

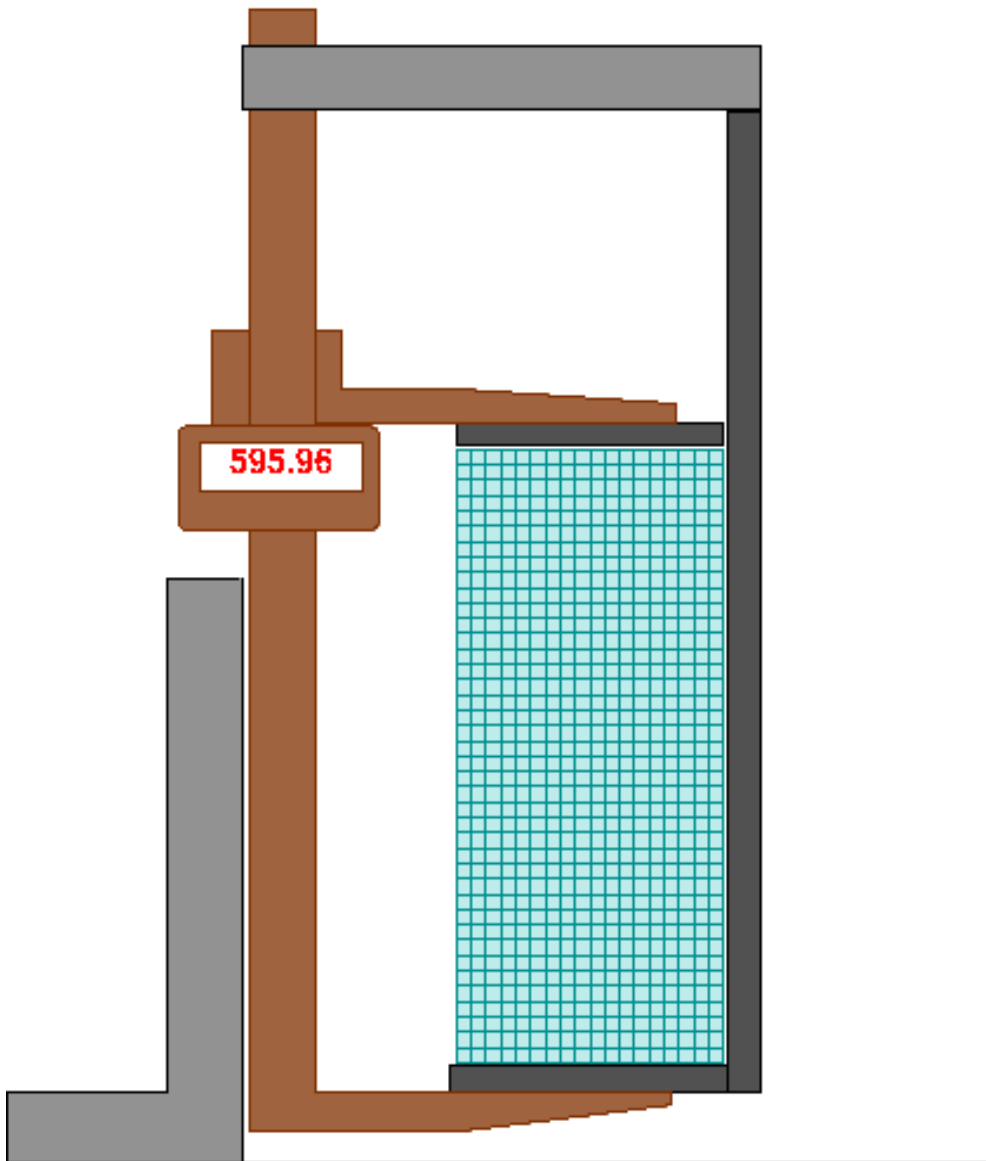
# Vertical pitch

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# The setup scheme to measure the vertical pitch



3D orthogonal frame with high geometrical accuracy was built of milled steel plates.

The alignment was done with two steel measuring squares.

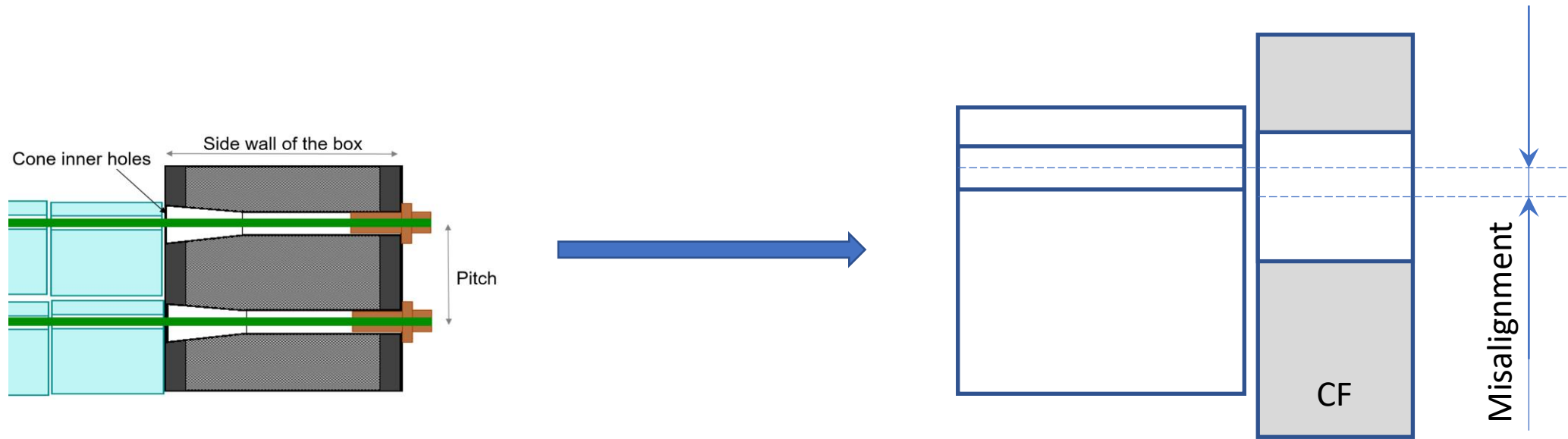
**56** layers of **18x15** cube pads are assembled on **1 mm** fishing lines in horizontal direction. The 1 mm fishing line imitates the WLS fiber. No vertical fishing lines.

Three different samples of the cubes were measured.

We observed the pitch vs time and temperature change for the 3d set.

Average temperature was 20-25 °C.

# Definition of the misalignment

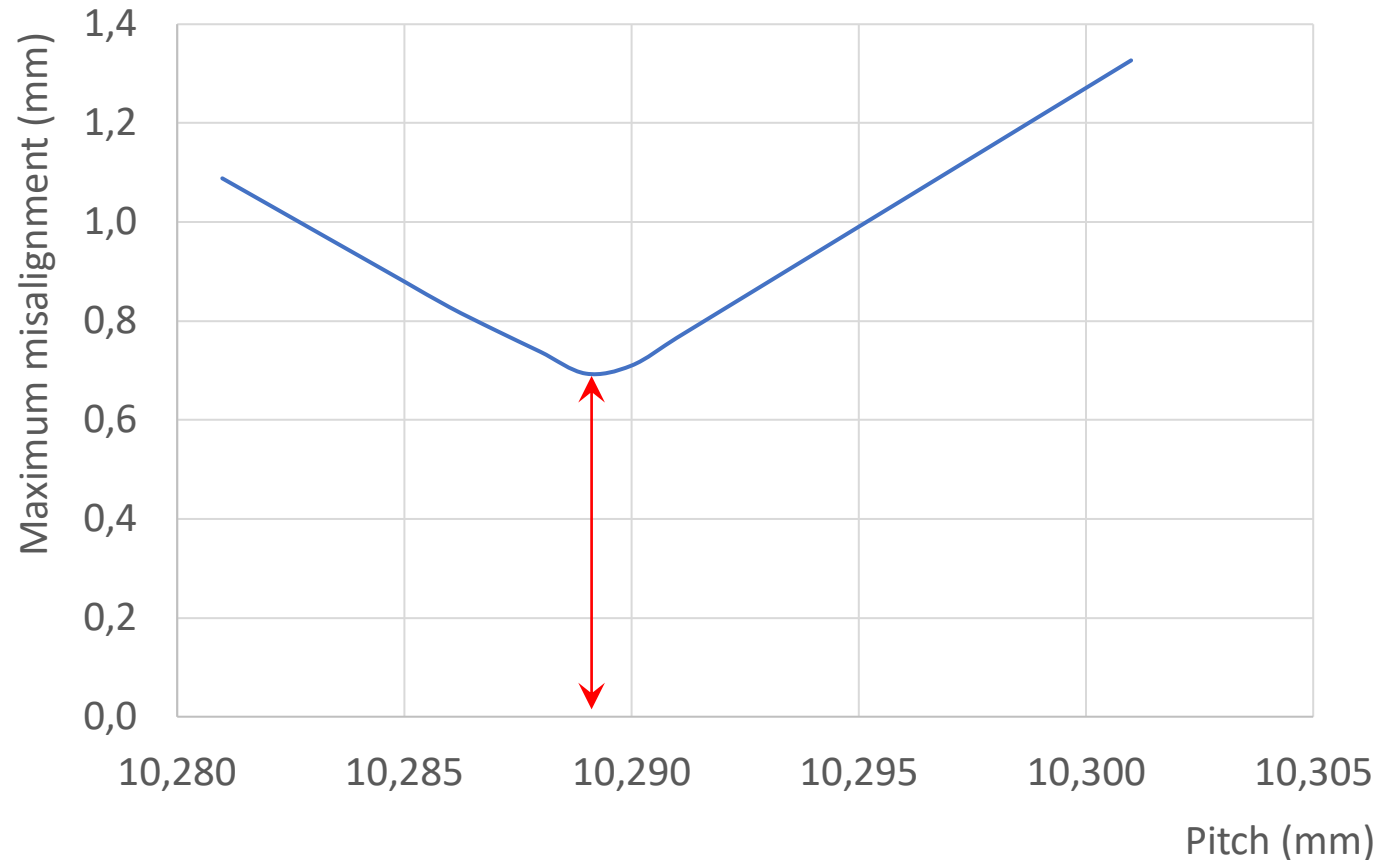


Misalignment is measured as vertical shift between matching holes in cubes and box. The misalignment was calculated for each measurement vs height.

The **average** pitch was calculated as the maximum height divided by 56.

The **optimal** pitch was calculated to minimize the maximum misalignment for each set of cubes.

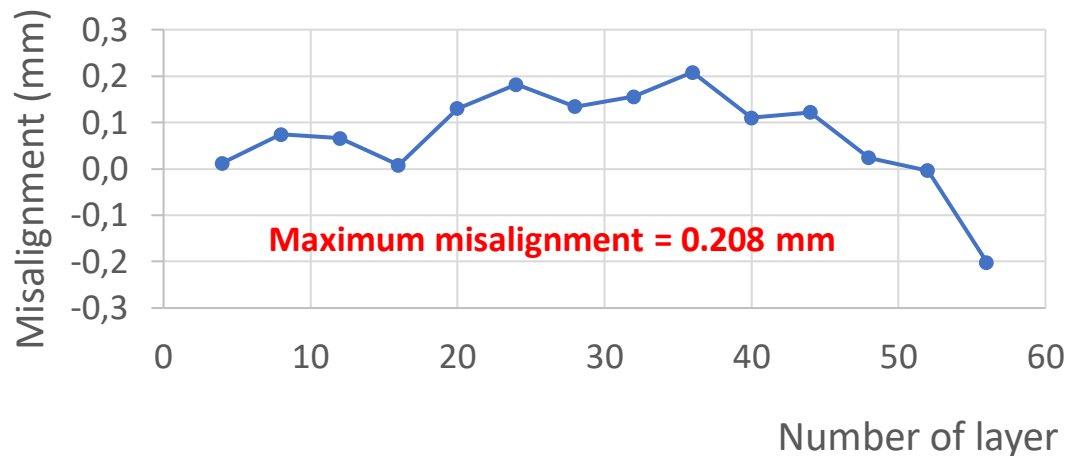
# The optimum vertical pitch value



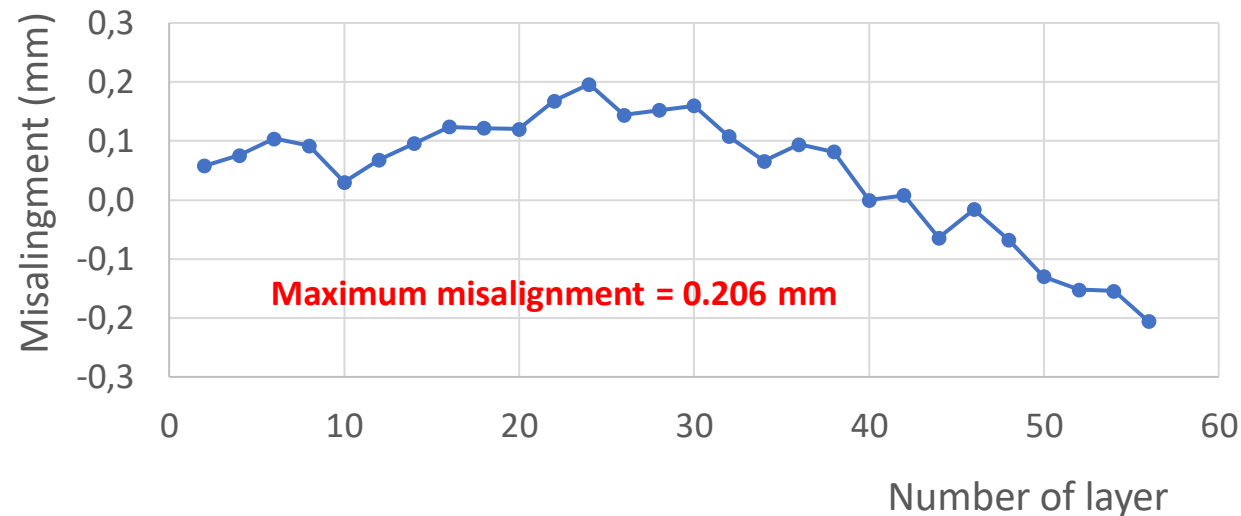
- Sum of 6 measurements for 3 sets of cubes
- Plot shows the function of the maximum misalignment vs pitch value
- Optimal pitch = 10.289 mm provides minimum misalignment for sum of 3 cube sets
- Maximum misalignment is 0.694 mm for optimal pitch. During assembling we hope to adjust cubes heights and the maximum misalignment will be  $\sim 0.3$  mm.

# The misalignment for optimal pitch for 3 sets of cubes

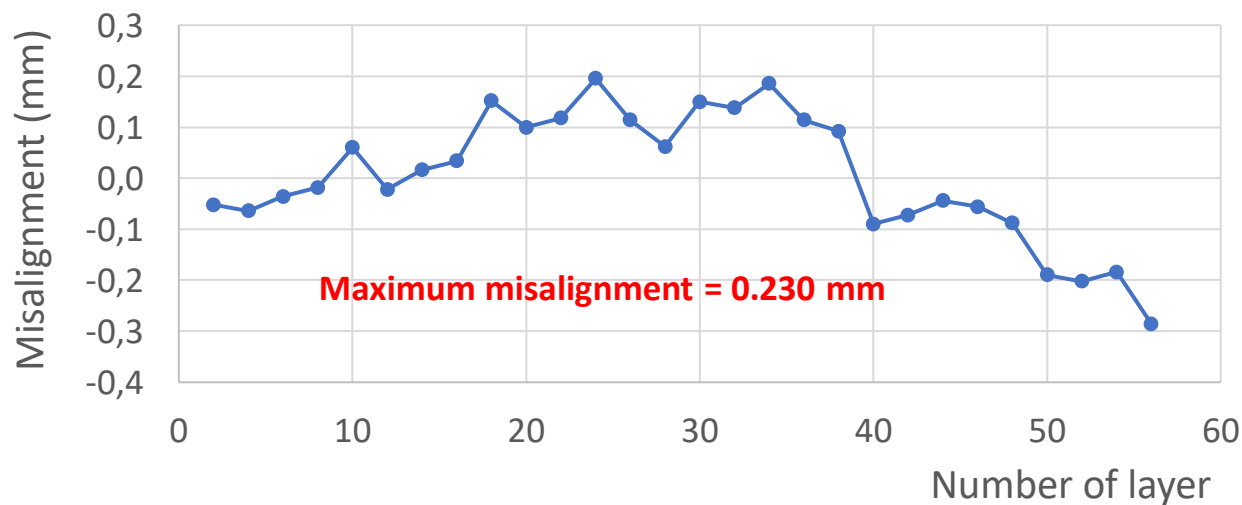
Cubes sample set #1, Optimal pitch = 10.302 mm



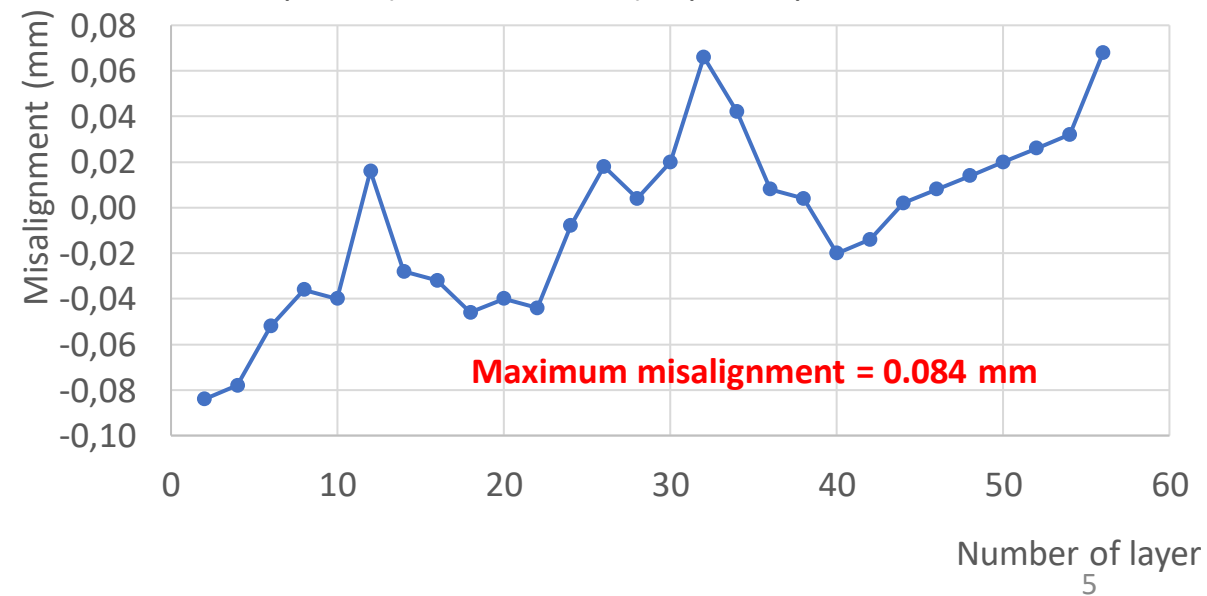
Cubes sample set #2 (measurement 3), Optimal pitch = 10.281 mm



Cube sample set #3 (measurement 1), Optimal pitch = 10.292 mm



Cube sample #3 (measurement 2), Optimal pitch = 10.292 mm

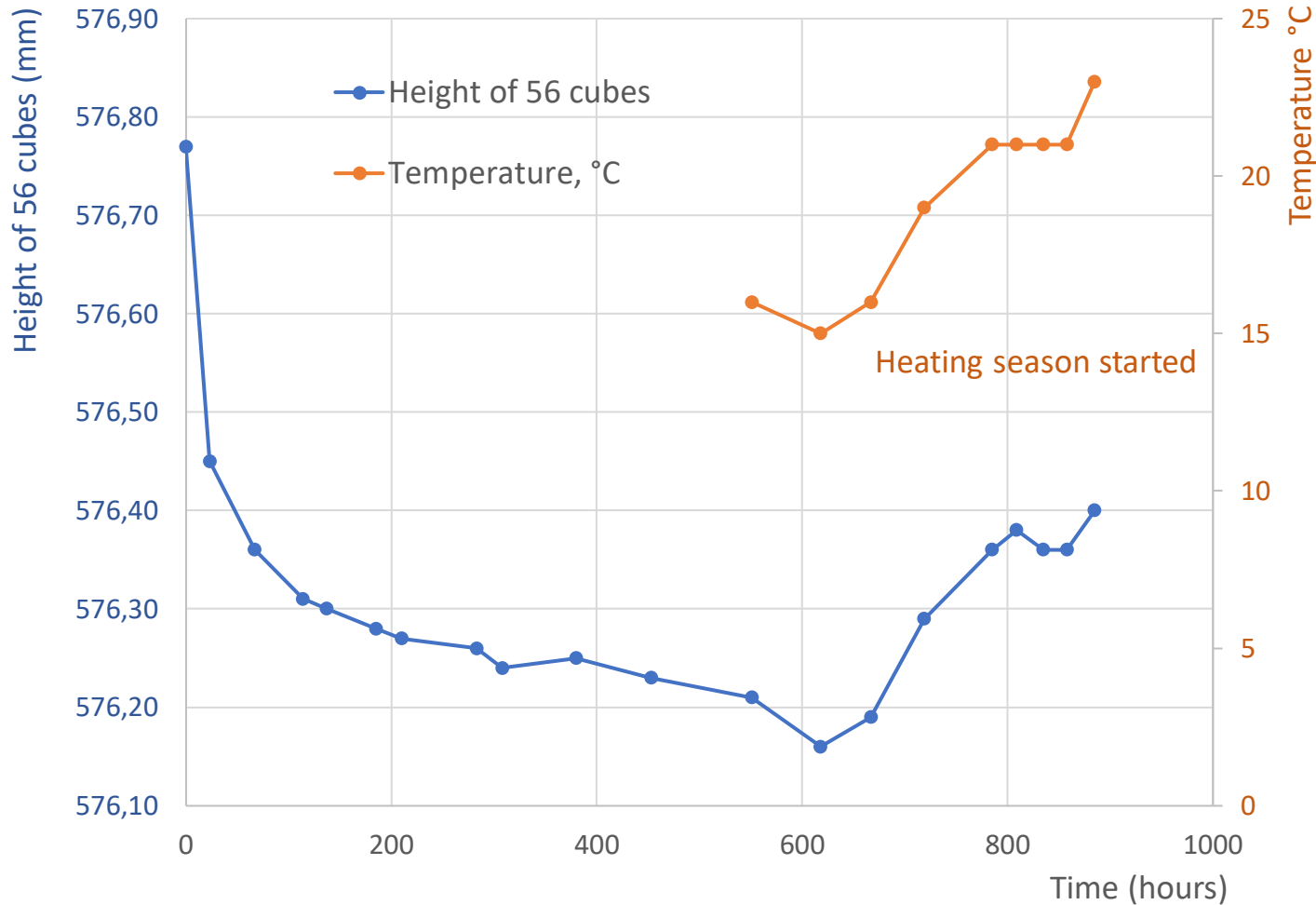


# Results

Cube sample set	Cubes production year	Height of 56 layers (mm)	The average pitch (mm)	Maximum misalignment for the average pitch (mm)	The optimal pitch (mm)	Maximum misalignment for the optimal pitch (mm)
<b>#1</b>	2020	576,71	10,298	0,352	10,302	0,208
<b>#2</b> (measurement 1)	2019	575,79	10,282	0,212	10,285	0,170
<b>#2</b> (measurement 2)	2019	575,91	10,284	0,322	10,288	0,242
<b>#2</b> (measurement 3)	2019	575,53	10,277	0,292	10,281	0,206
<b>#3</b> (measurement 1)	2020	576,57	10,296	0,356	10,292	0,230
<b>#3</b> (measurement 2)	2020	576,43	10,293	0,084	10,291	0,084

Optimal and average pitches depend on 56 cubes height. We hope to adjust the heights during assembling.

# 56 layers height: temperature effect on the 3<sup>rd</sup> set of cubes



Initial drop is caused by compressing of cube array. Then ambient temperature effect changes the height.

The coefficient of vertical expansion was estimated to be  $52 \mu\text{m}/(\text{m} \cdot ^\circ\text{C})$ .

Polystyrene thermal expansion is specified as  $\sim 70 \mu\text{m}/(\text{m} \cdot ^\circ\text{C})$ .

# Summary

We propose to have the following values for the pitches:

**Vertical pitch – 10.28 mm**

The total height is reduced with time, but the effect is rather small and comparable with temperature variations. The pitch value is based on many measurements of heights:

- wall prototype of 15x192x56 cubes
- height of 46 full layers
- 3 sets of cubes of 15x18x56 cubes

Maximum misalignment is estimated to be **~300 μm** in vertical direction and depends on assembling.