FBK SiPMs pre-production boards Testing

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Photo-sensors Meeting

13th February 2024

Ciemat DUNE

First FBK delivery for production validation

100 SIPMs boards (600 SiPMs) received on Nov 2023 for the mass production validation

5 Trays x 20 boards

Tests plan

- ➢ **Detailed characterization at CIEMAT** of 5 boards (30 SiPMs) following the standard procedure:

  - ✓ Room Temp.: I-V characterization (Vbd and Rq)
  - ✓ LN2 1st cycle : I-V characterization

  - ✓ + 17 Cycles LN2 - RT (around 20min each).

  - ✓ LN2 19th cycle : I-V characterization
  - ✓ LN2 20th cycle: Gain, DCR, Xtalk and After-pulses (at three OV)

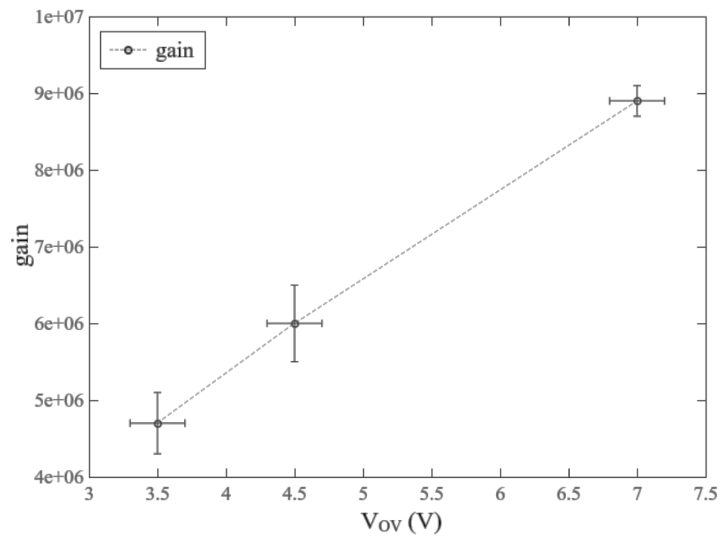   (I-V results already presented on the 5th of December meeting)

- ➢ **Physical measurements at CIEMAT** of 50 boards to check the mechanical specifications.

- ➢ The rest of the boards (50) will be tested on a **CACTUS setup**. Sent to Bologna on January.

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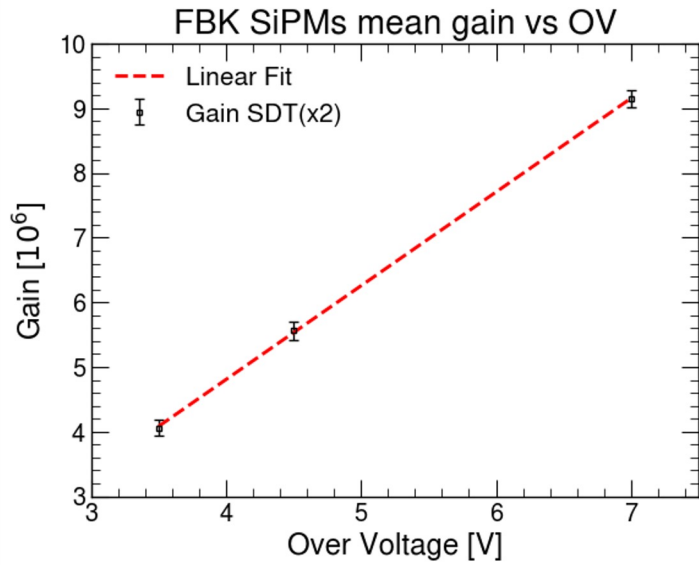
GAIN Results

PREPRODUCTION SAMPLE RESULTS

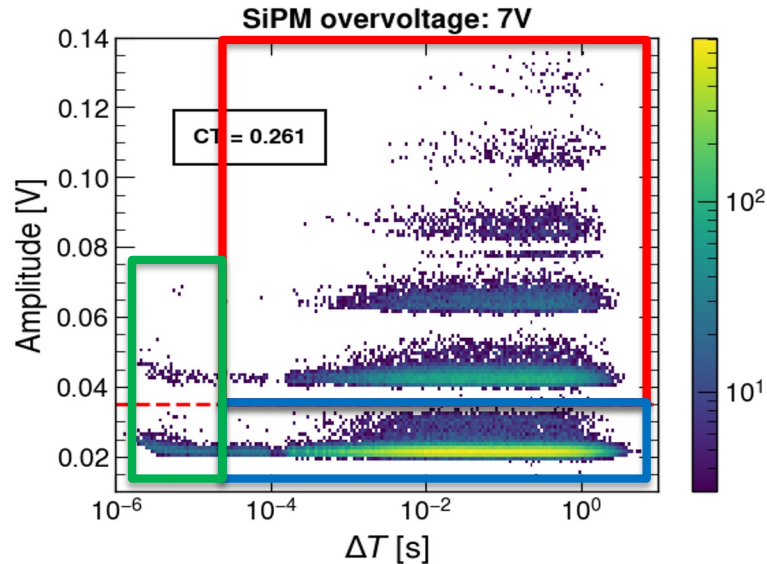| OV [V]	GAIN x1e6	GAIN STD x1e6
3.50	4.06	0.06
4.50	5.57	0.07
7.00	9.14	0.07

PREVIOUS RESULTS

OV [V]	GAIN x1e6
3.50	4.7
4.50	6.0
7.00	8.8

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DCR AND CORRELATED NOISE

Afterpulses = $\Delta T < 2 \times 10^{-5}$

Main pulse = $\Delta T < 2 \times 10^{-5}$ & A<1.5 pe

Crosstalk = A>1.5 pe / A<1.5 pe

- For dark measurements, waveforms were acquired in dark condition, triggering at 0.5 pe level.

- As **crosstalk** the ration between events with peak > 1.5 pe and the ones with peak > 0.5 pe is considered.

- The **afterpulse** probability is the number of events with one or more peaks after the **main pulse**, divided by the number of main pulses.

DCR AND CORRELATED NOISE

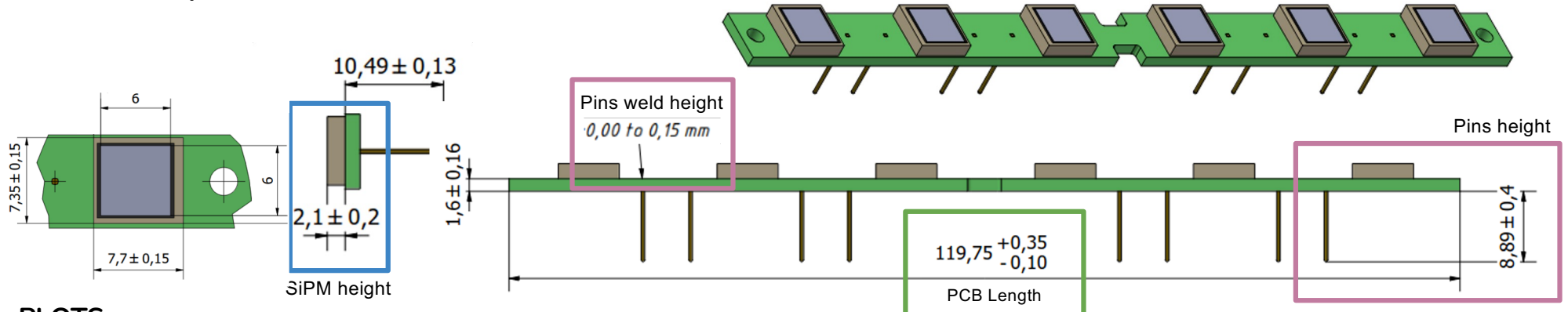| OV [V]	XT [%]	XT STD	AP [%]	AP STD	Total DCR [mHz/mm²]	STD [mHz/mm²]
3.50	11.71	1.07	1.45	0.87	88.3	0.002
4.50	15.35	1.01	1.58	0.49	105.27	0.001
7.00	26.12	2.19	2.27	0.68	121.94	0.001

PREPRODUCTION SAMPLE RESULTS

OV (V)	XT (%)	AP (%)	Total DCR [mHz/mm²]
3.5	12	1.5	53
4.5	16	2	59
7	32	4	73

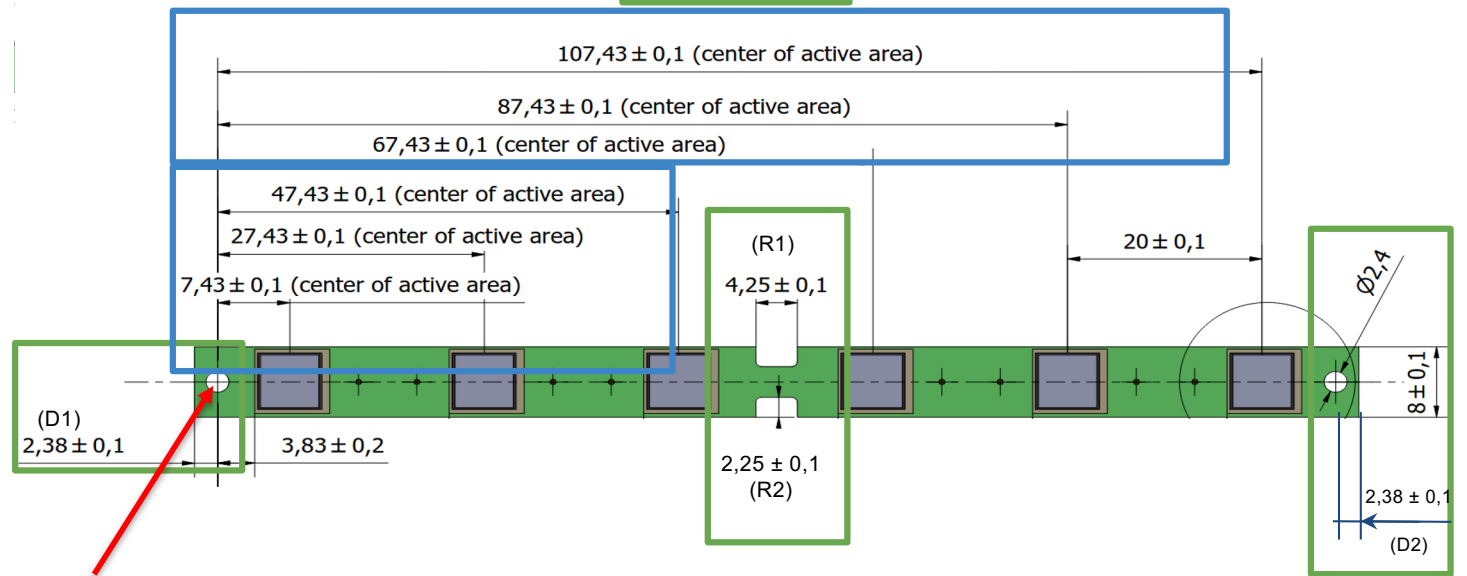PREVIOUS RESULTS (250 SiPMs batch)
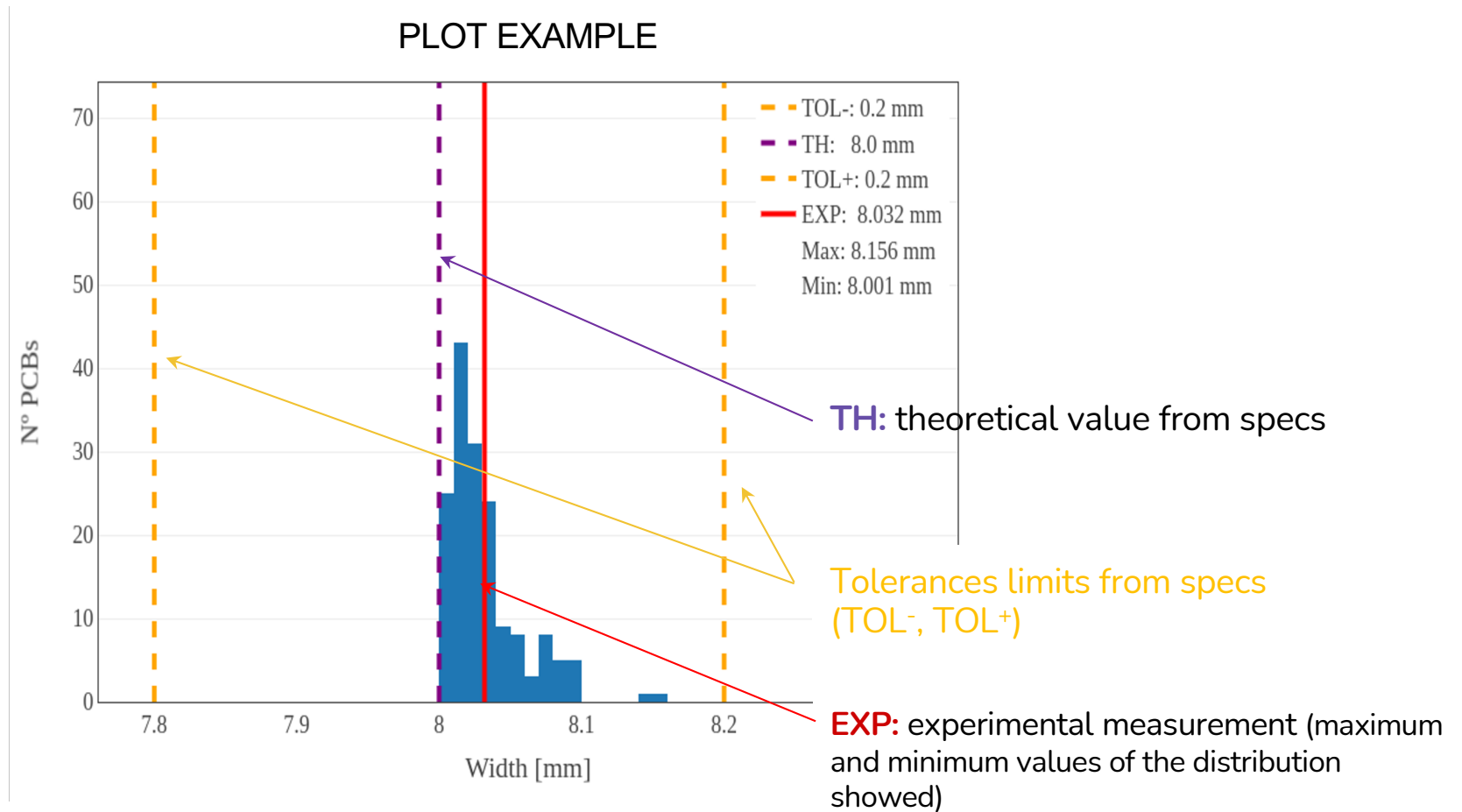
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MECHANICAL MEASUREMENTS

FBK Specifications

PLOTS

- **PCB Width**
- **PCB Length**
- **Distances to drill (D1, D2)**
- **Burr length/width (R1/R2)**

- **Pins Height**
- **Pins - weld height**
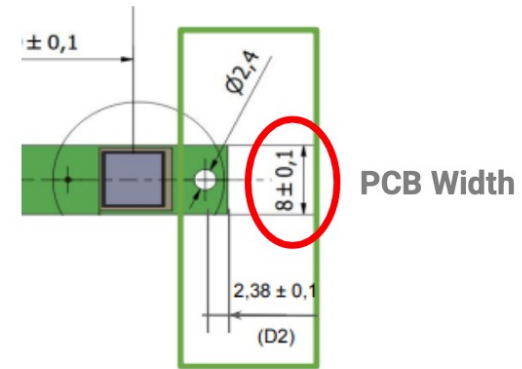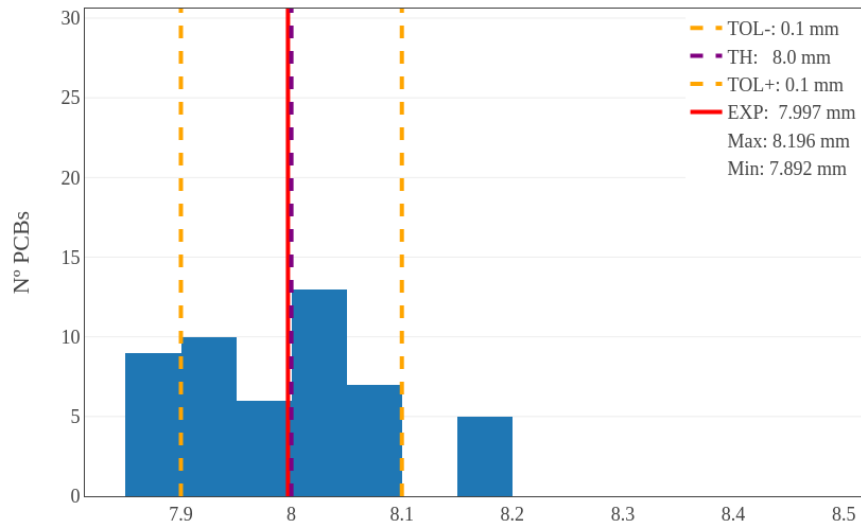
- **SiPMs Height**
- **SiPMs Position Y (L1-6)**

Coordinates origin (D1) for the SiPMs positions

MECHANICAL MEASUREMENTS

PLOT EXAMPLE

Legend:
- TOL-: 0.2 mm
- TH: 8.0 mm
- TOL+: 0.2 mm
- EXP: 8.032 mm
- Max: 8.156 mm
- Min: 8.001 mm

TH: theoretical value from specs

Tolerances limits from specs (TOL⁻, TOL⁺)

EXP: experimental measurement (maximum and minimum values of the distribution showed)
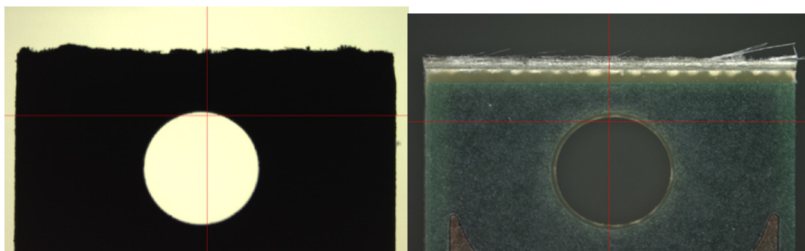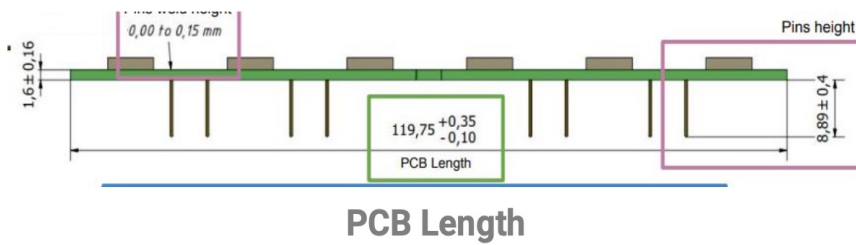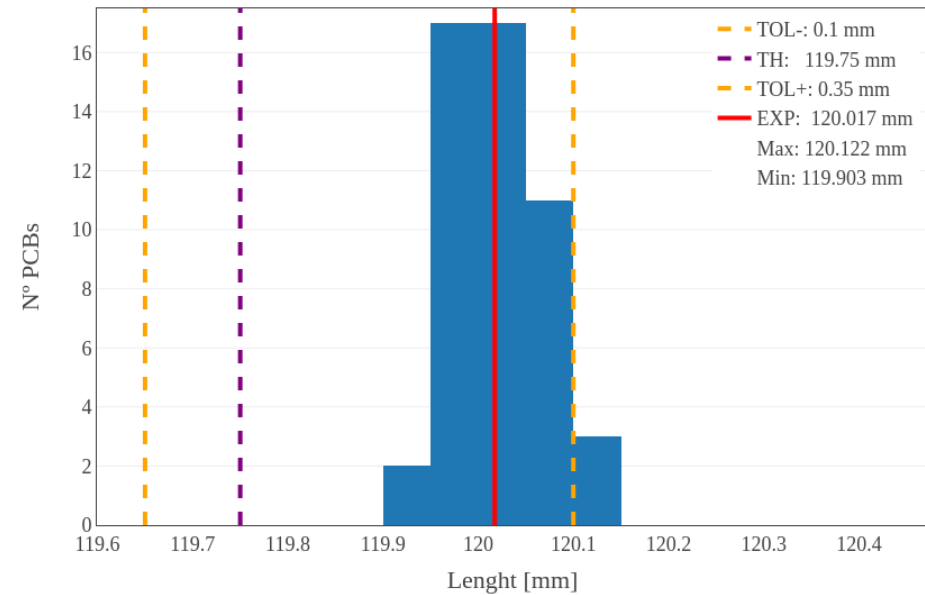
Axis labels: N° PCBs (y-axis), Width [mm] (x-axis)

PCB Length and width

PCB - Width

- TOL-: 0.1 mm
- TH: 8.0 mm
- TOL+: 0.1 mm
- EXP: 7.997 mm
- Max: 8.196 mm
- Min: 7.892 mm

PCB Width

$8 \pm 0,1$

$2,38 \pm 0,1$

(D2)

$\pm 0,1$

$\varnothing 2,4$

PCB - Length

Pins weld height
0,00 to 0,15 mm

Pins height

$1,6 \pm 0,16$
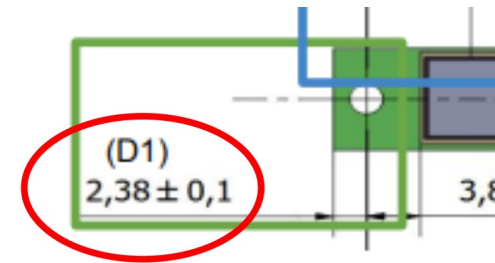
$119,75 \, {}^{+0,35}_{-0,10}$

PCB Length

$8,89 \pm 0,4$

PCB Length

PCB cuts on the short side are not clean making the measurement less precise and larger than it should be
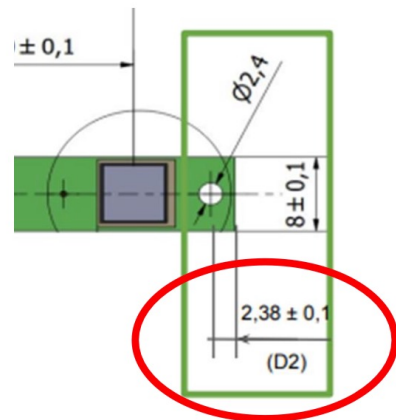
- TOL-: 0.1 mm
- TH: 119.75 mm
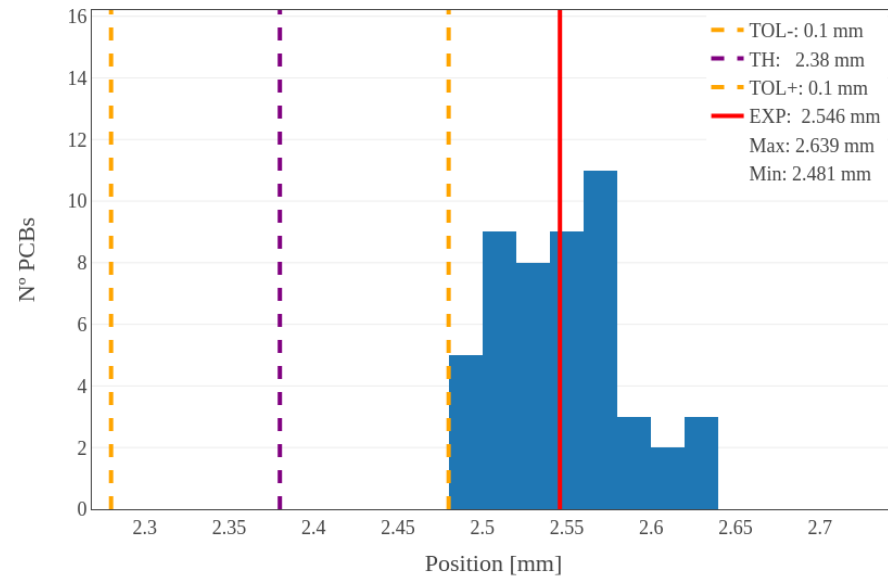- TOL+: 0.35 mm
- EXP: 120.017 mm
- Max: 120.122 mm
- Min: 119.903 mm

Lenght [mm]

N° PCBs

PCB edges distances to drills

PCB - Distance to Drill (D1)

Legend:
- TOL-: 0.1 mm
- TH: 2.38 mm
- TOL+: 0.1 mm
- EXP: 2.418 mm
- Max: 2.556 mm
- Min: 2.316 mm

Distance to Drill (D1)

(D1)
2,38 ± 0,1

Distance to Drill (D2)

PCB - Distance to Drill (D2)

Legend:
- TOL-: 0.1 mm
- TH: 2.38 mm
- TOL+: 0.1 mm
- EXP: 2.546 mm
- Max: 2.639 mm
- Min: 2.481 mm

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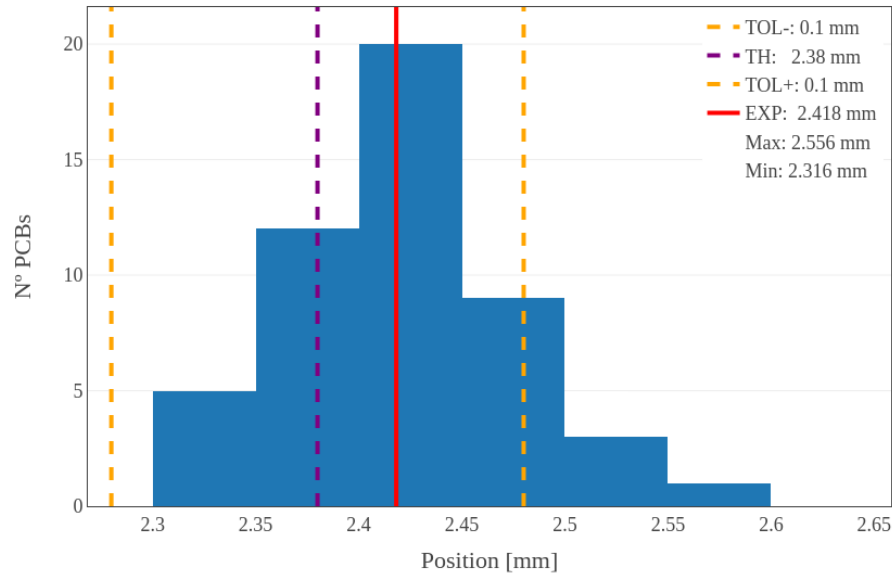
PCB Notch

PCB - burr lenght (R1)

Legend:
- TOL-: 0.1 mm
- TH: 4.25 mm
- TOL+: 0.1 mm
- EXP: 4.268 mm
- Max: 4.329 mm
- Min: 4.23 mm

Axes: Nº PCBs vs Length [mm]

PCB - burr lenght (R2)

Legend:
- TOL-: 0.1 mm
- TH: 4.25 mm
- TOL+: 0.1 mm
- EXP: 4.259 mm
- Max: 4.332 mm
- Min: 4.22 mm

Axes: Nº PCBs vs Longitud rebaje izquierdo

Notch width (R1)

(R1)

4,25 ± 0,1

2,25 ± 0,1
(R2)

Notch length (R2)

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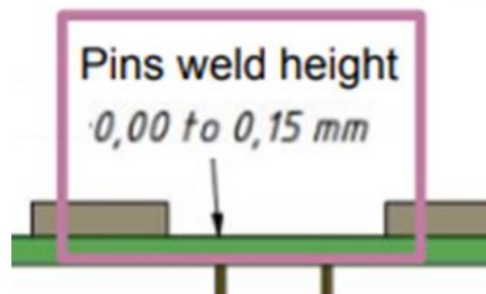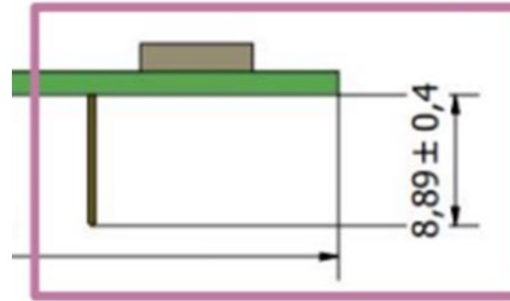
Pins

SiPMs Placement along X (short side)
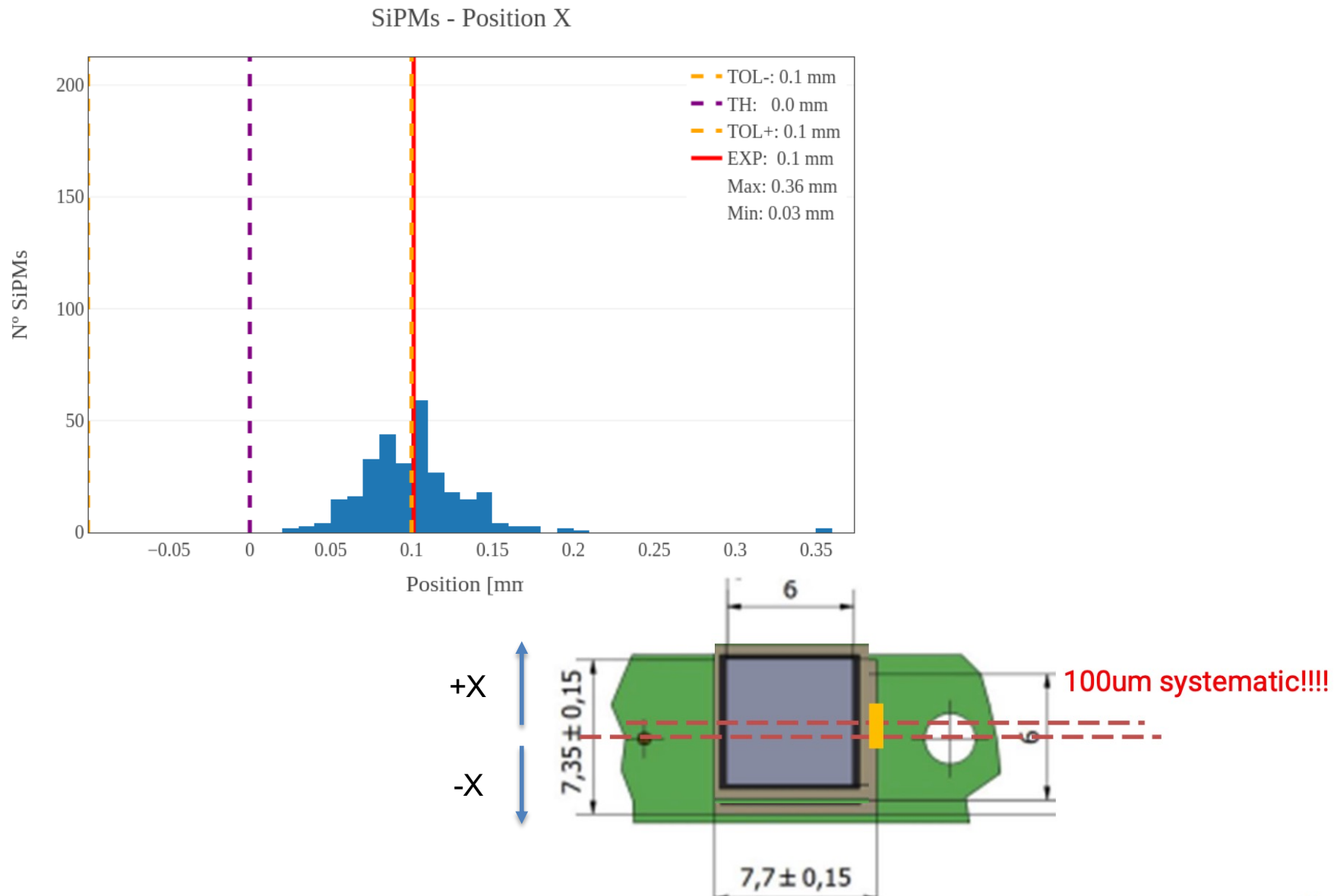
SiPMs - Position X

Legend:
- TOL-: 0.1 mm
- TH: 0.0 mm
- TOL+: 0.1 mm
- EXP: 0.1 mm
- Max: 0.36 mm
- Min: 0.03 mm

100um systematic!!!!
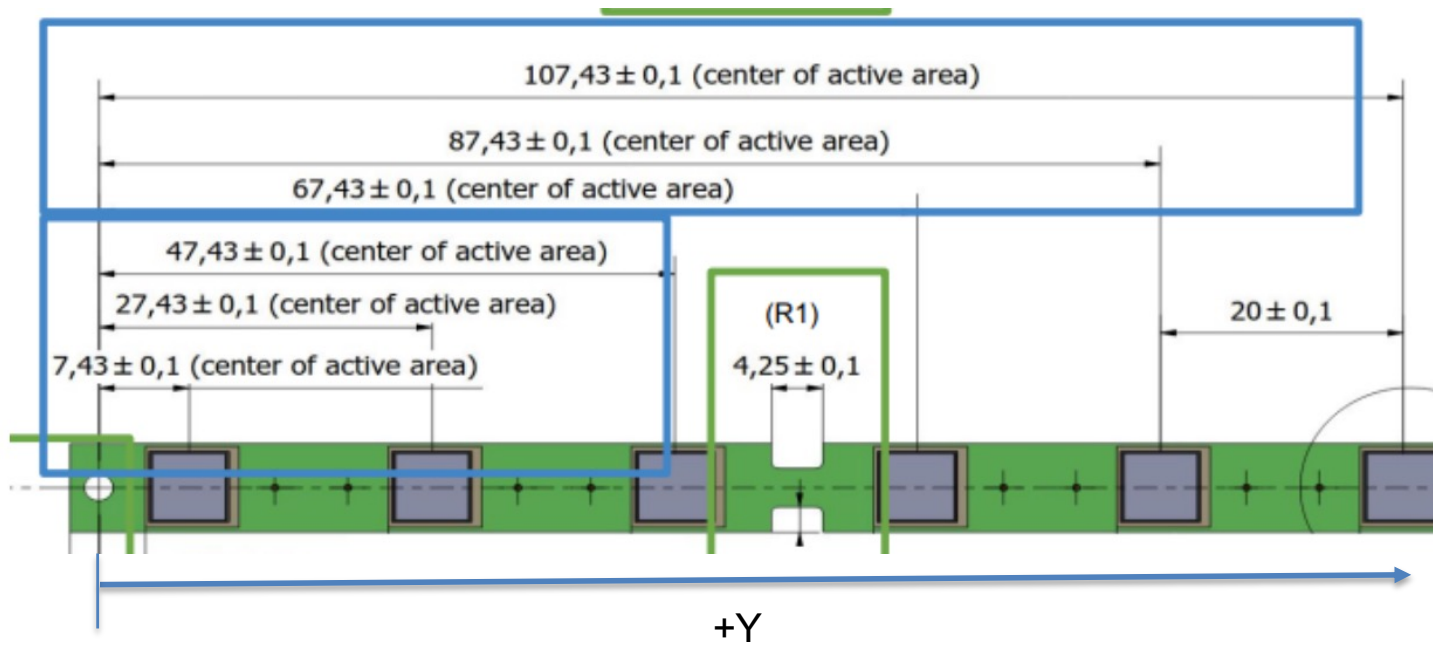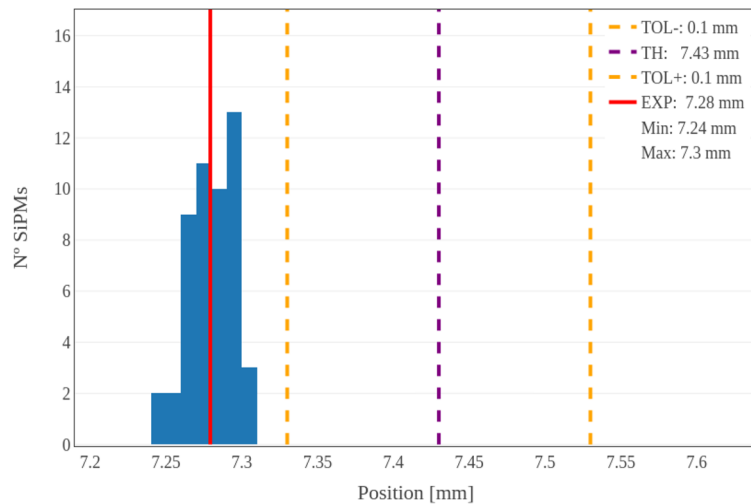
SIPMs Placement along Y (long side)
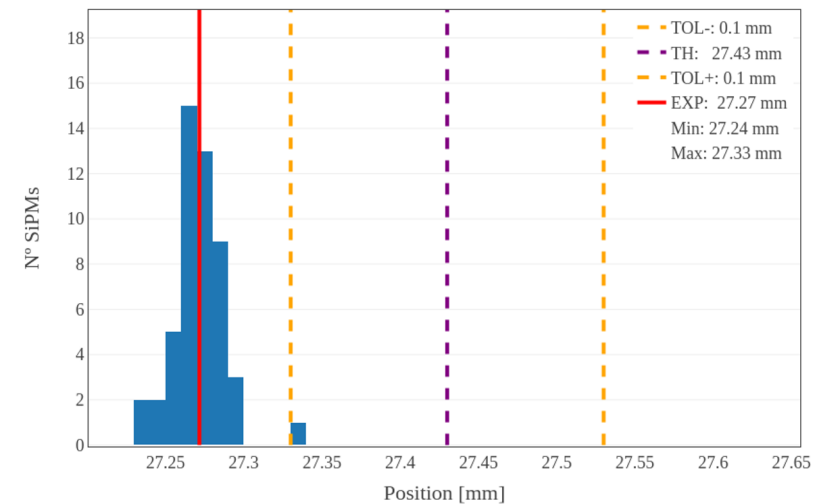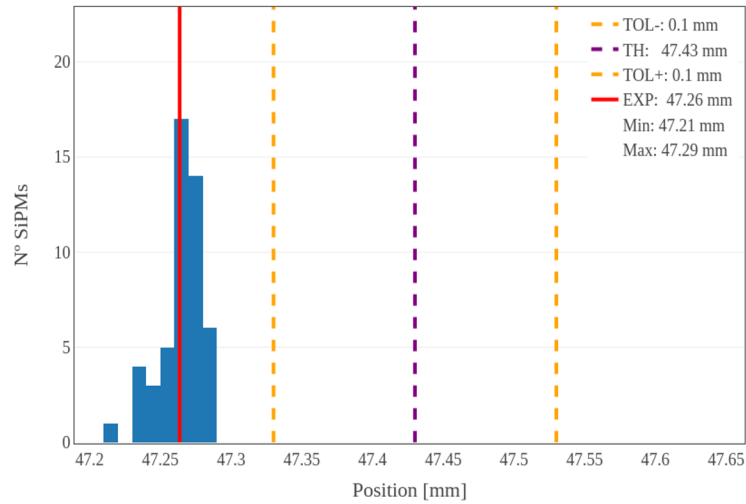
SIPMs Placement along Y (long side)

SiPM #3 - Position Y (L3)

TOL-: 0.1 mm
TH: 47.43 mm
TOL+: 0.1 mm
EXP: 47.26 mm
Min: 47.21 mm
Max: 47.29 mm

SiPM #4 - Position Y (L4)

TOL-: 0.1 mm
TH: 67.43 mm
TOL+: 0.1 mm
EXP: 67.26 mm
Min: 67.23 mm
Max: 67.28 mm

SiPM #5 - Position Y (L5)

TOL-: 0.1 mm
TH: 87.43 mm
TOL+: 0.1 mm
EXP: 87.25 mm
Min: 87.22 mm
Max: 87.28 mm

SiPM #6 - Position Y (L6)

TOL-: 0.1 mm
TH: 107.43 mm
TOL+: 0.1 mm
EXP: 107.24 mm
Min: 107.21 mm
Max: 107.26 mm
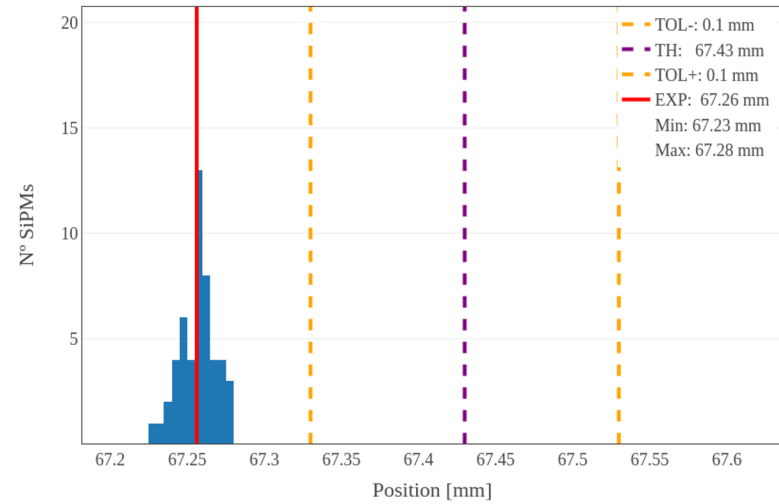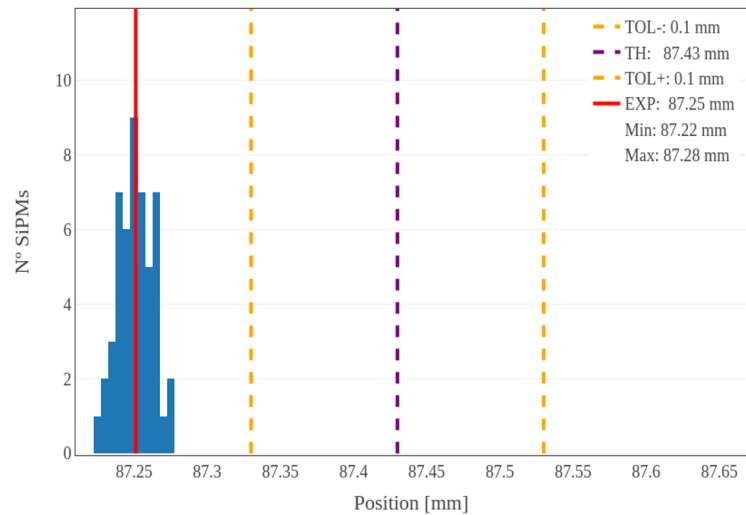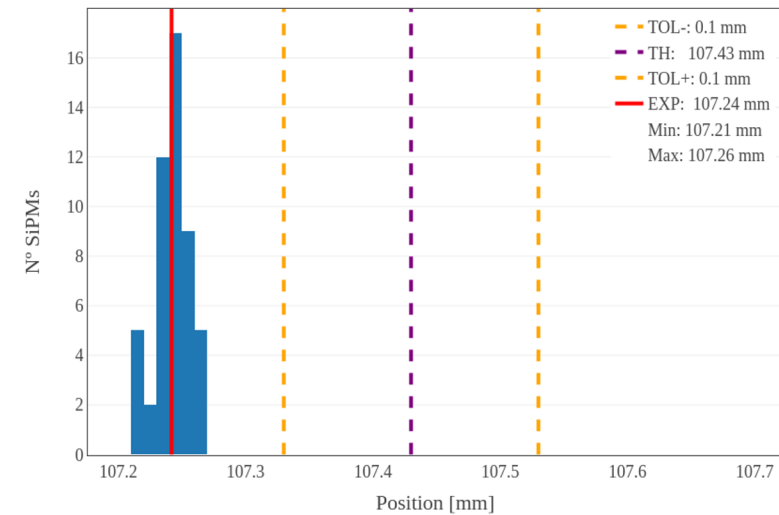
SIPMs Placement along Y (long side)

	Y L1	Y L2	Y L3	Y L4	Y L5	Y L6
min	7.33	27.33	47.33	67.33	87.33	107.33
TH	7.43	27.43	47.43	67.43	87.43	107.43
max	7.53	27.53	47.53	67.53	87.53	107.53
EXP	7.28	27.27	47.26	67.26	87.25	107.24
min	7.24	27.24	47.21	67.23	87.22	107.21
max	7.3	27.33	47.29	67.28	87.28	107.26
EXP-TH	-0.15	-0.16	-0.17	-0.17	-0.18	-0.19

There is a systematic shift of around -170um from the origin (D1) to the SiPMs active área center

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SiPMs height measurement
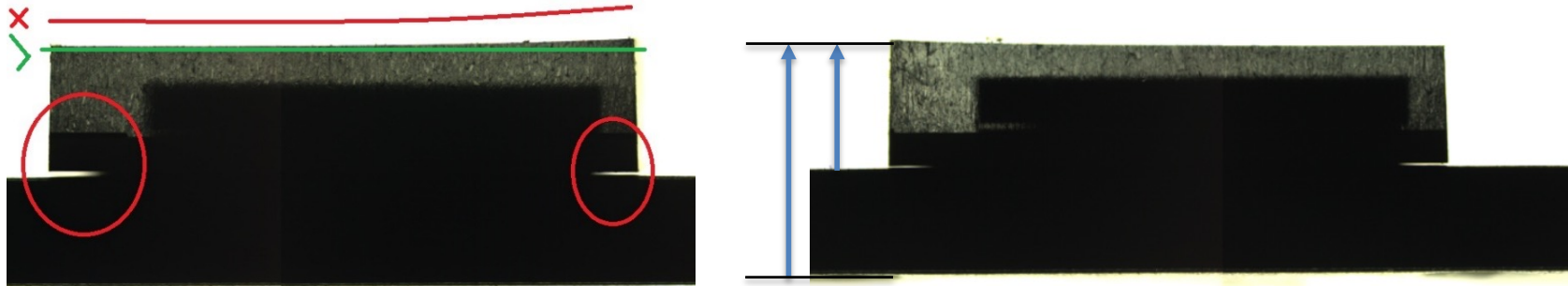
Looking at the SiPMs from the board side we observe that the surface of the SiPMs has some curvature, so we have taken four measurements for each SiPM: maximum and average from the top of the PCB and from the bottom of the PCB.
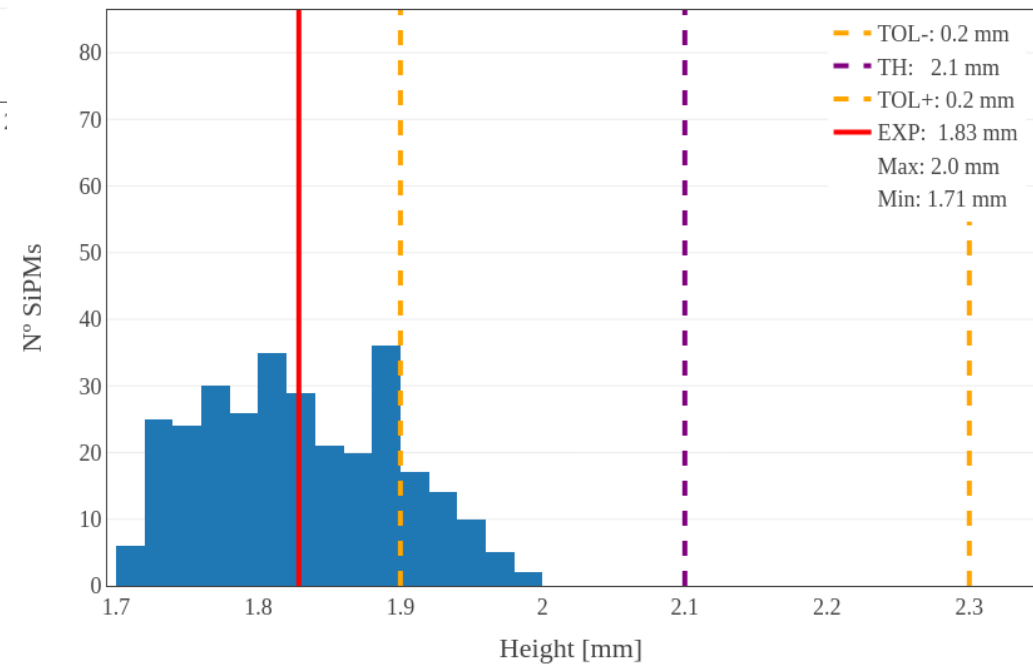
SiPMs height from PCB front

SiPMs - Height (mean front)

TOL-: 0.2 mm
TH: 2.1 mm
TOL+: 0.2 mm
EXP: 1.75 mm
Max: 1.91 mm
Min: 1.64 mm

PCB

2,1 ± 0,2
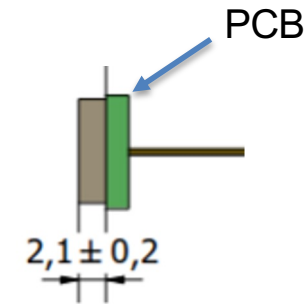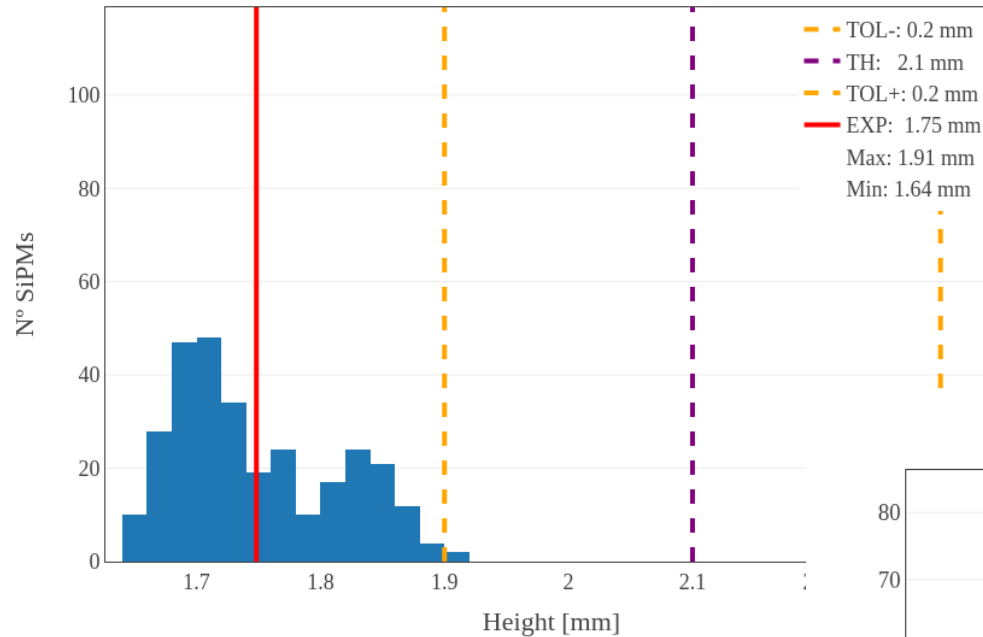
SiPM height from PCB front

SiPMs - Height (max front)

TOL-: 0.2 mm
TH: 2.1 mm
TOL+: 0.2 mm
EXP: 1.83 mm
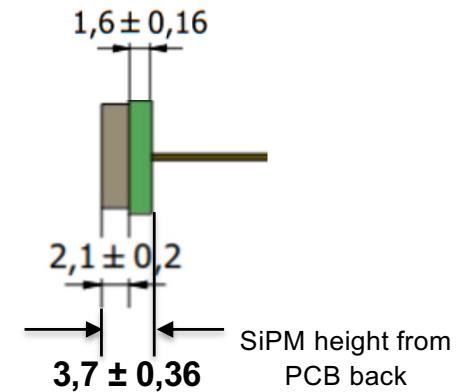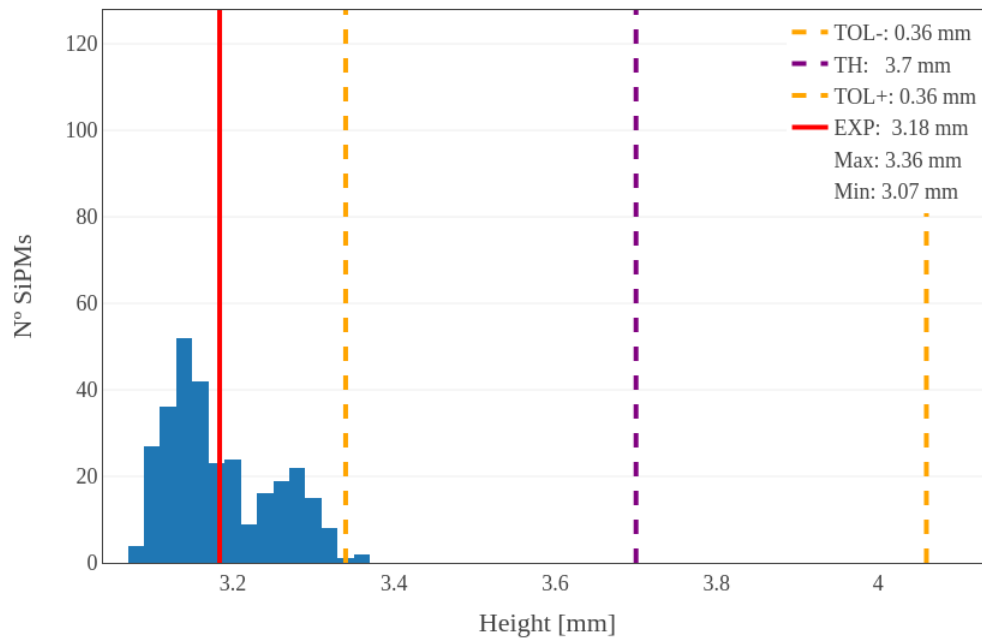Max: 2.0 mm
Min: 1.71 mm

There is a systematic shift of around -350um with respect to the expected SiPM height

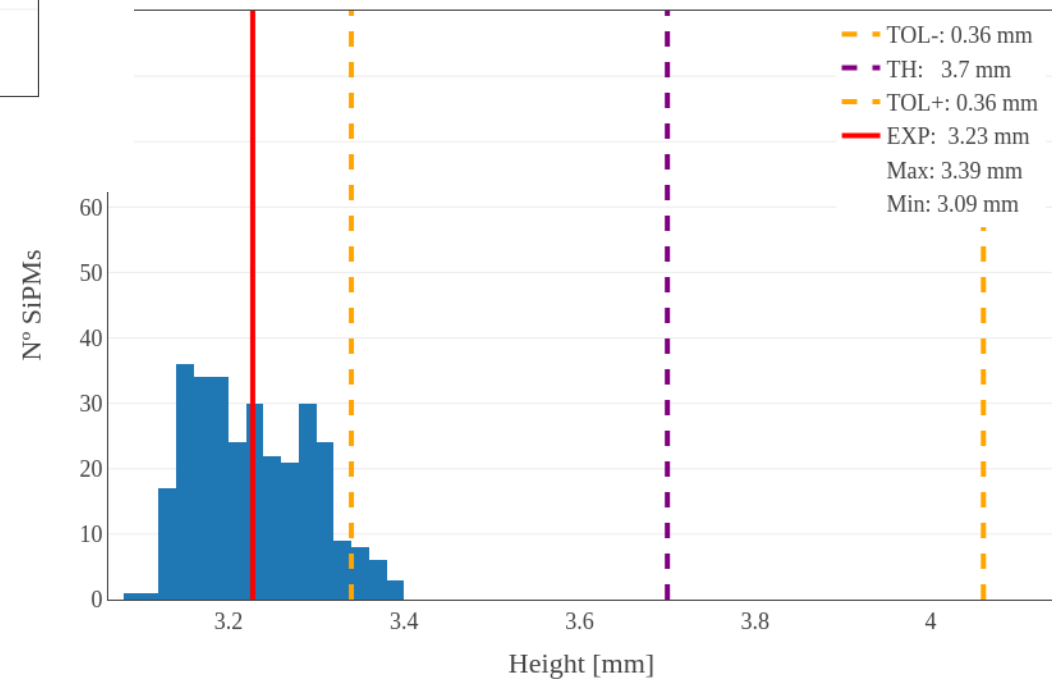The difference between the average and the max height is around 80um

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SiPMs height from PCB back

SiPMs - Height (mean back)

- TOL-: 0.36 mm
- TH: 3.7 mm
- TOL+: 0.36 mm
- EXP: 3.18 mm
- Max: 3.36 mm
- Min: 3.07 mm

1,6 ± 0,16

2,1 ± 0,2

3,7 ± 0,36

SiPM height from PCB back

SiPMs - Height (max back)

- TOL-: 0.36 mm
- TH: 3.7 mm
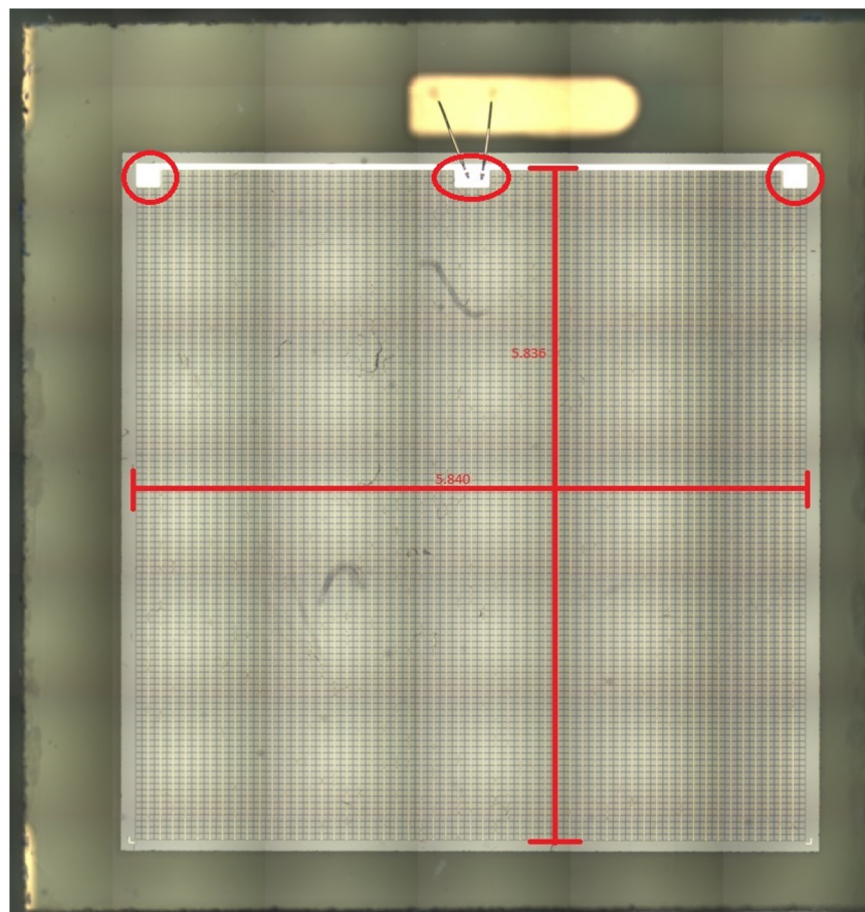- TOL+: 0.36 mm
- EXP: 3.23 mm
- Max: 3.39 mm
- Min: 3.09 mm

From the PCB back the shift is around -520um with respect to the expected.

The difference between the average and the max height is around 50um.
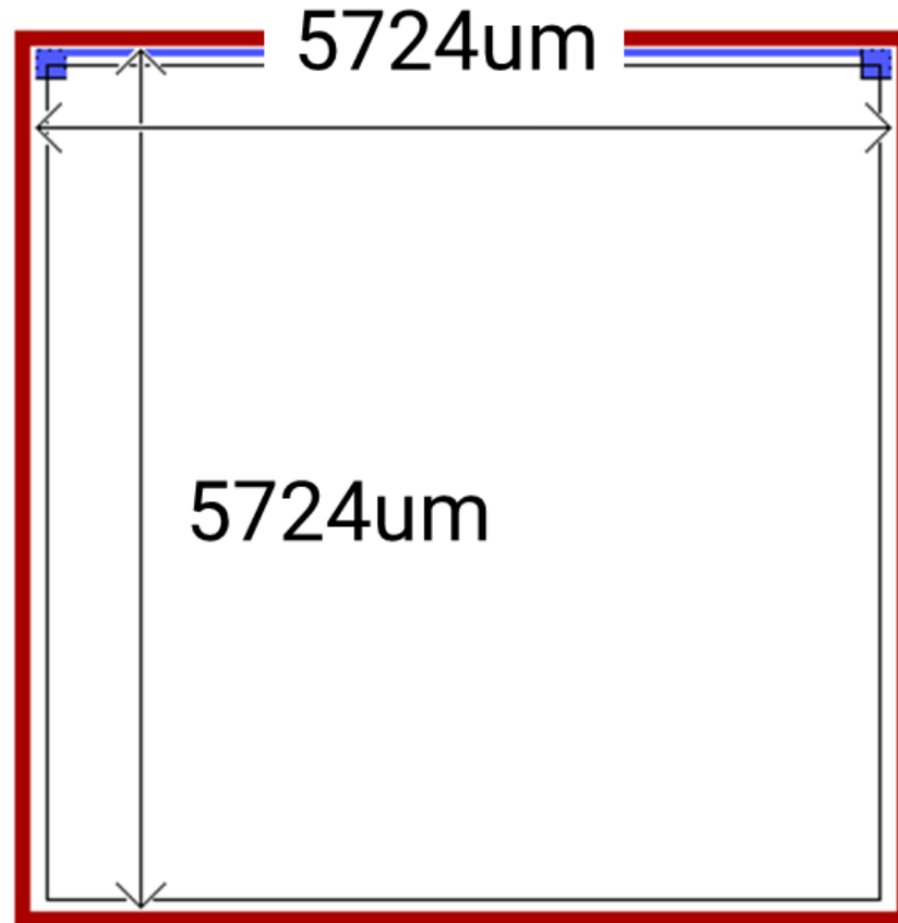
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Active Area

In our measurements the active area looks like 5,836 X 5,840 mm. The areas occupied by the contacts (red circles) are not discounted.

Active Area confirmed by FBK

11188 Active cells (54um)
(48 cells removed for the
bonding pads)

Active área -9.4% wrt 6x6mm

Production Status

- FBK is in contact with the packaging company to reduce the mechanical tolerances.

- We plan to have a new meeting with FBK after sending the last results showed on this presentation (probably this week).

- Your comments to discuss with them are wellcome !

- If the 50 boards sent to Bologna are already tested we can also report those results to FBK.

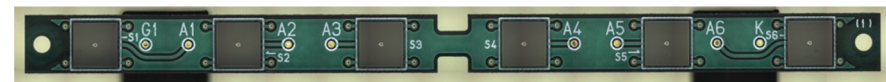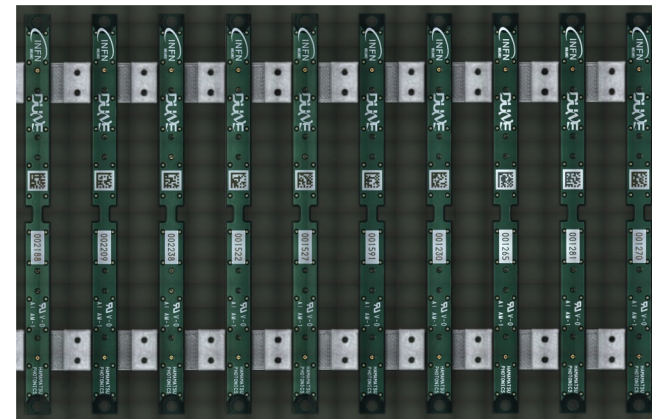- FBK will send us (soon) a new lot of PCBs for mechanical verification.
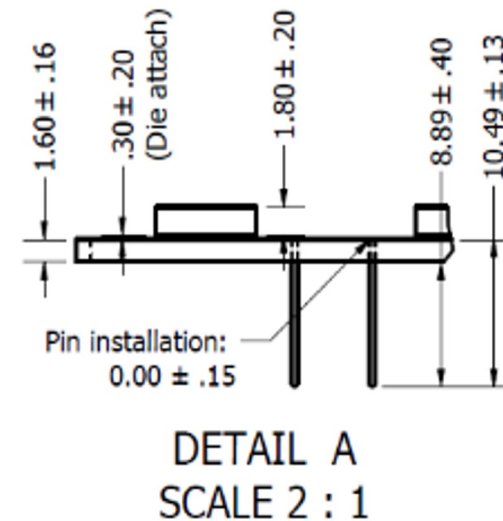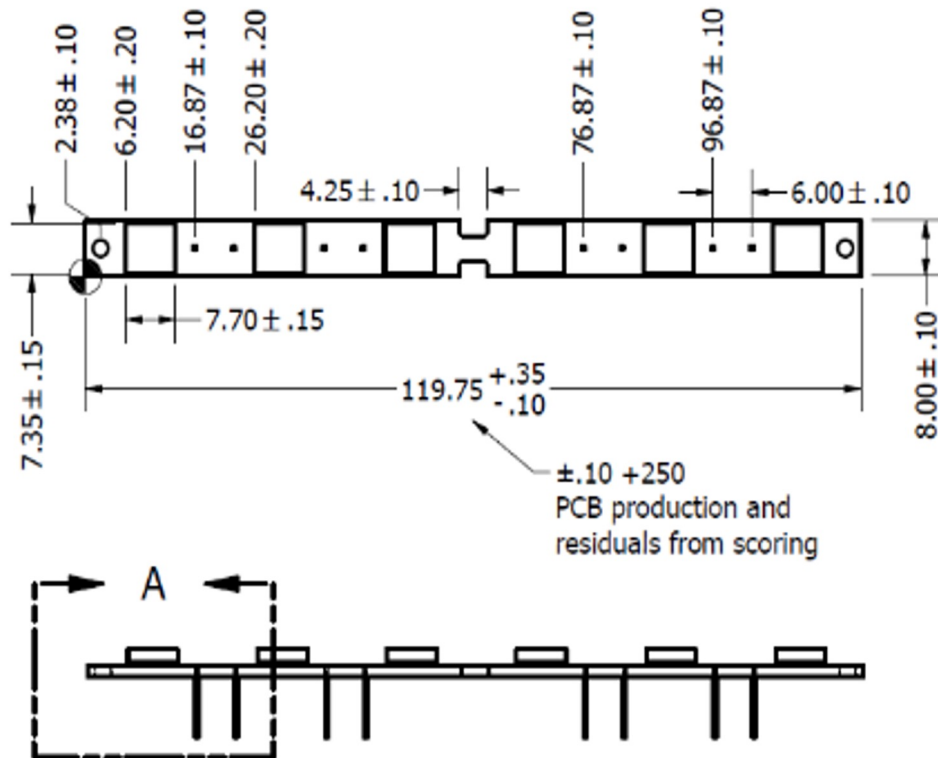
Thank you !

How do we measure?
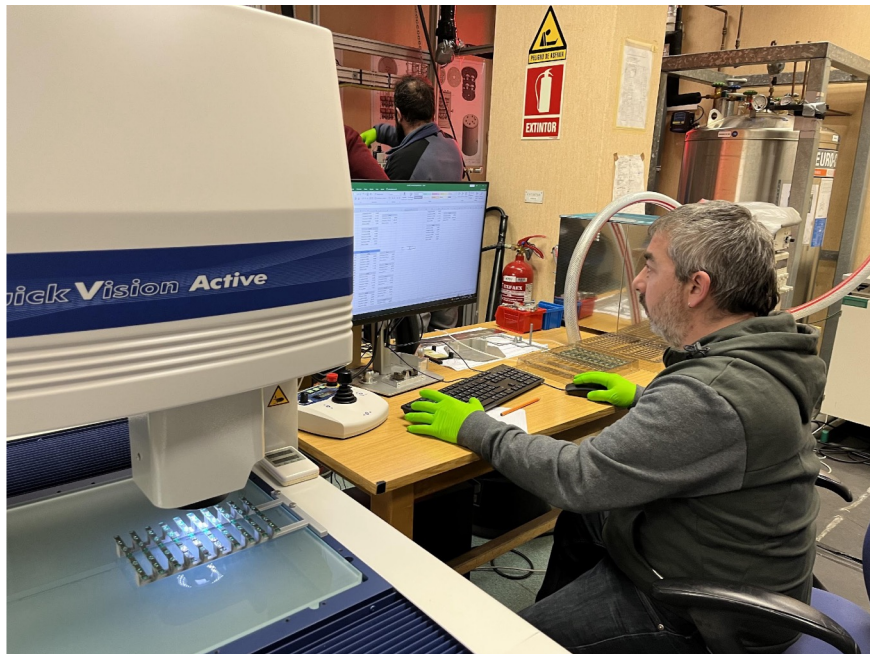
Measurements made with a **3D vision machine**
Model: QUICK VISION Active 404
Precision: ±1.5 μm

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FBK Specifications on datasheet and contract
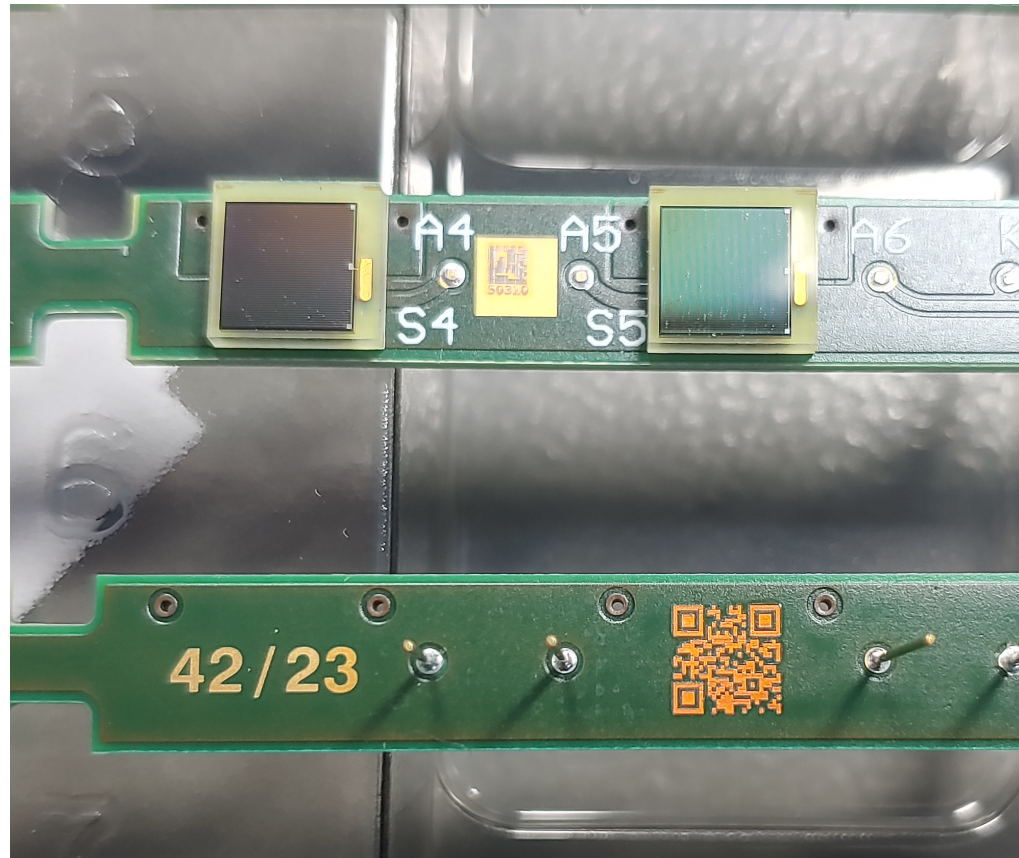

DETAIL A
SCALE 2 : 1

First observations

Inhomogeneous placement of silicon in the packages

First observations

QR instead of DM code at the bottom of the board
DM at the top but too small and difficult to read

First Measurements

Board	SiPM	Room Temp		LN2	
		Vbd	Rq	Vbd	Rq
337	1	32,63	54	26,8	251,1
	2	32,63	54,9	26,82	252,8
	3	32,68	53,8	26,82	246,5
	4	32,68	52,5	26,8	239,9
	5	32,67	52,7	26,82	238,9
	6	32,70	51,7	26,82	231,5
225	1	32,68	52,4	26,86	239,8
	2	32,68	52,2	26,88	237,6
	3	32,63	53,5	26,84	249,6
	4	32,80	51,6	26,82	233,8
	5	32,68	54,8	26,86	240,5
	6	32,67	53	26,84	240,8
247	1	32,70	52,4	26,82	245,6
	2	32,63	52,5	26,86	245,7
	3	32,78	53,7	26,86	250,1
	4	32,72	52,5	26,9	242,1
	5	32,63	54,8	26,78	238,4
	6	32,70	51,7	26,82	241,4
310	1	32,75	51,3	26,9	234,6
	2	32,61	52,3	26,86	241,4
	3	32,63	52,9	26,84	240,9
	4	32,65	52,9	26,9	236,6
	5	32,68	55,6	26,88	241,1
	6	32,72	52,3	26,8	240,8
295	1	32,72	51,2	26,8	237,6
	2	32,68	51	26,8	235,2
	3	32,70	51,9	26,88	238,6
	4	32,63	51	26,82	235,9
	5	32,70	55,3	26,84	229,9
	6	32,68	51,3	26,9	237,5

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First Measurements
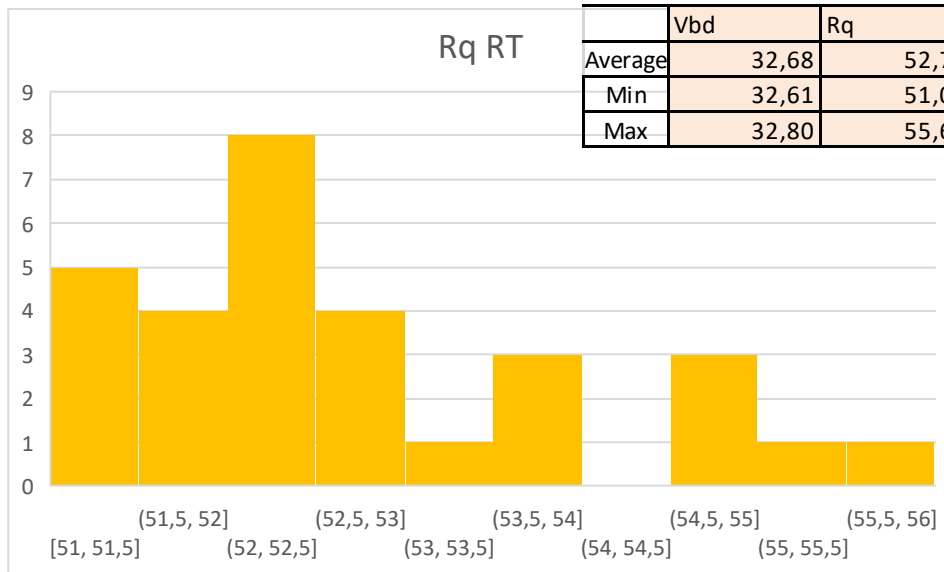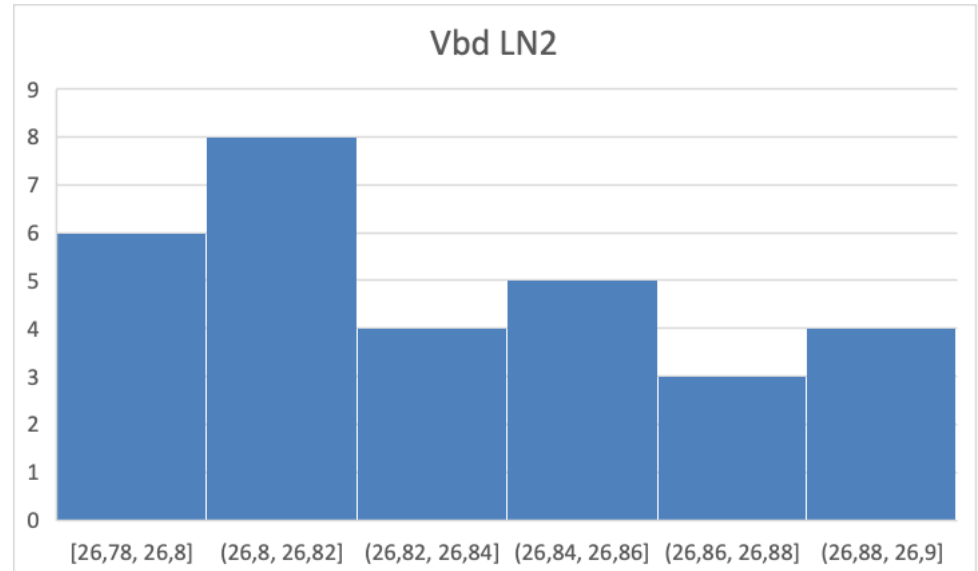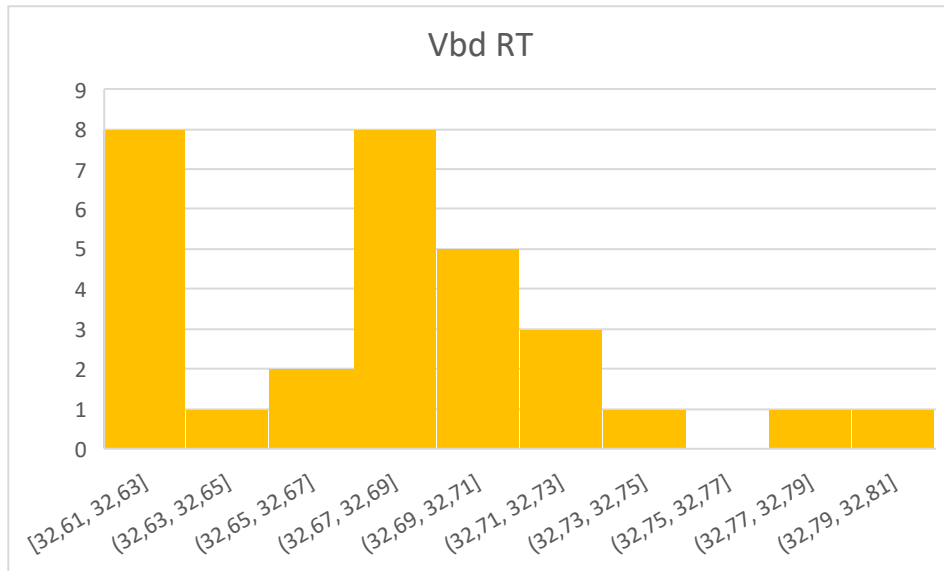
	Vbd	Rq	Vbd	Rq
Average	32,68	52,79	26,84	240,54
Min	32,61	51,00	26,78	229,90
Max	32,80	55,60	26,90	252,80