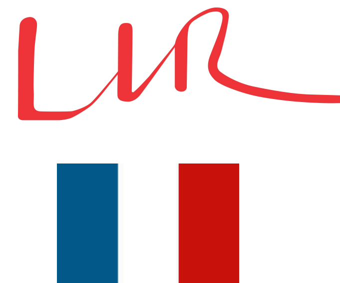
Task 8.2.1: SiW ECAL ASUs - PCB Metrology and Hybridisation

Roman Pöschl

On behalf of



AIDAinnova Annual Meeting - WP8 Session March 2024

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WP8 Deliverables

#D	Description	Task	LEad	Type	Dissemination	Due
D8.1	Demonstrator of a combined read-out system of highly granular electromagnetic and hadronic calorimeters	8.2	DESY	DEM	PU	M36
D8.2	Report on prototypes construction, performance and assessment of industrialisation	8.3	CERN	R	PU	M35
D8.3	Qualification of neutron irradiated SiPMs at different temperatures.	8.4	JSI	R	PU	M44
D8.4	Construction and qualification with beam of 10×10 cm^2, 2 m long, prototypes	8.4	INFN-MI	DEM	PU	M46

- Will have to shift D8.1 by 6 months

WP8 – Reasoning for delay of D8.1

- D8.1 :
  - Demonstrator of a combined read-out system of highly granular electromagnetic and hadronic calorimeters” **is due M36 (March, 2024)**
    - The development of common DAQ interfaces imply a knowledge/technological transfer from the SiW ECAL
      to the AHCAL
    - The process is started, but the board design, testing and operation are delayed
  - External events prevents delivery in due time:
    - The SiW-ECAL wafer-PCB delamination problem needs to be solved before any further test can be made; it was raised as the highest priority on the path to the production of new ASUs.
    - The DESY AHCAL team is responsible for the production of the board for the CMS HGCAL HCAL part;
      the unexpected observation of the freezing of radiation damage annealing at -35°C in scintillators forced an urgent change of design, especially of the electronics boards, which has the priority.
  - A delay of the deliverable by six months to M42 (September, 2024) would allow to produce a few boards for a proof-of-principle test of the SiW-ECAL, which would then form the basis of the transfer to the AHCAL.
    A combined test of a couple of layers at DESY SiW-ECAL+AHCAL is foreseen for June 2024.

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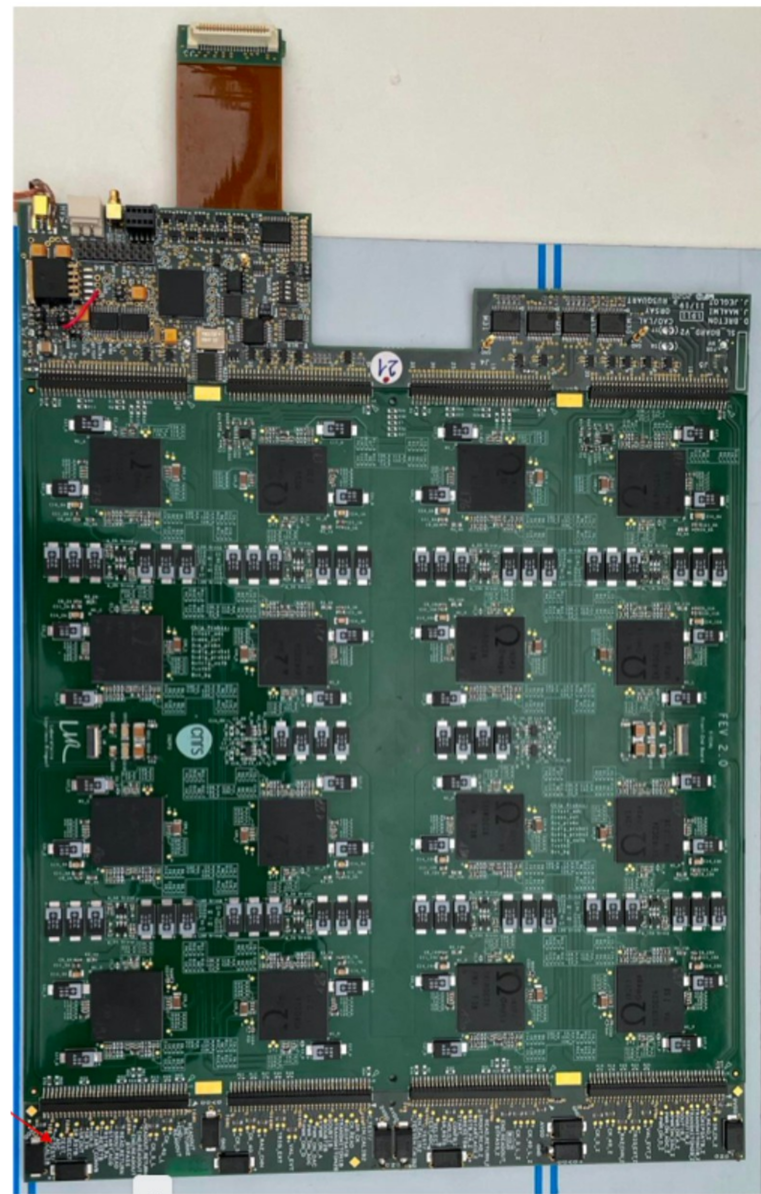
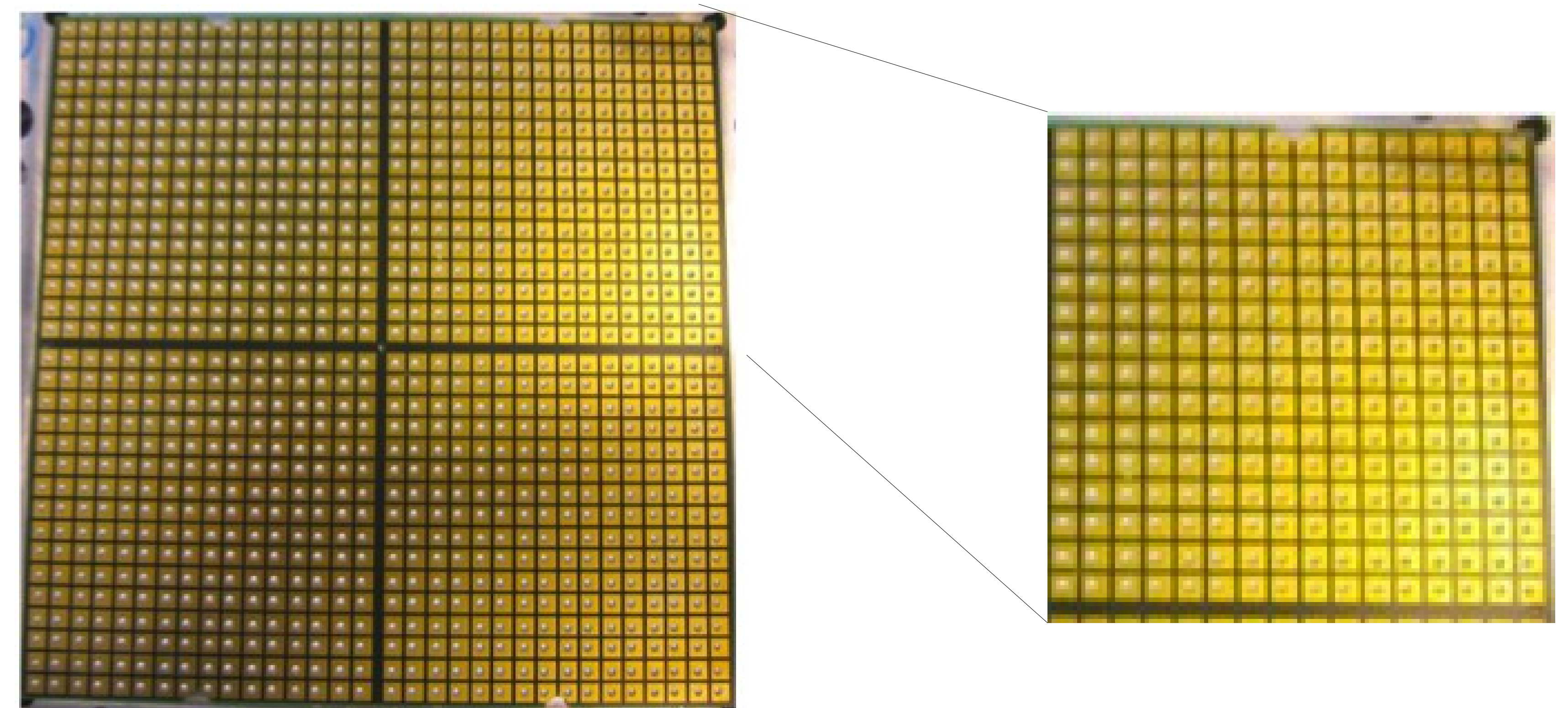
SiW Ecal Active Signal Unit - ASU

Overall size – 18x18x~0.5cm^3

Upside: PCB with Electronics

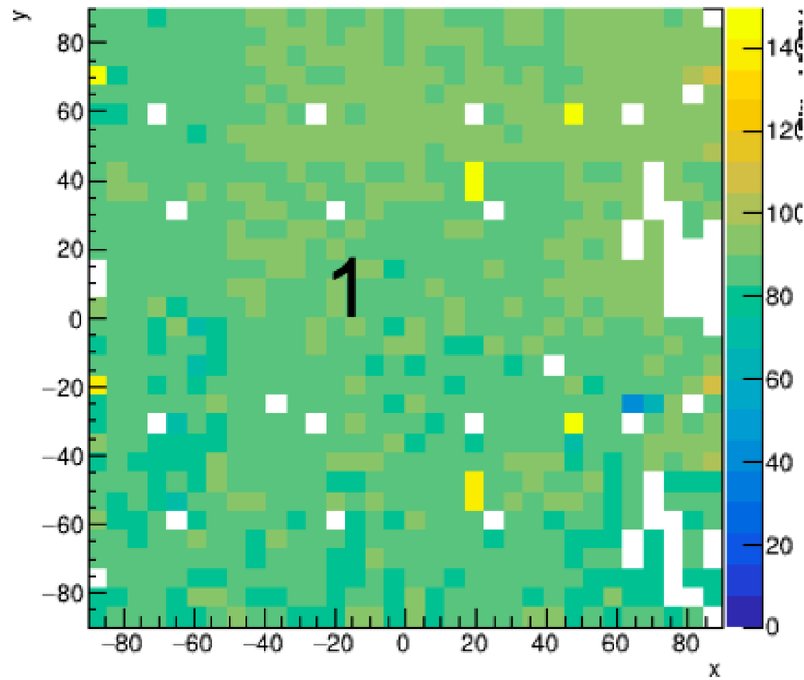


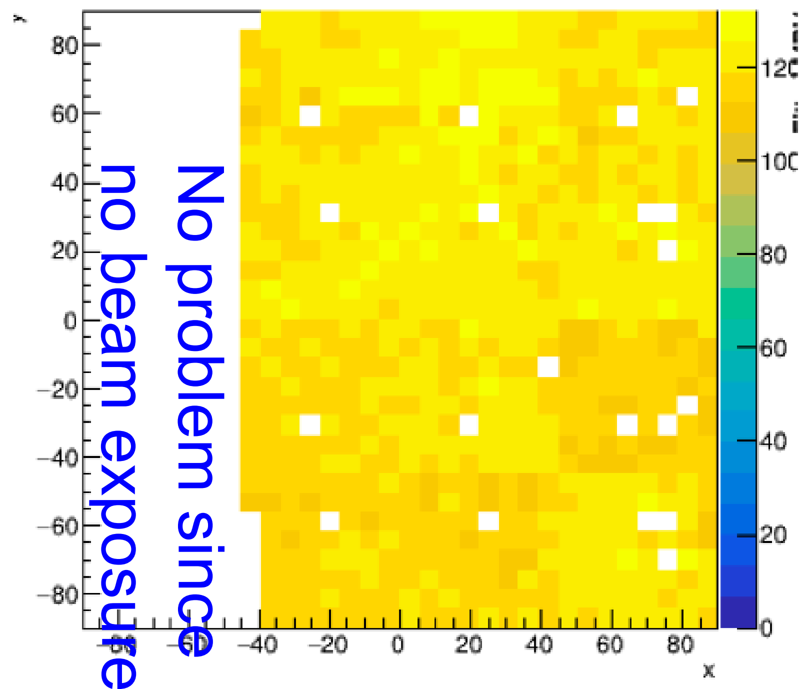
Downside: Si sensors (here glass plates) glued to PCB



Glue: Epotek 4110 (conductive glue)
Dimensions of glue dots ~Ø 2.5mmx0.1mm

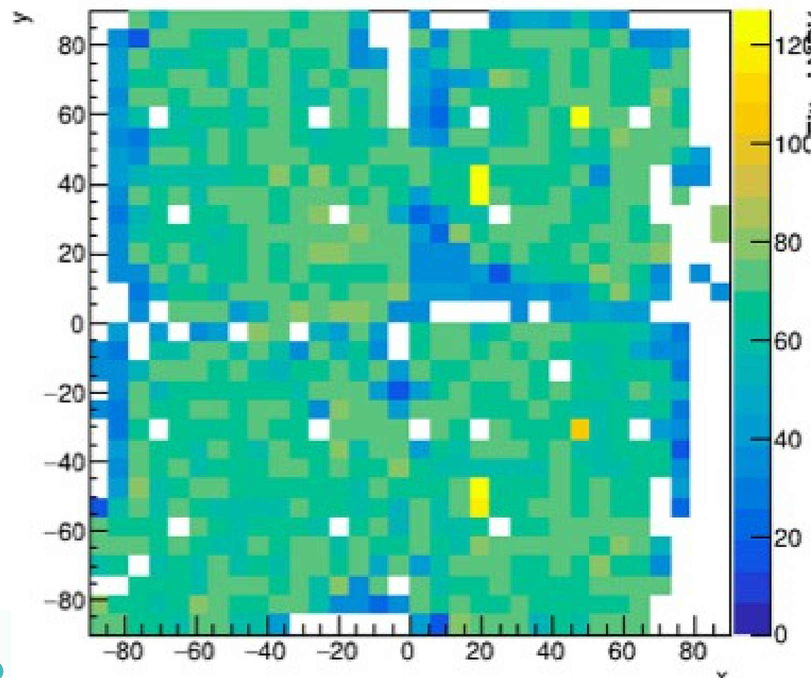
Sensor delamination





We have good layers ...

- Homogeneous response to MIPs over layer surface
- > 90% efficiency for MIPs
- Here white cells are masked cells due to PCB routing
  - understood and will be corrected



... and bad layers

Inhomogeneous response to MIPs

- Partially even no response at all, in particular at the wafer boundaries
- Visusl inspection confirmed with electrical tests show that the sensor
- Got delaminated from the PCB -> glus dots have failed
- ***Intensive topic of study***

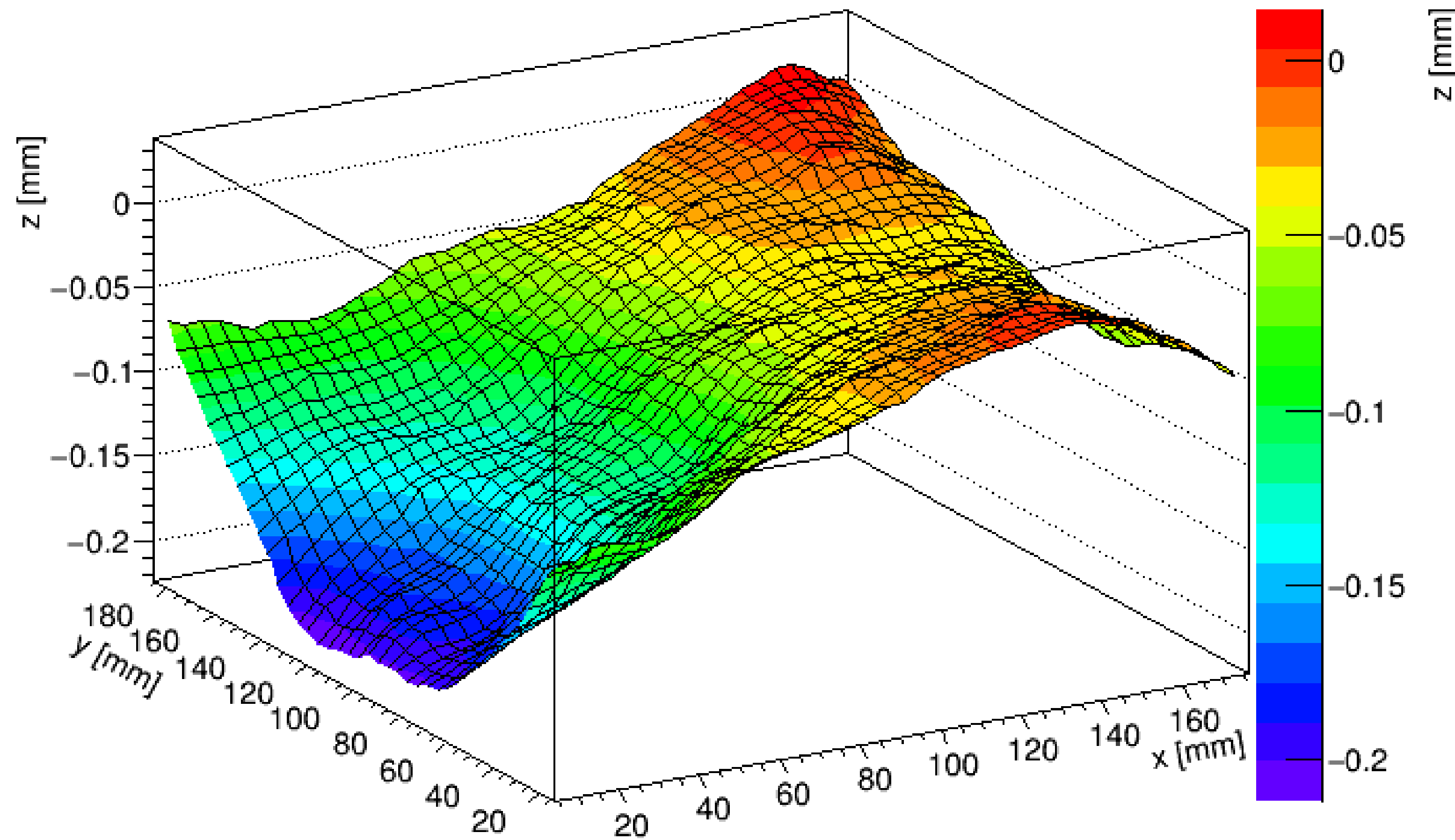
Sensor Delamination – Steps of study

- Hypothesis and foundation
  - Deformation of PCBs pull on glue dots
  - Conductive glue has no mechanical stability and unpredictable behaviour (dixit Epotek)
  - Replace Epotek 4110 by Epotek H20E after consultation of other research teams and Epotek
- Metrology
  - What are the deformations we are dealing with?
- Hybridisation
  - Develop methods that allow keeping constant the distance between PCB and sensor
- Stress tests

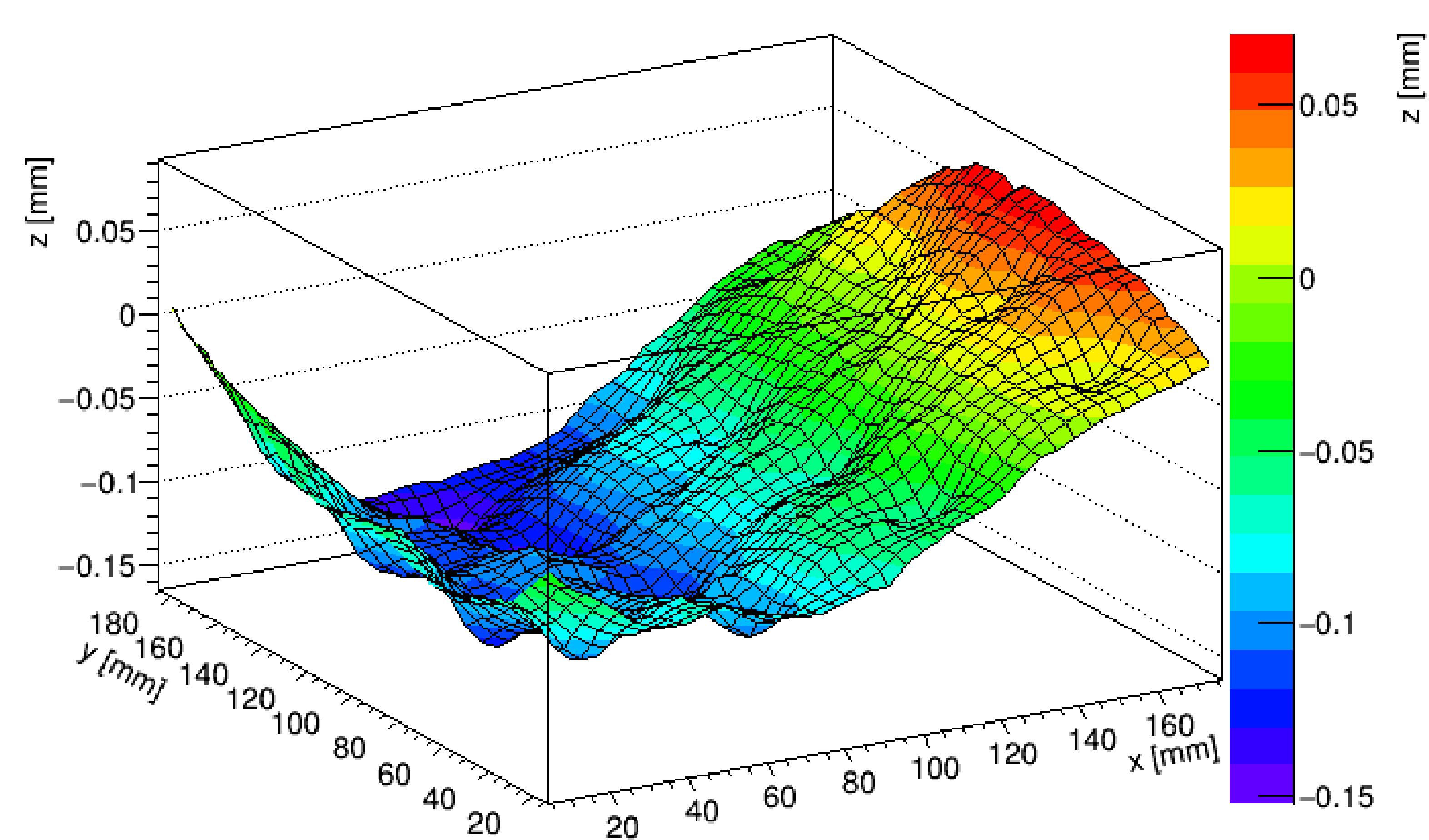
PCB Metrology at IJCLab

Several PCBs were measured at IJCLab before and after mounting of components in IJCLab Workshop
Component mounting includes a short (~10s) heating cycle to about 300°C

Before:



After:



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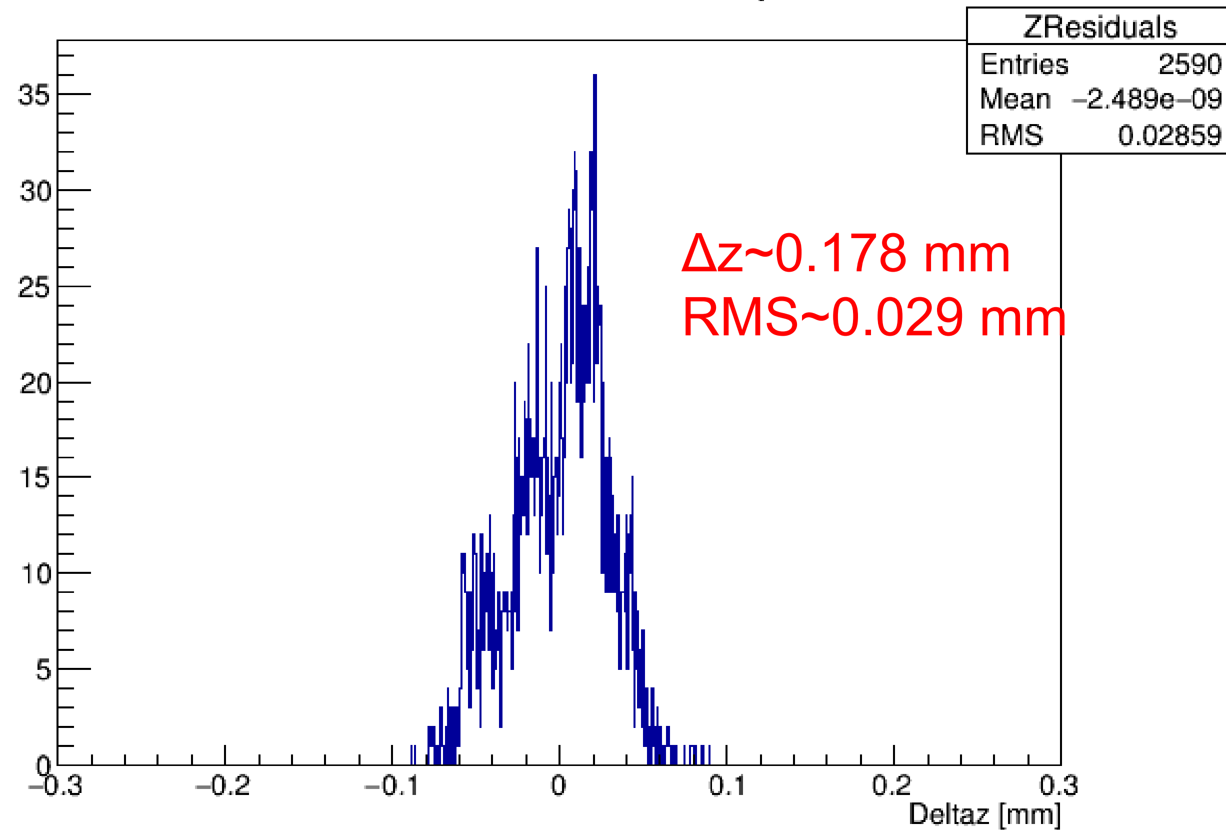
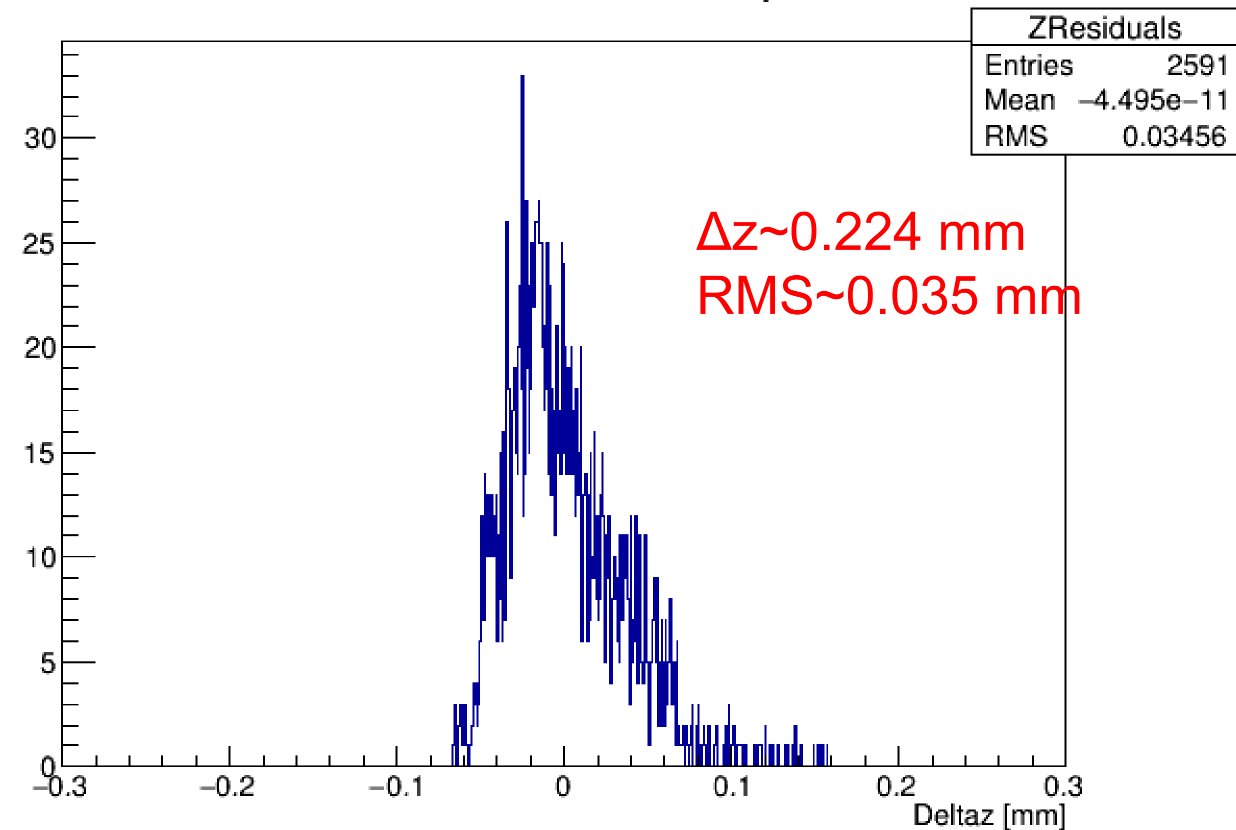
PCB Metrology at IJCLab cont'd

A plane was fitted to the point cloud of measurements
Residuals w.r.t. fitted plane

Before:



After:



- Major part of deformation before mounting of component
- Recent measurement confirms deformation of “naked board” and allows for estimating systematic error to be of O(10mum)

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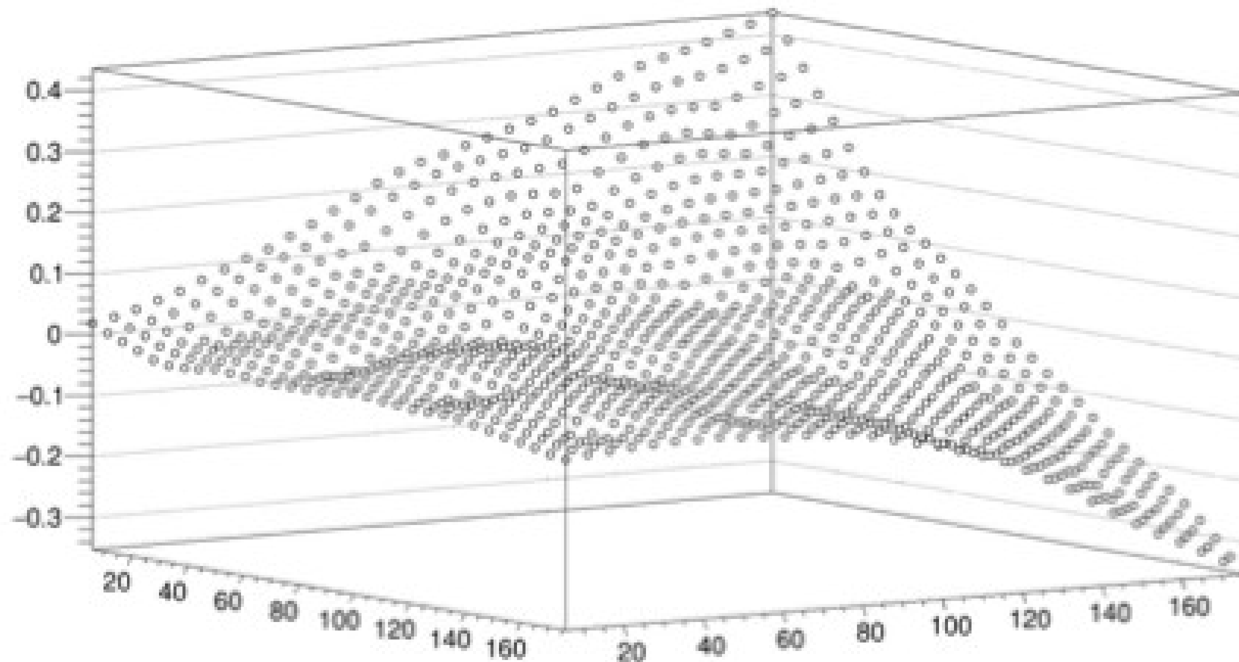
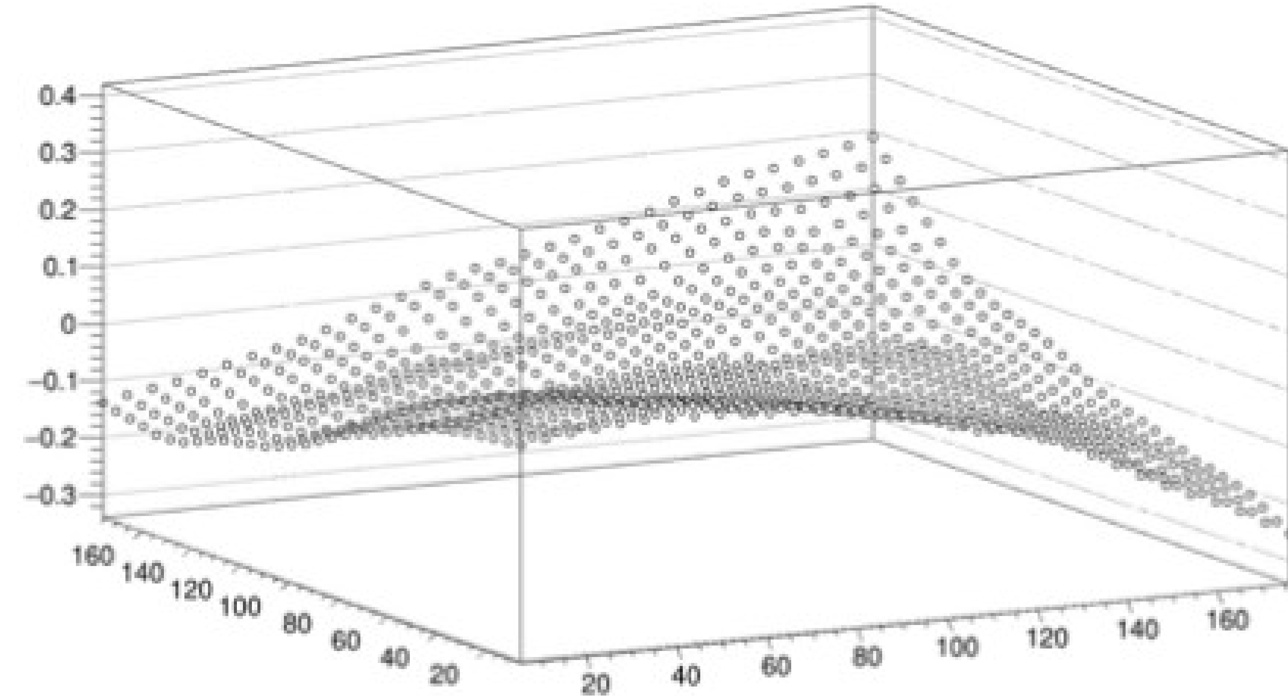
PCB Metrology at IFIC – Overview

Measurement device: Mitutoyo Quick Vision Accel, Modelo 808





- Current results are surprising
  - Left: Equipped PCB after reception at IFIC from IJCLab, up to 800um deformation
    - N.B.: to be compared with right hand sides on previous two slides
  - Right: Same PCB after having been carefully “dried out”, deformation reduced to 450um)
  - In addition the PCB was subject to humidity cycles
- Systematic study to understand differences between IFIC and IJCLab ongoing
  - Metrology with well defined protocol

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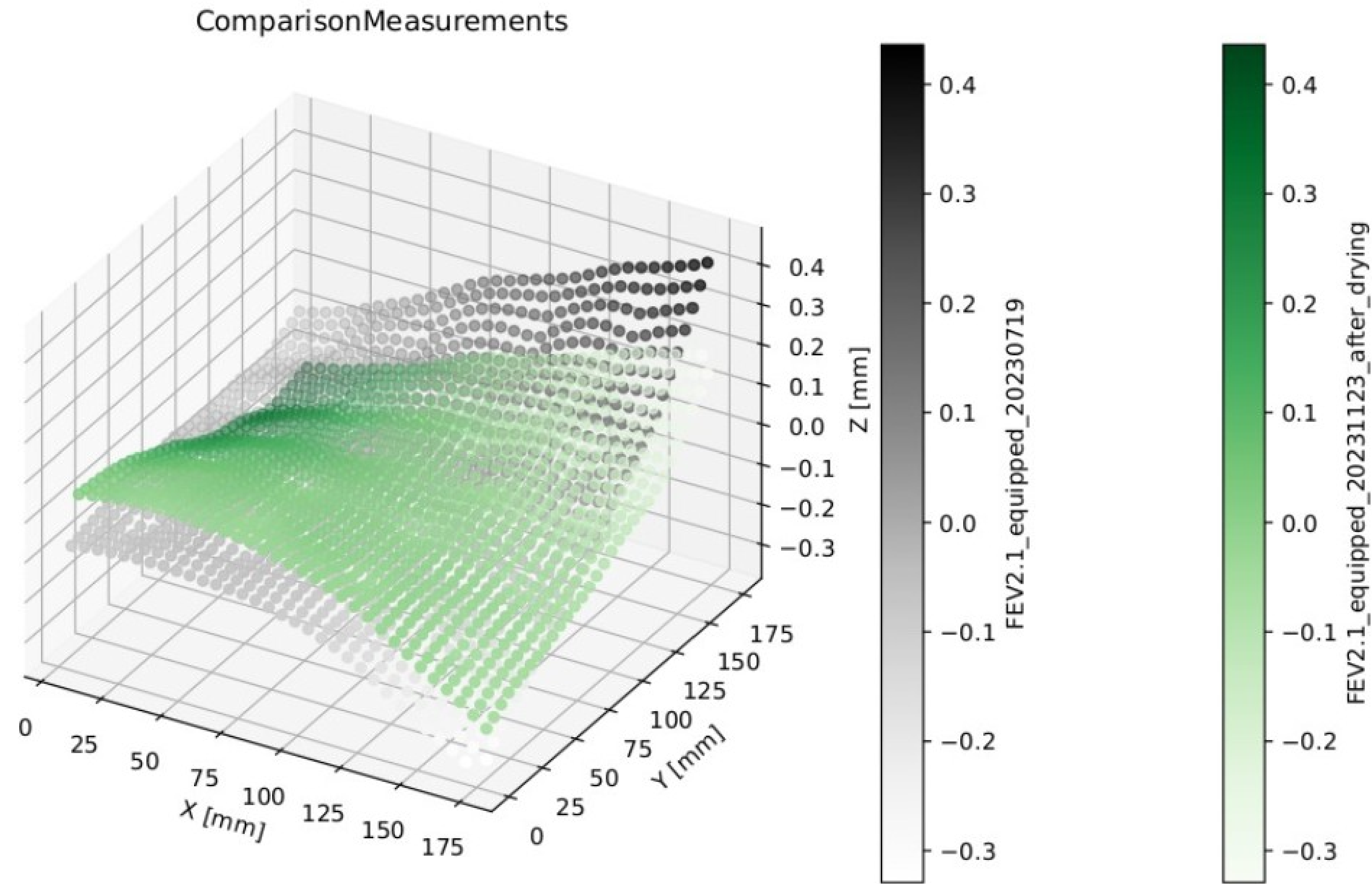
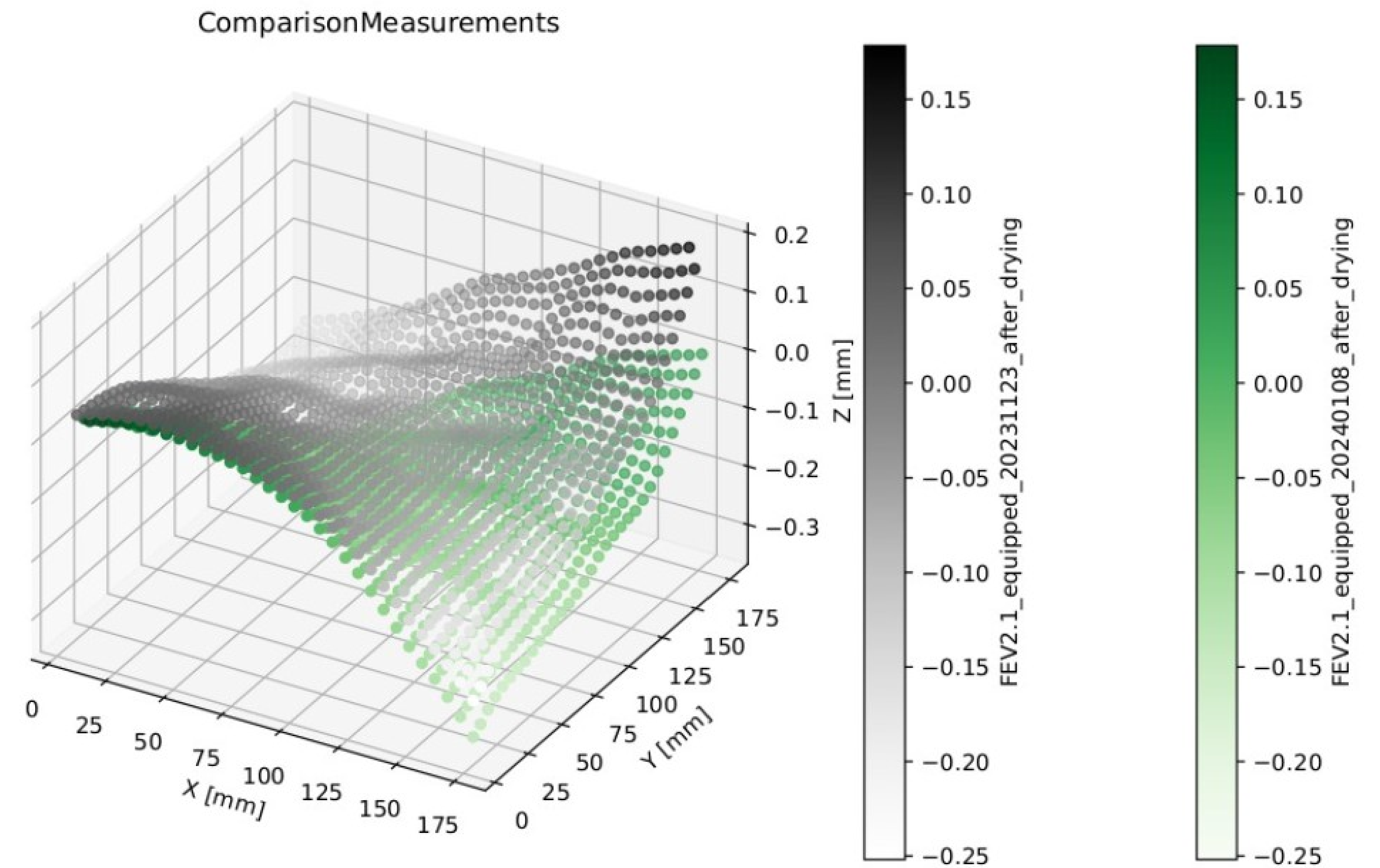
PCB Metrology at IFIC – Details I

Deformation upon reception and after drying for 10 days in dry cabinet and heating for 24 hours at 50°C



Immediately after drying and after drying + 1day



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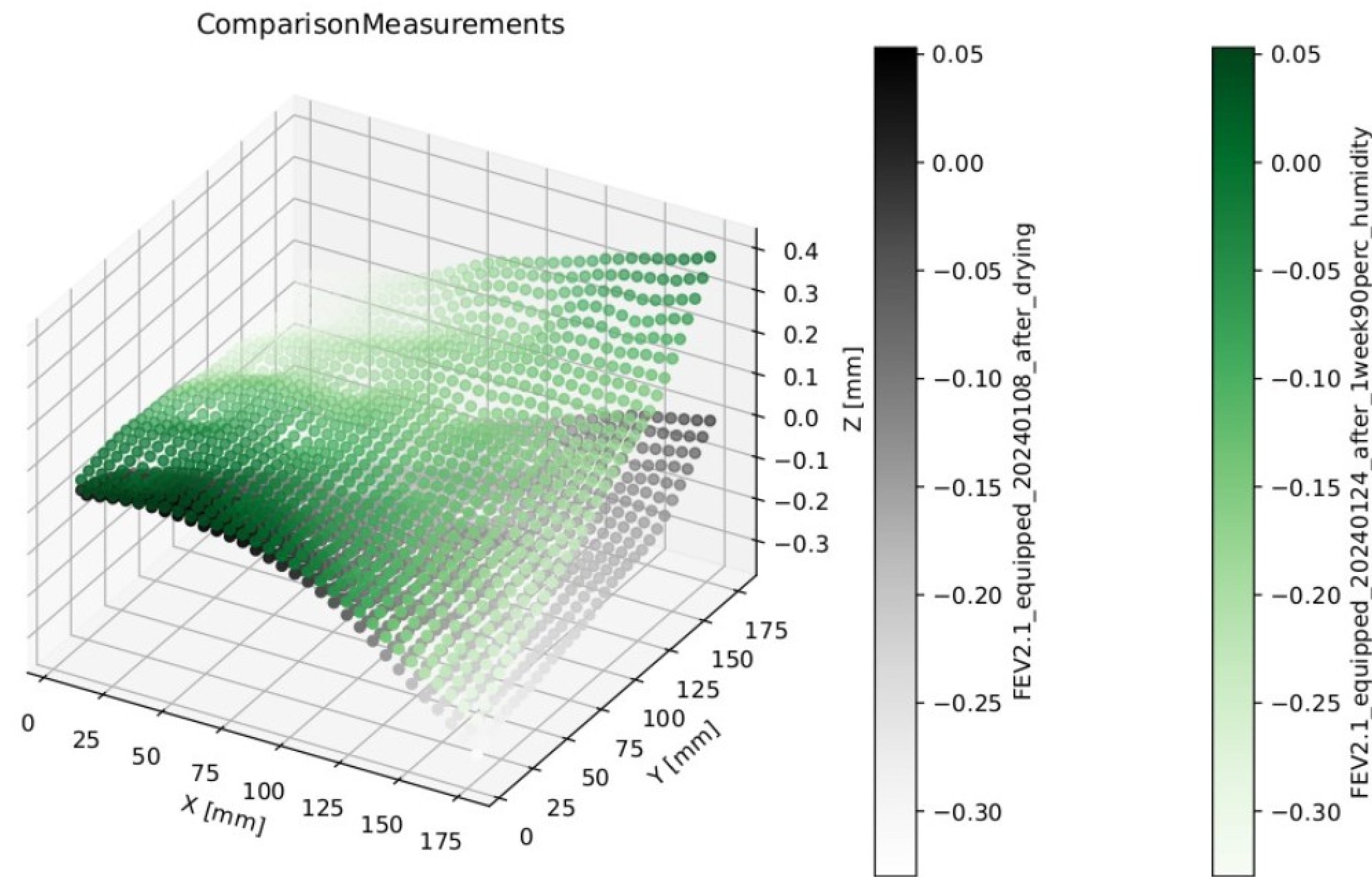
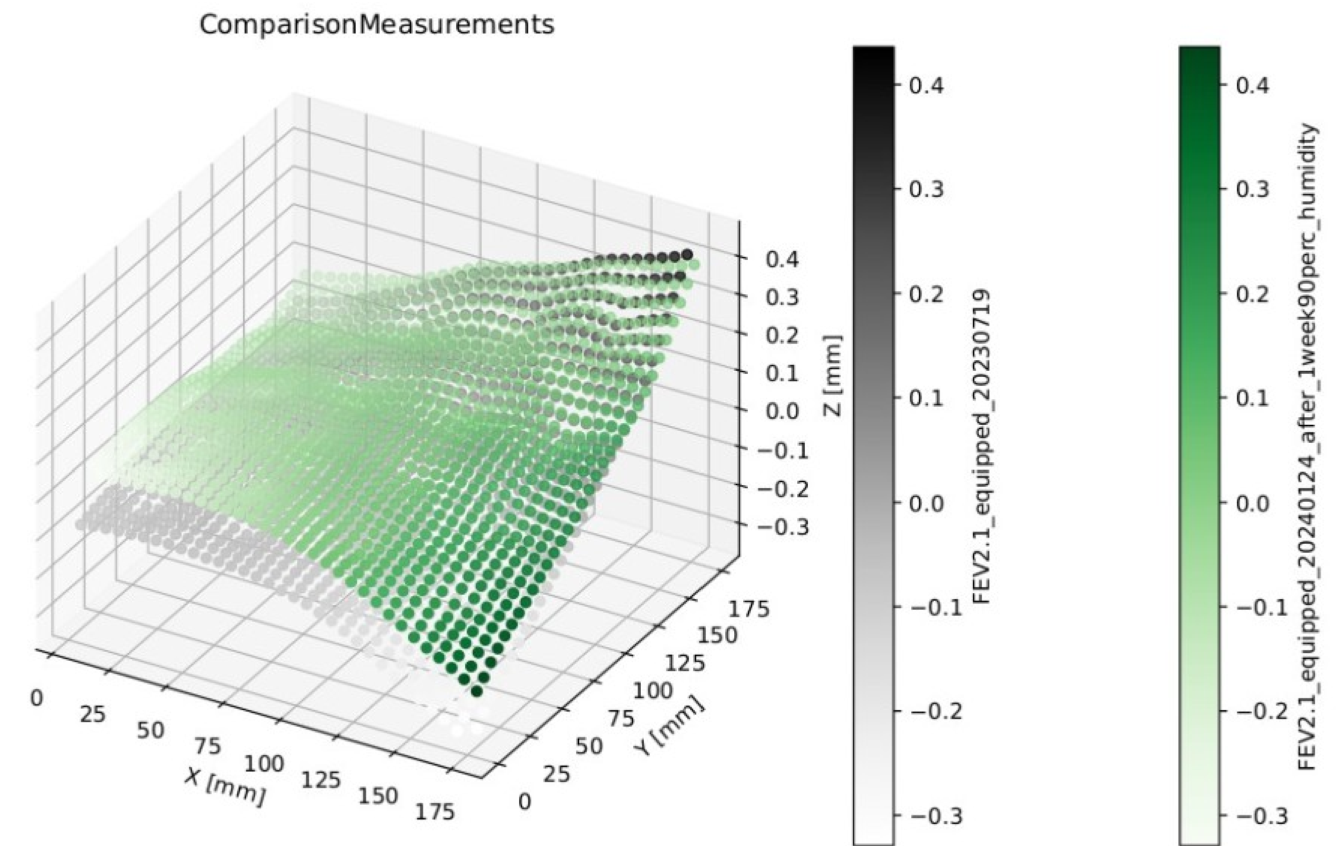
PCB Metrology at IFIC – Details II

Additional drying and humidity cycles
3x72 cycles during nine days at 90% and 30°C



Humidity cycles and PCB upon reception



PCB back in old shape (?)

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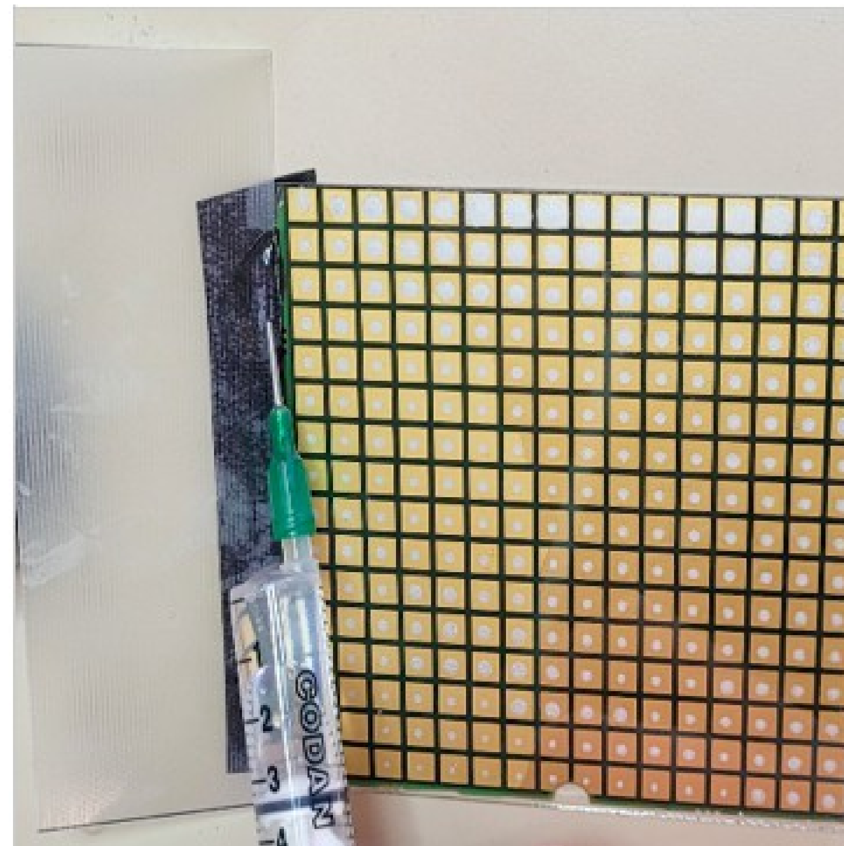
Hybridisation - Underfill

Support conductive glue dots with supplementary adhesive

EPO-TEK® 301-2

- From Data sheet
  - Two component optical and semiconductor grade epoxy resin
  - Low viscosity, long potlife and good handling characteristics

Injection of underfill



- Resin propagates via capillary effect
- Takes ~20 min. to fill 9x9 cm^2 surface

Requires curing at 80^oC

... but remains flexible after curing

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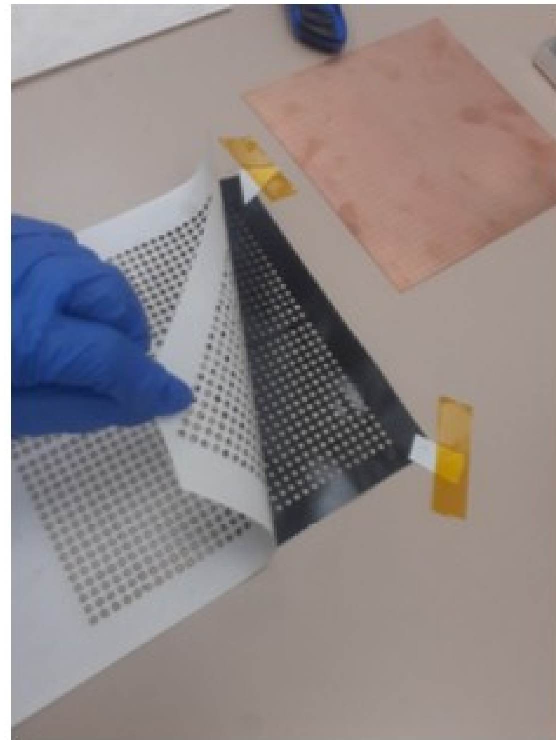
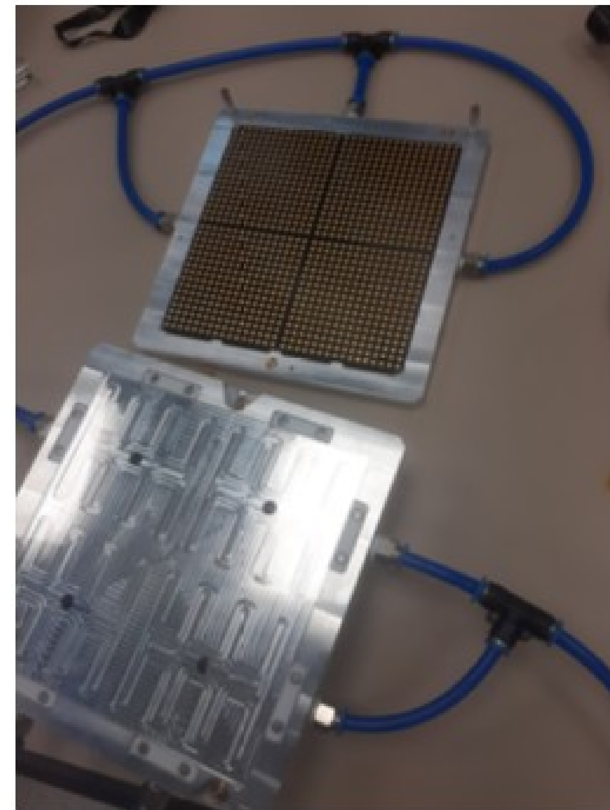
Hybridisation – Double Sided Tape

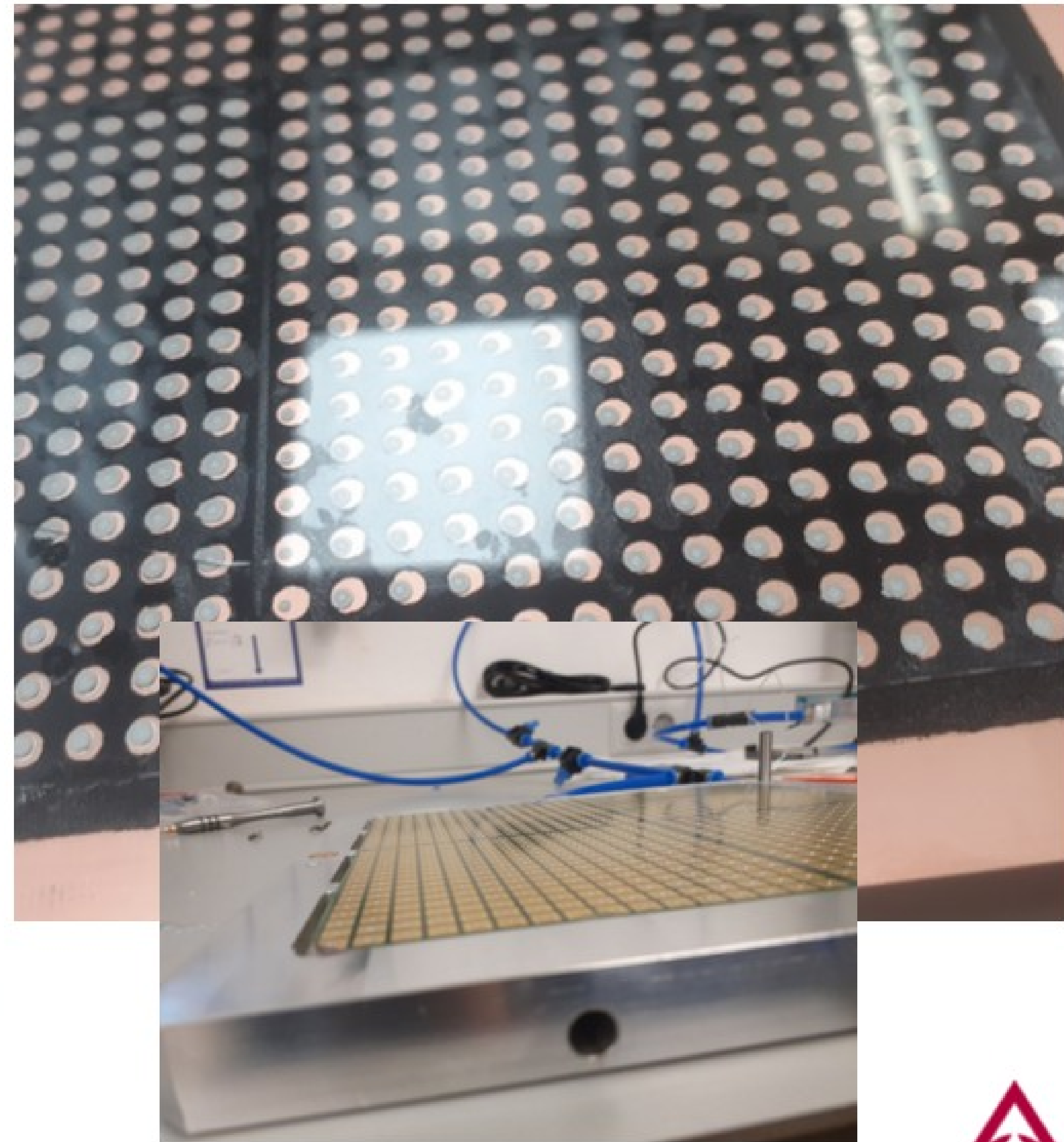
- Perforated stencil of thin 250um double tape 3M VHB 5907F
- Idea inspired by CMS HGCAL



Stencil made at IFIC (laser drill)



One 18x18cm^2 model completed at IFIC



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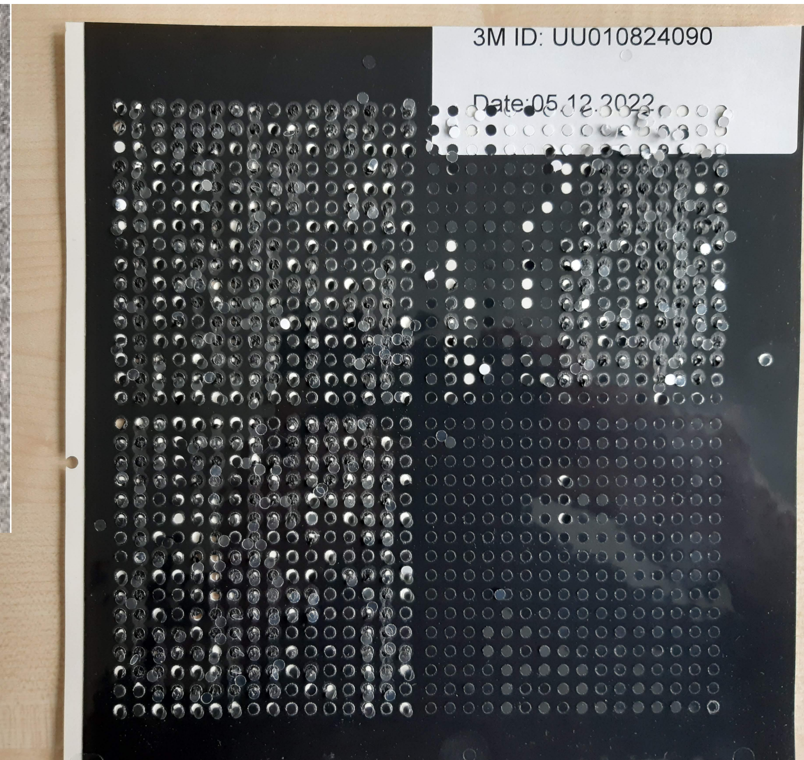
Hybridisation – Double Sided Tape – Alternative perforation

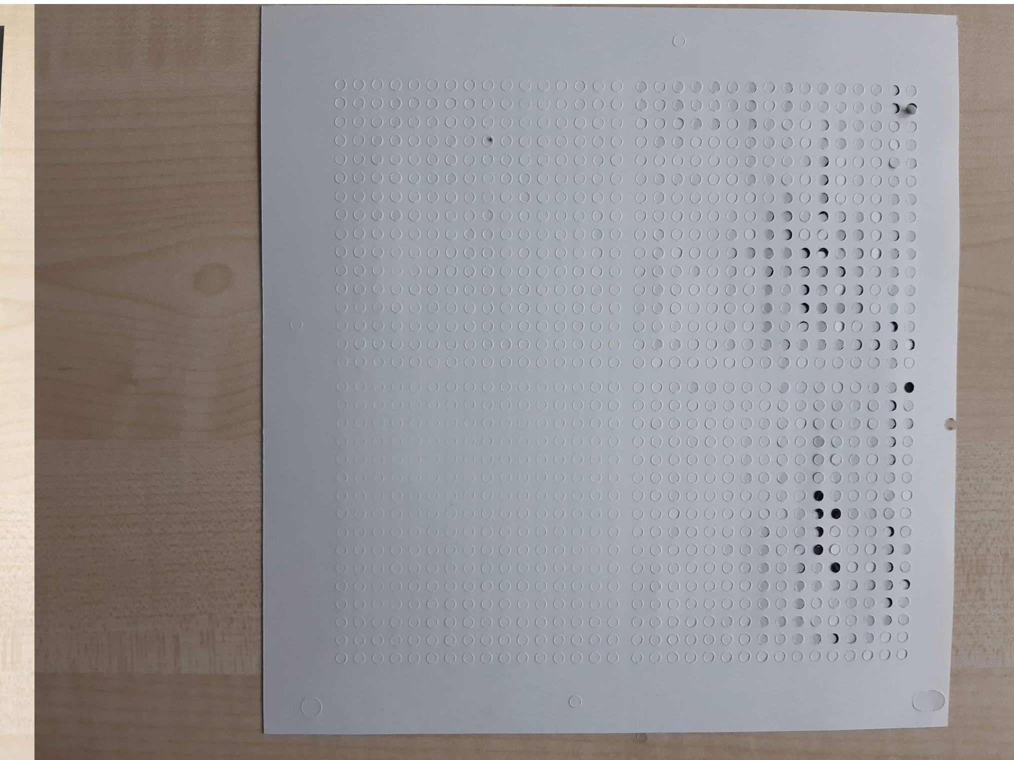
Aristo@DESY

Die cutter

3M Front Side

3M Back Side

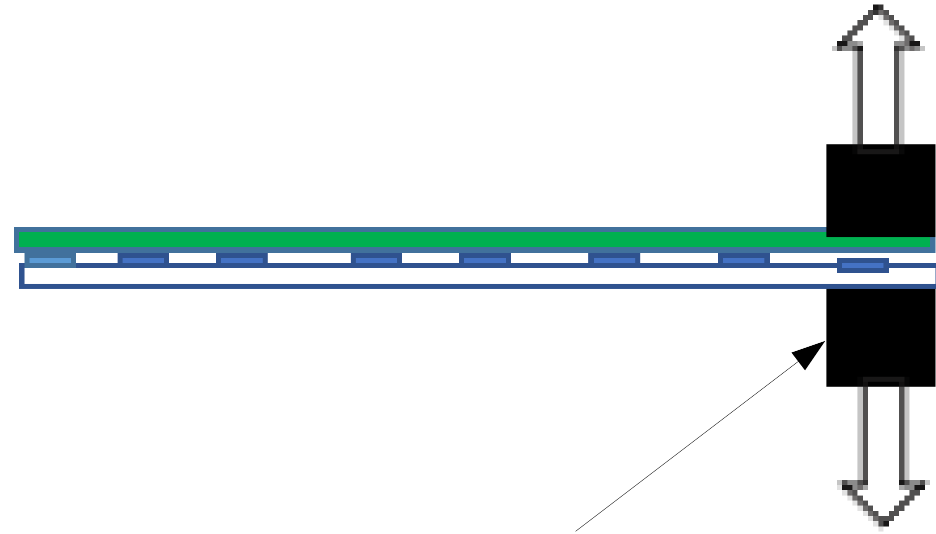




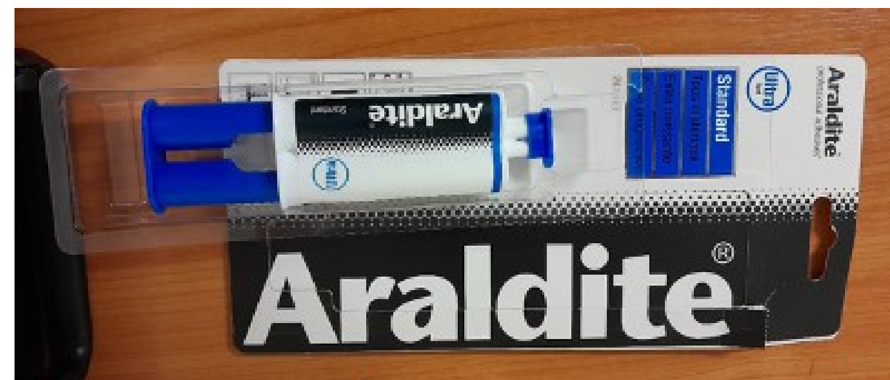
- 1024 hiles in 15 minutes
  - Much faster than laser cutting
- Action coordinated by Dirk thanks to DMLAB (French-German Lab)
- Perforated foil now at IFIC
- Thanks to DESY engineers !!!

Tensile tests

Principle of tensile test



Bars are glued
to transmit force
to card under test



Test stand@IJCLab

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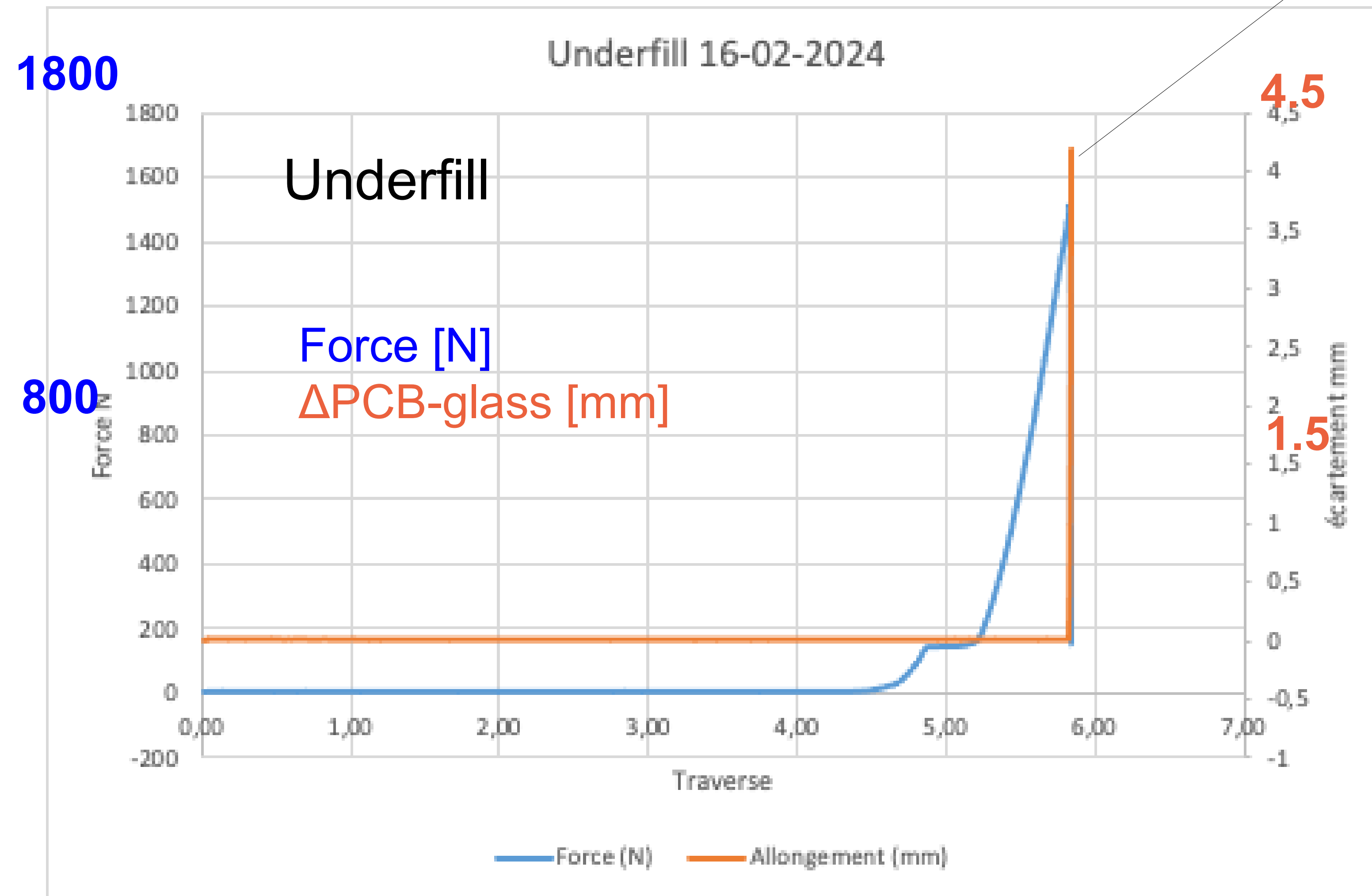
Tensile tests – (First) results

Bar dissolves from card under test



- First test reveals that underfill resists to even strong external forces

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Summary and Conclusions

- Understanding of sensor delamination problem are at the heart of current R&D

- Systematic studies throughout 2023
  - Screening machines at IJClab and IFIC
  - Metrology seems to indicate that component mounting is not cuprit for deformation
  - Drying seems to help, avoid humidity?
  - Discrepancies between screening results at IJCLab and IFIC to be understood

- Progress on two methods for for hybridisation
  - Underfilll
  - Double sided tape (after all a “pre-polymerised material)
  - Have to learn now how to build ASUs using these technologies
    - Proper perforation and placement of perforated tape
    - Application of underfill to 18x18 cm^2 surface

- Tensile test stand operational and first results are available

Backup

Workpackage 8 - Beneficiaries and Associated Partners

Beneficiaries:

CAEN (Industry)
CERN
CNRS-IJCLab, CNRS-LLR, CNRS-LPNHE
CUNI
DESY
FBK ("Interface to industry")
FZU
INFN-BO, INFN-LNF, INFN-PD, INFN-PG, INFN-PV, INFN-TO
JSI
JGU
MPP-MPG
TAU
University of Bergen
University of Sussex
Vilnius University

Associated Partners:

FOTON (Industry)
GLASS2POWER (Industry)
Minsk
HZDR
Crytur

Details – Drying and Humidification at IFIC

▷ **Drying a PCB**

- We store it for 10days or more in a dry cabinet (0.5% humidity)
- and/or we heat it up for 24h at 50° → following advice by Rompal (spanish company for PCB component assembly)

▷ **Humidity cycles**

- Cycles in a climatic chamber at 90% humidity and 30°
- 1 week of 72h cycles