IFIC – SiWECAL activities: gluing and more

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Outline

Part1

- Draft of COB paper → noise comparison with BGAs → tomorrow!

Part 2

- Preparation for resistivity studies
  - Dummy test to check viability of the tools (climatic chamber, ohmmeter) and qualitative results

Part 3

- Preparation of tools for gluing + first tests with PCBs
  - Aspiration plate in aluminum for sensor and pcb alignment (xy and z)
  - Use of an old batch of glue (EJ2189) and transparent fake wafers
  - The tools require small adaptations for the new CALICE FEV2 PCBs and the new ECAL-e flex PCBs

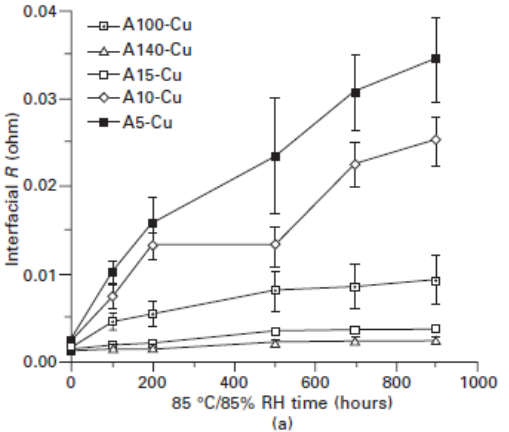
Part 4

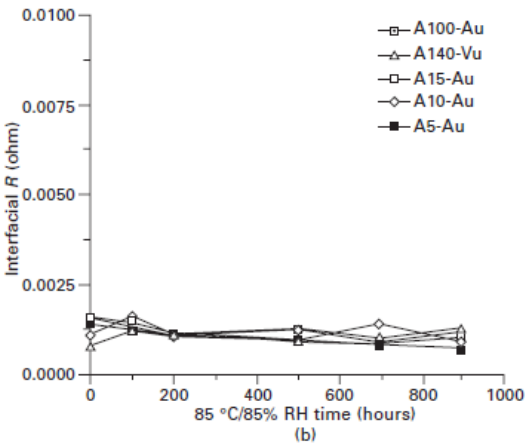
- PCB deformations tests after temperature/humidity cycles

Part 2: resistivity evolution

Resistivity of conductive epoxy

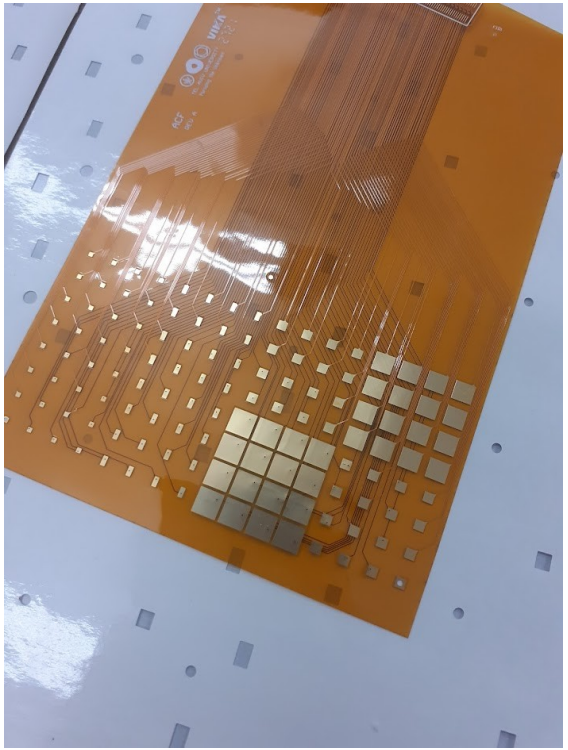
- Several issues of sensor dellamination have been reported by SiW-ECAL
- Main suspects are the limited mechanical strength of the glue and the initial deformation of the PCBs
- However, we should not discard all other reasons
  - Conductive epoxys (silver balls) and aluminium can suffer oxydation, degrading the resistivity.

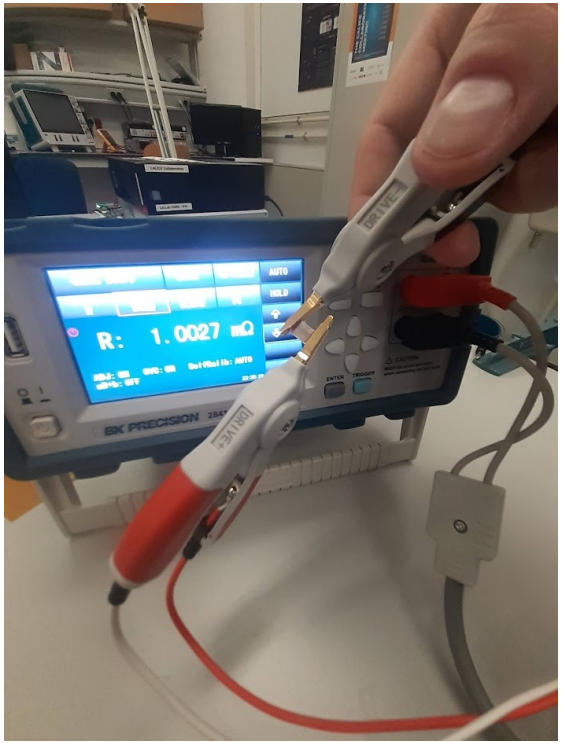




4.9 Ag ICA contact resistance changes at 85/85: (a) on Cu contacts, (b) on Au contacts, with (c) corresponding bulk resistivity variations.

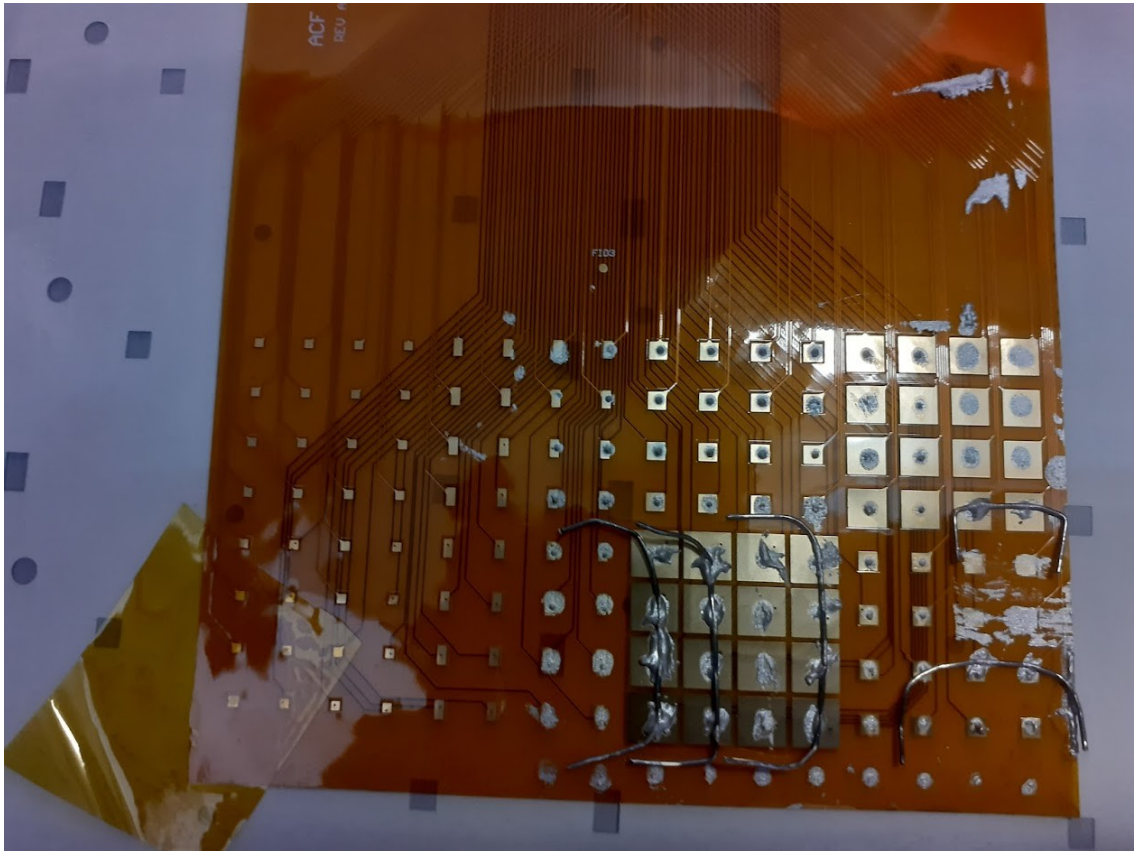
Dummy tests using a flex pcb (FCAL)





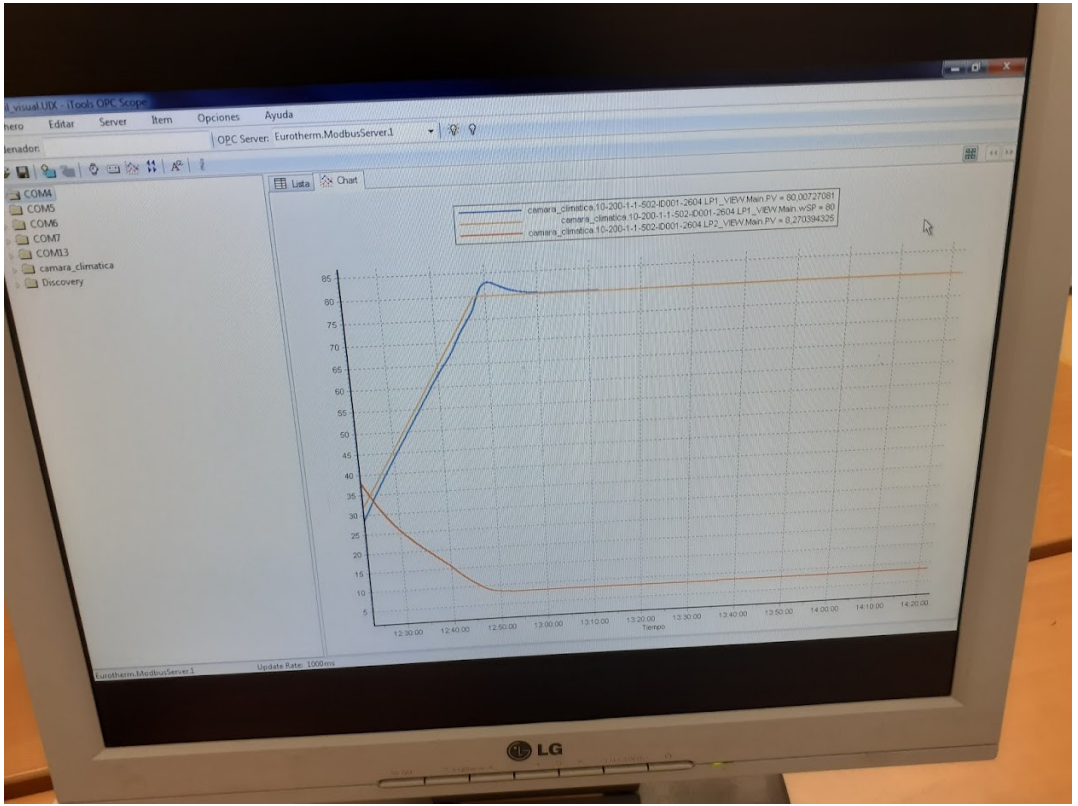
- Use EJ2189 (default one in the last years) as soldering paste
  - Solder wires to different pads (with resistivity measured)

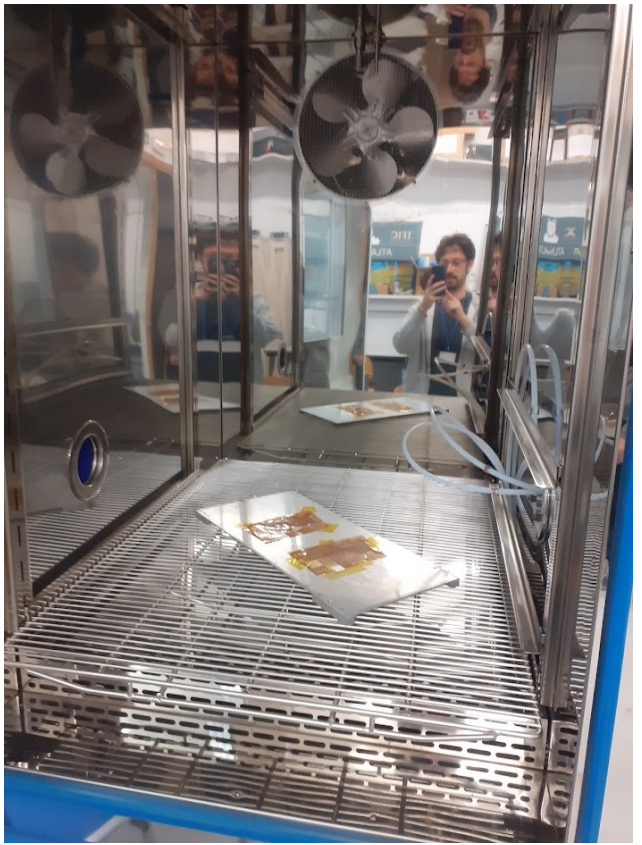
Curing in a climatic chamber



- Ugly result
  - But good enough to give qualitative results
- The resistivity between specific pads is measured after several humidity/temperature cycles performed

Curing in a climatic chamber

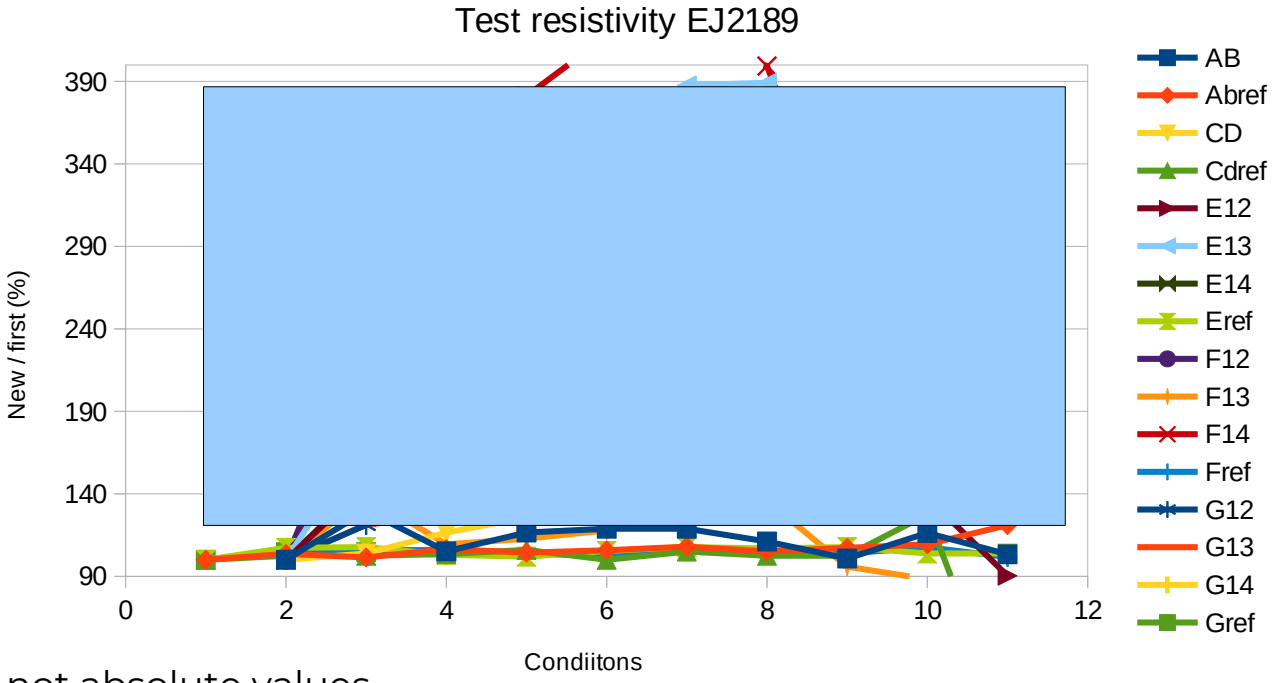




- Follow the datasheet, minimal time is 80degrees 3h
  - Very low humidity during the full process (10%)

Resistivity measurements

1 Initial setting
2 Curing 80deg, 8% humi.
3 24h 80%, 30degrees
4 72h room
5 24h 80%, 30degrees
6 24h 80%, 30degrees
7 24h 80%, 30degrees
8 16h 80%, 30degrees
9 4h 80% an 80degrees
10 12 days holidays – room temp
11 45 days room temp



- We should look only at tendencies, not absolute values
- **The G12-Gref (horizontal lines in 100%) are the reference values**

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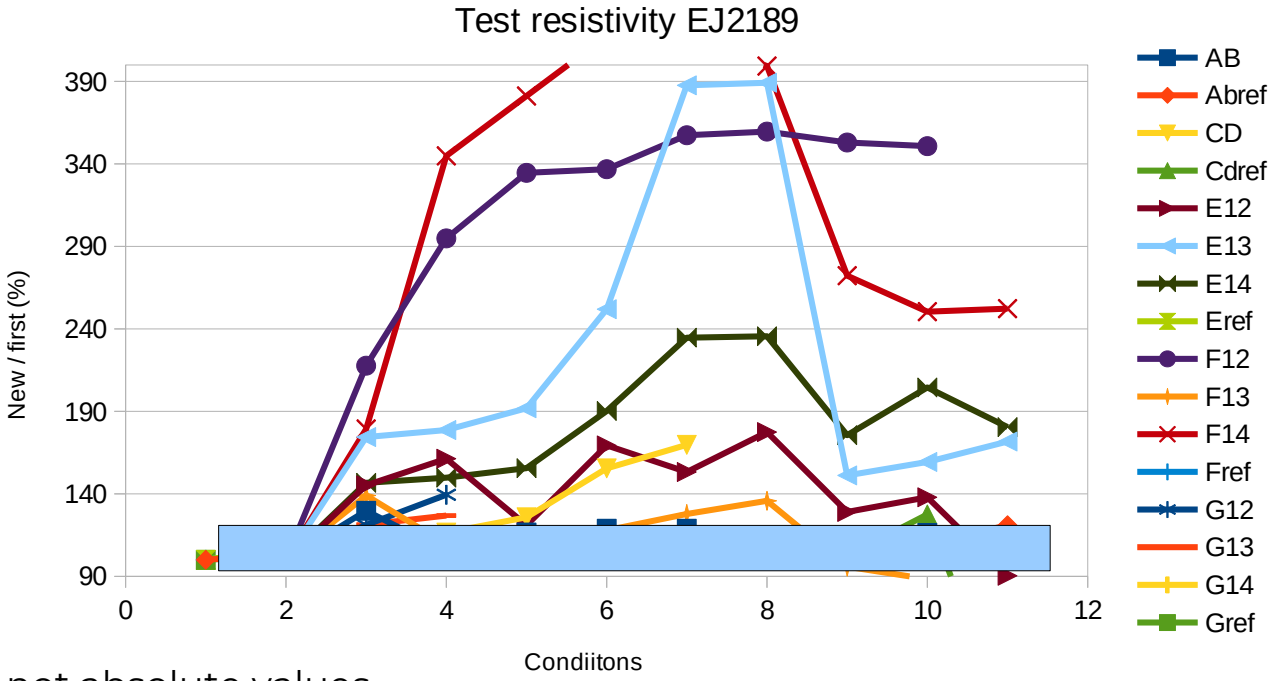

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- **Resistivity increase after each humidity cycle**

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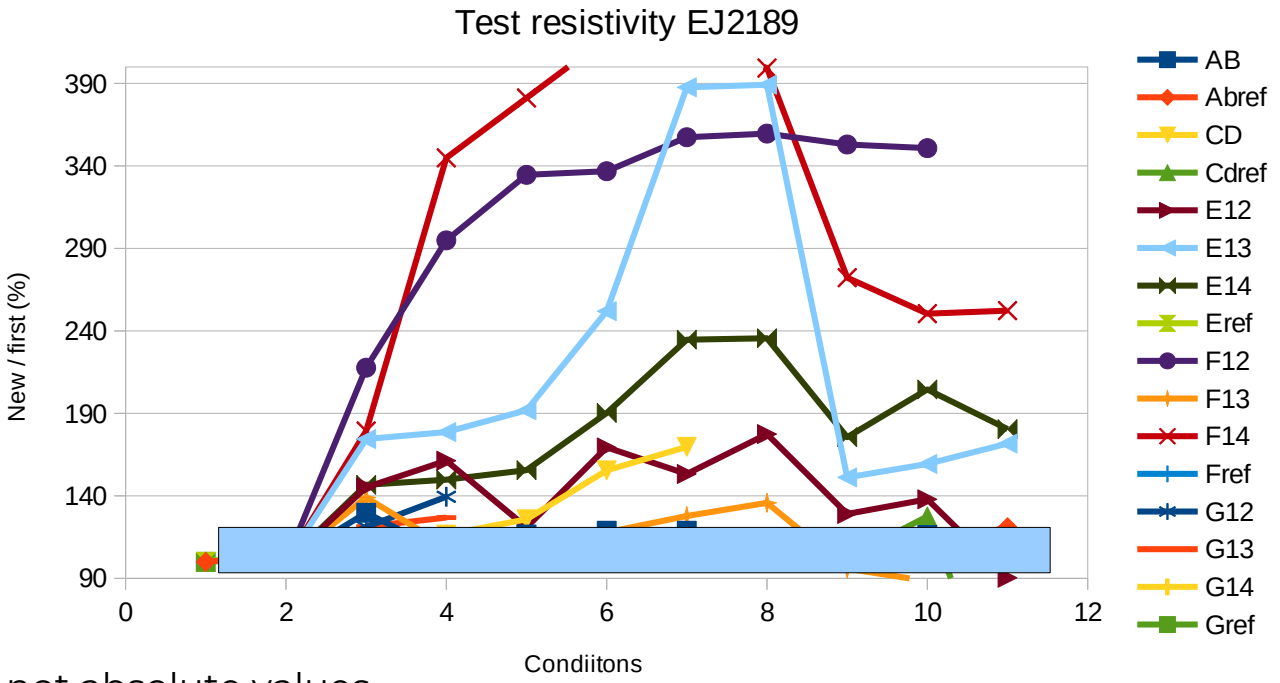
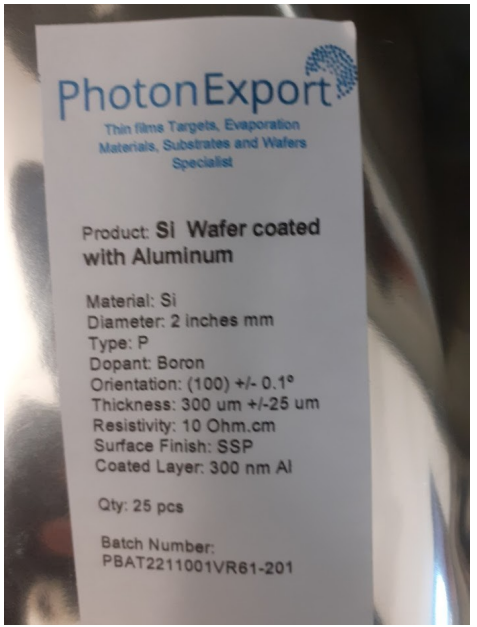
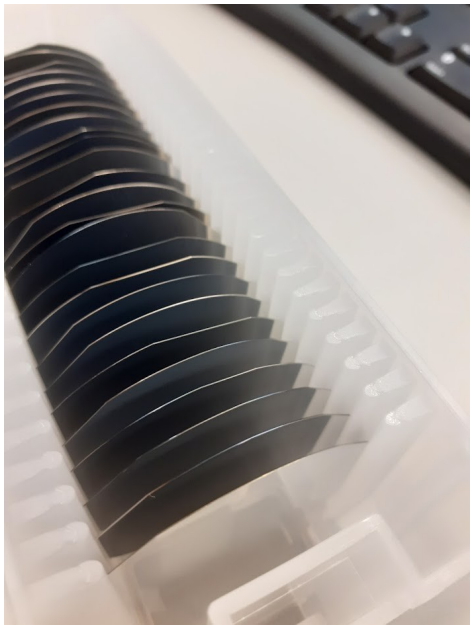


- We should look only at tendencies, not absolute values
- The G12-Gref (horizontal lines in 100%) are the reference values
- Resistivity increase after each humidity cycle
- **Step 9: Resistivity decreased after a heat cycle (with high humidity) → re-curing?**
  - **The minimal requirements in the datasheet should be seen as the very minimum**

to-do

- This is simply an exercise involving a fair amount of **bricolage**...
- A proper measurement is on preparation:
  - Using new glue batches (H20E and EJ2189)
  - Using specifically designed flex PCBs (w.i.p. by Yan-FCAL) and dummy silicon sensors (with the same type of aluminum plating that the real sensors)
  - Using proper tools for glue dispensing (robot or stencil...)
  - Using cold plasma gun to clean the sensors before
  - Systematic measurements and comparisons
- Lots of work which require restructuring of the lab and the new postdoc to arrive.. w.i.p.





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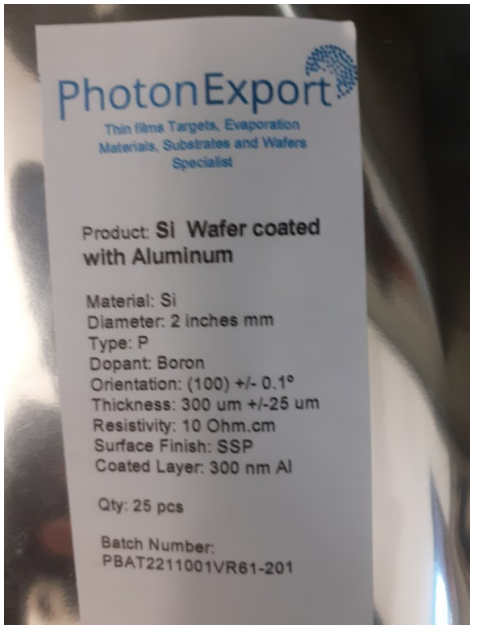
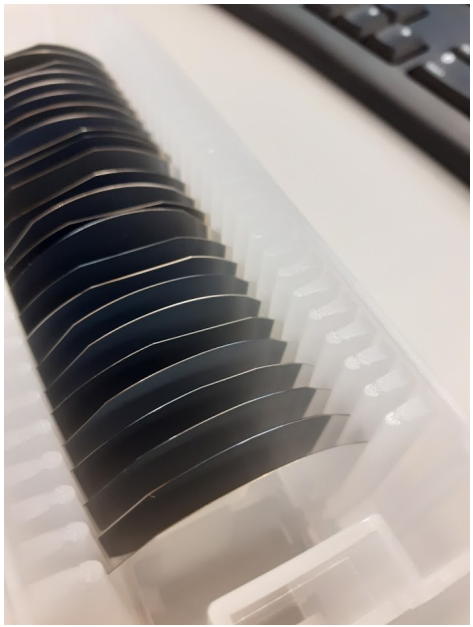




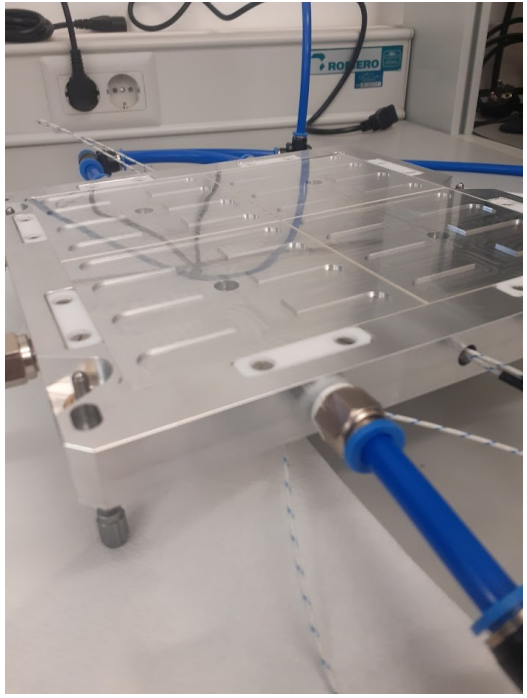
Extra – under consideration: mechanical pull tests (with IJCLab) and irradiation tests with neutrons (in nTOF NEAR)

Part 3: gluing training

Glue

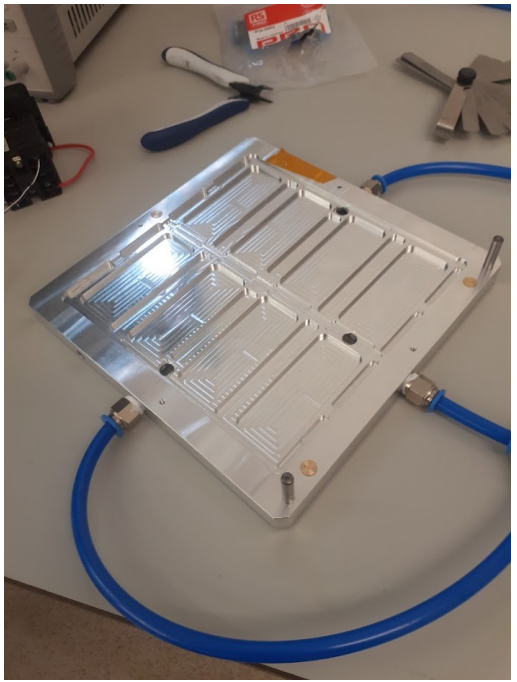
- Preparing the mix
  - New equipment!

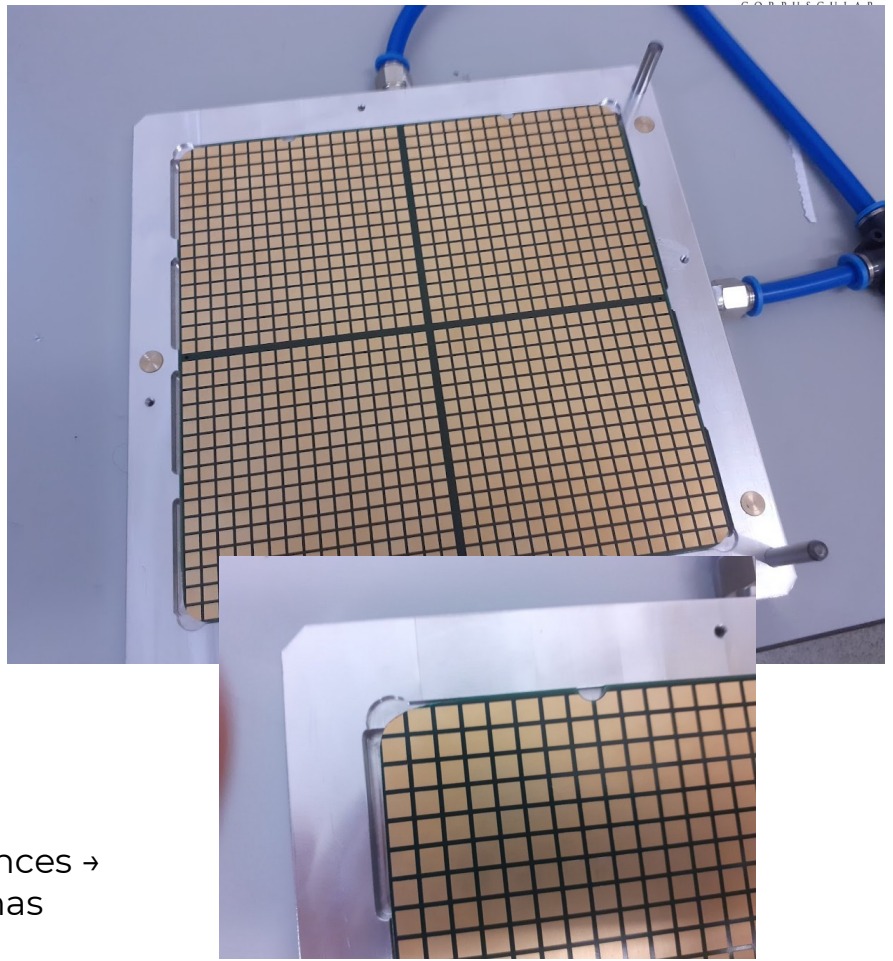
Fake wafers -xy alignment



- Alignment of fake transparent sensors
  - 500um

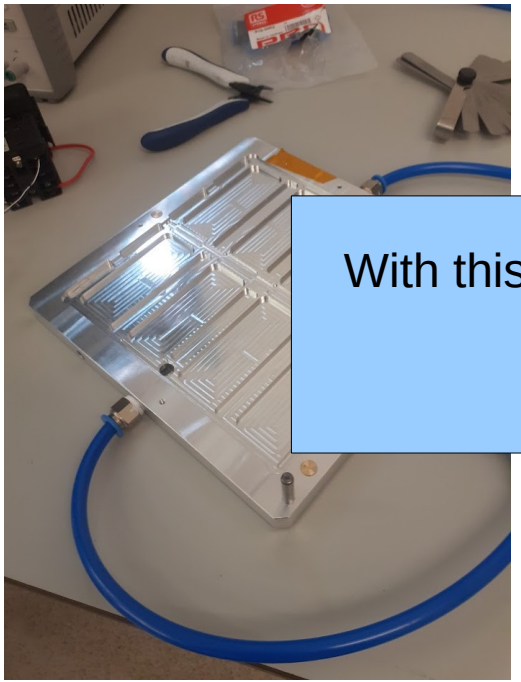
PCB -xy alignment

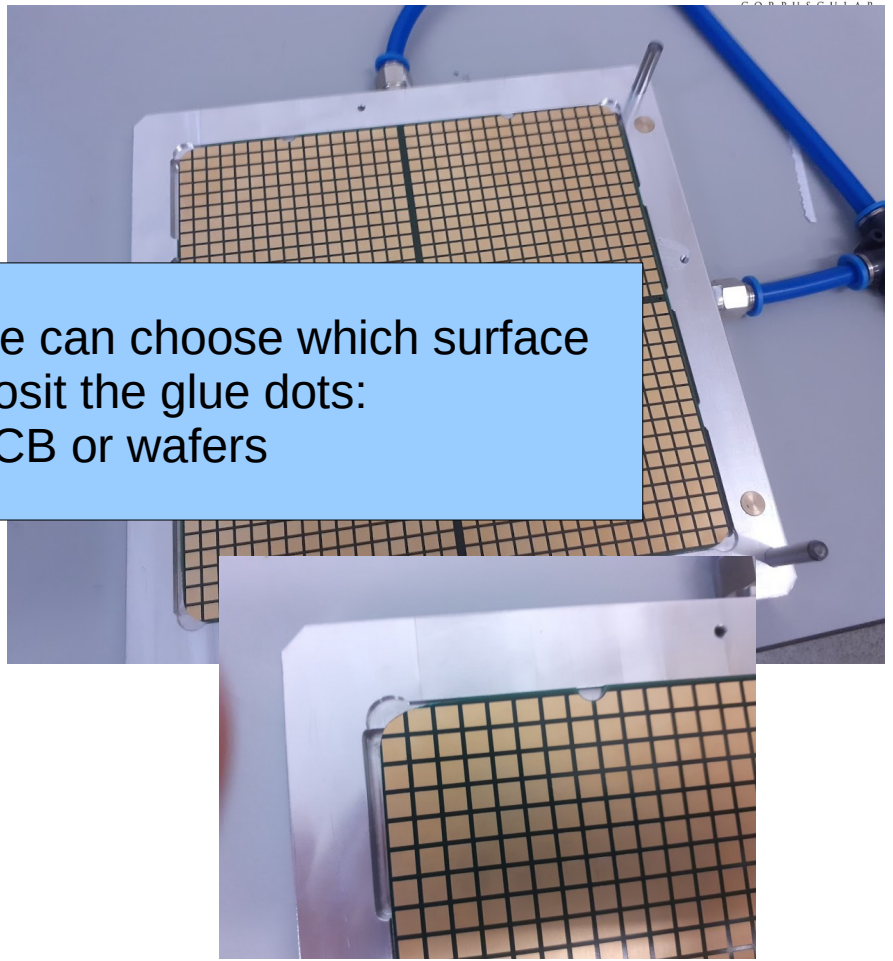




- Alignment of the PCB
  - Design of the plates optimized to FEV2 & tolerances → the FEV12 seems to be slightly larger. The PCB has been machined to fit in the plate
  - PCB without components

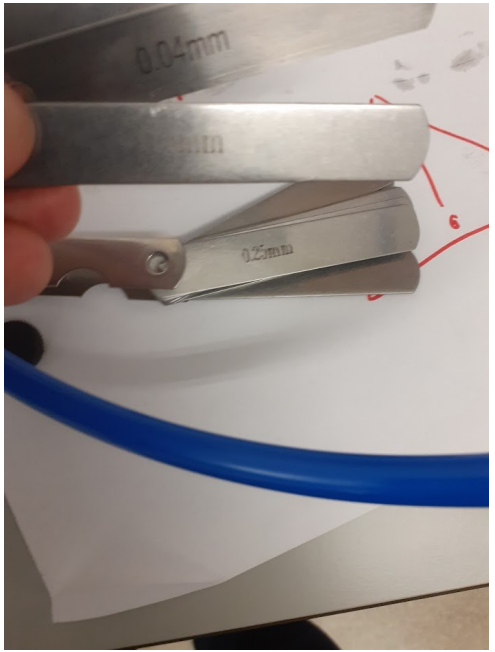
PCB -xy alignment

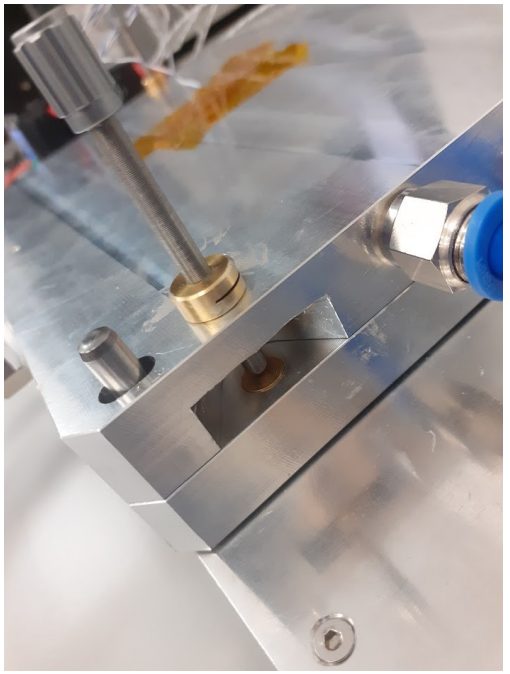




With this setup we can choose which surface to deposit the glue dots:
PCB or wafers

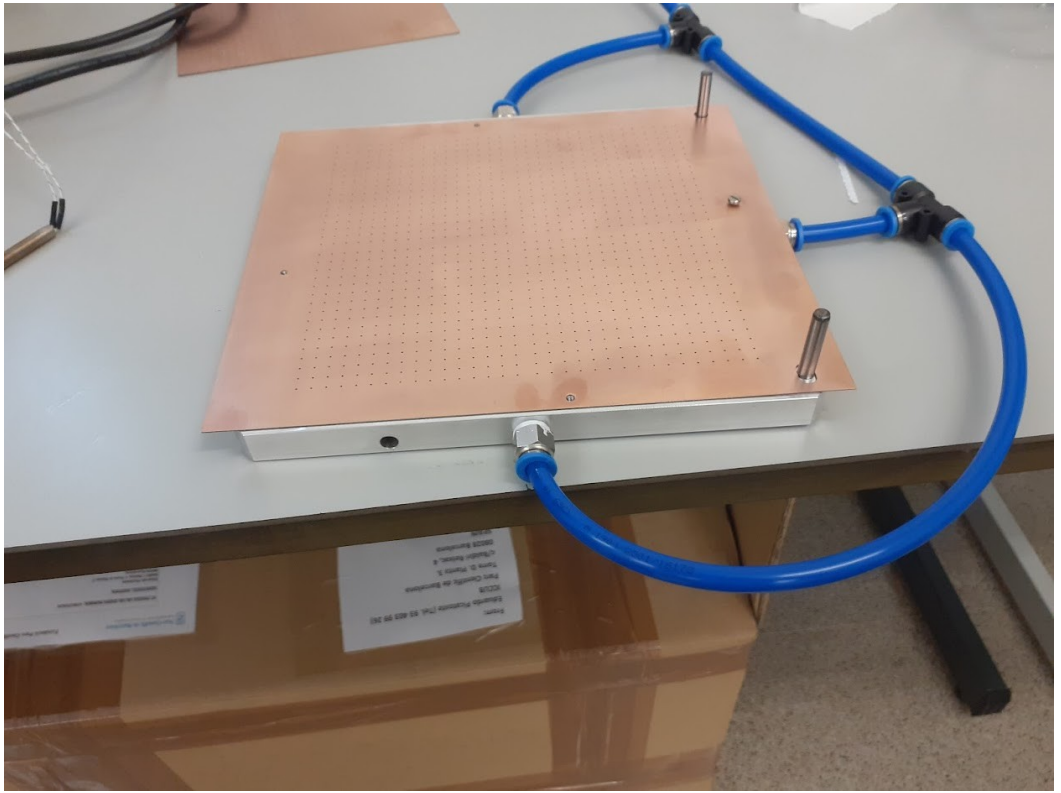
Z-alignment



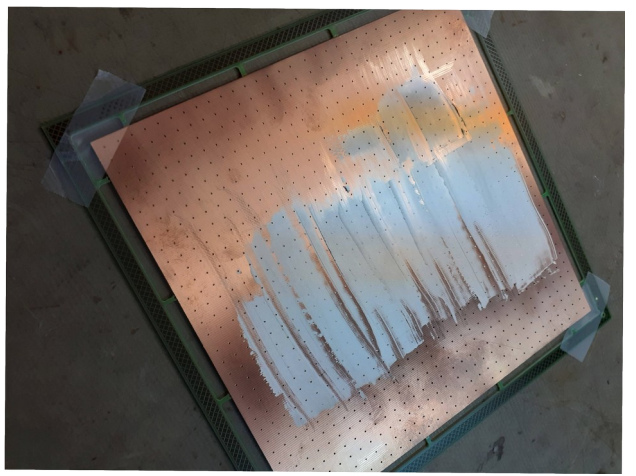


- Tuneable for each use, using precision 3 micrometric screws together with feeler gauges
- Z-alignment performed at 150um (separation between wafer and the pcb)

Glue repartition

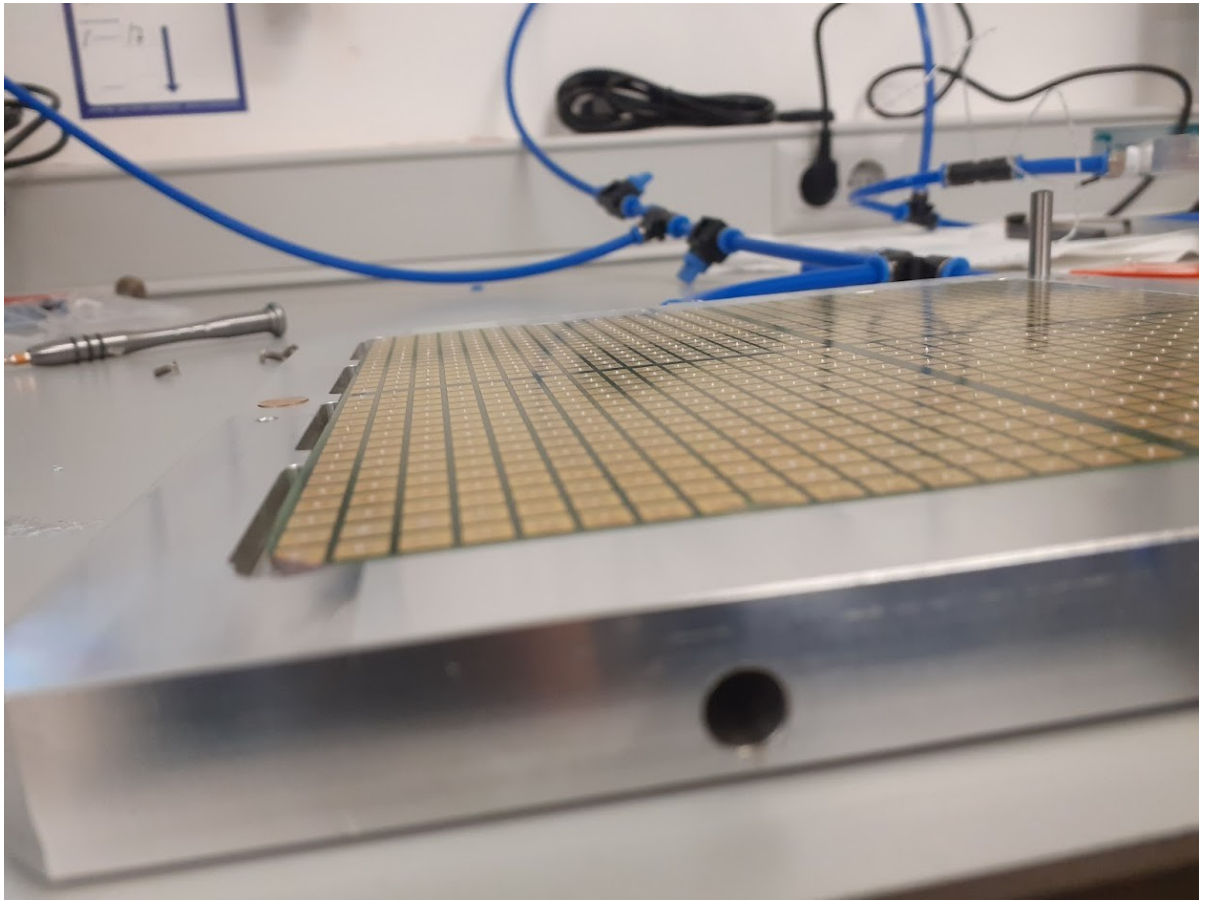


- Stencil
  - 500um copper plate
  - Holes of 0.8 or 1.2 mm diameter
- Stencil is a nice solution to keep the developments ongoing. **Final solution should a robot.**



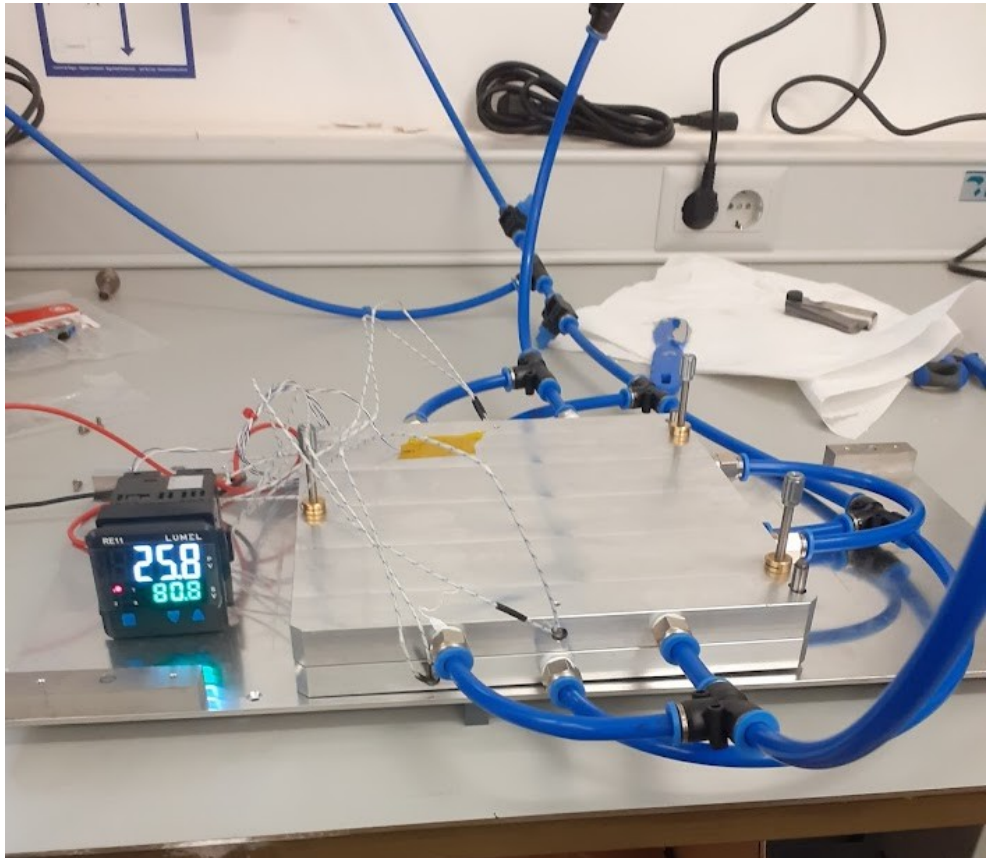
(old pic without aspiration plate)

Glue repartition



- For the first try, we only add glue in 3 of the 4 sectors

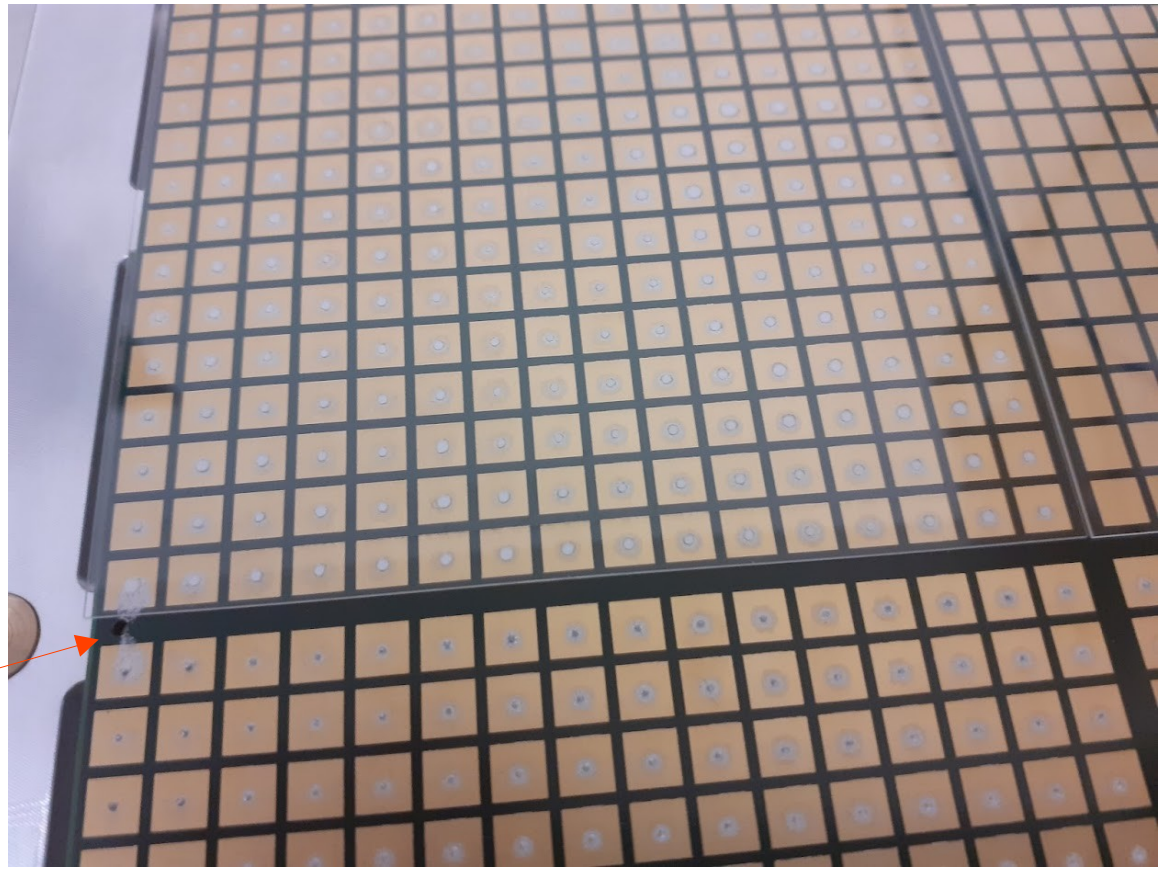
curing



- 4 resistors (2 per aspiration plate)
- 80 degrees during 12h
  - + full weekend at room temp

results

- Only one wafer glued (up left in the photo
  - Still small adjustments on x-y the alignment needed (but seem straightforward)
- The z-alignment seems improvable → more amount of glue per dot needed
  - A new test is done with 1.2mm diameter holes instead
  - This is to be better defined with the gluing robot and dosification system
- Some glue spread around PCB holes (due to the aspiration)



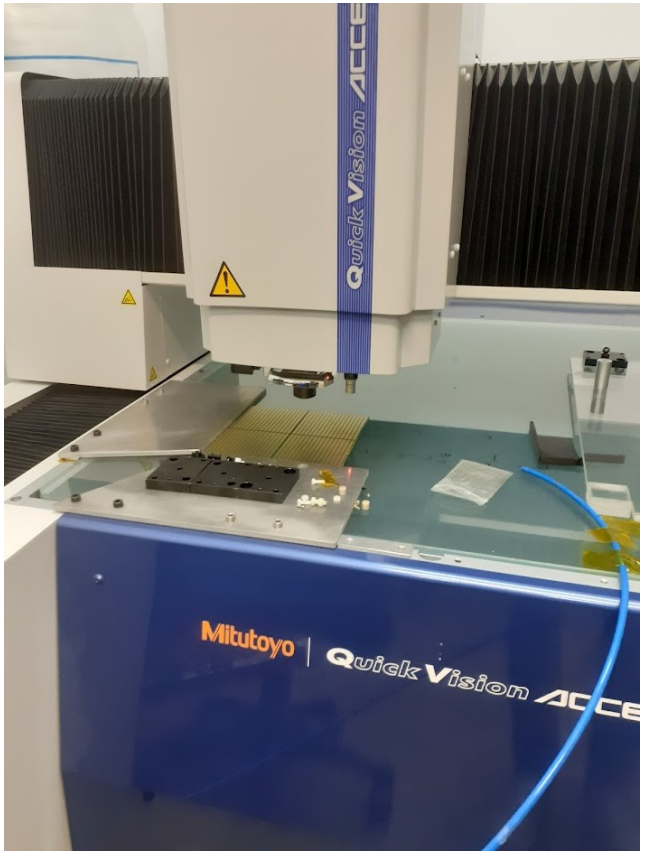
Summary & next steps

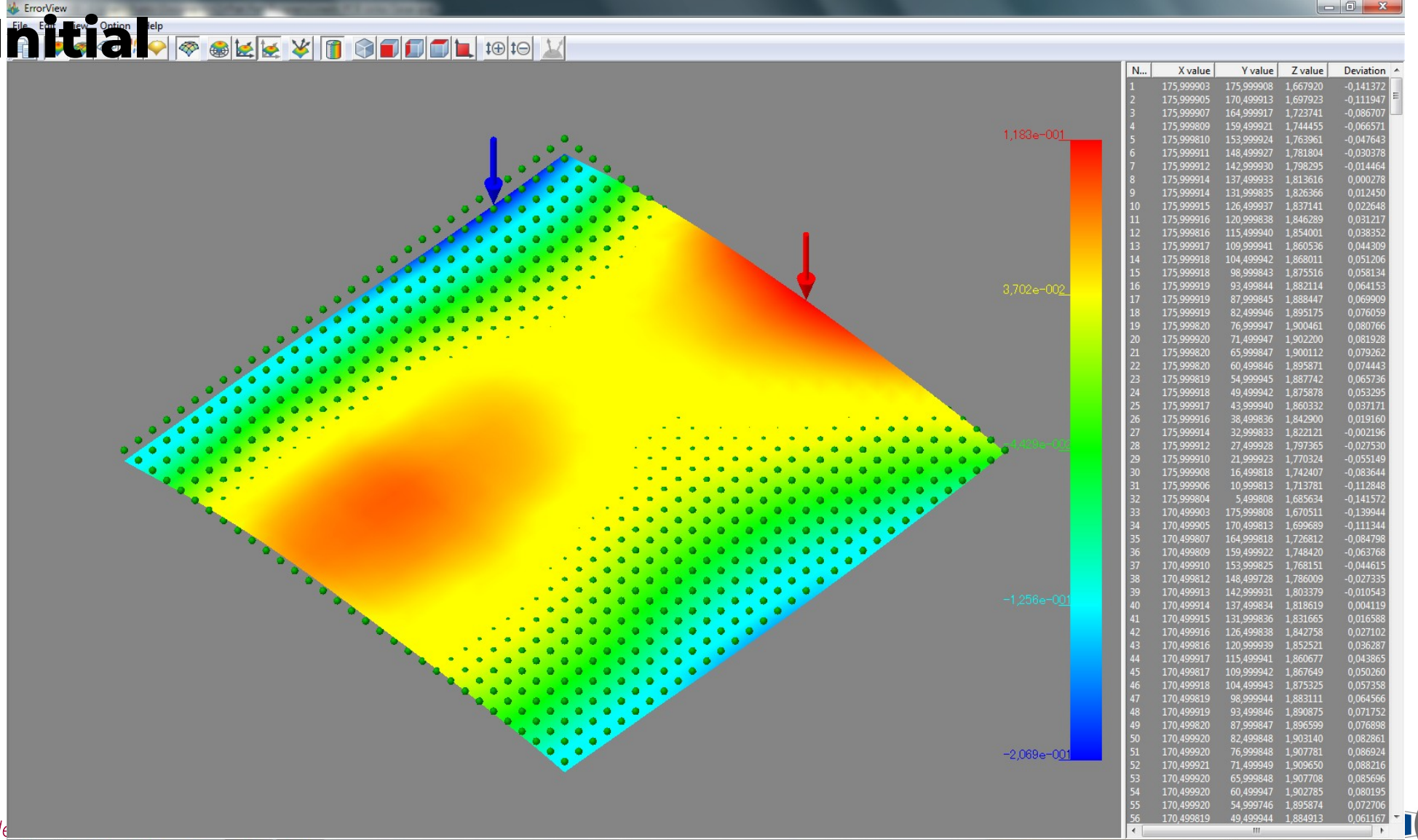
- The basic design of the tools and the procedure has been validated
- New FEV2 are needed → the
- Fine tunning needed to optimize the alignment
  - Close collaboration with mechanical engineering services at IFIC (César as liason).
- Stencil approach to be overruled by robot and volumetric dosification system (already ordered)
  - Precifluid & POLY DISPENSING SYSTEMS

Part 4: PCB deformations

tools

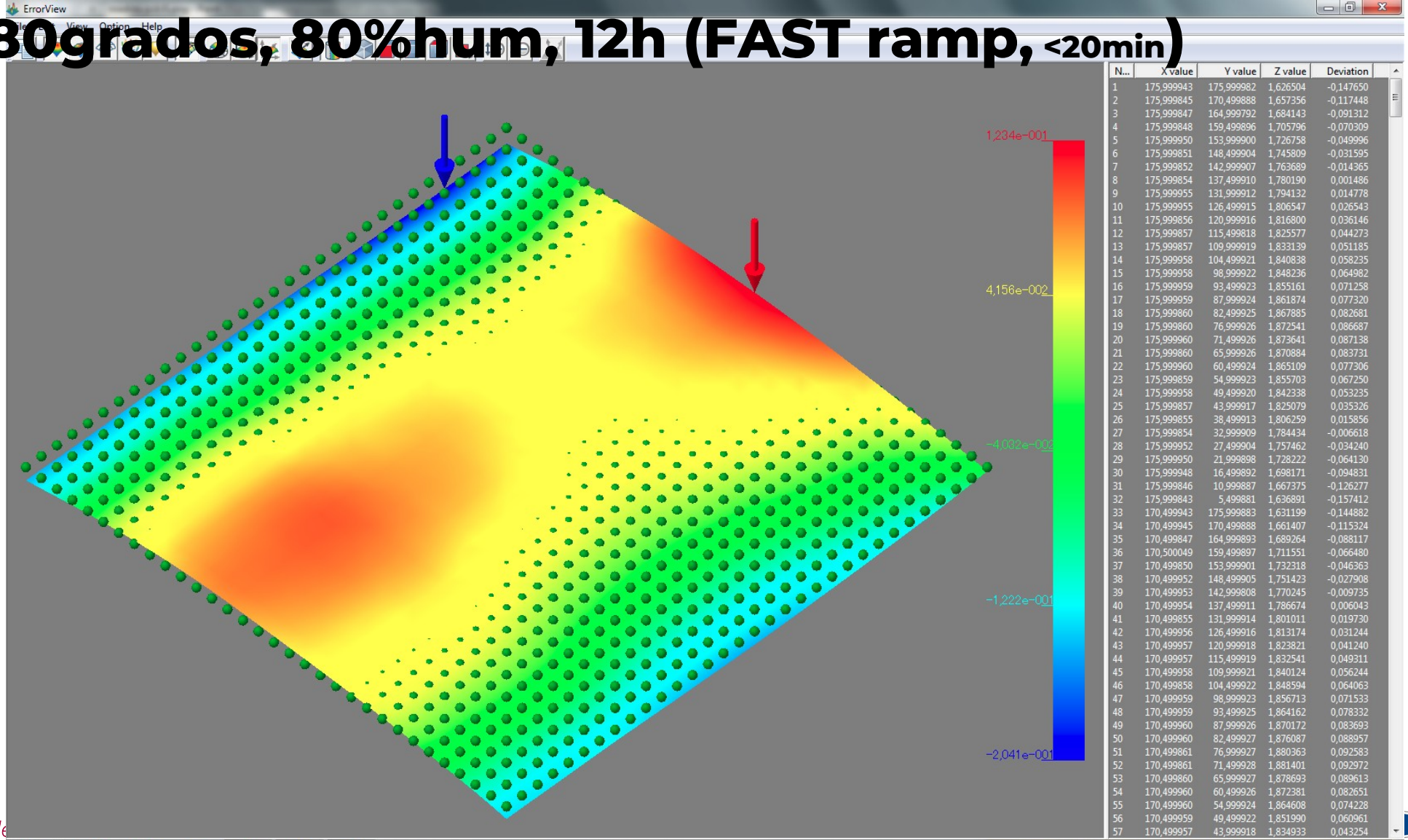
- FEV 12 naked
  - Not the same that we used for the glue tests.
- Climatic chamber
- Tool for z-axis characterization via optical focus
  - Mitutyo Quick Vision Accel, Modelo 808
  - https://www.mitutoyo.com/webfoo/wp-content/uploads/2118_Quick_Vision.pdf
- Several 12-24h cycles with 80-100 degrees, 10-80% humidity





N...	X value	Y value	Z value	Deviation
1	175,999903	175,999908	1,667920	-0,141372
2	175,999905	170,499913	1,697923	-0,111947
3	175,999907	164,999917	1,723741	-0,086707
4	175,999809	159,499921	1,744455	-0,066571
5	175,999810	153,999924	1,763961	-0,047643
6	175,999911	148,499927	1,781804	-0,030378
7	175,999912	142,999930	1,798295	-0,014464
8	175,999914	137,499933	1,813616	0,000278
9	175,999914	131,999835	1,826366	0,012450
10	175,999915	126,499937	1,837141	0,022648
11	175,999916	120,999838	1,846289	0,031217
12	175,999816	115,499940	1,854001	0,038352
13	175,999917	109,999941	1,860536	0,044309
14	175,999918	104,499942	1,868011	0,051206
15	175,999918	98,999843	1,875516	0,058134
16	175,999919	93,499844	1,882114	0,064153
17	175,999919	87,999845	1,888447	0,069909
18	175,999919	82,499946	1,895175	0,076059
19	175,999820	76,999947	1,900461	0,080766
20	175,999920	71,499947	1,902200	0,081928
21	175,999820	65,999847	1,900112	0,079262
22	175,999820	60,499846	1,895871	0,074443
23	175,999819	54,999945	1,887742	0,065736
24	175,999918	49,499942	1,875878	0,053295
25	175,999917	43,999940	1,860332	0,037171
26	175,999916	38,499836	1,842900	0,019160
27	175,999914	32,999833	1,822121	-0,002196
28	175,999912	27,499928	1,797365	-0,027530
29	175,999910	21,999923	1,770324	-0,055149
30	175,999908	16,499818	1,742407	-0,083644
31	175,999906	10,999813	1,713781	-0,112848
32	175,999804	5,499808	1,685634	-0,141572
33	170,499903	175,999808	1,670511	-0,139944
34	170,499905	170,499813	1,699689	-0,111344
35	170,499807	164,999818	1,726812	-0,084798
36	170,499809	159,499922	1,748420	-0,063768
37	170,499910	153,999825	1,768151	-0,044615
38	170,499812	148,499728	1,786009	-0,027335
39	170,499913	142,999931	1,803379	-0,010543
40	170,499914	137,499834	1,818619	0,004119
41	170,499915	131,999836	1,831665	0,016588
42	170,499916	126,499838	1,842758	0,027102
43	170,499816	120,999939	1,852521	0,036287
44	170,499917	115,499941	1,860677	0,043865
45	170,499817	109,999942	1,867649	0,050260
46	170,499918	104,499943	1,875325	0,057358
47	170,499819	98,999944	1,883111	0,064566
48	170,499919	93,499846	1,890875	0,071752
49	170,499820	87,999847	1,896599	0,076898
50	170,499920	82,499848	1,903140	0,082861
51	170,499920	76,999848	1,907781	0,086924
52	170,499921	71,499949	1,909650	0,088216
53	170,499920	65,999848	1,907708	0,085696
54	170,499920	60,499947	1,902785	0,080195
55	170,499920	54,999746	1,895874	0,072706
56	170,499819	49,499944	1,884913	0,061167

80grados, 80%hum, 12h (FAST ramp, <20min)



N...	X value	Y value	Z value	Deviation
1	175,999943	175,999982	1,626504	-0,147650
2	175,999845	170,499888	1,657356	-0,117448
3	175,999847	164,999792	1,684143	-0,091312
4	175,999848	159,499896	1,705796	-0,070309
5	175,999950	153,999900	1,726758	-0,049996
6	175,999851	148,499904	1,745809	-0,031595
7	175,999852	142,999907	1,763689	-0,014365
8	175,999854	137,499910	1,780190	0,001486
9	175,999955	131,999912	1,794132	0,014778
10	175,999955	126,499915	1,806547	0,026543
11	175,999856	120,999916	1,816800	0,036146
12	175,999857	115,499818	1,825577	0,044273
13	175,999857	109,999919	1,833139	0,051185
14	175,999958	104,499921	1,840838	0,058235
15	175,999958	98,999922	1,848236	0,064982
16	175,999959	93,499923	1,855161	0,071258
17	175,999959	87,999924	1,861874	0,077320
18	175,999860	82,499925	1,867885	0,082681
19	175,999860	76,999926	1,872541	0,086687
20	175,999960	71,499926	1,873641	0,087138
21	175,999860	65,999926	1,870884	0,083731
22	175,999960	60,499924	1,865109	0,077306
23	175,999859	54,999923	1,855703	0,067250
24	175,999958	49,499920	1,842338	0,053235
25	175,999857	43,999917	1,825079	0,035326
26	175,999855	38,499913	1,806259	0,015856
27	175,999854	32,999909	1,784434	-0,006618
28	175,999952	27,499904	1,757462	-0,034240
29	175,999950	21,999898	1,728222	-0,064130
30	175,999948	16,499892	1,698171	-0,094831
31	175,999846	10,999887	1,667375	-0,126277
32	175,999843	5,499881	1,636891	-0,157412
33	170,499943	175,999883	1,631199	-0,144882
34	170,499945	170,499888	1,661407	-0,115324
35	170,499847	164,999893	1,689264	-0,088117
36	170,500049	159,499897	1,711551	-0,066480
37	170,499850	153,999901	1,732318	-0,046363
38	170,499952	148,499905	1,751423	-0,027908
39	170,499953	142,999808	1,770245	-0,009735
40	170,499954	137,499911	1,786674	0,006043
41	170,499855	131,999914	1,801011	0,019730
42	170,499956	126,499916	1,813174	0,031244
43	170,499957	120,999918	1,823821	0,041240
44	170,499957	115,499919	1,832541	0,049311
45	170,499958	109,999921	1,840124	0,056244
46	170,499858	104,499922	1,848594	0,064063
47	170,499959	98,999923	1,856713	0,071533
48	170,499959	93,499925	1,864162	0,078332
49	170,499960	87,999926	1,870172	0,083693
50	170,499960	82,499927	1,876087	0,088957
51	170,499861	76,999927	1,880363	0,092583
52	170,499861	71,499928	1,881401	0,092972
53	170,499860	65,999927	1,878693	0,089613
54	170,499960	60,499926	1,872381	0,082651
55	170,499960	54,999924	1,864608	0,074228
56	170,499959	49,499922	1,851990	0,060961
57	170,499957	43,999918	1,834933	0,043254

results

- Basically no extra deformation observed after the cycles
  - But an initial +120um, -200um deformation from the middle plane

- Curing at 100degrees may not be an issue at all.
  - Tests done without sensors/components!

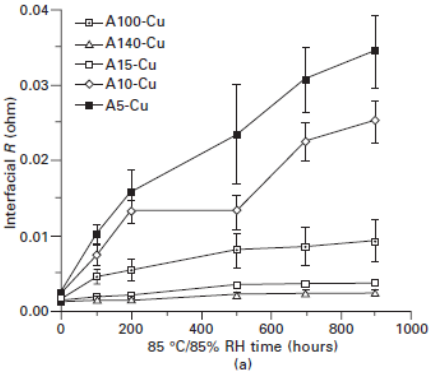
- Would this PCB have been used for gluing sensors?
  - The aspiration plate was capable of support it removing the deformation….

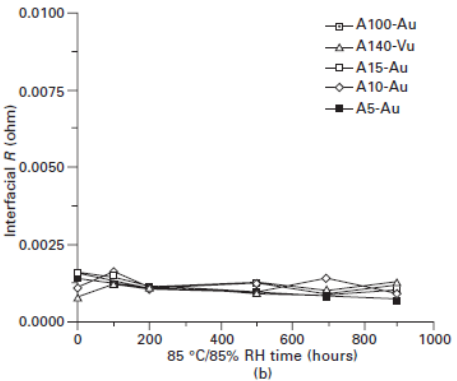
- However, the component soldering is done in more extreme conditions
  - 200-250 degrees with very quick peaks of temperature. Studies to be done…

back-up

Tests to be done January-April 2023

- We have purchased a set of dummy substrates with aluminum and gold bath (as the Hammatsu sensors)
  - Delivery in ~ January
- We have orderd the epoxys (still waiting for the note on the gold based).
  - Delivery in January-February
- Yan is designing a special kapton fanout to be glued to the dummy sensors and perform resitance measurements of the glue dots.
  - Using a precision ohmemetre to measure mOhms.
  - Production/delivery?March?
- We are getting trained in the use of a climatic chamber here at IFIC: the idea is to tests the different glues and surfaces after several humidity cycles and check the resistivity.
- Also access to a x-ray machine for a “visual” inspection.



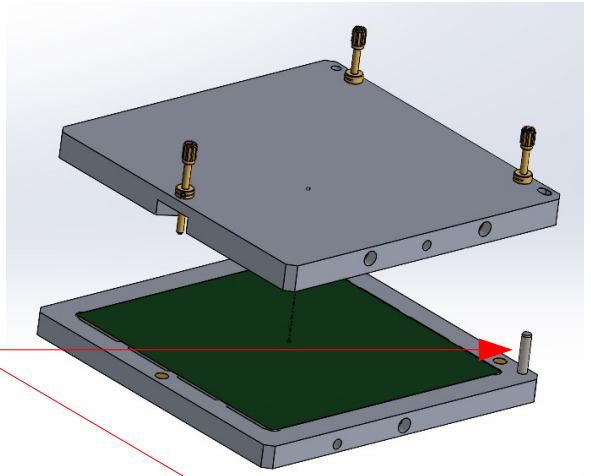


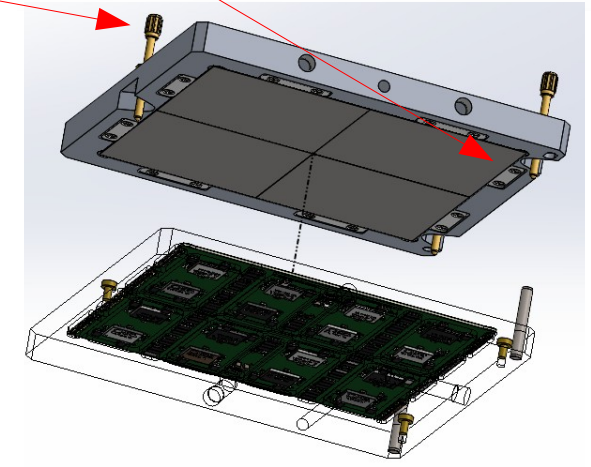
4.9 Ag ICA contact resistance changes at 85/85: (a) on Cu contacts, (b) on Au contacts, with (c) corresponding bulk resistivity variations.

Bibliography reference on epoxy+silver glues performance (attached to the agenda)

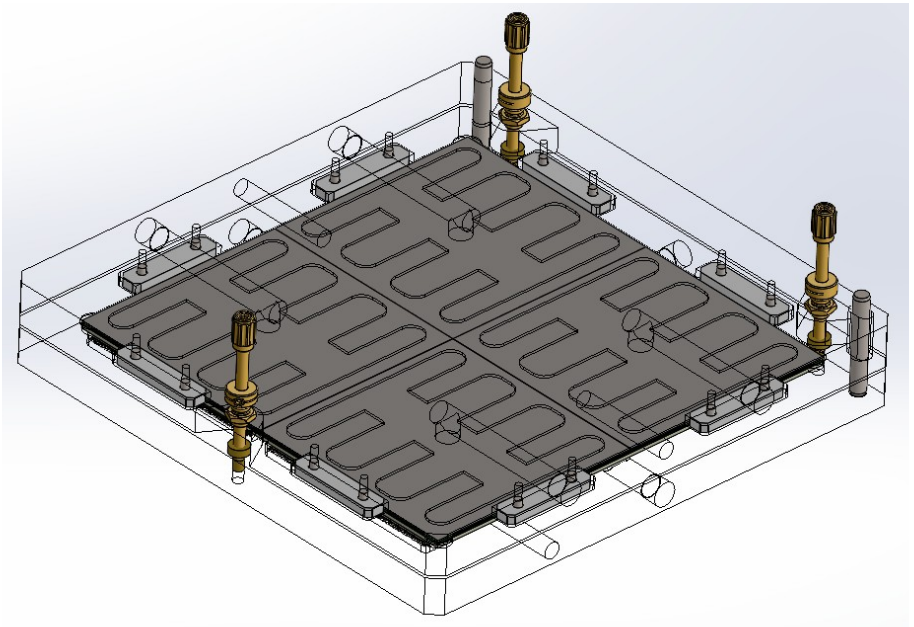
aspiration plates design

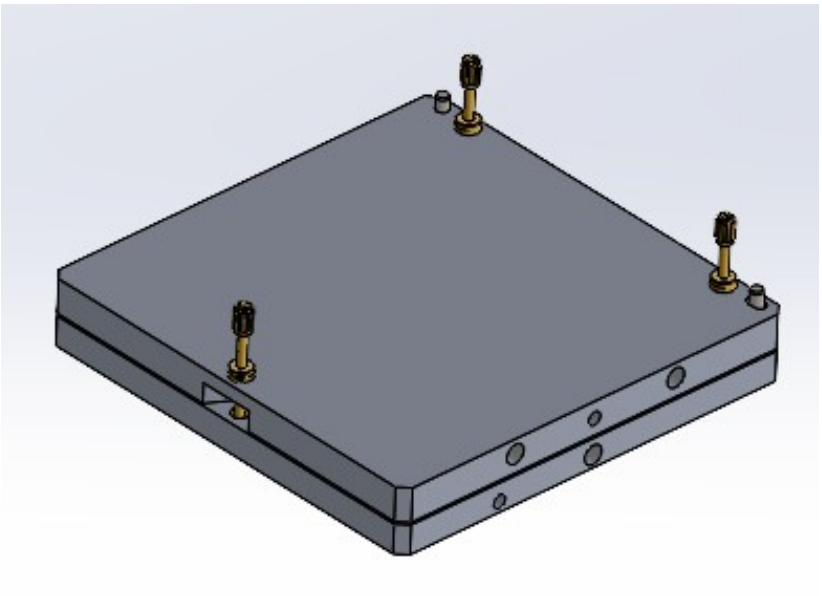
- Sandwich-maker style
- Two aspiration plates
  - One for the wafers
  - One for the PCBs (with components in it)
- Alignment in x-y done by the aspirations themselves and pivot tools
- Alignment in z done with micrometric screws
  - To deal with the PCB thickness tolerances (of possible hundreds of um)





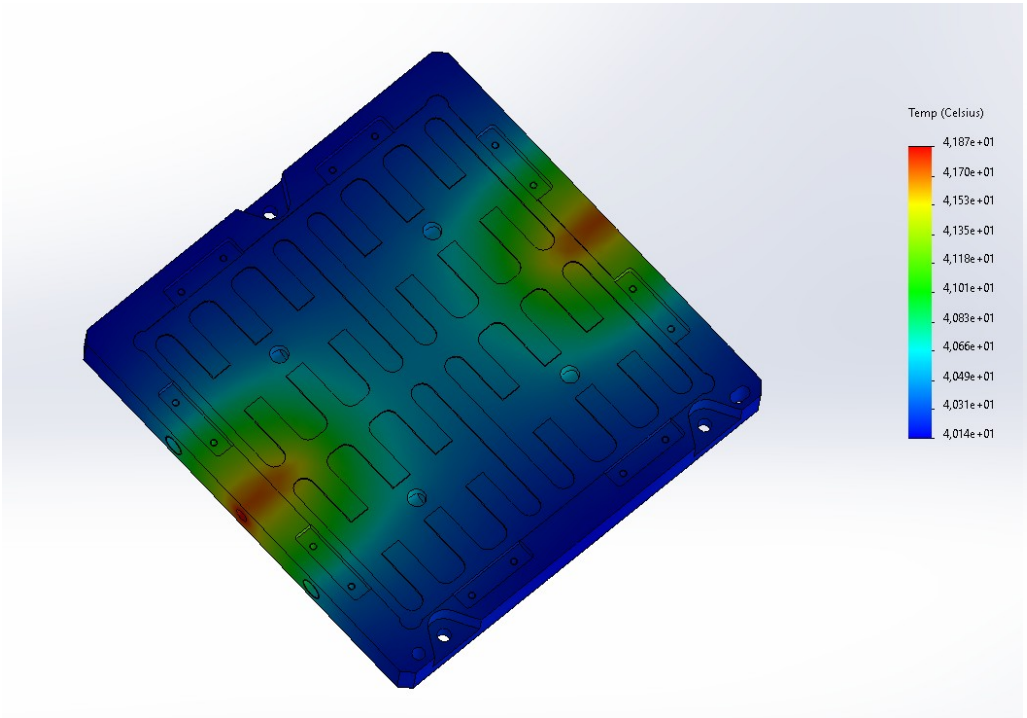
Activity 1 – aspiration plates design

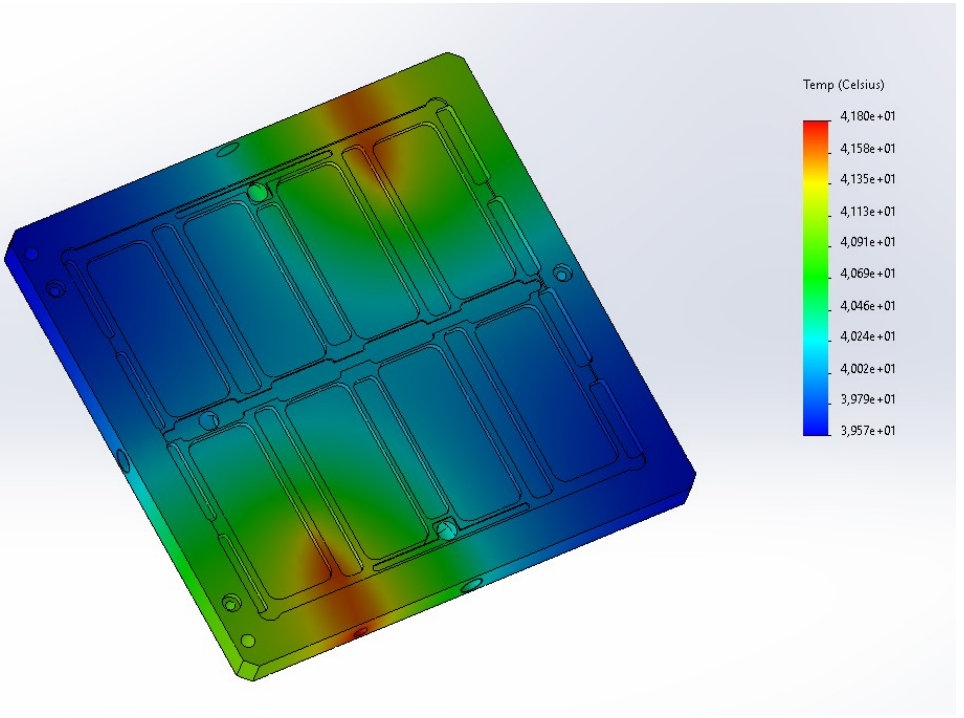




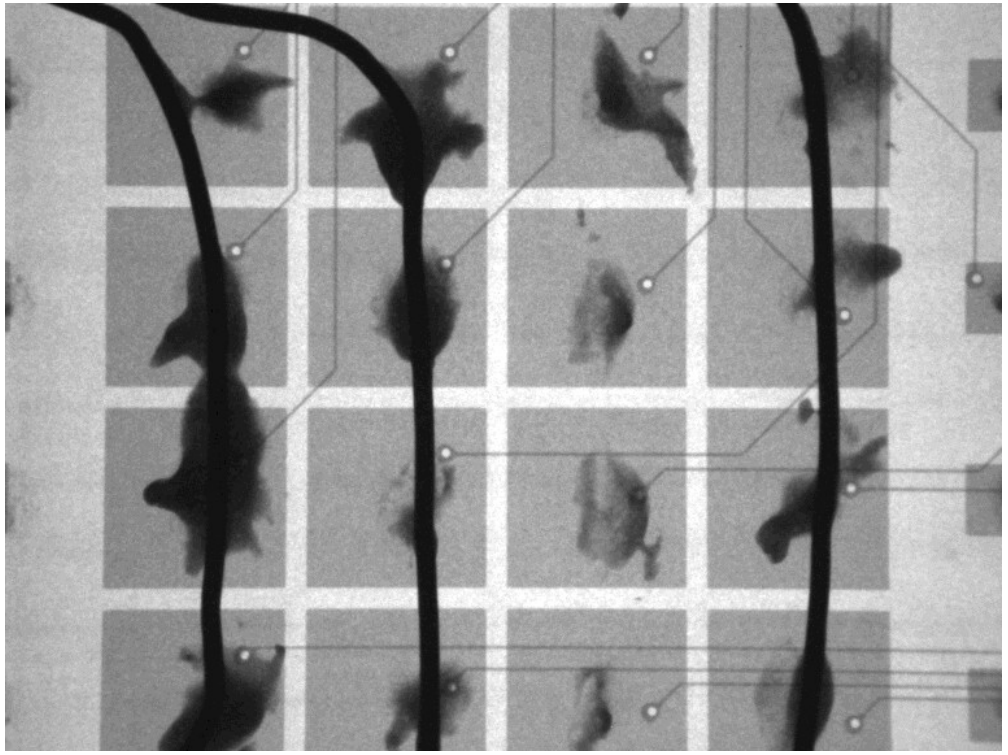
Activity 1 – aspiration plates design

- Also thermal curing using resistance and APDs for temperature control

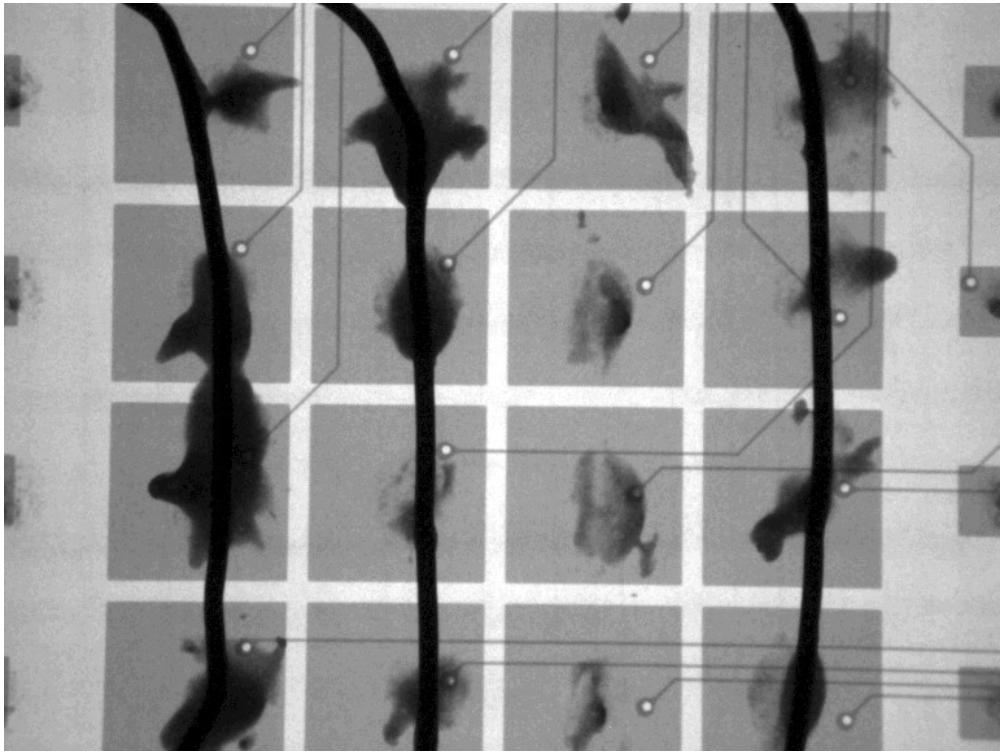




X-rays exploration



Before curing

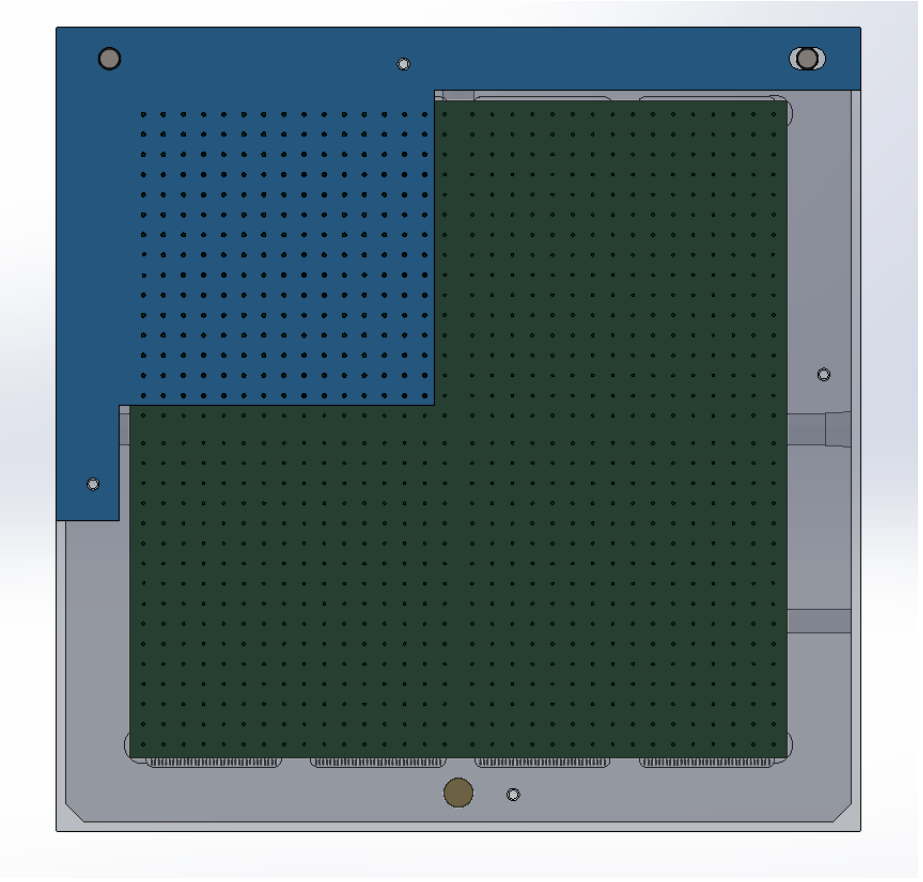


After all cycles

I don’t appreciate any difference...

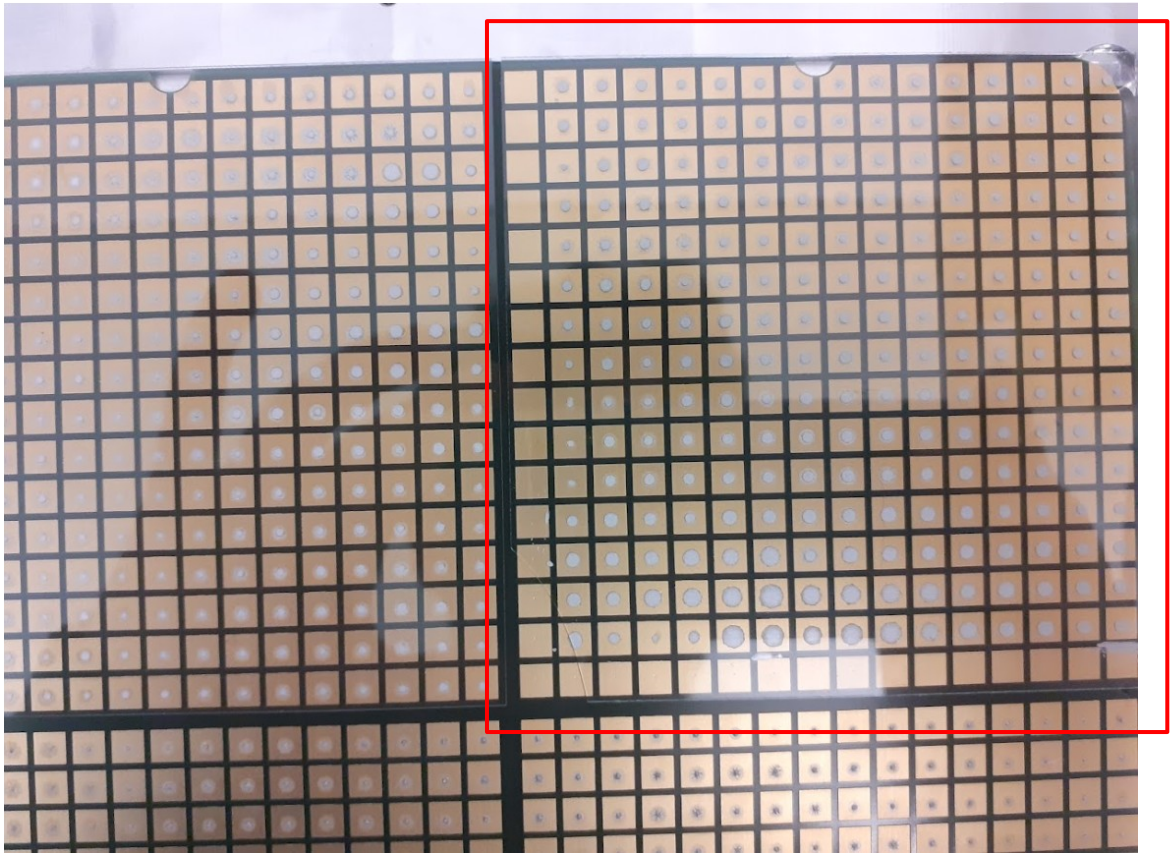
Follow up tests

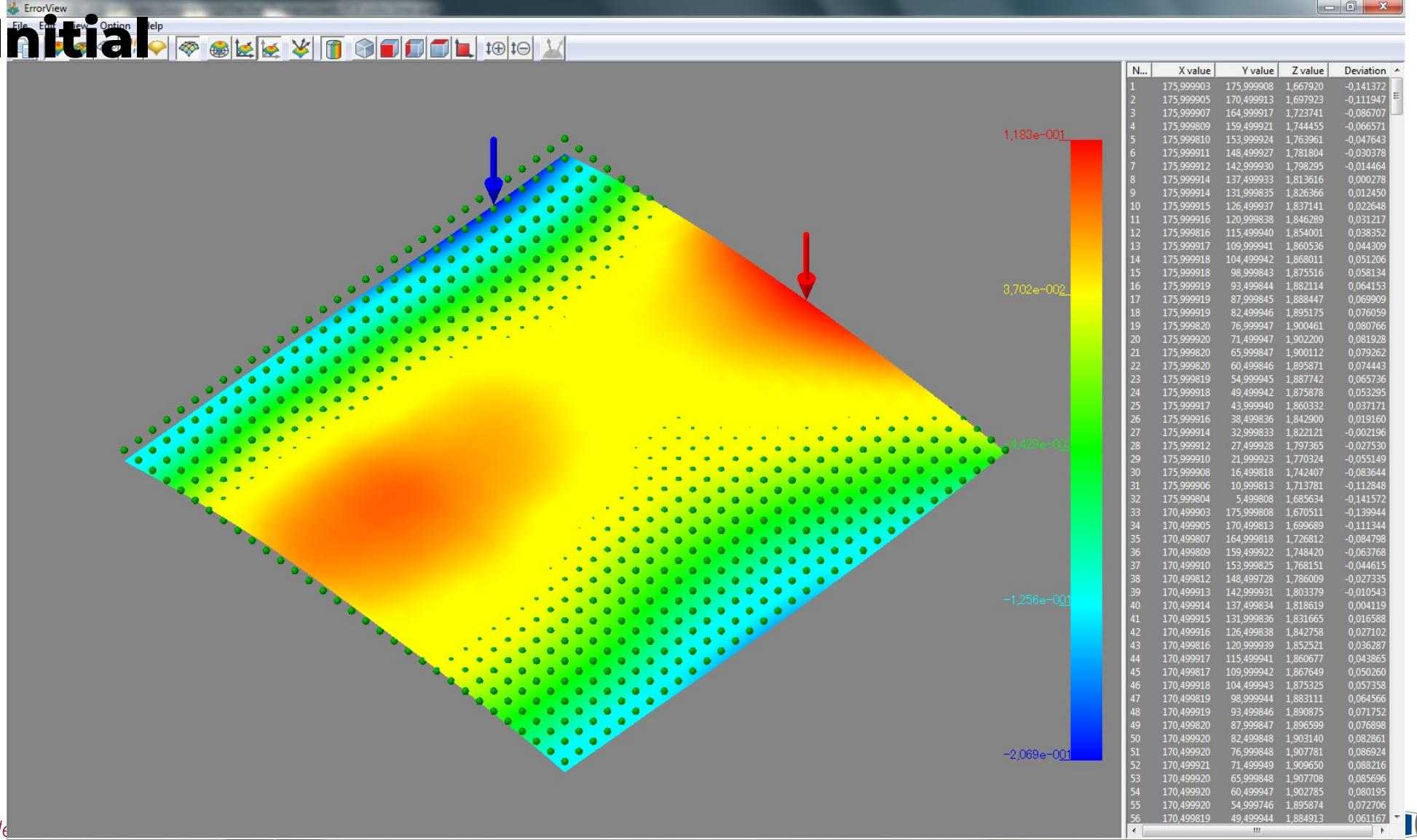
- Last drops of EJ2189 glue.
- New stencil for only one quarter
  - 1.2mm holes instead of 0.8
- Z-alignment performed at 150um
- Warm-up from 25 to 80 degrees took 1h15min
  - After that time, we remove the z-axis limitations of 150um
  - The plates did not move



Follow up tests

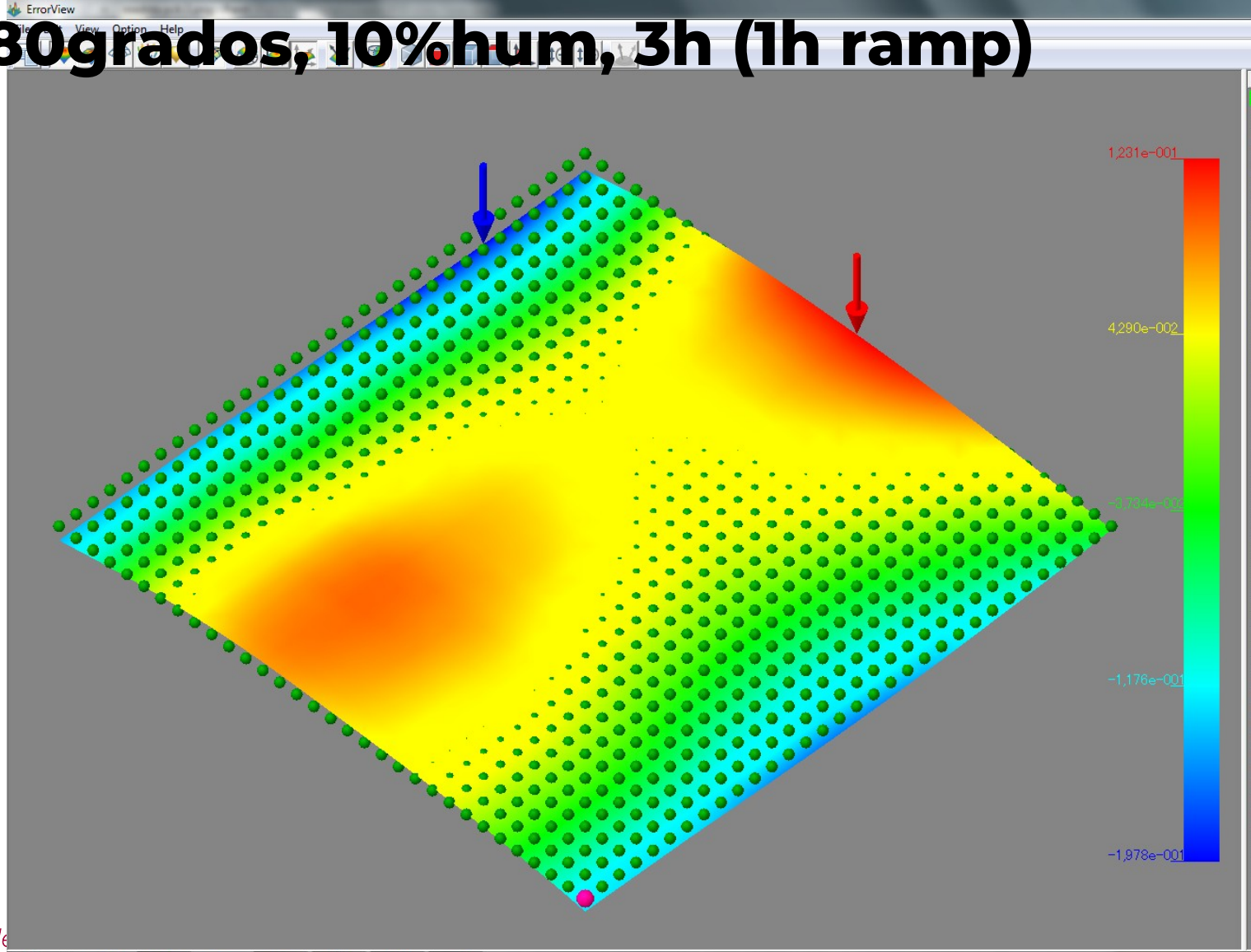
- Last drops of EJ2189 glue.
- New stencil for only one quarter
  - 1.2mm holes instead of 0.8
- A-alignment performed at 150um
- Warm-up from 25 to 80 degrees took 1h15min
  - After that time, we remove the z-axis limitations of 150um
  - The plates did not move





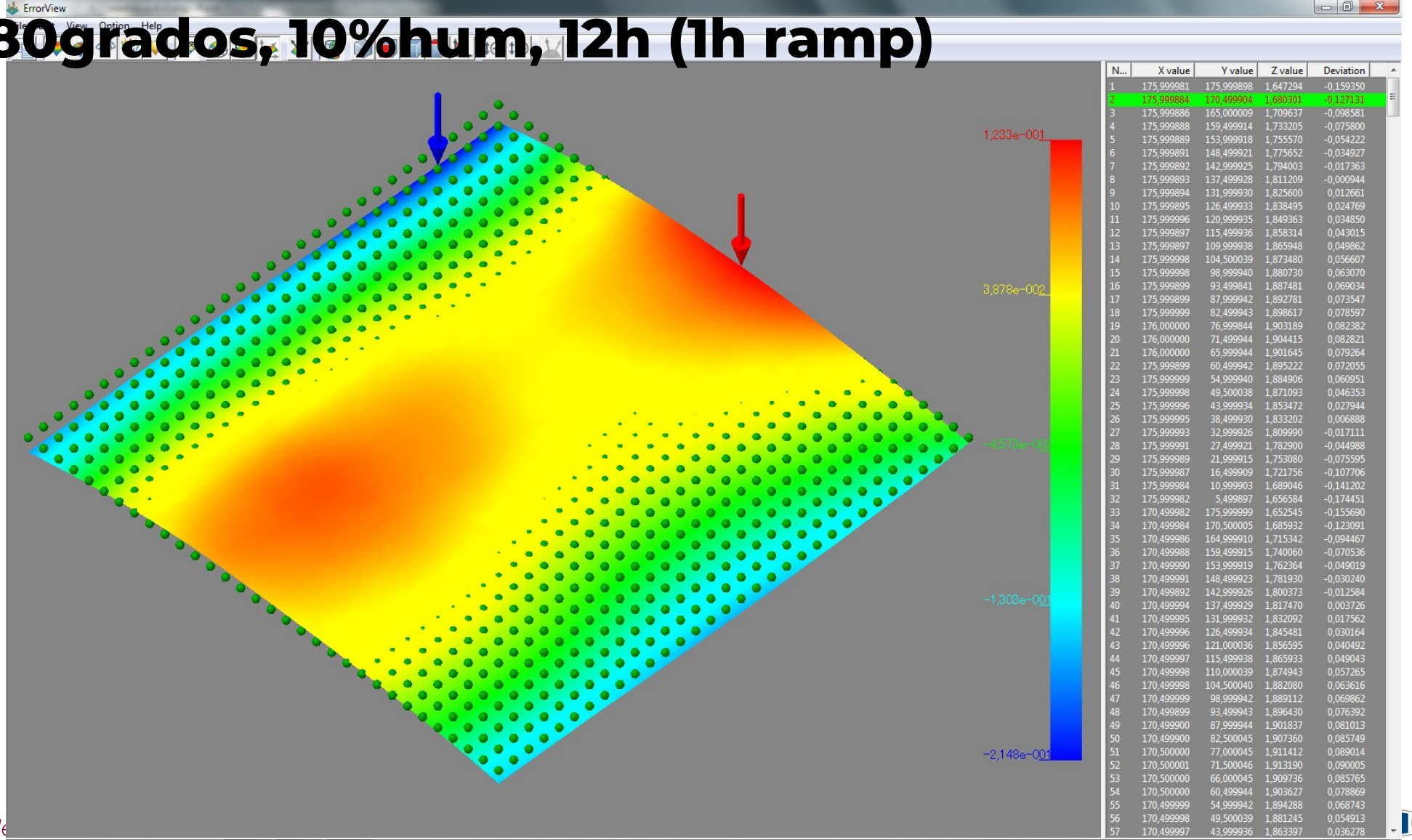
N...	X value	Y value	Z value	Deviation
1	175,999903	175,999908	1,667920	-0,141372
2	175,999905	170,499913	1,697923	-0,111947
3	175,999907	164,999917	1,723741	-0,086707
4	175,999809	159,499921	1,744455	-0,066571
5	175,999810	153,999924	1,763961	-0,047643
6	175,999911	148,499927	1,781804	-0,030378
7	175,999912	142,999930	1,798295	-0,014464
8	175,999914	137,499933	1,813616	0,000278
9	175,999914	131,999835	1,826366	0,012450
10	175,999915	126,499937	1,837141	0,022648
11	175,999916	120,999838	1,846289	0,031217
12	175,999816	115,499940	1,854001	0,038352
13	175,999917	109,999941	1,860536	0,044309
14	175,999918	104,499942	1,868011	0,051206
15	175,999918	98,999843	1,875516	0,058134
16	175,999919	93,499844	1,882114	0,064153
17	175,999919	87,999845	1,888447	0,069909
18	175,999919	82,499946	1,895175	0,076059
19	175,999820	76,999947	1,900461	0,080766
20	175,999920	71,499947	1,902200	0,081928
21	175,999820	65,999847	1,900112	0,079262
22	175,999820	60,499846	1,895871	0,074443
23	175,999819	54,999945	1,887742	0,065736
24	175,999918	49,499942	1,875878	0,053295
25	175,999917	43,999940	1,860332	0,037171
26	175,999916	38,499836	1,842900	0,019160
27	175,999914	32,999833	1,822121	-0,002196
28	175,999912	27,499928	1,797365	-0,027530
29	175,999910	21,999923	1,770324	-0,055149
30	175,999908	16,499818	1,742407	-0,083644
31	175,999906	10,999813	1,713781	-0,112848
32	175,999804	5,499808	1,685634	-0,141572
33	170,499903	175,999808	1,670511	-0,139944
34	170,499905	170,499813	1,699689	-0,111344
35	170,499807	164,999818	1,726812	-0,084798
36	170,499809	159,499922	1,748420	-0,063768
37	170,499910	153,999825	1,768151	-0,044615
38	170,499812	148,499728	1,786009	-0,027335
39	170,499913	142,999931	1,803379	-0,010543
40	170,499914	137,499834	1,818619	0,004119
41	170,499915	131,999836	1,831665	0,016588
42	170,499916	126,499838	1,842758	0,027102
43	170,499816	120,999939	1,852521	0,036287
44	170,499917	115,499941	1,860677	0,043865
45	170,499817	109,999942	1,867649	0,050260
46	170,499918	104,499943	1,875325	0,057358
47	170,499819	98,999944	1,883111	0,064566
48	170,499919	93,499846	1,890875	0,071752
49	170,499820	87,999847	1,896599	0,076898
50	170,499920	82,499848	1,903140	0,082861
51	170,499920	76,999848	1,907781	0,086924
52	170,499921	71,499949	1,909650	0,088216
53	170,499920	65,999848	1,907708	0,085696
54	170,499920	60,499947	1,902785	0,080195
55	170,499920	54,999746	1,895874	0,072706
56	170,499819	49,499944	1,884913	0,061167

80grados, 10%hum, 3h (1h ramp)



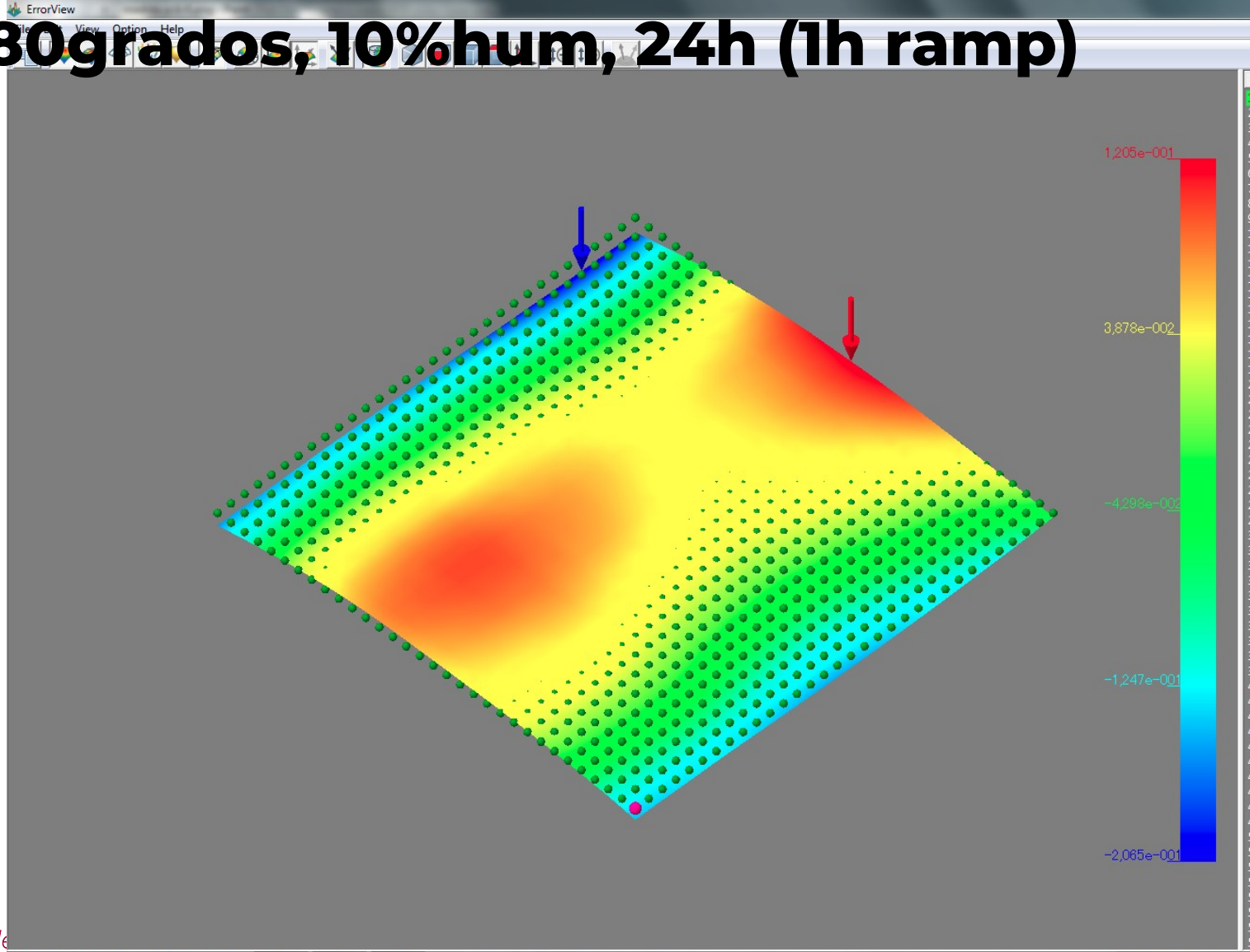
N...	X value	Y value	Z value	Deviation
1	176,000006	175,999942	1,645559	-0,141072
2	175,999909	170,499948	1,676910	-0,110292
3	176,000011	164,999953	1,704523	-0,083250
4	175,999912	159,499957	1,726640	-0,061705
5	175,999914	153,999961	1,747400	-0,041516
6	176,000015	148,499964	1,765947	-0,023540
7	175,999916	142,999967	1,782956	-0,007102
8	175,999918	137,499970	1,798667	0,008037
9	175,999918	131,999872	1,811931	0,020731
10	176,000019	126,499974	1,823223	0,031452
11	176,000020	120,999976	1,832794	0,040452
12	176,000021	115,499977	1,841058	0,048144
13	176,000021	109,999979	1,847572	0,054087
14	175,999922	104,499980	1,854223	0,060167
15	175,999922	98,999981	1,860894	0,066267
16	175,999923	93,499982	1,867118	0,071919
17	175,999923	87,999983	1,872969	0,077199
18	175,999923	82,499984	1,878856	0,082515
19	175,999924	76,999985	1,883534	0,086621
20	175,999924	71,499985	1,885159	0,087676
21	175,999924	65,999984	1,882717	0,084662
22	175,999923	60,499883	1,876840	0,078214
23	175,999923	54,999981	1,867778	0,068581
24	175,999922	49,499979	1,855063	0,055295
25	175,999920	43,999976	1,838664	0,038324
26	175,999919	38,499972	1,819355	0,018444
27	176,000017	32,999968	1,797074	-0,004408
28	175,999916	27,500063	1,771367	-0,030686
29	176,000013	21,999957	1,743124	-0,059500
30	176,000011	16,499852	1,713082	-0,090113
31	176,000009	10,999946	1,681786	-0,121980
32	176,000007	5,499840	1,651587	-0,152751
33	170,499907	175,999843	1,651396	-0,138788
34	170,499909	170,499949	1,682640	-0,108115
35	170,500011	164,999954	1,710843	-0,080483
36	170,499913	159,499858	1,733654	-0,058243
37	170,500014	153,999962	1,754657	-0,037812
38	170,500016	148,499965	1,772440	-0,020600
39	170,499917	142,999968	1,789739	-0,003872
40	170,500018	137,499971	1,805450	0,011267
41	170,500019	131,999973	1,818678	0,023925
42	170,500020	126,499976	1,830712	0,035387
43	170,500021	120,999977	1,841152	0,045256
44	170,500021	115,499979	1,849311	0,052844
45	170,500022	109,999980	1,857274	0,060236
46	170,499922	104,500081	1,864101	0,066491
47	170,500023	98,999983	1,870720	0,072539
48	170,499923	93,499984	1,877169	0,078416
49	170,500124	87,999985	1,882572	0,083249
50	170,500024	82,499986	1,888471	0,088577
51	170,499924	76,999886	1,892744	0,092279
52	170,499925	71,499987	1,894715	0,093678
53	170,499924	65,999886	1,892145	0,090537
54	170,499924	60,499885	1,886313	0,084134
55	170,499923	54,999883	1,877746	0,074996
56	170,499922	49,499881	1,865494	0,062172
57	170,499921	43,999978	1,848828	0,044935

80grados, 10%hum, 12h (1h ramp)



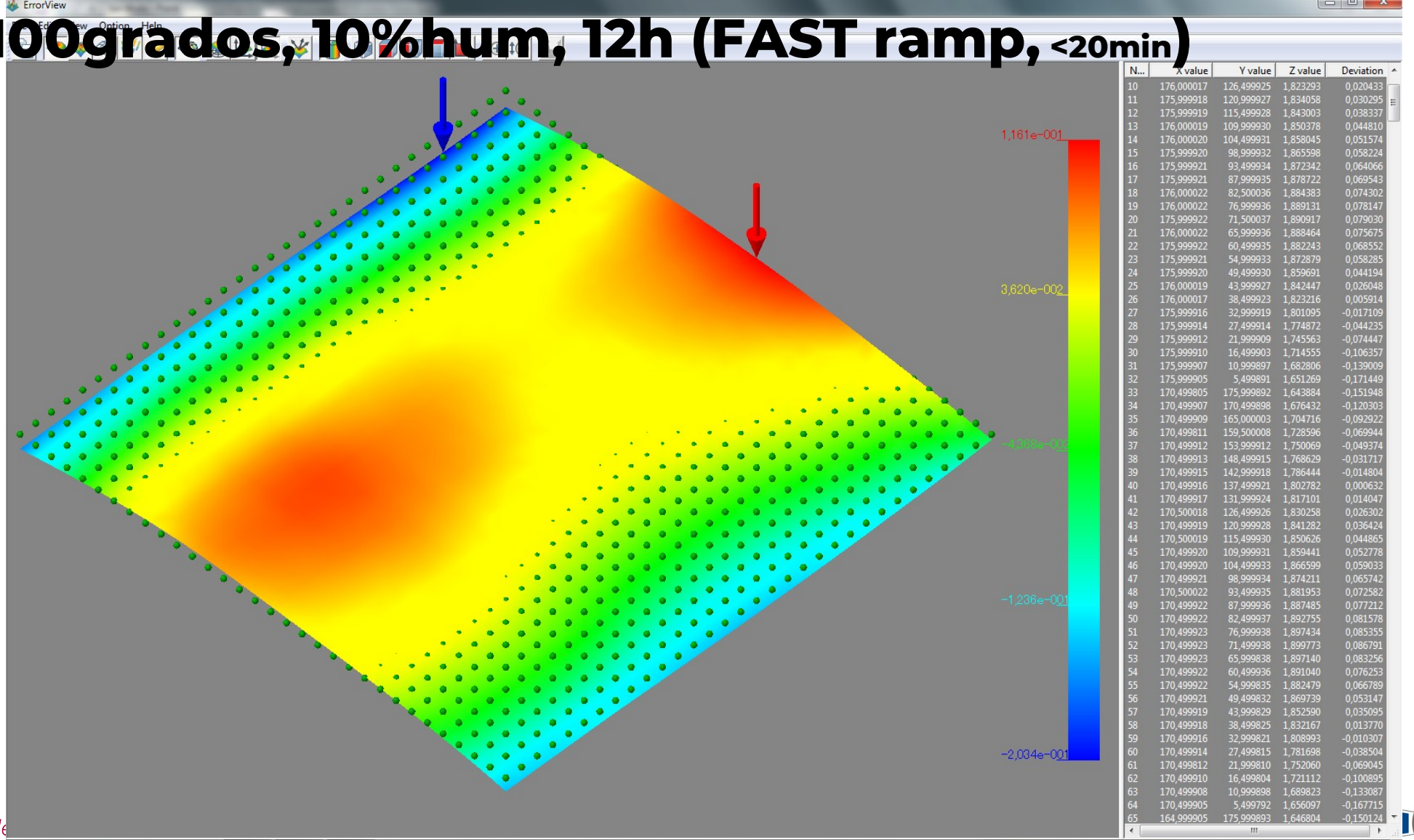
N...	X value	Y value	Z value	Deviation
1	175,999981	175,999898	1,647294	-0,159350
2	175,999884	170,499904	1,680301	-0,127131
3	175,999886	165,000009	1,709637	-0,098581
4	175,999888	159,499914	1,733205	-0,075800
5	175,999889	153,999918	1,755570	-0,054222
6	175,999891	148,499921	1,775652	-0,034927
7	175,999892	142,999925	1,794003	-0,017363
8	175,999893	137,499928	1,811209	-0,000944
9	175,999894	131,999930	1,825600	0,012661
10	175,999895	126,499933	1,838495	0,024769
11	175,999996	120,999935	1,849363	0,034850
12	175,999897	115,499936	1,858314	0,043015
13	175,999897	109,999938	1,865948	0,049862
14	175,999998	104,500039	1,873480	0,056607
15	175,999998	98,999940	1,880730	0,063070
16	175,999899	93,499841	1,887481	0,069034
17	175,999899	87,999942	1,892781	0,073547
18	175,999999	82,499943	1,898617	0,078597
19	176,000000	76,999844	1,903189	0,082382
20	176,000000	71,499944	1,904415	0,082821
21	176,000000	65,999944	1,901645	0,079264
22	175,999899	60,499942	1,895222	0,072055
23	175,999999	54,999940	1,884906	0,060951
24	175,999998	49,500038	1,871093	0,046353
25	175,999996	43,999934	1,853472	0,027944
26	175,999995	38,499930	1,833202	0,006888
27	175,999993	32,999926	1,809990	-0,017111
28	175,999991	27,499921	1,782900	-0,044988
29	175,999989	21,999915	1,753080	-0,075595
30	175,999987	16,499909	1,721756	-0,107706
31	175,999984	10,999903	1,689046	-0,141202
32	175,999982	5,499897	1,656584	-0,174451
33	170,499982	175,999999	1,652545	-0,155690
34	170,499984	170,500005	1,685932	-0,123091
35	170,499986	164,999910	1,715342	-0,094467
36	170,499988	159,499915	1,740060	-0,070536
37	170,499990	153,999919	1,762364	-0,049019
38	170,499991	148,499923	1,781930	-0,030240
39	170,499892	142,999926	1,800373	-0,012584
40	170,499994	137,499929	1,817470	0,003726
41	170,499995	131,999932	1,832092	0,017562
42	170,499996	126,499934	1,845481	0,030164
43	170,499996	121,000036	1,856595	0,040492
44	170,499997	115,499938	1,865933	0,049043
45	170,499998	110,000039	1,874943	0,057265
46	170,499998	104,500040	1,882080	0,063616
47	170,499999	98,999942	1,889112	0,069862
48	170,499899	93,499943	1,896430	0,076392
49	170,499900	87,999944	1,901837	0,081013
50	170,499900	82,500045	1,907360	0,085749
51	170,500000	77,000045	1,911412	0,089014
52	170,500001	71,500046	1,913190	0,090005
53	170,500000	66,000045	1,909736	0,085765
54	170,500000	60,499944	1,903627	0,078869
55	170,499999	54,999942	1,894288	0,068743
56	170,499998	49,500039	1,881245	0,054913
57	170,499997	43,999936	1,863397	0,036278

80grados, 10%hum, 24h (1h ramp)



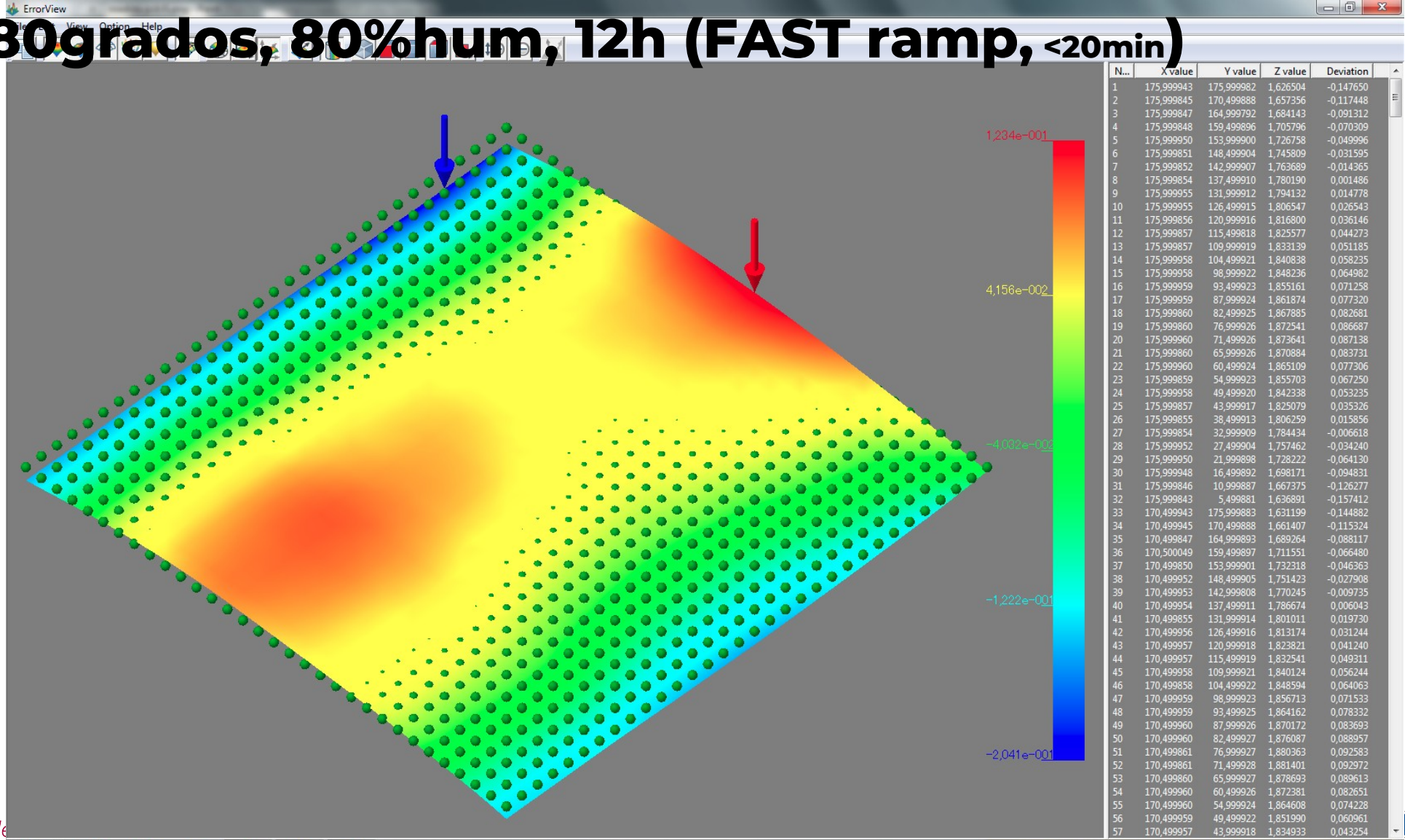
N...	X value	Y value	Z value	Deviation
1	175,999892	176,000028	1,639109	-0,158176
2	175,999895	170,500034	1,671495	-0,126267
3	175,999897	165,000039	1,699429	-0,098810
4	175,999898	159,499943	1,722327	-0,076389
5	175,999900	153,999947	1,743762	-0,055432
6	175,999901	148,500051	1,763329	-0,036342
7	175,999903	143,000054	1,781306	-0,018843
8	175,999904	137,500057	1,797945	-0,002681
9	175,999905	132,000060	1,812064	0,010960
10	175,999906	126,499962	1,824657	0,023077
11	175,999907	121,000064	1,834941	0,032883
12	175,999907	115,500066	1,843810	0,041275
13	175,999908	110,000067	1,851111	0,048098
14	175,999908	104,500068	1,858293	0,054803
15	175,999909	99,000070	1,865359	0,061392
16	175,999909	93,500071	1,871977	0,067533
17	176,000010	87,999972	1,877933	0,073011
18	175,999910	82,500073	1,884029	0,078629
19	175,999910	76,999974	1,888520	0,082643
20	175,999911	71,500074	1,889769	0,083415
21	175,999910	66,000073	1,886507	0,079675
22	175,999910	60,499972	1,880293	0,072984
23	175,999909	54,999970	1,870057	0,062271
24	176,000008	49,500067	1,856454	0,048190
25	175,999907	44,000063	1,838093	0,029353
26	175,999905	38,500060	1,818833	0,009615
27	176,000004	32,999955	1,795718	-0,013977
28	176,000002	27,500050	1,768381	-0,041792
29	176,000000	22,000044	1,738695	-0,071955
30	175,999997	16,499938	1,707834	-0,103293
31	175,999895	10,999932	1,675707	-0,135898
32	175,999893	5,500026	1,644025	-0,168057
33	170,499993	176,000029	1,645387	-0,153449
34	170,499895	170,500035	1,677186	-0,122127
35	170,499897	164,999940	1,706221	-0,093569
36	170,499899	159,500045	1,729977	-0,070291
37	170,499900	153,999949	1,751037	-0,049708
38	170,499902	148,500052	1,770146	-0,031076
39	170,500003	142,999956	1,788261	-0,013439
40	170,499904	137,499959	1,804651	0,002474
41	170,500005	131,999961	1,818909	0,016255
42	170,499906	126,500064	1,831794	0,028662
43	170,500007	121,000066	1,843006	0,039397
44	170,499908	115,500067	1,852443	0,048356
45	170,499908	110,000069	1,859495	0,054931
46	170,500009	104,500070	1,867373	0,062332
47	170,499909	99,000071	1,874447	0,068929
48	170,499910	93,499973	1,881876	0,075880
49	170,499910	88,000073	1,886937	0,080464
50	170,499911	82,500074	1,893032	0,086082
51	170,499911	77,000075	1,897377	0,089949
52	170,499911	71,499975	1,898964	0,091059
53	170,499911	66,000075	1,895811	0,087428
54	170,499911	60,500073	1,889073	0,080213
55	170,499910	54,999971	1,879797	0,070459
56	170,500009	49,499969	1,866417	0,056603
57	170,500008	44,000065	1,848440	0,038148

100grados, 10%hum, 12h (FAST ramp, <20min)



N...	X value	Y value	Z value	Deviation
10	176,000017	126,499925	1,823293	0,020433
11	175,999918	120,999927	1,834058	0,030295
12	175,999919	115,499928	1,843003	0,038337
13	176,000019	109,999930	1,850378	0,044810
14	176,000020	104,499931	1,858045	0,051574
15	175,999920	98,999932	1,865598	0,058224
16	175,999921	93,499934	1,872342	0,064066
17	175,999921	87,999935	1,878722	0,069543
18	176,000022	82,500036	1,884383	0,074302
19	176,000022	76,999936	1,889131	0,078147
20	175,999922	71,500037	1,890917	0,079030
21	176,000022	65,999936	1,888464	0,075675
22	175,999922	60,499935	1,882243	0,068552
23	175,999921	54,999933	1,872879	0,058285
24	175,999920	49,499930	1,859691	0,044194
25	176,000019	43,999927	1,842447	0,026048
26	176,000017	38,499923	1,823216	0,005914
27	175,999916	32,999919	1,801095	-0,017109
28	175,999914	27,499914	1,774872	-0,044235
29	175,999912	21,999909	1,745563	-0,074447
30	175,999910	16,499903	1,714555	-0,106357
31	175,999907	10,999897	1,682806	-0,139009
32	175,999905	5,499891	1,651269	-0,171449
33	170,499805	175,999892	1,643884	-0,151948
34	170,499907	170,499898	1,676432	-0,120303
35	170,499909	165,000003	1,704716	-0,092922
36	170,499811	159,500008	1,728596	-0,069944
37	170,499912	153,999912	1,750069	-0,049374
38	170,499913	148,499915	1,768629	-0,031717
39	170,499915	142,999918	1,786444	-0,014804
40	170,499916	137,499921	1,802782	0,000632
41	170,499917	131,999924	1,817101	0,014047
42	170,500018	126,499926	1,830258	0,026302
43	170,499919	120,999928	1,841282	0,036424
44	170,500019	115,499930	1,850626	0,044865
45	170,499920	109,999931	1,859441	0,052778
46	170,499920	104,499933	1,866599	0,059033
47	170,499921	98,999934	1,874211	0,065742
48	170,500022	93,499935	1,881953	0,072582
49	170,499922	87,999936	1,887485	0,077212
50	170,499922	82,499937	1,892755	0,081578
51	170,499923	76,999938	1,897434	0,085355
52	170,499923	71,499938	1,899773	0,086791
53	170,499923	65,999838	1,897140	0,083256
54	170,499922	60,499936	1,891040	0,076253
55	170,499922	54,999835	1,882479	0,066789
56	170,499921	49,499832	1,869739	0,053147
57	170,499919	43,999829	1,852590	0,035095
58	170,499918	38,499825	1,832167	0,013770
59	170,499916	32,999821	1,808993	-0,010307
60	170,499914	27,499815	1,781698	-0,038504
61	170,499812	21,999810	1,752060	-0,069045
62	170,499910	16,499804	1,721112	-0,100895
63	170,499908	10,999898	1,689823	-0,133087
64	170,499905	5,499792	1,656097	-0,167715
65	164,999905	175,999893	1,646804	-0,150124

80grados, 80%hum, 12h (FAST ramp, <20min)



N...	X value	Y value	Z value	Deviation
1	175,999943	175,999982	1,626504	-0,147650
2	175,999845	170,499888	1,657356	-0,117448
3	175,999847	164,999792	1,684143	-0,091312
4	175,999848	159,499896	1,705796	-0,070309
5	175,999950	153,999900	1,726758	-0,049996
6	175,999851	148,499904	1,745809	-0,031595
7	175,999852	142,999907	1,763689	-0,014365
8	175,999854	137,499910	1,780190	0,001486
9	175,999955	131,999912	1,794132	0,014778
10	175,999955	126,499915	1,806547	0,026543
11	175,999856	120,999916	1,816800	0,036146
12	175,999857	115,499818	1,825577	0,044273
13	175,999857	109,999919	1,833139	0,051185
14	175,999958	104,499921	1,840838	0,058235
15	175,999958	98,999922	1,848236	0,064982
16	175,999959	93,499923	1,855161	0,071258
17	175,999959	87,999924	1,861874	0,077320
18	175,999860	82,499925	1,867885	0,082681
19	175,999860	76,999926	1,872541	0,086687
20	175,999960	71,499926	1,873641	0,087138
21	175,999860	65,999926	1,870884	0,083731
22	175,999960	60,499924	1,865109	0,077306
23	175,999859	54,999923	1,855703	0,067250
24	175,999958	49,499920	1,842338	0,053235
25	175,999857	43,999917	1,825079	0,035326
26	175,999855	38,499913	1,806259	0,015856
27	175,999854	32,999909	1,784434	-0,006618
28	175,999952	27,499904	1,757462	-0,034240
29	175,999950	21,999898	1,728222	-0,064130
30	175,999948	16,499892	1,698171	-0,094831
31	175,999846	10,999887	1,667375	-0,126277
32	175,999843	5,499881	1,636891	-0,157412
33	170,499943	175,999883	1,631199	-0,144882
34	170,499945	170,499888	1,661407	-0,115324
35	170,499847	164,999893	1,689264	-0,088117
36	170,500049	159,499897	1,711551	-0,066480
37	170,499850	153,999901	1,732318	-0,046363
38	170,499952	148,499905	1,751423	-0,027908
39	170,499953	142,999808	1,770245	-0,009735
40	170,499954	137,499911	1,786674	0,006043
41	170,499855	131,999914	1,801011	0,019730
42	170,499956	126,499916	1,813174	0,031244
43	170,499957	120,999918	1,823821	0,041240
44	170,499957	115,499919	1,832541	0,049311
45	170,499958	109,999921	1,840124	0,056244
46	170,499858	104,499922	1,848594	0,064063
47	170,499959	98,999923	1,856713	0,071533
48	170,499959	93,499925	1,864162	0,078332
49	170,499960	87,999926	1,870172	0,083693
50	170,499960	82,499927	1,876087	0,088957
51	170,499861	76,999927	1,880363	0,092583
52	170,499861	71,499928	1,881401	0,092972
53	170,499860	65,999927	1,878693	0,089613
54	170,499960	60,499926	1,872381	0,082651
55	170,499960	54,999924	1,864608	0,074228
56	170,499959	49,499922	1,851990	0,060961
57	170,499957	43,999918	1,834933	0,043254