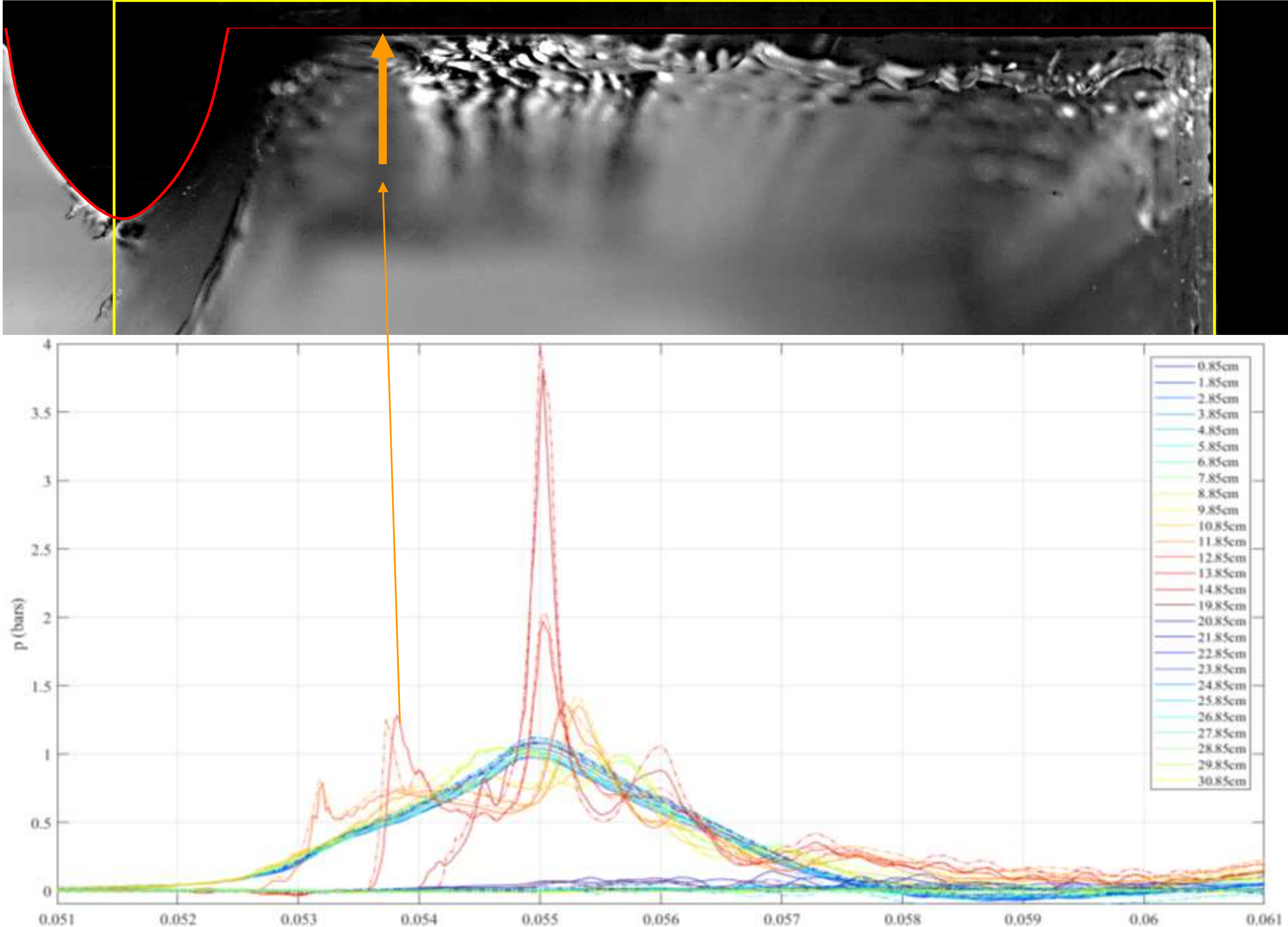


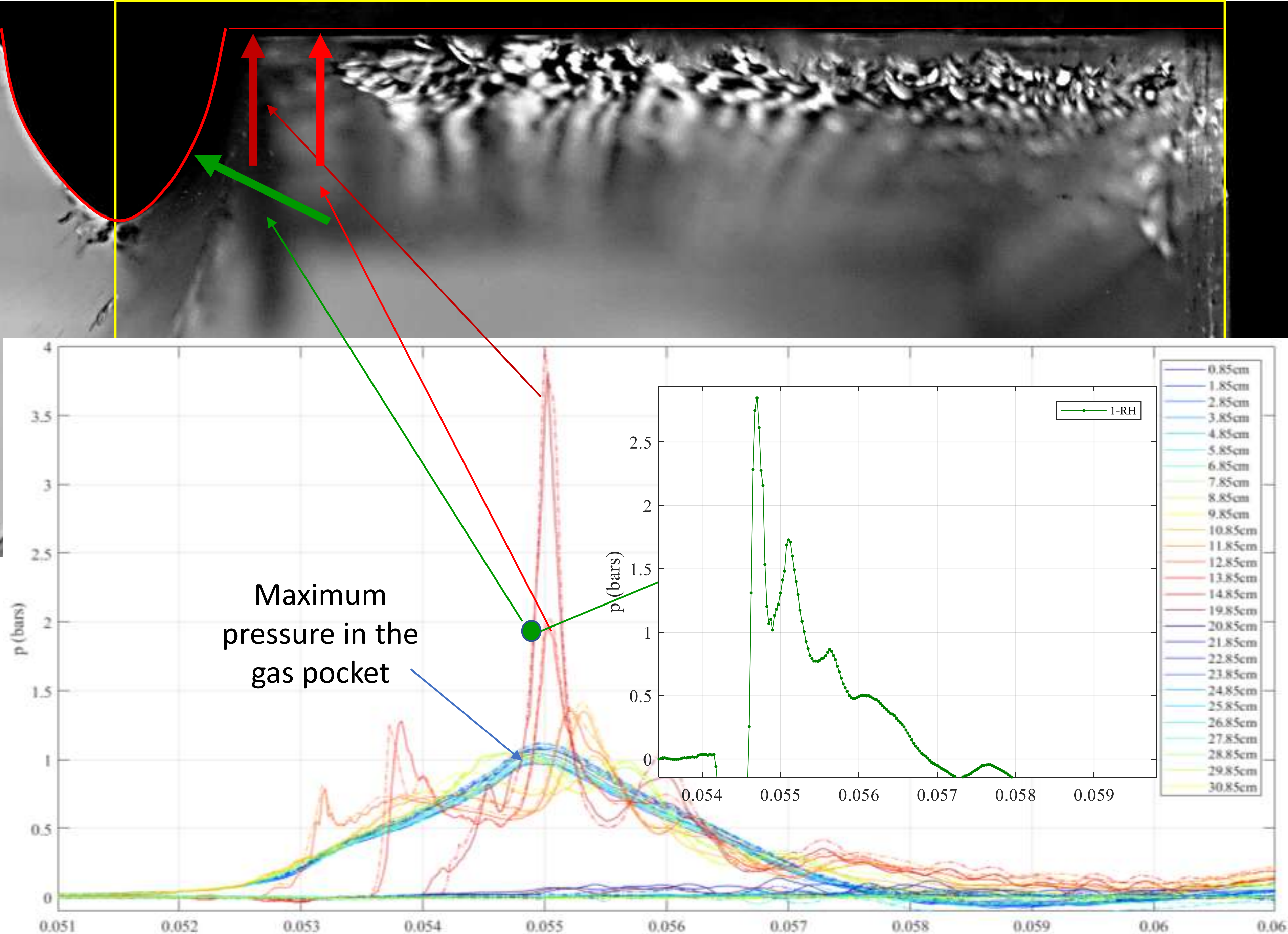


High pressures between the two corrugations

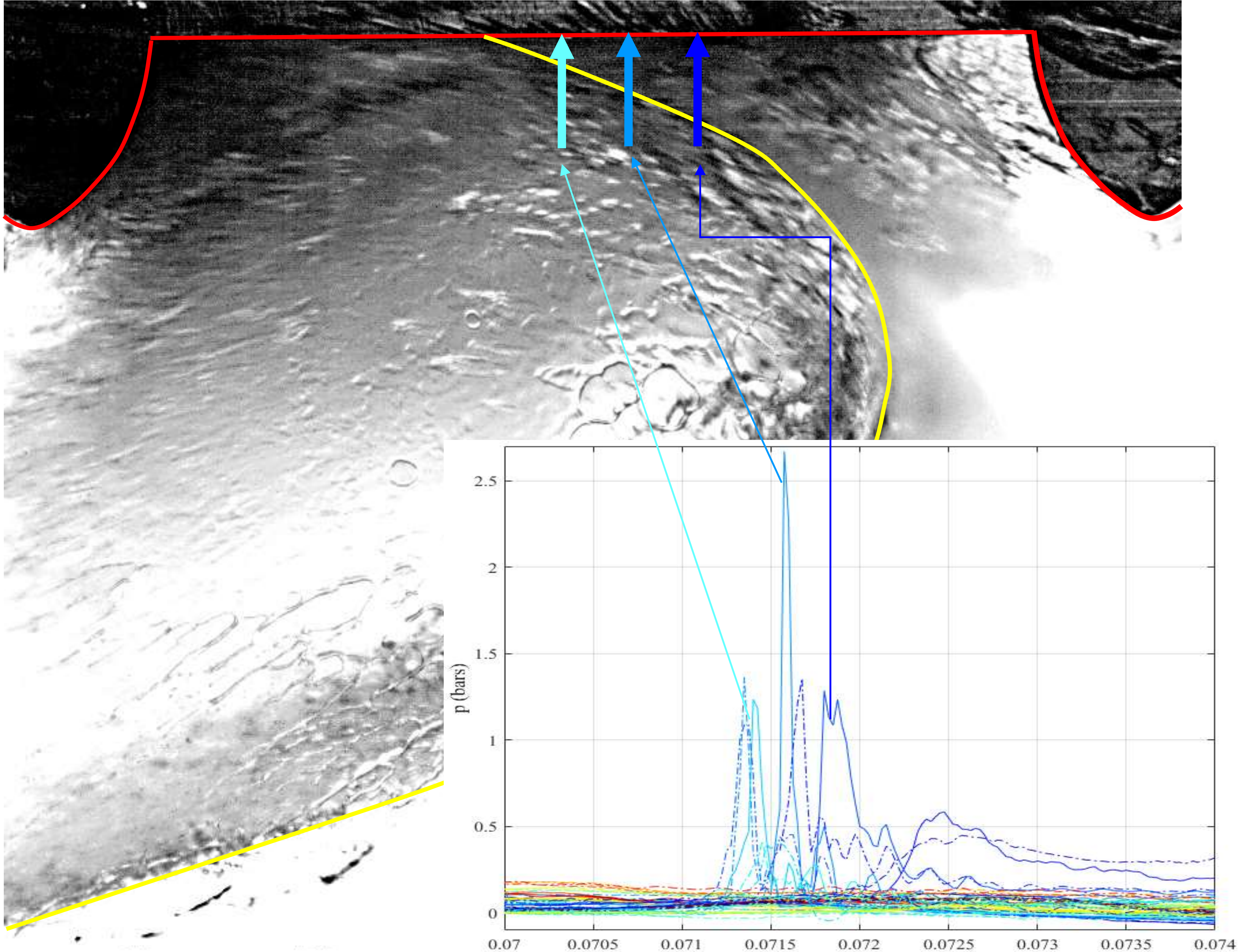
Tests n°20 & 26, T_1=2.617s, H_1=0.300m, x_1=x_{wall}+0.75m, T_2=1.825s, H_2=0.115m, x2=x_{wall}-0.05m


Compression of the gas pocket
p (bars)
0
0.5
1
1.5
2
2.5
3
3.5
4
0.051
0.052
0.053
0.054
0.055
0.056
0.057
0.058
0.059
0.06
0.061
0.85cm
1.85cm
2.85cm
3.85cm
4.85cm
5.85cm
6.85cm
7.85cm
8.85cm
9.85cm
10.85cm
11.85cm
12.85cm
13.85cm
14.85cm
19.85cm
20.85cm
21.85cm
22.85cm
23.85cm
24.85cm
25.85cm
26.85cm
27.85cm
28.85cm
29.85cm
30.85cm

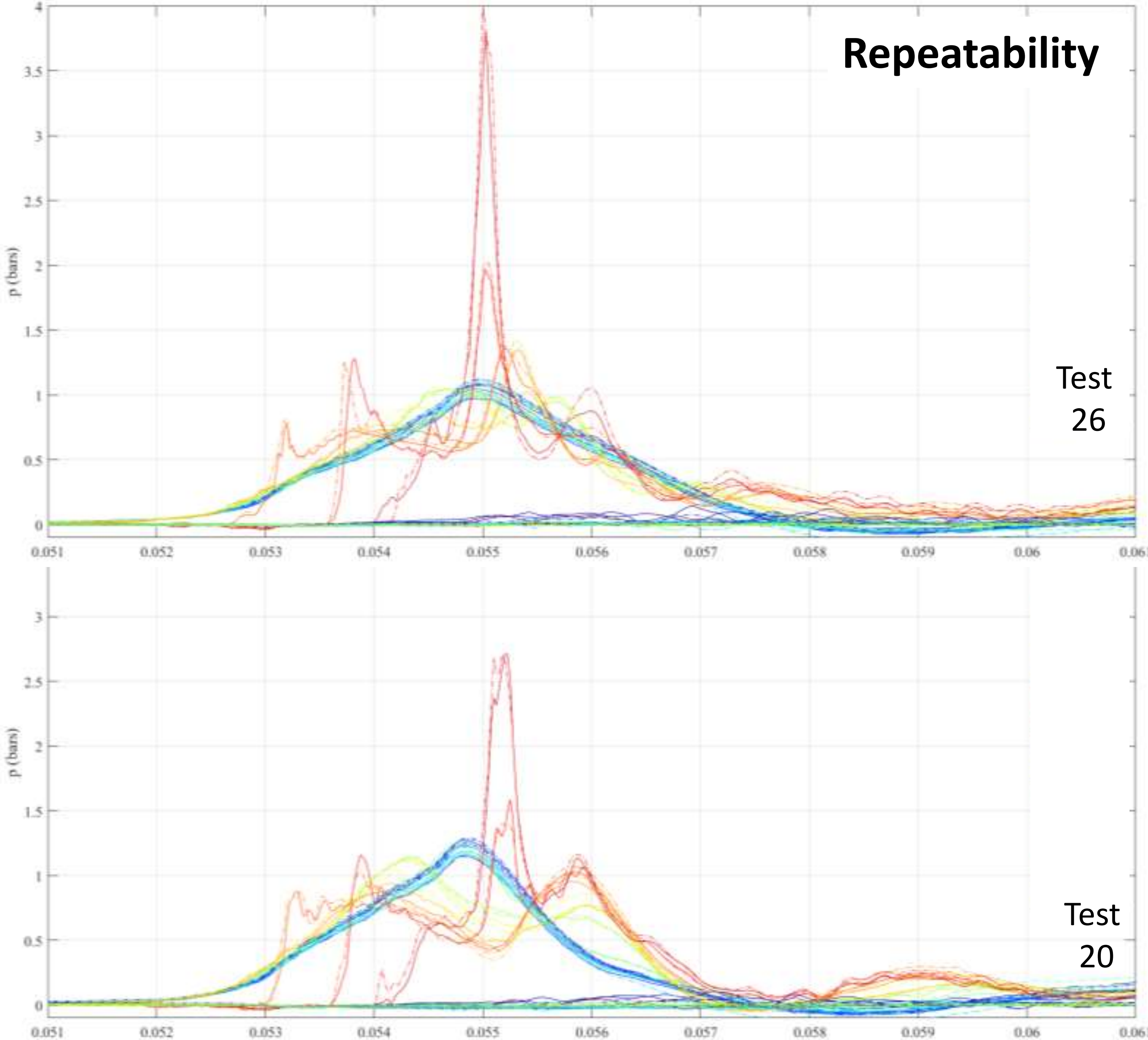

0.85cm
1.85cm
2.85cm
3.85cm
4.85cm
5.85cm
6.85cm
7.85cm
8.85cm
9.85cm
10.85cm
11.85cm
12.85cm
13.85cm
14.85cm
19.85cm
20.85cm
21.85cm
22.85cm
23.85cm
24.85cm
25.85cm
26.85cm
27.85cm
28.85cm
29.85cm
30.85cm
p (bars)
0
0.5
1
1.5
2
2.5
3
3.5
4
0.051
0.052
0.053
0.054
0.055
0.056
0.057
0.058
0.059
0.06
0.061



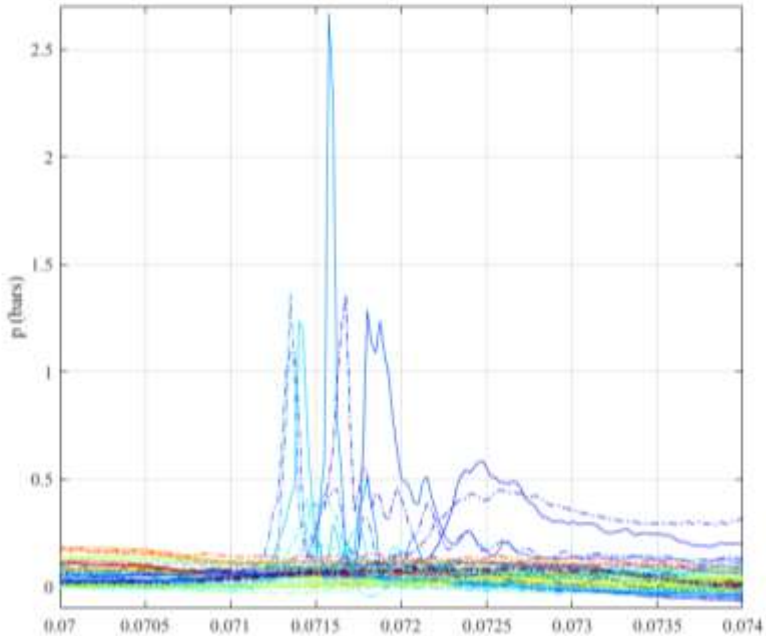
Maximum pressure in the gas pocket
p (bars)
1-RH
0.85cm
1.85cm
2.85cm
3.85cm
4.85cm
5.85cm
6.85cm
7.85cm
8.85cm
9.85cm
10.85cm
11.85cm
12.85cm
13.85cm
14.85cm
19.85cm
20.85cm
21.85cm
22.85cm
23.85cm
24.85cm
25.85cm
26.85cm
27.85cm
28.85cm
29.85cm
30.85cm


2.5
2
1.5
1
0.5
0
p (bars)
0.07
0.0705
0.071
0.0715
0.072
0.0725
0.073
0.0735
0.074

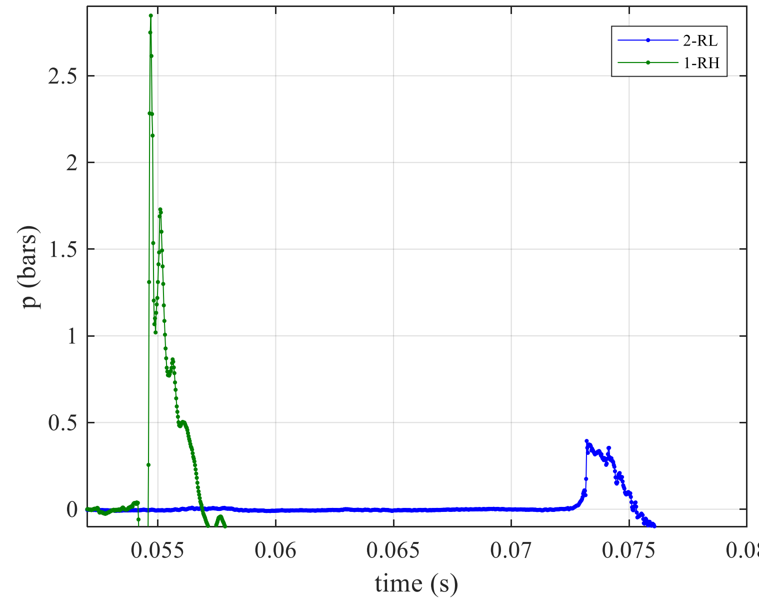
Repeatability

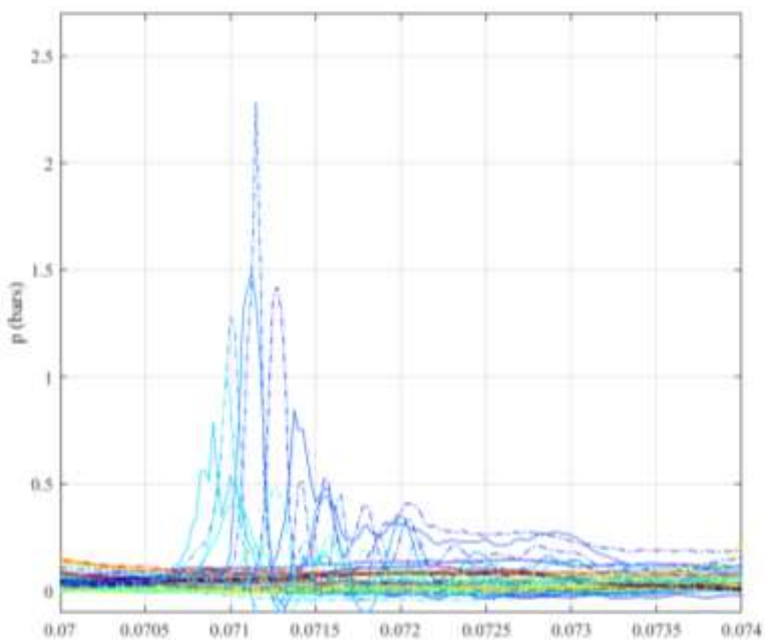


Repeatability

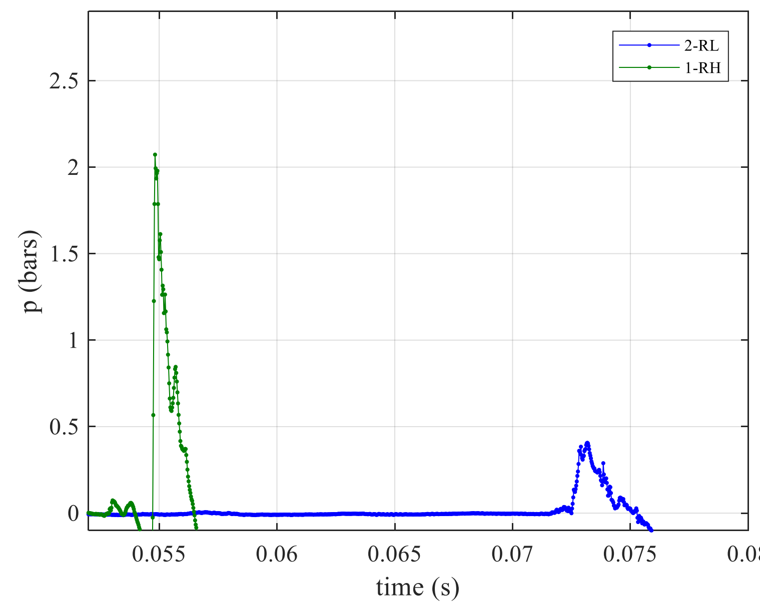


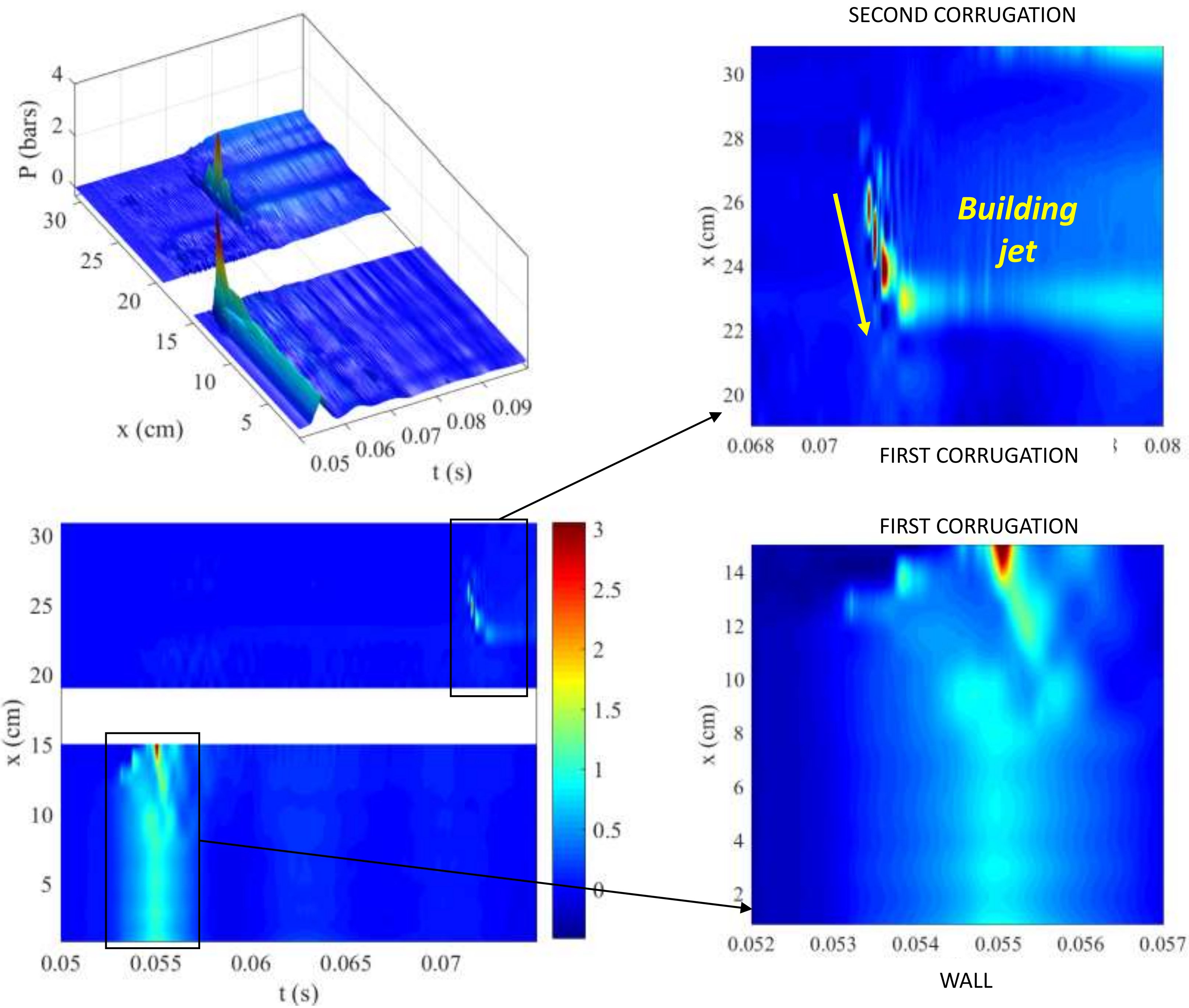
Test 26





Test 20




SECOND CORRUGATION
Building
jet
FIRST CORRUGATION
FIRST CORRUGATION
WALL
P (bars)
x (cm)
t (s)

Conclusions

- **During the first campaign (2014)**
  - High pressures were measured on the ceiling (12 bars) but at the corner between the ceiling and the vertical wall.
  - For a case (repeat once), the jet-induced flow leaded to noteworthy pressures on the right side of the second corrugations (3.5 bars).
  - Only one pressure sensor on the height of the corrugation. Limitation to capture the measurement of the maximum pressure.
- **During the second Campaign (2017)**
  - Three pressure sensors were installed on the height of corrugations. Unfortunately only one sensor worked during the campaign. Probably due to the reuse of the sensors of the 2014 campaign. The wires that connect the sensors are very tiny and are maybe cut.
  - New interesting cases with high pressures on ceiling far from the wall and on the first corrugation (8 bars).
  - Relatively high pressures measure on the ceiling between the two corrugations (2.5 bars). This impact doesn't lead to high pressure on the second corrugation. The jet-induced flow doesn't propagates to the direction of the second corrugation.

Thank you for your attention