

SiW-ECAL:

Ideas & studies for large surface Si sensor connection to rigid PCBs using conductive glue.

Adrián Irles

**AITANA group at IFIC - CSIC/UV*

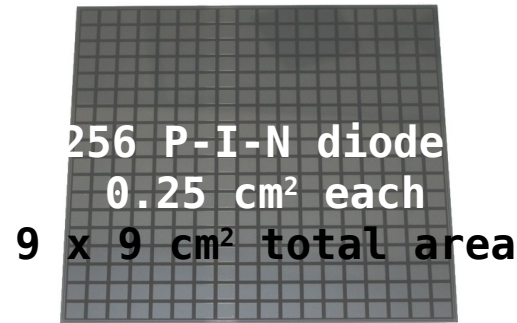
IFIC
INSTITUT DE FÍSICA
CORPUSCULAR



- ▶ Intro
- ▶ IFIC-preparation work
- ▶ PCB planarity issues
- ▶ Testing the glues and the gluing techniques
- ▶ Mechanical tests of glue strength
 - Ideas to improve its strength

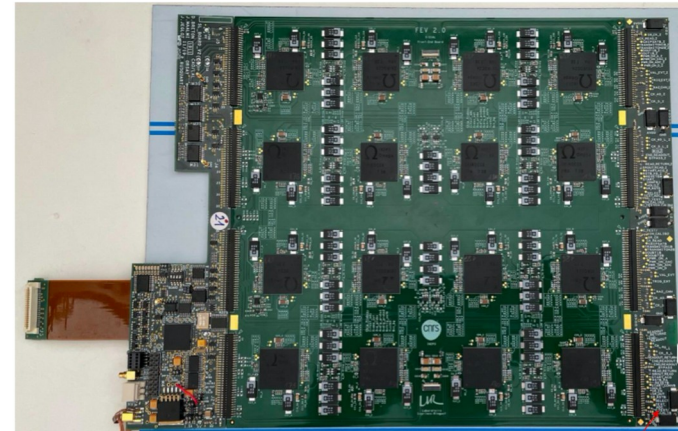
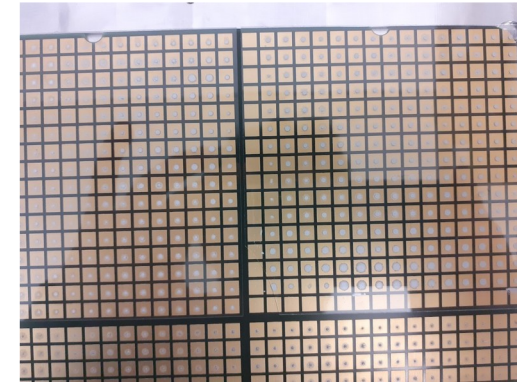


- ▶ Very dense PCBs
 - with ASICs (skirocs2a - Omega) handling the readout, buffering and digitization of signals
- ▶ 4 silicon sensors
 - PiN Diodes of $9 \times 9 \text{ cm}^2$
 - $0.5 \times 0.5 \text{ cm}^2$ cells
- ▶ No space for wirebonding
- ▶ Glue with conductive epoxys
 - epoxy+silver mixes
 - Low temperature curing (4-80 degrees)



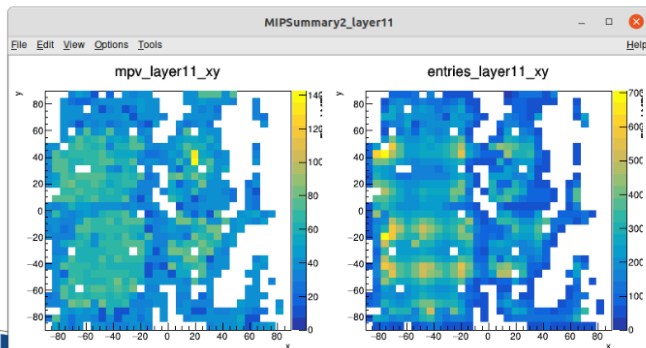
EUDET layout

Prototype from Hamamatsu



► Some slabs present problems...

- Associated to detachment of wafers (glued)
- Worrisome situation than is to be understood with high priority
- ~1/3 of 15 slabs seem difficult to be recovered
- Other slabs are in the pipeline (at least 3 equipped FEV13s + 2 new boards FEV12/COB/orFEV2.)



Irles A., 19th April, 2022

- Shown for the first time in Valencia Meeting 2022
 - Partial delamination of several sensors
 - Old and new sensors / modules
 - 500 and 320um
 - Glued at France and Japan
 - Observed in generations of FEV (except COBs)
- Large fraction of the slabs at the CERN beam test (summer 2022) had this issue

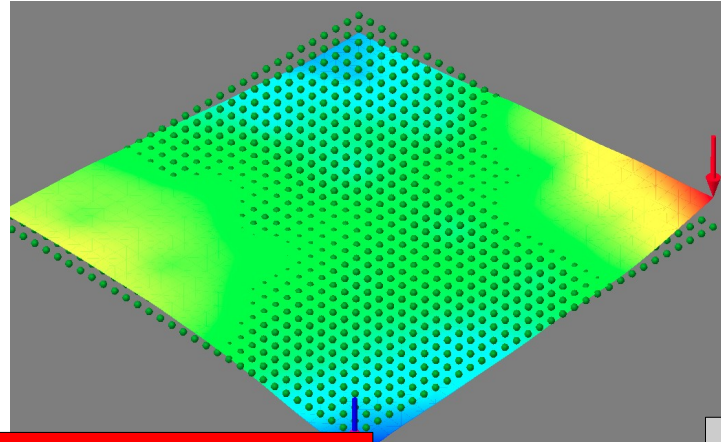
Probable causes

Gluing procedure?

Glue choice,
Mixing,
curing process...

Glue degradation?

Chemical oxidation
(silver vs aluminum),
Lifetime of glue...



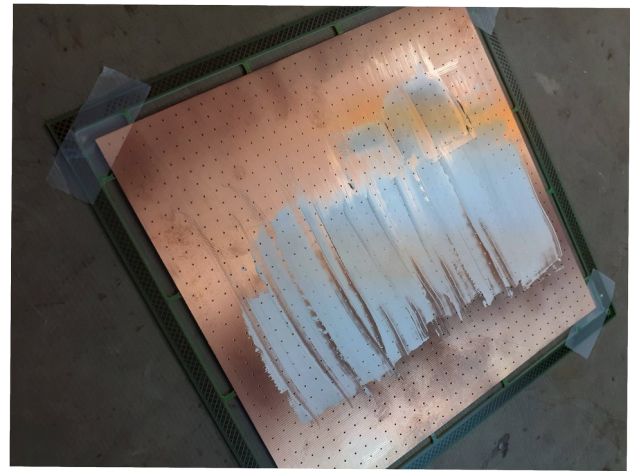
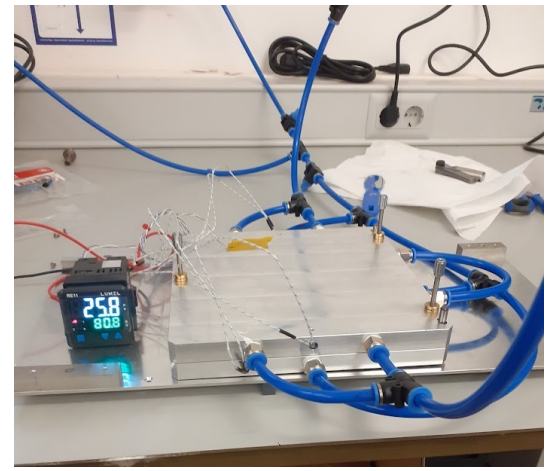
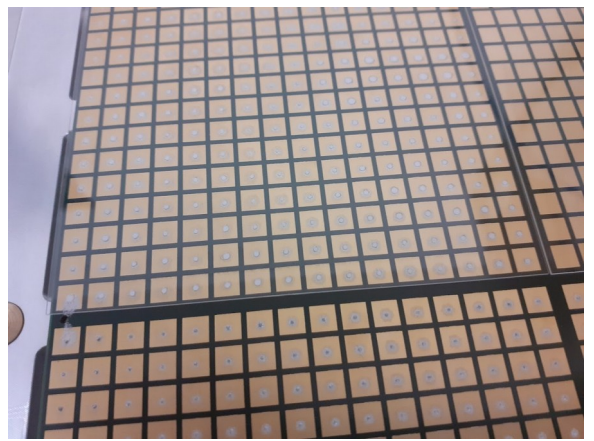
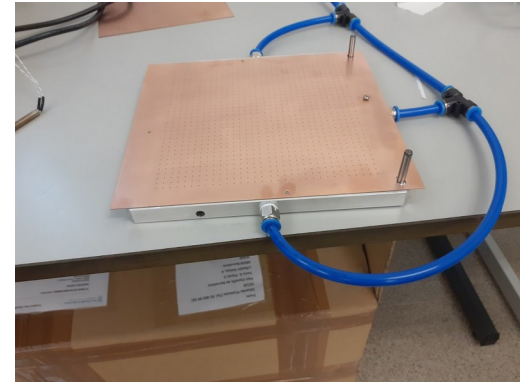
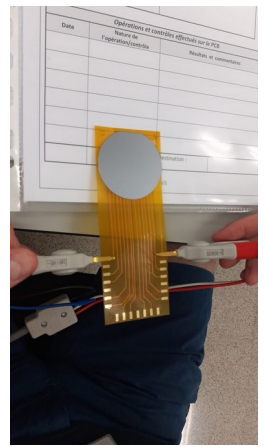
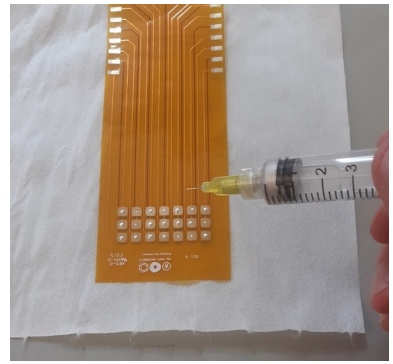
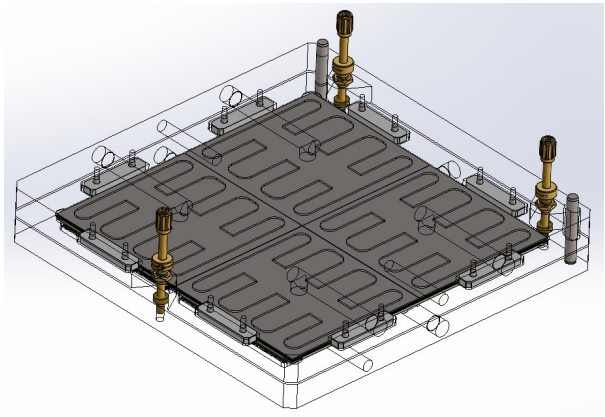
Mechanical deformation of the PCBs
Complex PCBs with “intense” thermal processes
for the assembly of the components

Storage and manipulations

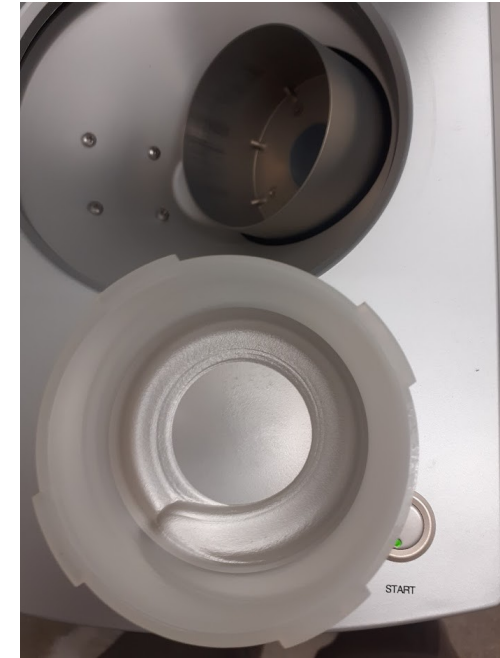
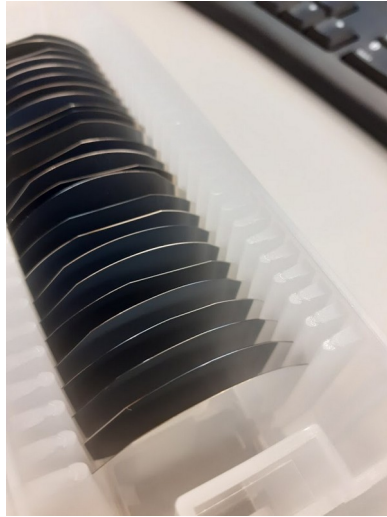
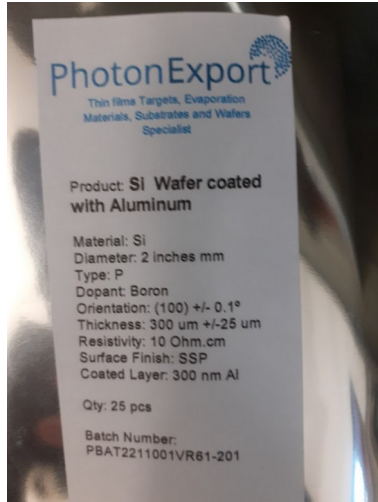
Lots of traveling
Commissioning procedure
etc



Revisiting the gluing - tools at IFIC



Revisiting the gluing - tools at IFIC



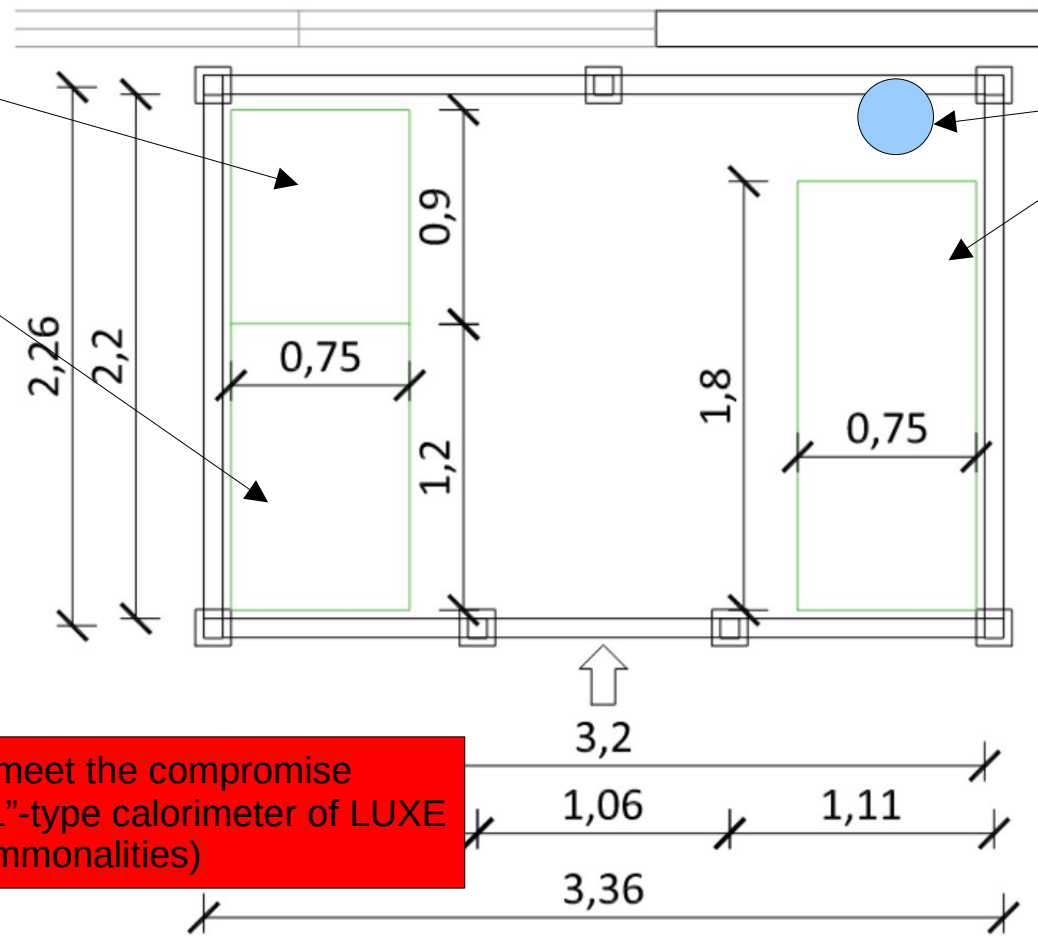
Tools acquired to meet the compromise of IFIC to glue the “FCAL”-type calorimeter of LUXE and the CALICE gluing R&D goals

Revisiting the gluing - tools at IFIC



Revisiting the gluing - tools at IFIC

- ▶ Gluing robot
 - + control
- ▶ Mixer and tooling for glue.
- ▶ Black box with cosmic stand
 - and/or small testbench



- ▶ Nitrogen cylinder
- ▶ Sensor probe station
 - Switch card+probe card
 - (see L. Diehl talk)
- ▶ Test bench

- ▶ Outside:
 - Dry cabinets
 - Curing cabinet
 - 2 tables/benches

Tools acquired to meet the compromise of IFIC to glue the "FCAL"-type calorimeter of LUXE (many commonalities)

Revisiting the gluing - tools at IFIC



Most material is
Ready or will arrive
In the coming weeks

Space for 2 operators

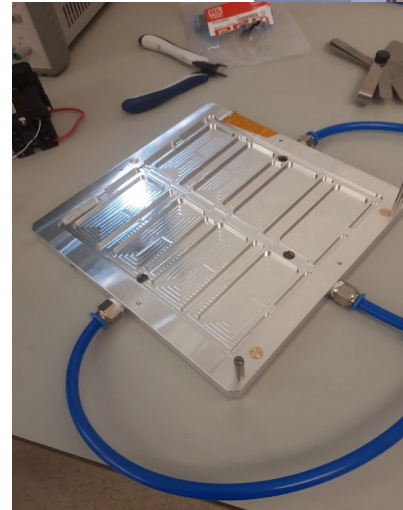
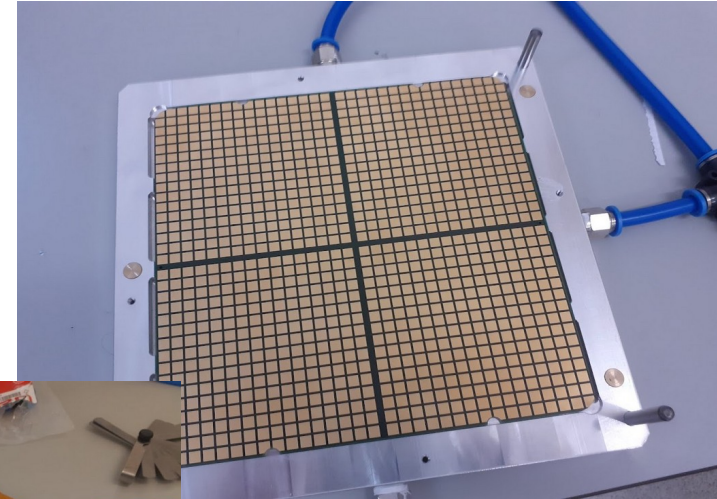


Most material is
Ready or will arrive
In the coming weeks

Space for 2 operators
Still in sketching phase



- ▶ Systematic metrology measurements have been performed at reception of the naked PCBs
 - FEV11,12,13, COBs
- ▶ After the assembly of components? Not always...
- ▶ Eventual deformations of PCBs were compensated by
 - Aspiration process to flatten the PCB during the gluing process
 - & large dot sizes to compensate for different distance of the PCB vs wafer
- ▶ Shall we remove the aspiration step?
- ▶ Shall we increase the threshold for acceptance of PCBs to be used for gluing?

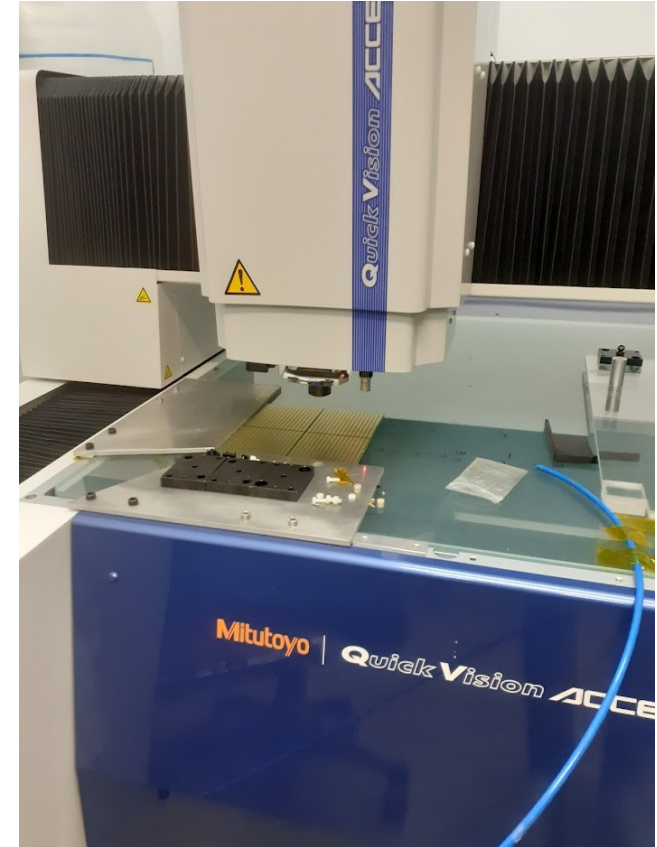


Examples of aspiration plates for PCBs (IFIC)

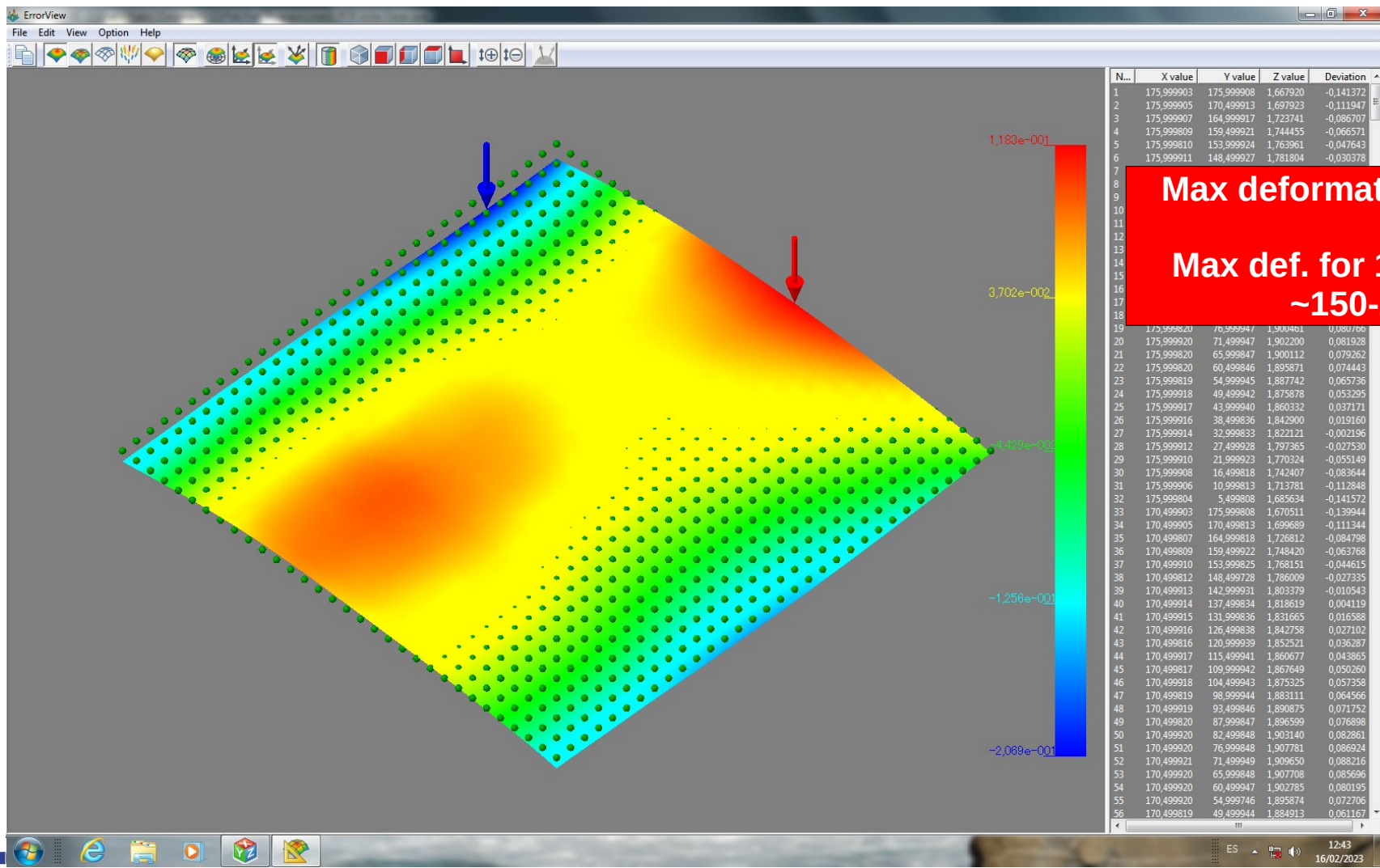
Similar plates/system were used by LPNHE

► Tool for z-axis characterization via optical focus

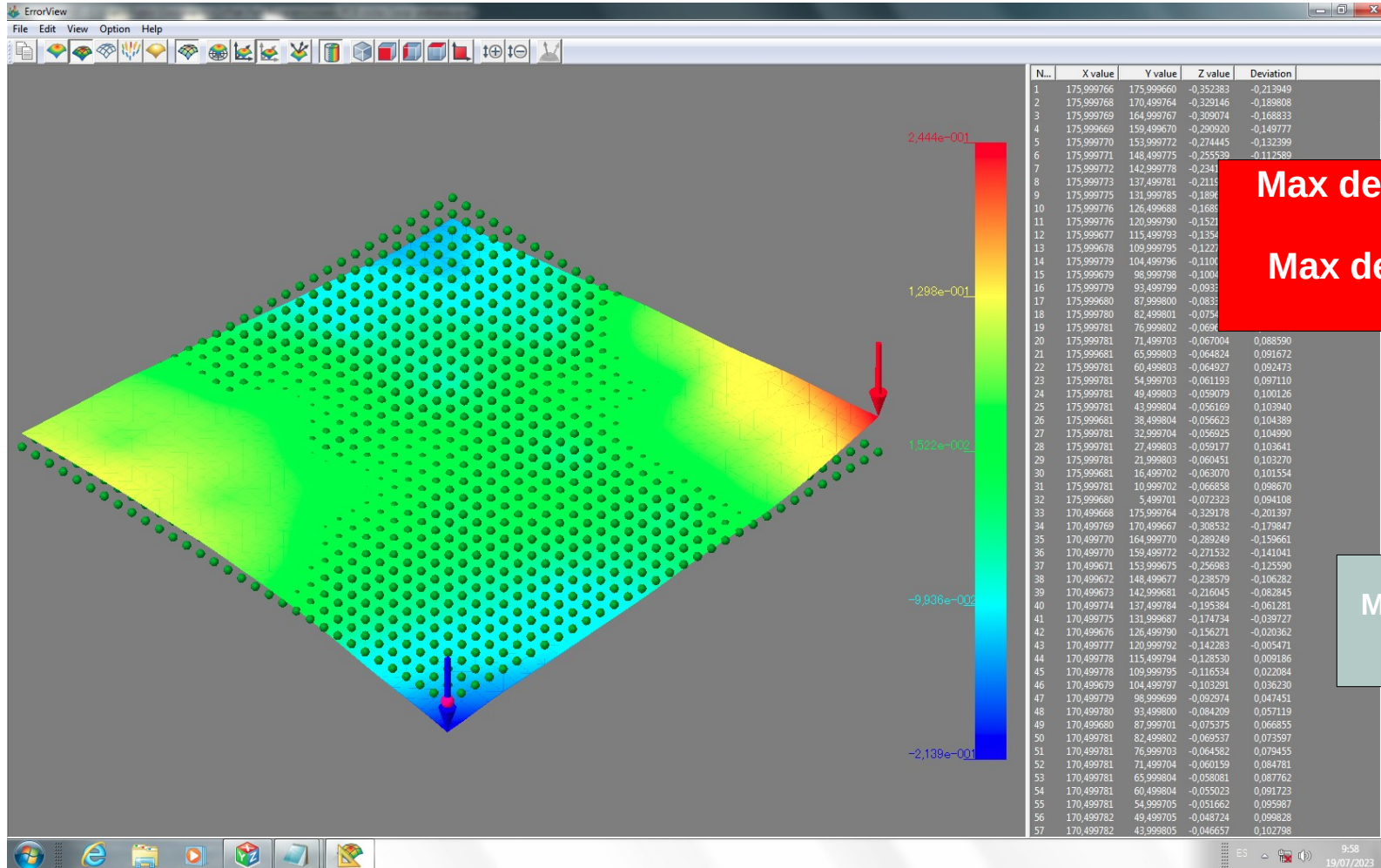
- Mitutoyo Quick Vision Accel, Modelo 808
- https://www.mitutoyo.com/webfoo/wp-content/uploads/2118_Quick_Vision.pdf



Naked FEV12 (old card)



New FEV2.1 with components



Max deformation of ~400um

Max def. for 1 wafer sector ~200um

Metrology before assembly:
Comparison to be done

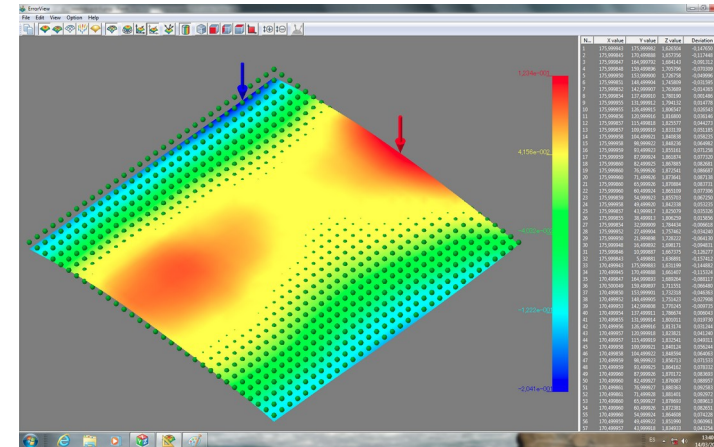
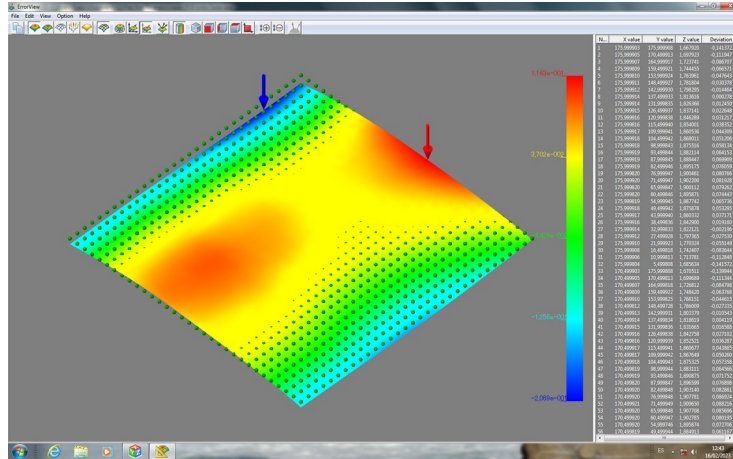
- ▶ (until last year) The final flatness requirement was given by the aspiration procedure
 - If it holds → it is candidate for gluing
- ▶ With such requirement
 - both cards would have been eligible for sensor gluing
- ▶ Are the conductive glue dots able to hold this mechanical stress?

- ▶ We should increase the threshold on planarity requirements for the PCB producer
- ▶ We should also study the optimization of the thermal process for the assembly
 - Peak temperatures of 200-280degrees
- ▶ Started discussions IFIC&IJCLAB with Rompal (spanish company) to study and optimize the thermal process during the assembly
 - Assembly companies as Rompal have several thermal programs (10-15 Rompal) depending on the type of PCB.
 - Test also the component assembly by external companies?
 - Examples in Spain: Rompal is a company for component assembly that usually works with/for PCB produced by Lab-Circuits (also spanish).

Deformations during the curing of glue?

Curing in oven (no mechanical stress due to aspiration)

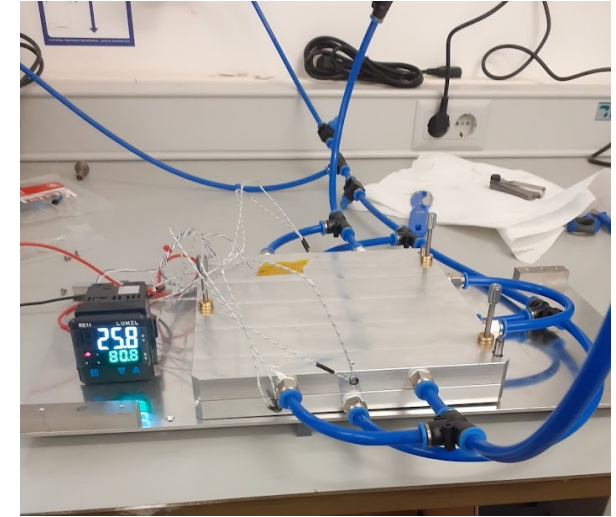
- ▶ The glue curing requires some temperature
 - Usually (for us) 40-80 degrees for 8-4h
- ▶ We did some tests in climatic chambers
 - Going to 80 and 100 degrees for several rounds of 12h
 - Also high humidity runs (80% at 30 degrees)
 - **No differences observed**



Deformations during the curing of glue?

Curing in aspiration plate

- ▶ The glue curing requires some temperature
 - Usually (for us) 40-80 degrees for 8-4h
- ▶ The temperature is applied via resistors in the aspiration plate
 - Point-like heat sources
 - Controlled with PID.
 - Mechanical stress during the heat.
 - Quick ramps
- ▶ **Important deformation observed**
 - Unfortunately, no metrologies available before and after...





Testing different glues

▶ EJ2189

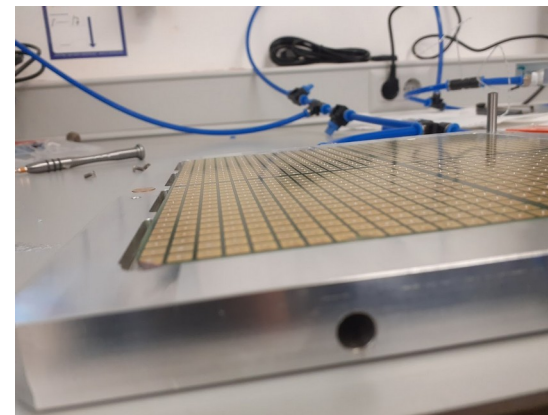
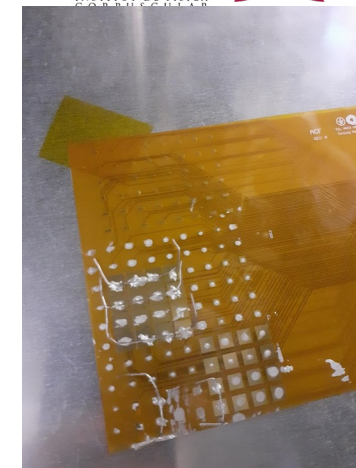
- Glue used since 2015
- Room temperature curing
- Lifetime of 2-3h
- It seems better for stencil application than dot

▶ H20E

- Recommended by vendors and other HEP projects
- Higher temperature curing (but 80degrees)
- 3 days lifetime
- Easy mix and better viscosity for dot deposit and/or stencil

▶ E4410

- Old glue, not used anymore.
- Similar to EJ2189.

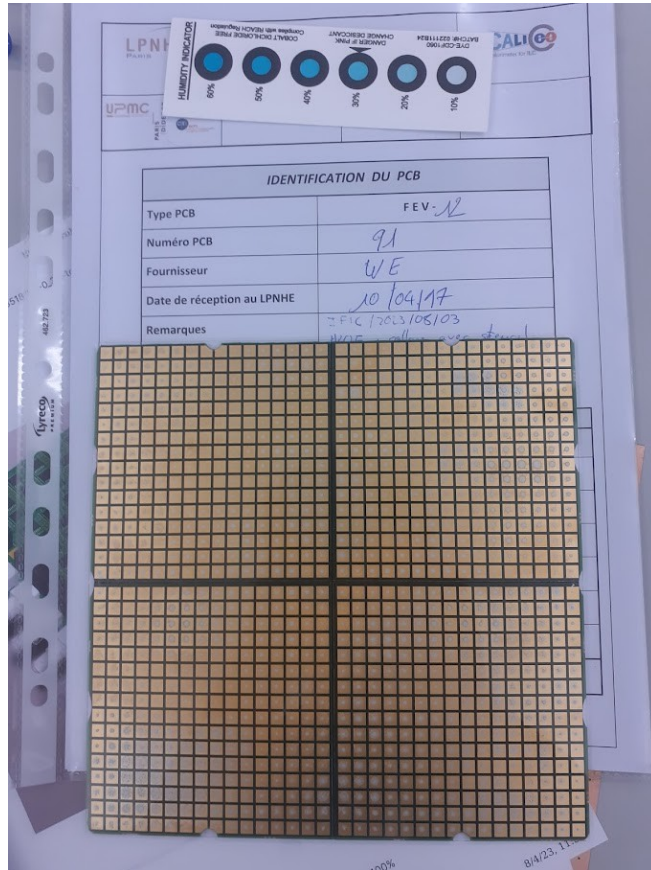


Testing different glues

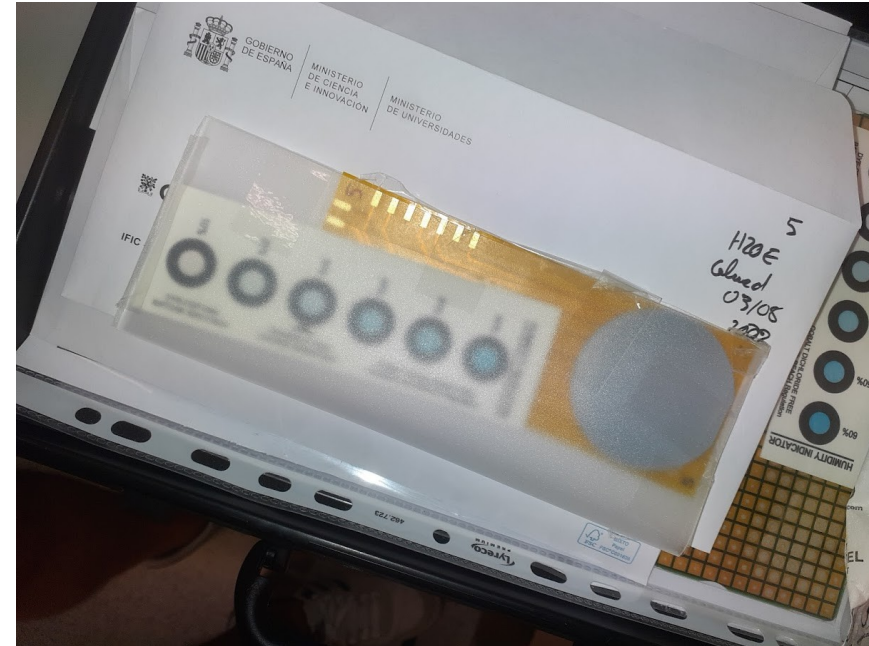


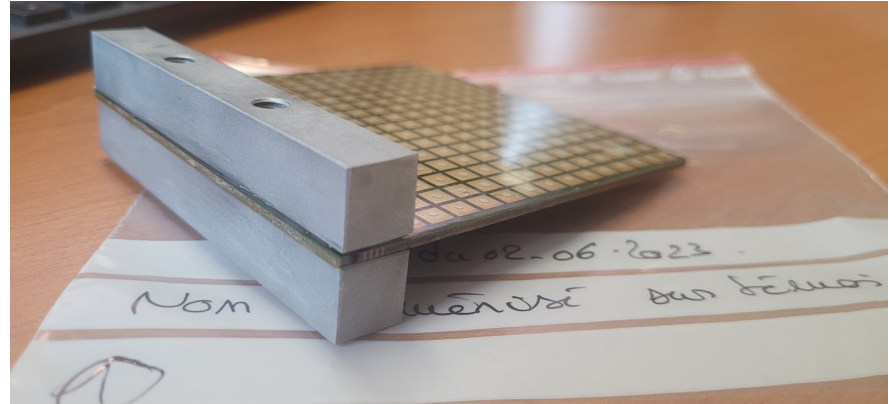
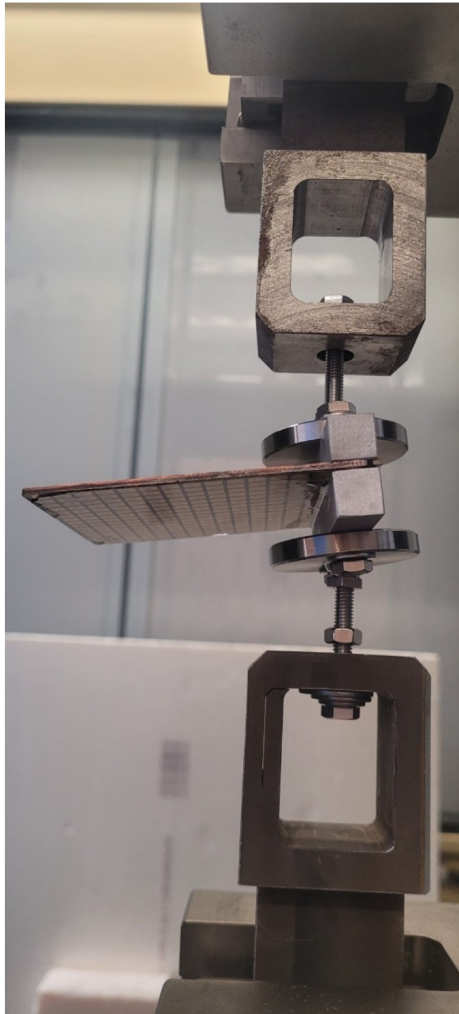
- ▶ Still in the beginning of the learning phase
 - Using ad-hoc tools (syringes, stencils) to understand the glue behaviour
- ▶ First lessons...
 - the H20E is the easier to handle
 - The E4410 shows important degradation in conductivity with time (~40% of the dots double the resistivity in one month)
- ▶ Still many open questions:
 - Optimal curing time? Curing temperature?

Tests with fake Wafers



► Batch of fake wafers sent to IJCLab for mechanical pull tests

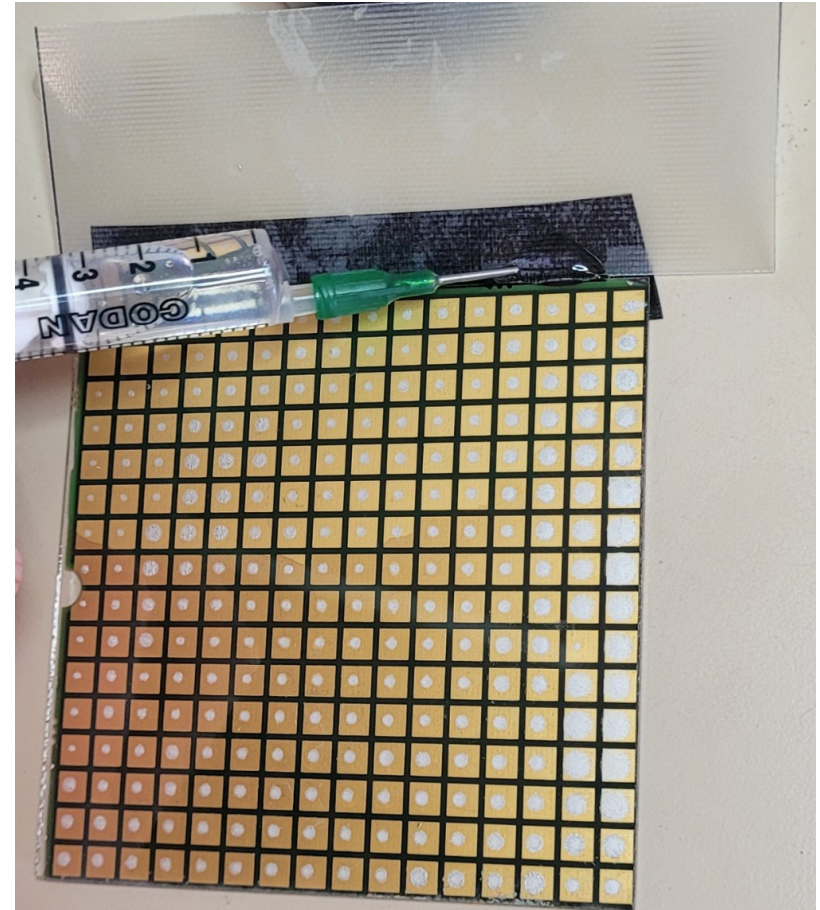
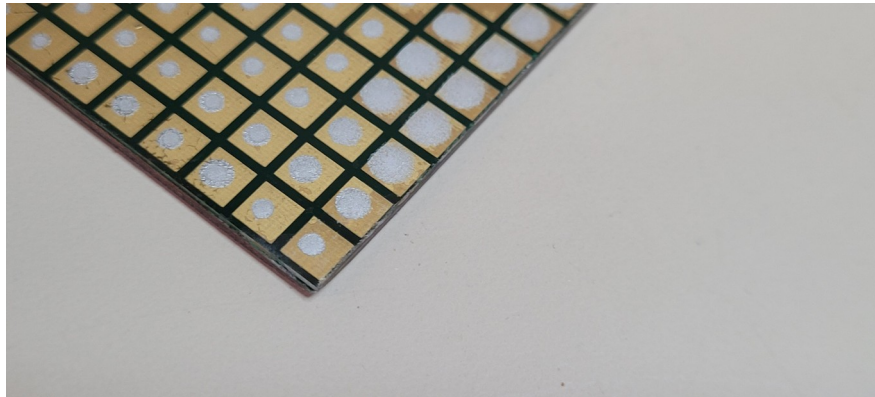




- ▶ Work in progress at IJCLab
- ▶ The FEVs are cutted in 4 (4 fake wafers)
 - It has been cut with a manual precision grinder.
- ▶ Planification of pull tests
 - for different glues
 - Curing times
 - Etc.

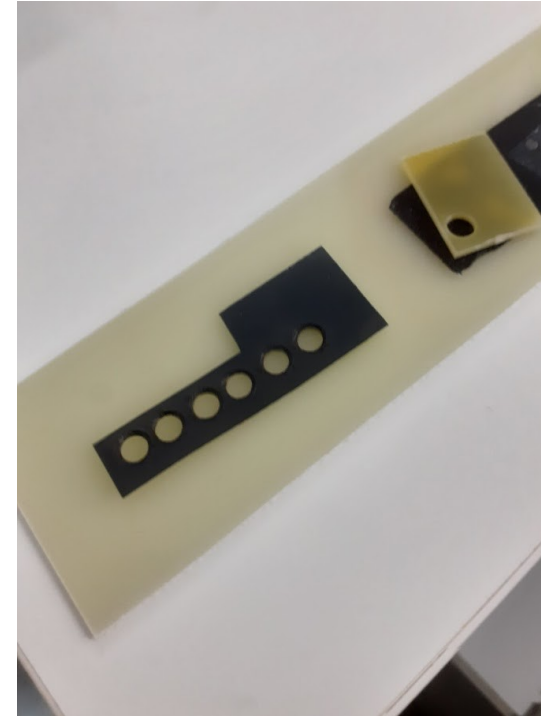
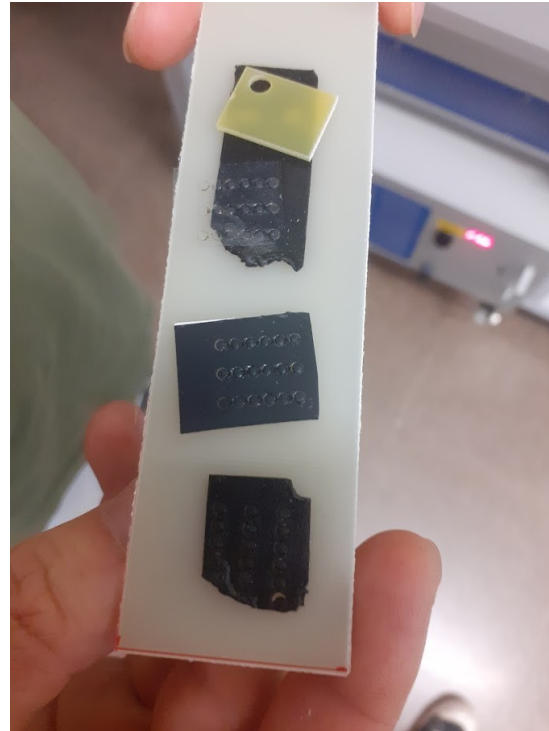
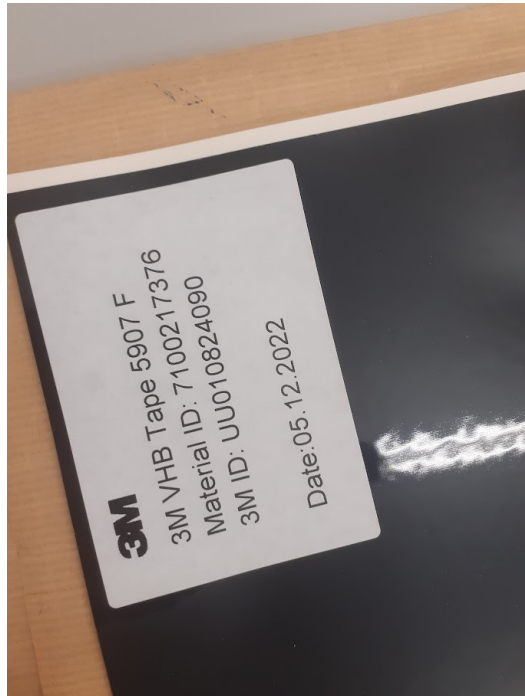
Harder glues? Underfill approach

- ▶ In IJCLab: a proposal to use an underfill
 - EPO-TEK 301-2FL
 - It expands by capilarity filling the full area
 - Requires a second curing process
- ▶ Work in progress
 - (first pull tests ongoing)

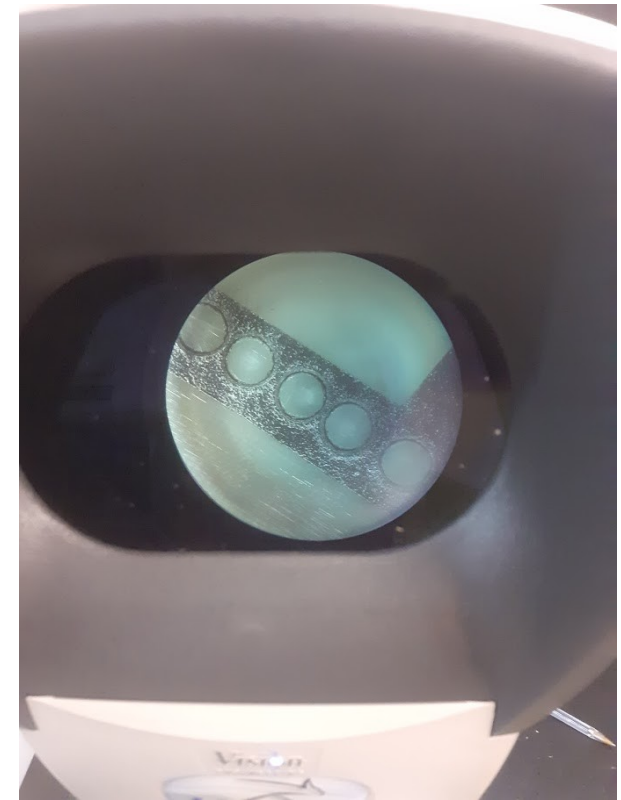


Testing the double tape approach

- ▶ Another approach is to use double tape
 - Dirk managed to get a sample of 150um which is perfectly okay for CALICE



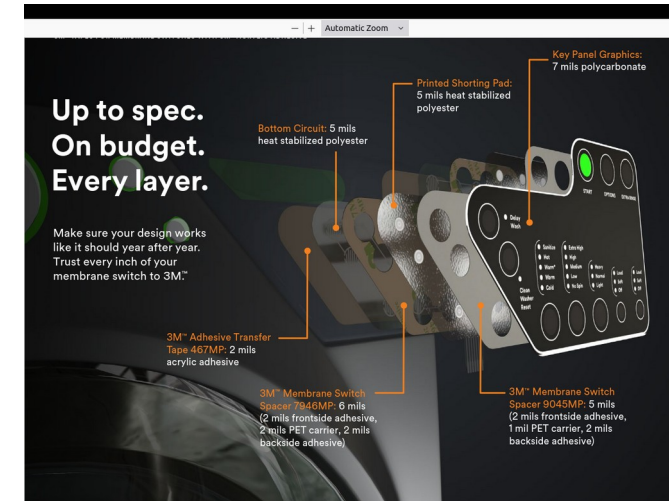
Testing the double tape approach



Testing the double tape approach

- ▶ As we speak
 - Stencil design ~~in process~~ finished (with holes of 3mm diameter)
 - Production will, hopefully, happen ~~before CALICE meeting~~ next week

- ▶ Questions (for underfill too)
 - What are the electrical properties of these solutions ?
- ▶ Discussions with 3M searching for alternative solutions



Summary & prospects

- ▶ Lots of preparation work... More to do.
- ▶ Gluing expertise need to be re-acquired by the SiW-ECAL group
 - Optimizations to be done, following previous experience and new ideas/tools
- ▶ Flat PCBs... still an issue to be understood
- ▶ Interesting alternatives in the industry

- ▶ More person power is crucial.

