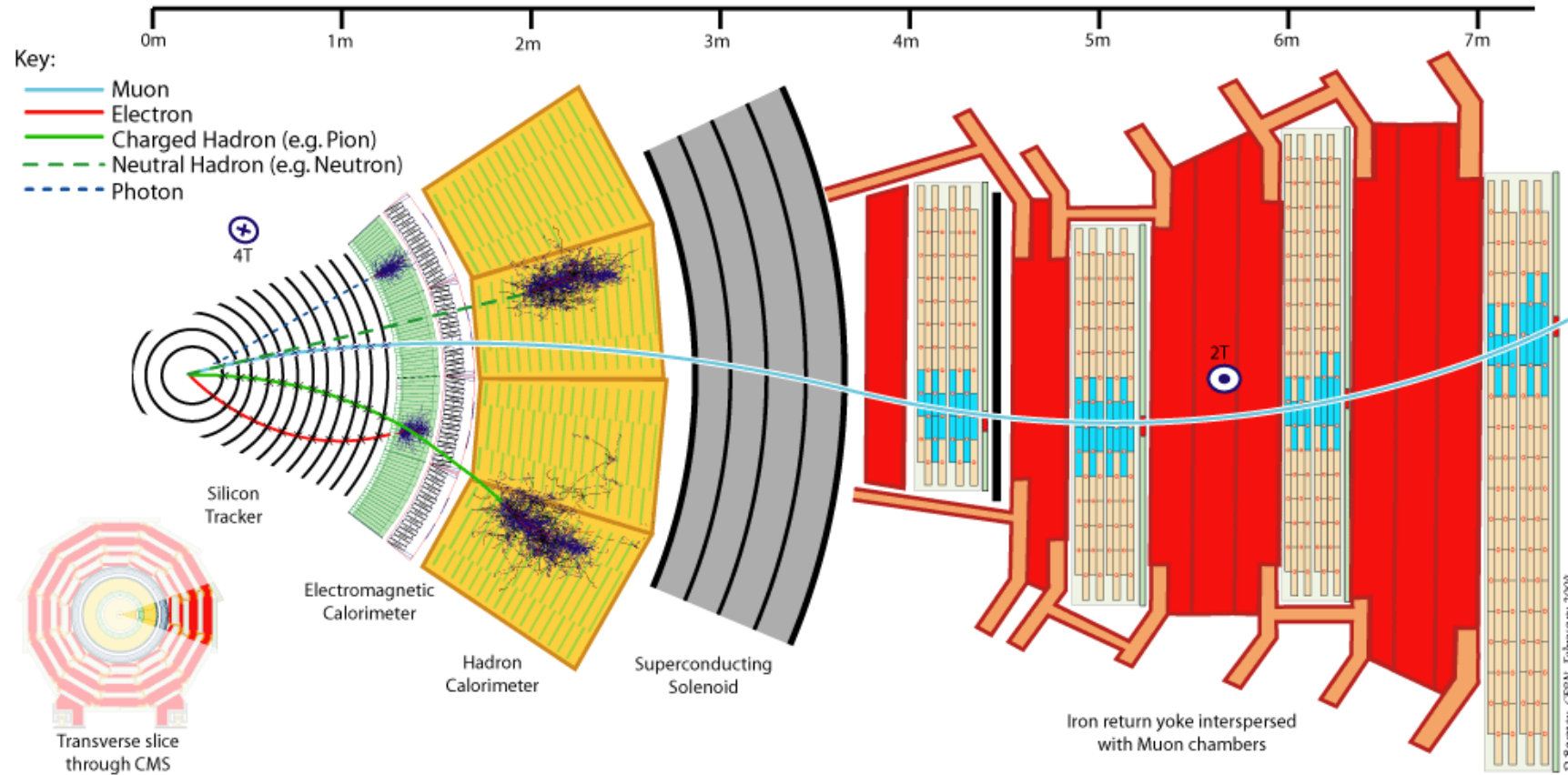


RBI team experience with Phase 2 digital module assembly

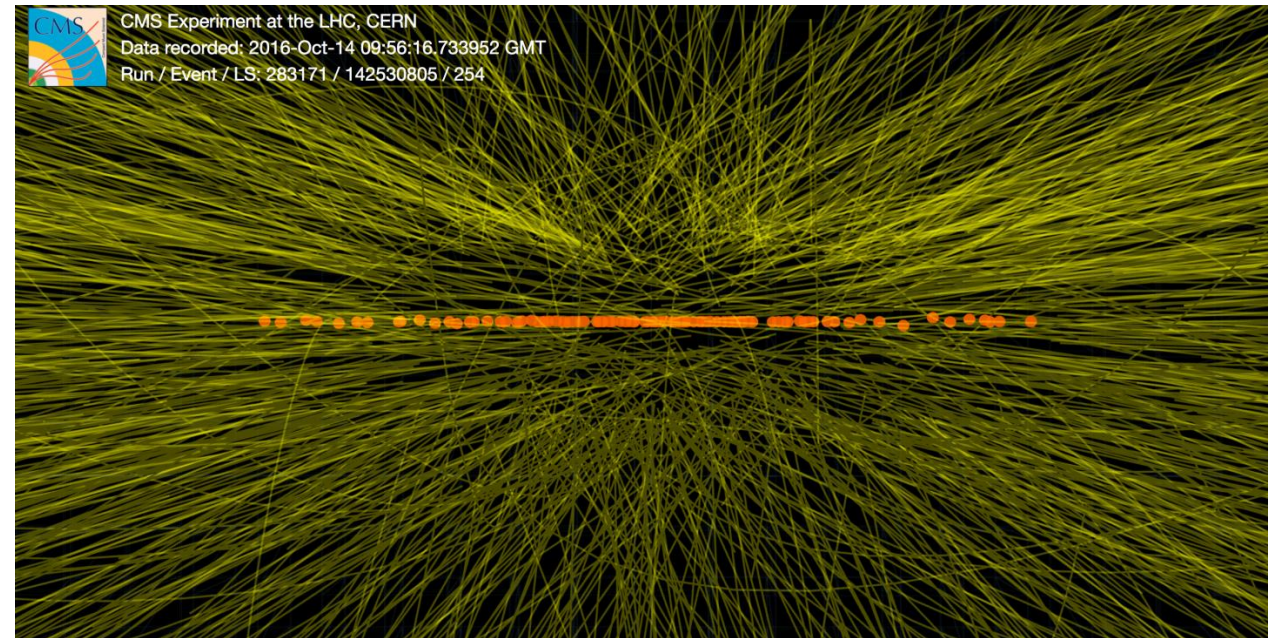
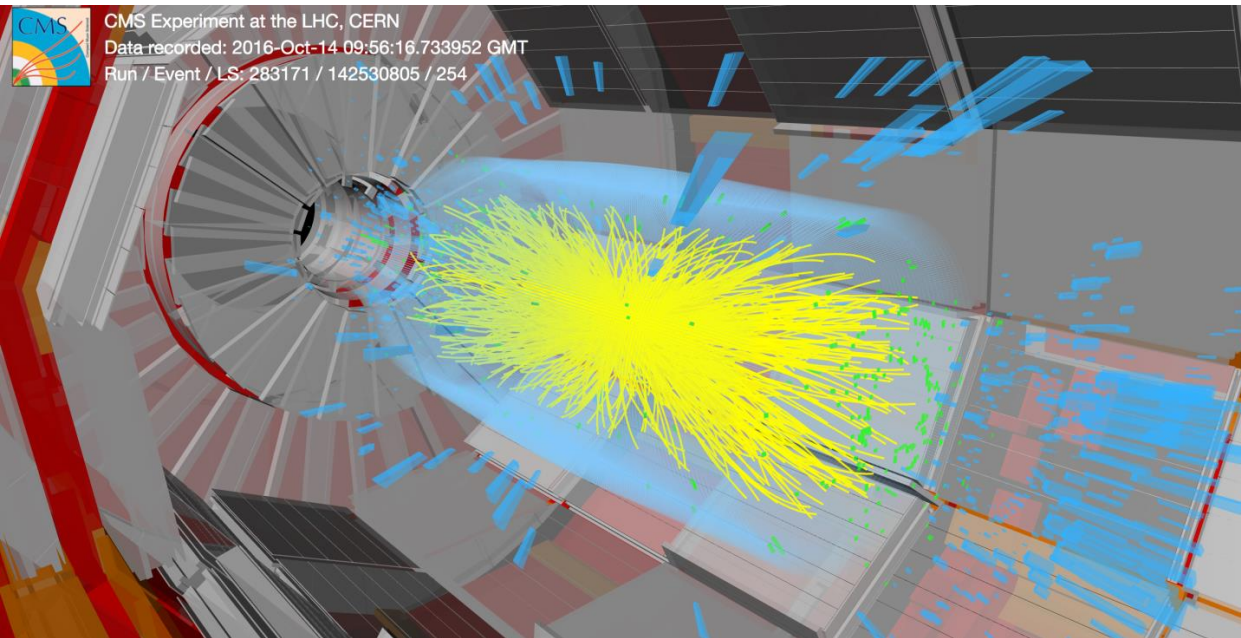
Matej Roguljić

Compact Muon Solenoid - CMS

- The Large Hadron Collider (LHC) is the world's largest and most powerful particle accelerator
- CMS is one of the four large detectors at LHC
- Collects data from high-energy pp collisions
- Subdetectors: **inner tracker**, outer tracker, ECAL, HCAL, Magnet, Muon Chambers

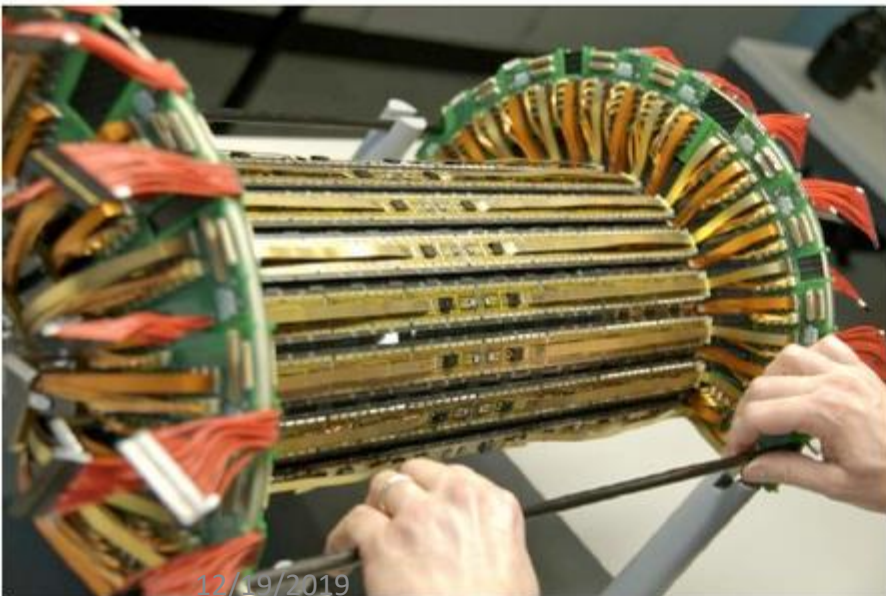


Track reconstruction at CMS

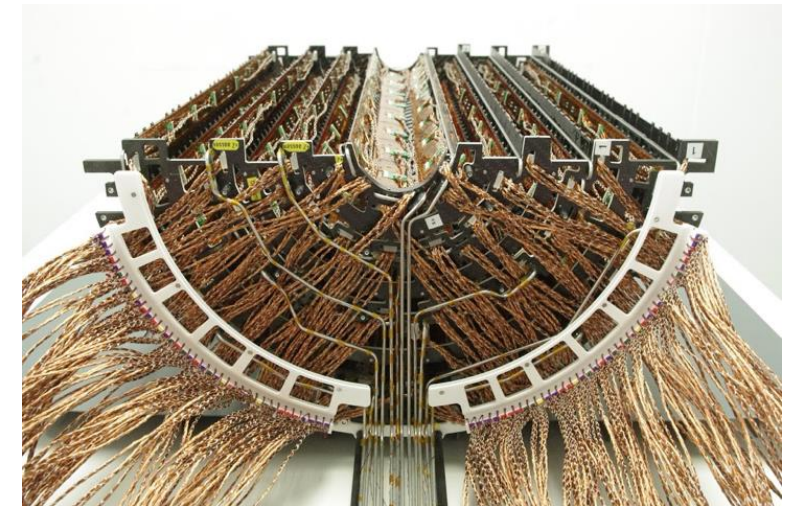
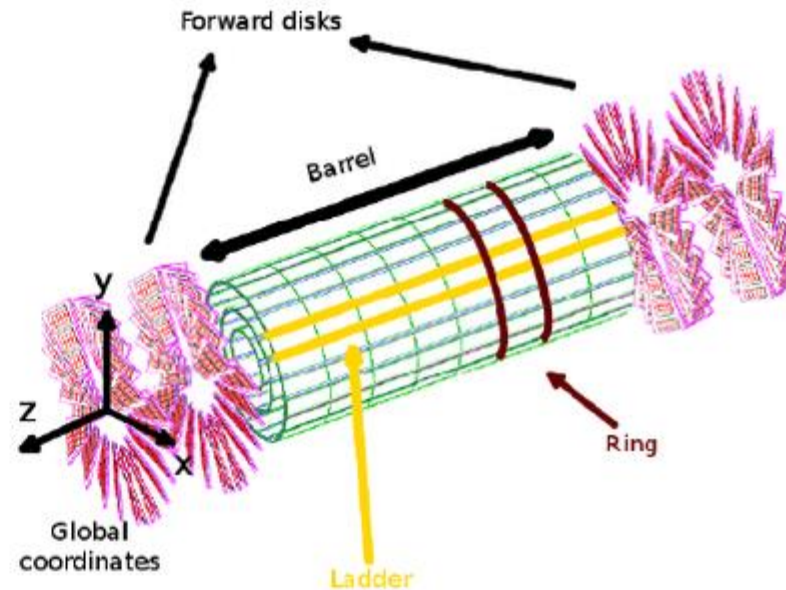


Inner tracker (pixel detector)

- Innermost subdetector
 - 125 million pixels
 - Crucial for track and vertex reconstruction
 - Harsh radiation conditions
- Made out of modules
 - 65000 pixels per module



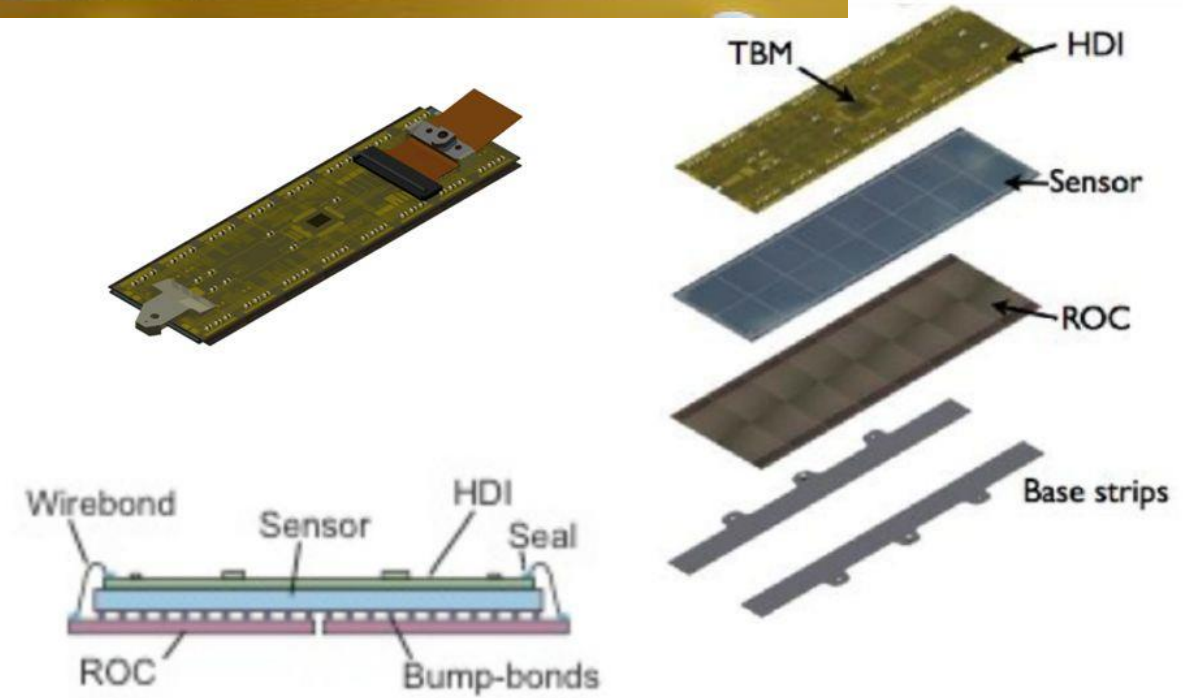
12/19/2019



Pixel detector module

- Sensor
 - Charge induced in it with the passage of a charged particle
 - Pixelated
 - Connected with bump-bonds to ROCs
- Readout chips (ROCs)
 - Collects hits from sensor
- High-density Interconnect
 - Connected to ROCs via wire-bonds
 - Collects signals from ROCs
 - Sends output to DAQ
- Assembly procedure:
 - Sensor bump-bonded to ROCs
 - HDI glued to sensor
 - HDI wire-bonded to ROCs
 - Protection cap glued to HDI

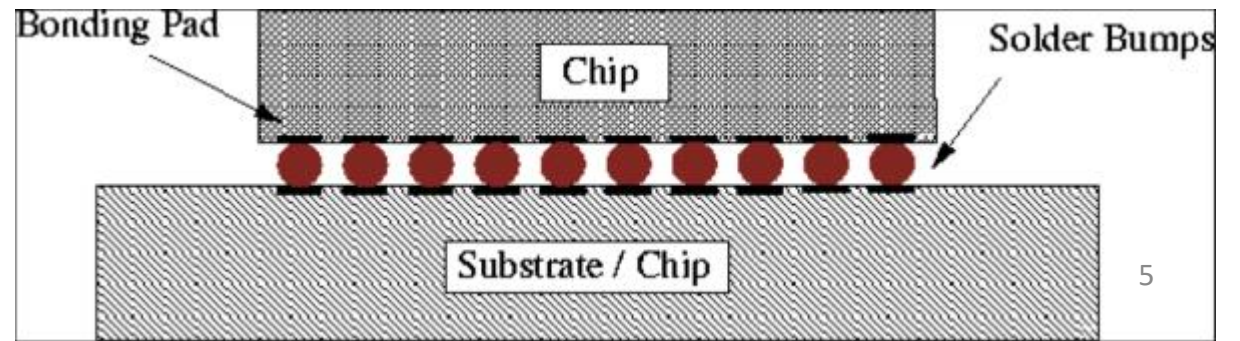
12/19/2019



Conett Huerta-E., [Jun 10, 2014]

An Overview of the FPIX Detector Upgrade – CMS Experiment

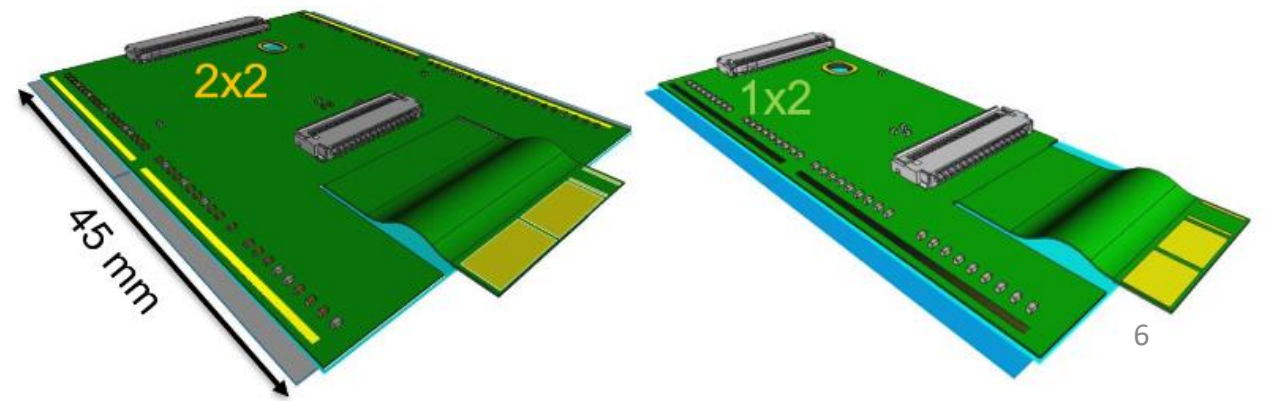
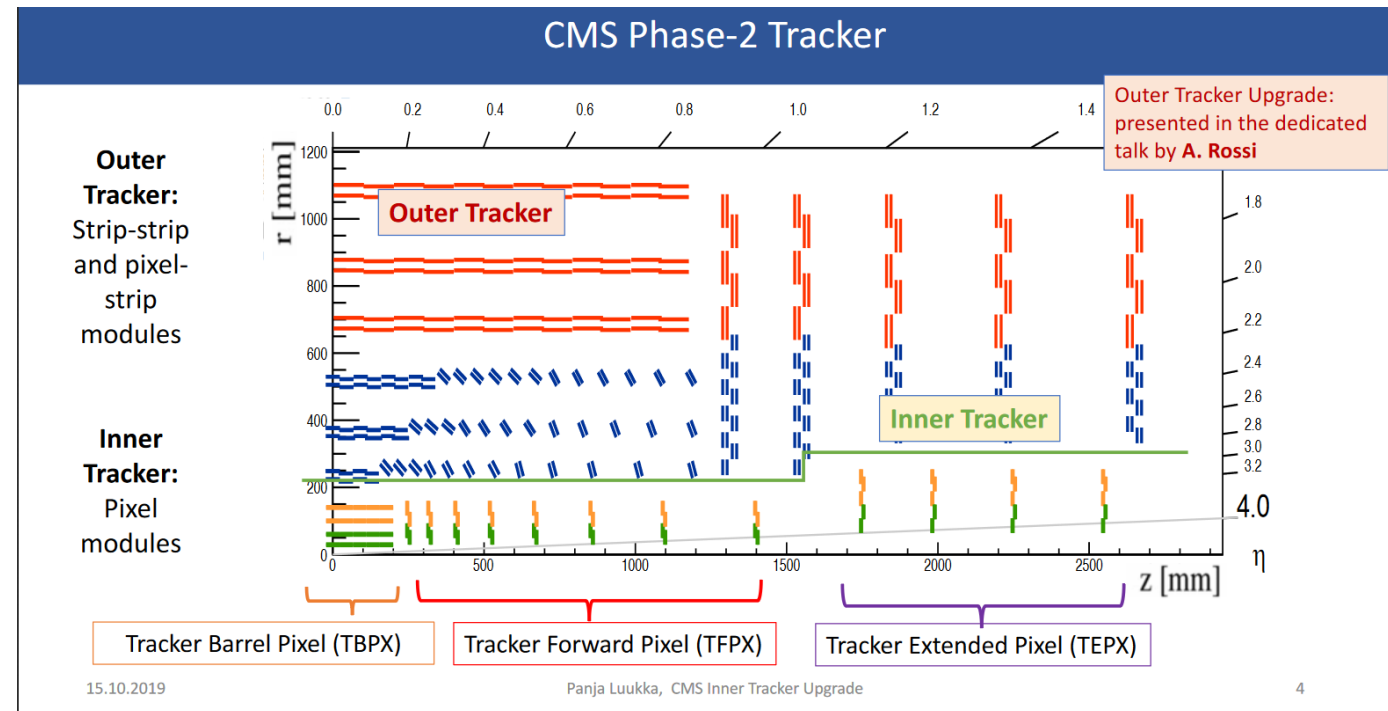
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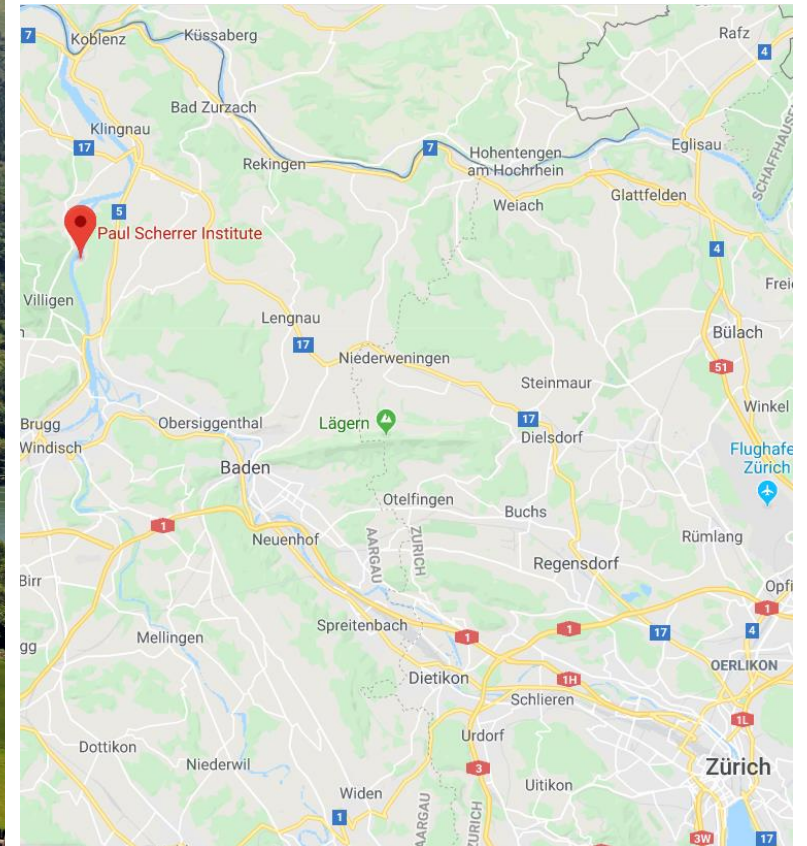
5

Phase 2 upgrade of the detector

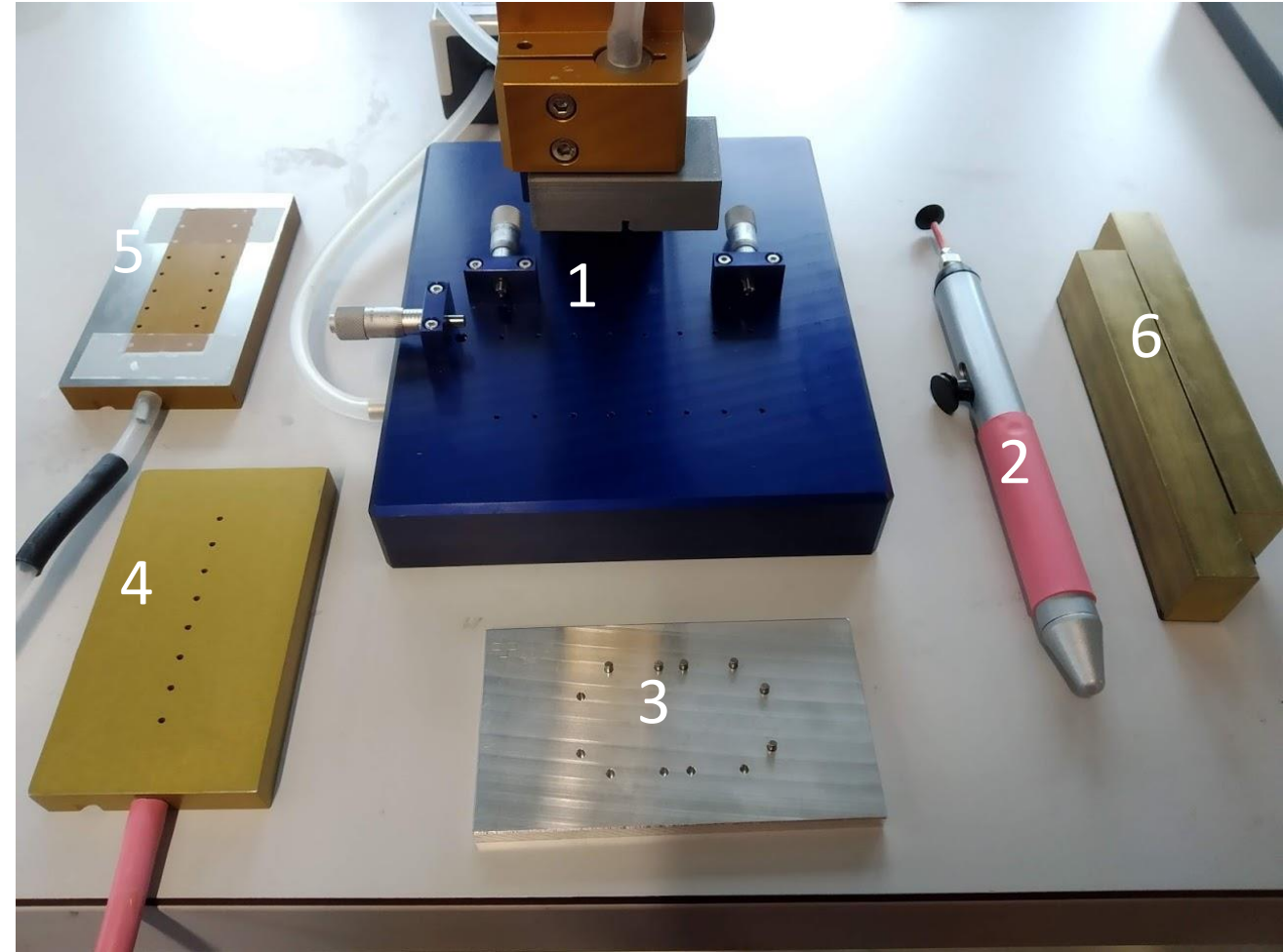
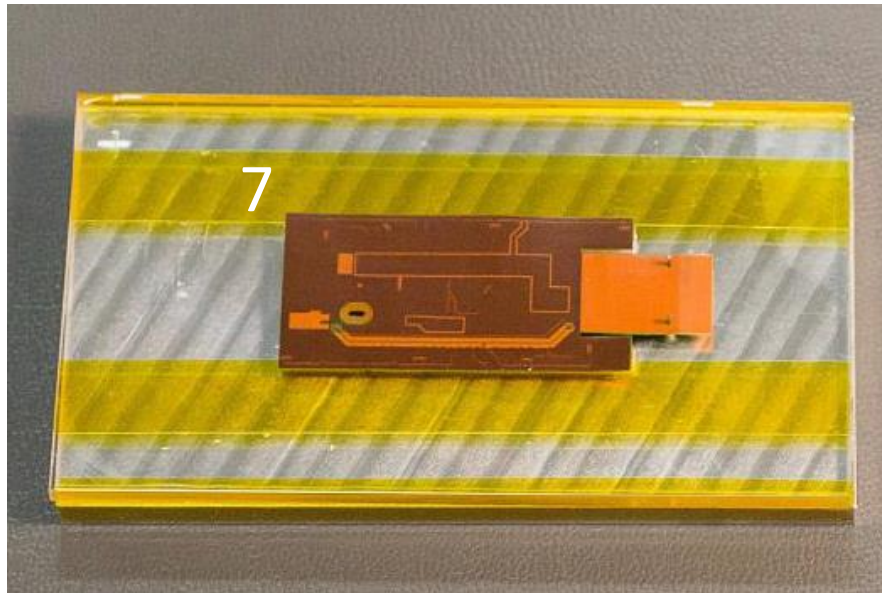
- High-Luminosity Large Hadron Collider upgrade - > 10x higher luminosity
- More radiation hard
 - 500 to 1000 Mrad
- Higher occupancy
 - Smaller pixels
 - $25\mu\text{m} \times 100\mu\text{m}$
 - $50\mu\text{m} \times 50\mu\text{m}$
 - Higher bandwidth



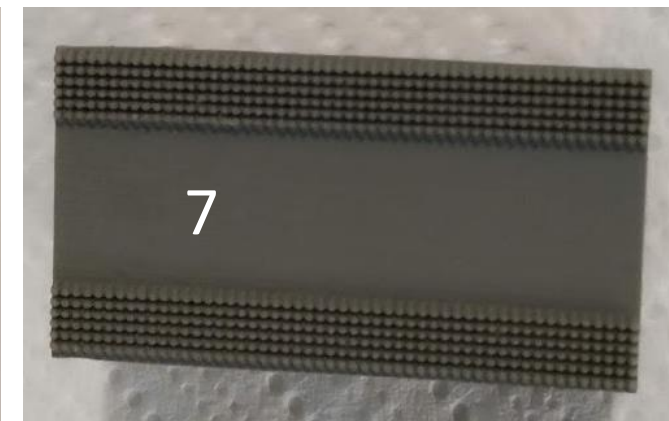
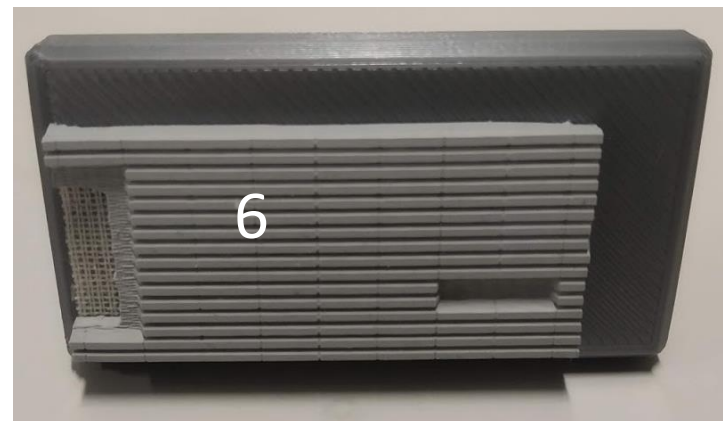
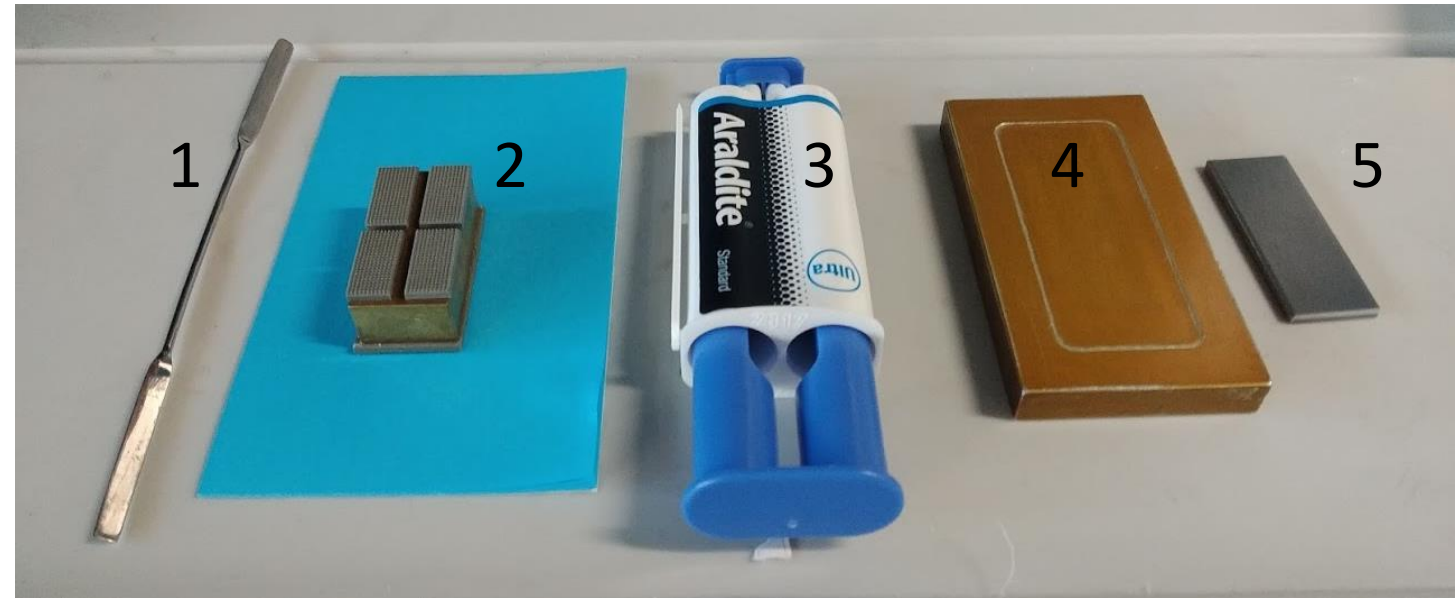
- Getting experience assembling a Phase 2 digital TBPX module with a dummy silicon sensor mechanically emulating bare module
- The procedure consists of gluing the sensor to the ROCs (no bump bonding) and gluing the HDI to the other side of the sensor
- Wire bonding the ROCs to the HDI is the final step
- Learning digital module test procedures



- 1) Phase 1 lift with micrometer screws, equipped with a vacuum head for holding ROCs
- 2) Chip pick-up tool
- 3) Chip alignment jig
- 4) Vacuum chuck to hold the alignment template
- 5) Vacuum chuck for the sensor
- 6) Metal weights
- 7) HDI holder

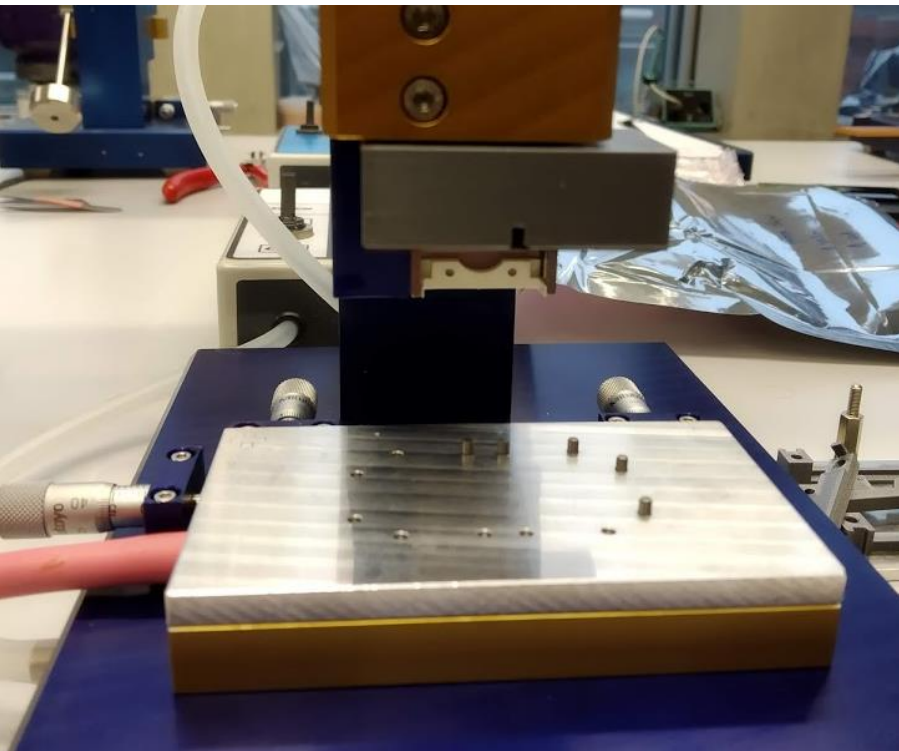


- 1) Stick for mixing glue
- 2) Glue applicator
- 3) Two-component Araldite Glue
- 4) Glue bath
- 5) Glue flattener
- 6) TBPX glue applicator (usable with the lift)
- 7) TEPX version glue applicator (manual)

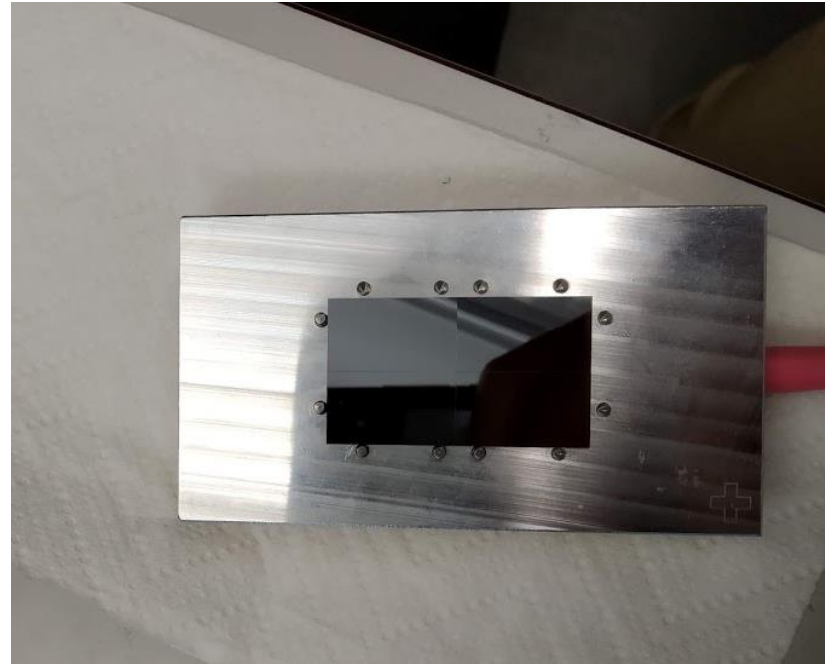


ROCs positioning

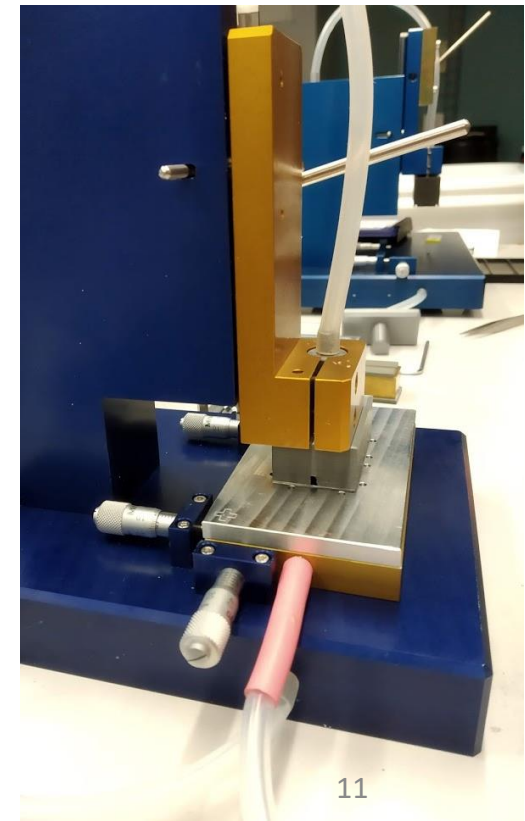
1. Adjust the micrometer screws so that the lift head nicely fits inside the alignment jig pins



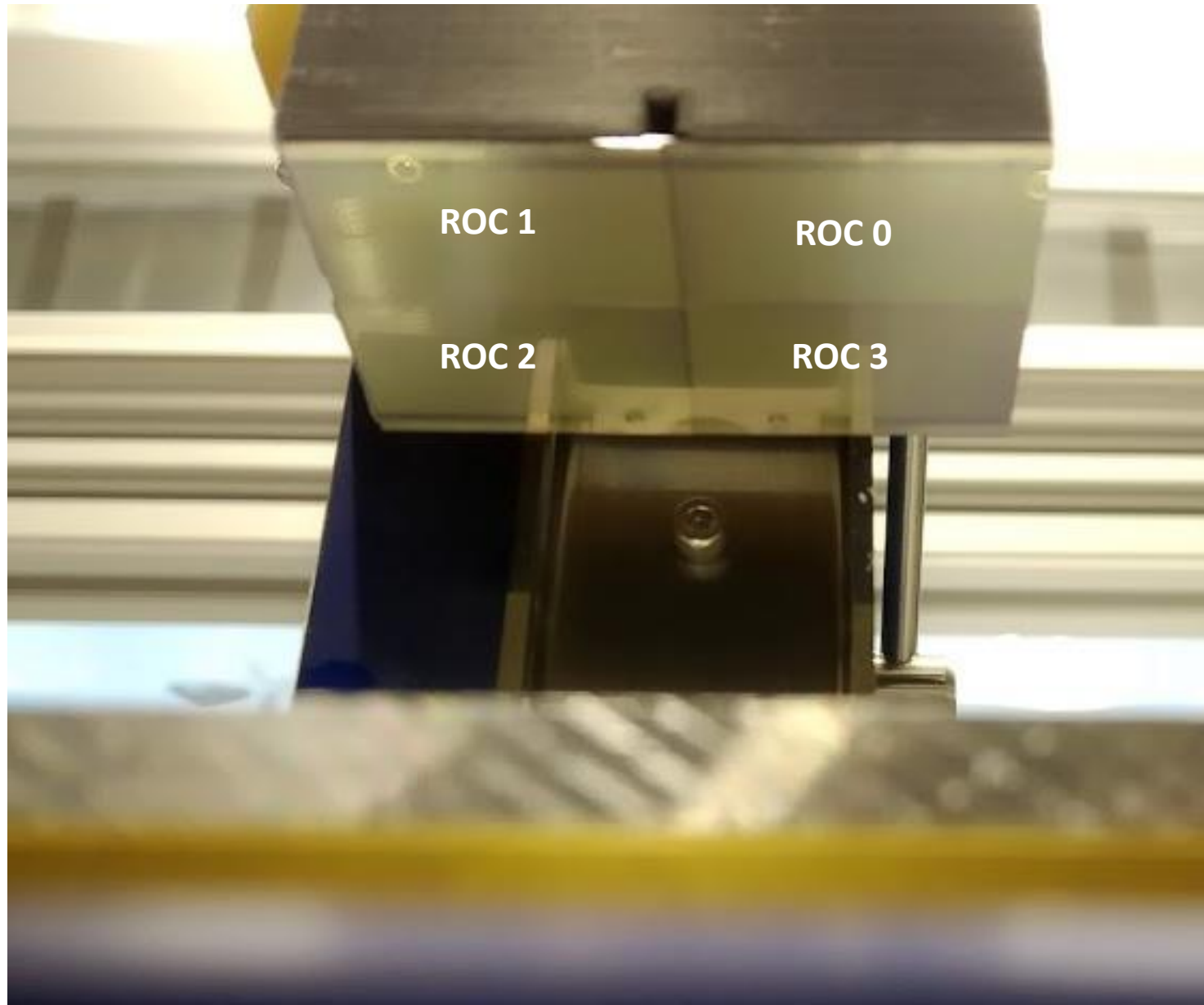
2. Arrange the ROCs on the alignment jig using the pins
 - ROCs should be face down, periphery on the outside



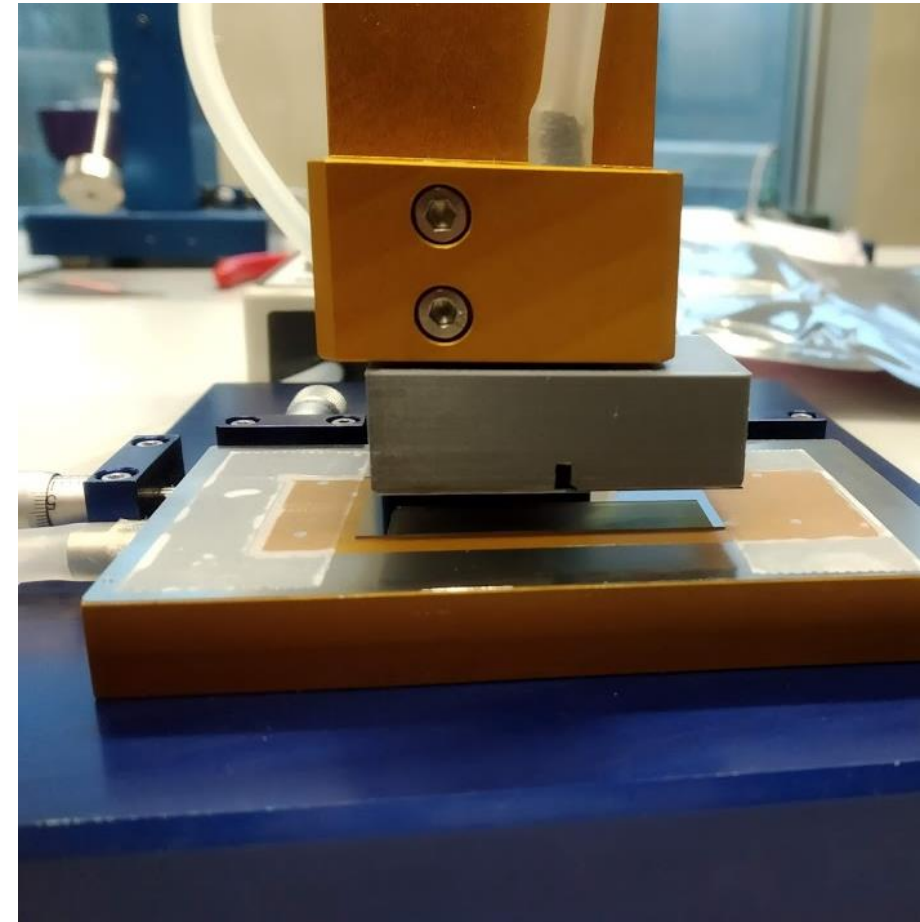
3. Place the jig on the base plate of the lift, turn on the base plate vacuum, lower the lift head and turn on the head vacuum



ROCs held by the lift head

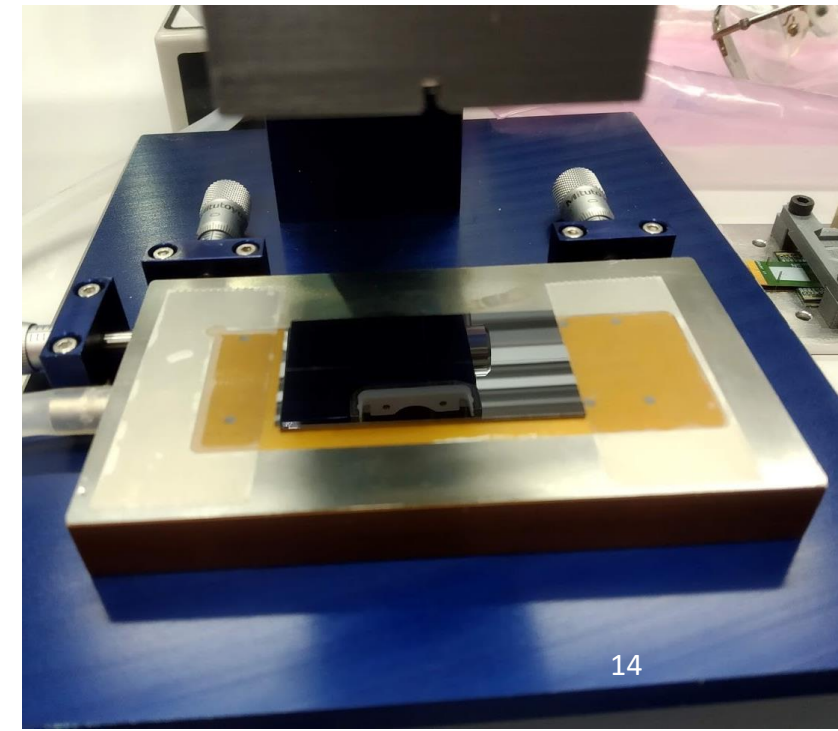
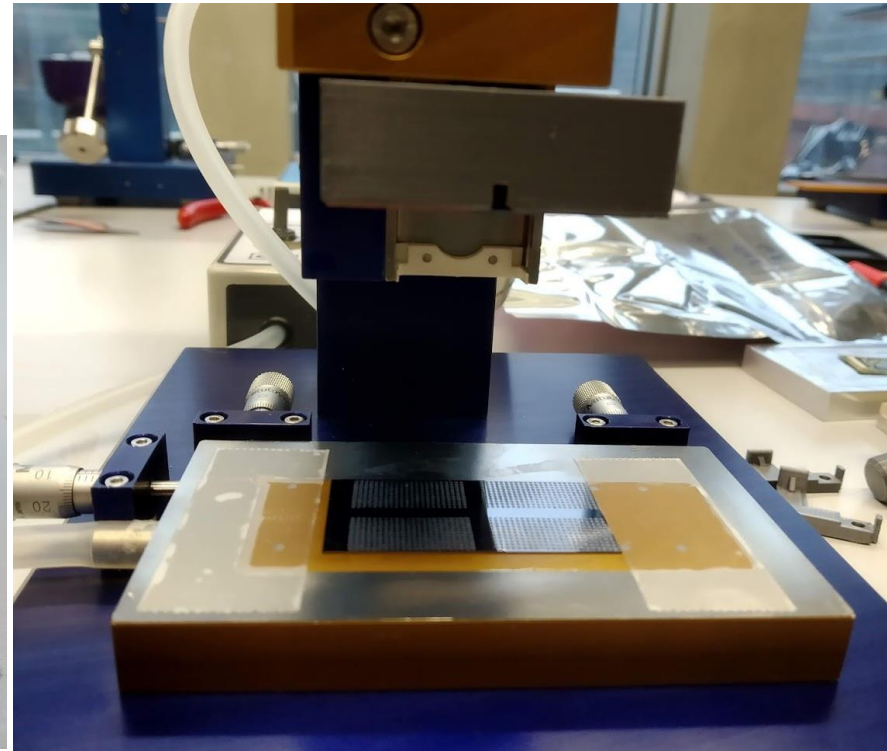
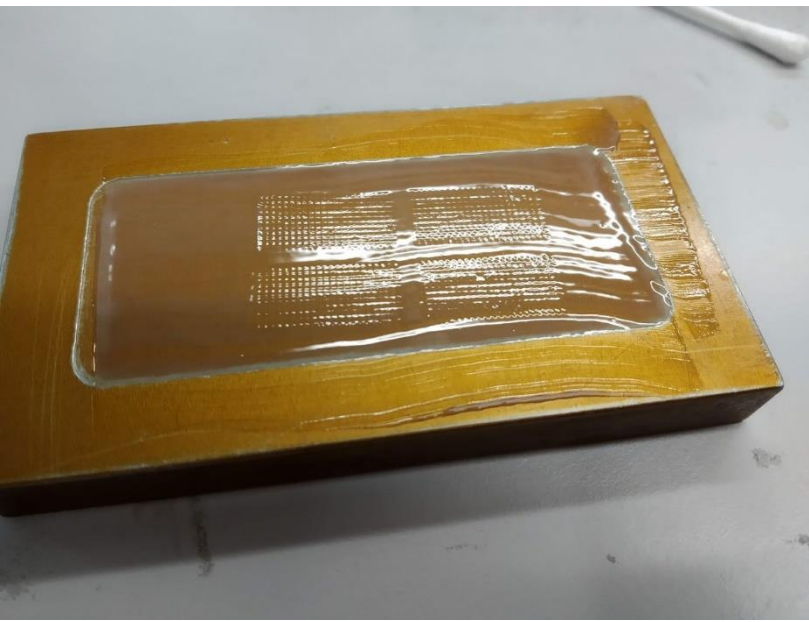


- Use Phase 1 chuck with manual alignment
- X alignment: the shorter edge of the sensor coincides with ROC0 and ROC3
- Y alignment: the ROCs extend over the both long sides evenly
- The alignment was done with micrometer screws manually



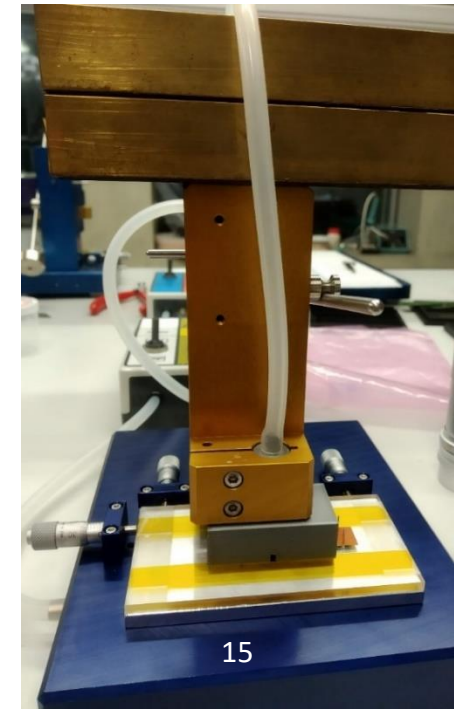
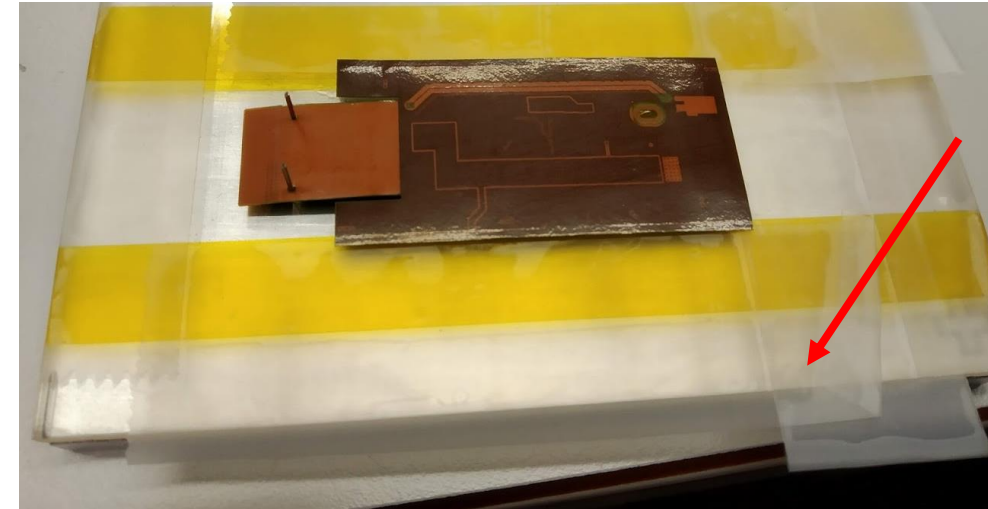
Gluing dummy sensor to ROCs

1. Two components of Araldite glue mixed and transferred to the glue bath
2. Excess glue removed with a piece of plastic
3. Glue applicator pressed into glue
4. Glue applied to sensor
 - This is also done by hand!
5. The chuck holding the sensor is put back on the lift base plate and the head holding the ROCs lowered to glue them to the sensor
6. Vacuum holding the ROCs to the head is then turned off and weights placed on it
7. Left for 6 hours for glue to dry
8. Visually inspected and picked up by the vacuum head again



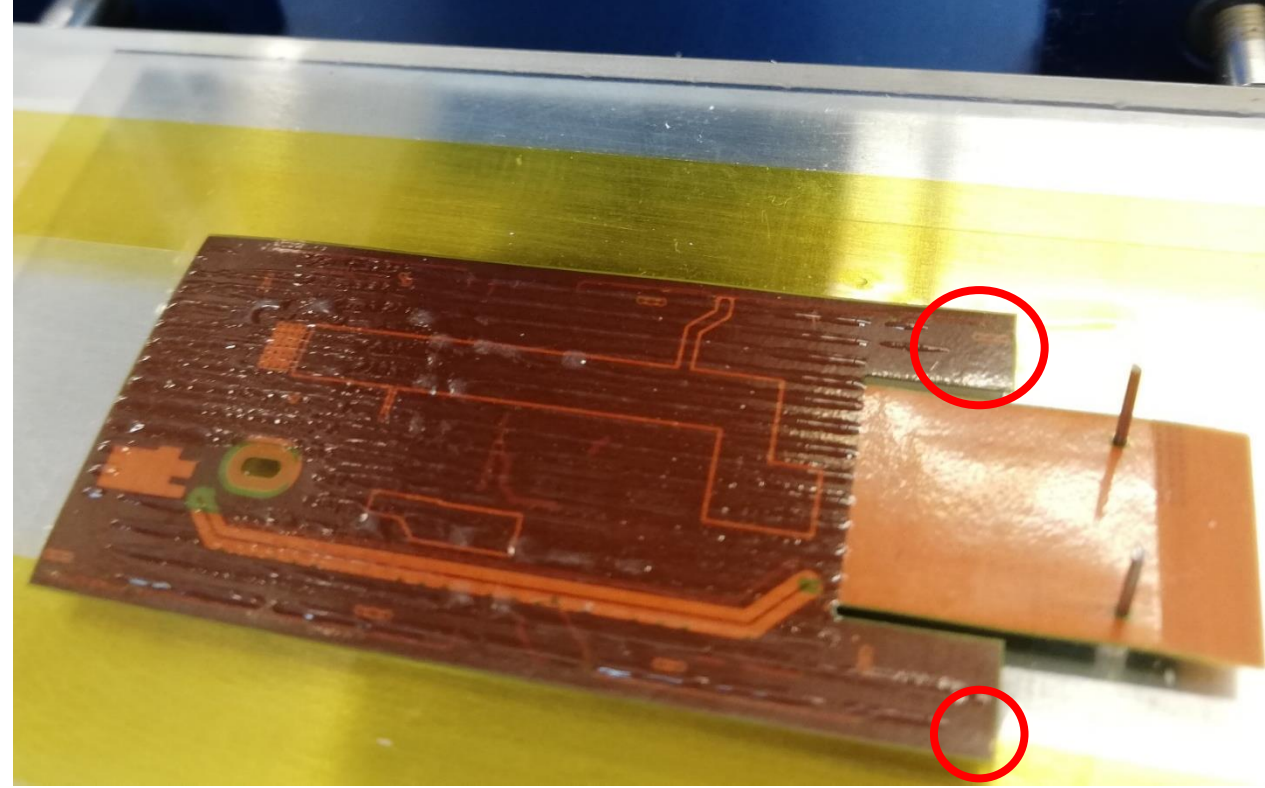
Gluing HDI to bare module

1. HDI is put on an HDI holder
 - Tape put around edges of HDI to prevent glue leak on HDI holder
2. Holder is placed on the lift base plate, micrometer screws adjusted
 - HDI is properly placed with respect to the ROCs
3. Glue is prepared, transferred to glue bath and excess removed
4. Glue application to HDI:
 - Using the TBPX applicator designed by ETHZ and described [here](#)
 - Using the TEPX applicator designed by PSI
5. HDI placed back on the lift baseplate
6. Head holding the ROCs and the sensor is lowered
7. Weight is placed on top of the lift for better contact

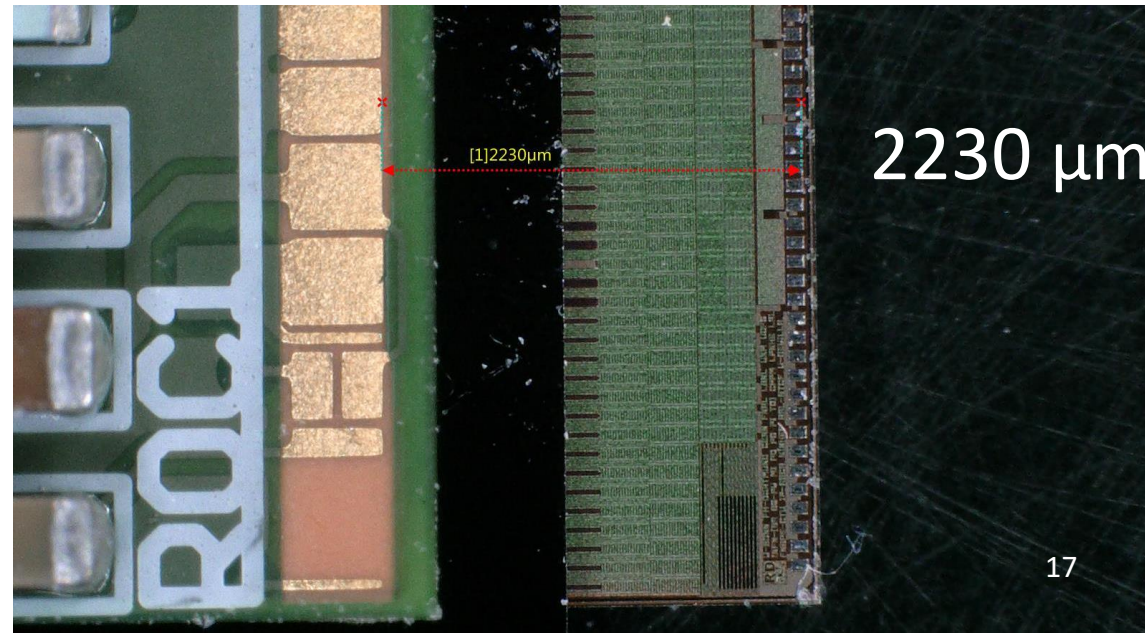
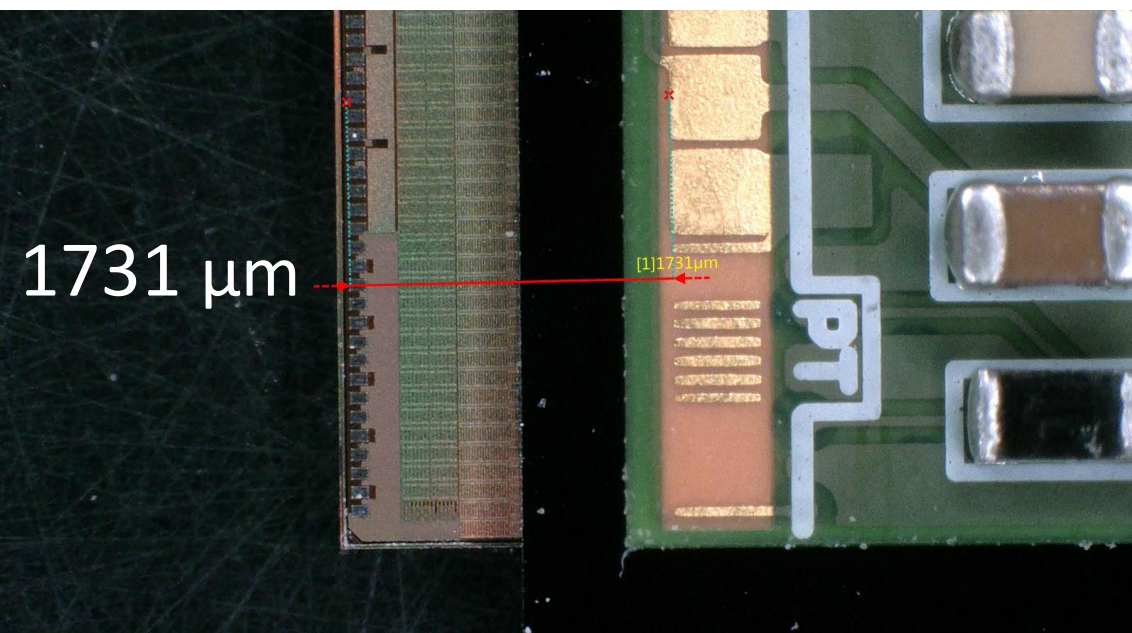
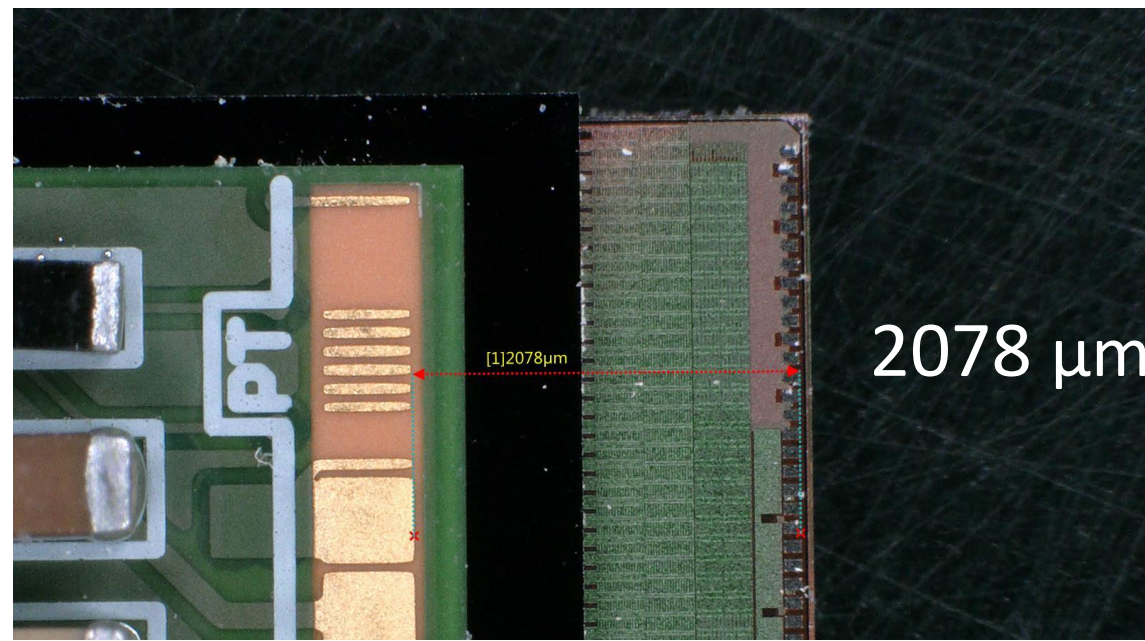
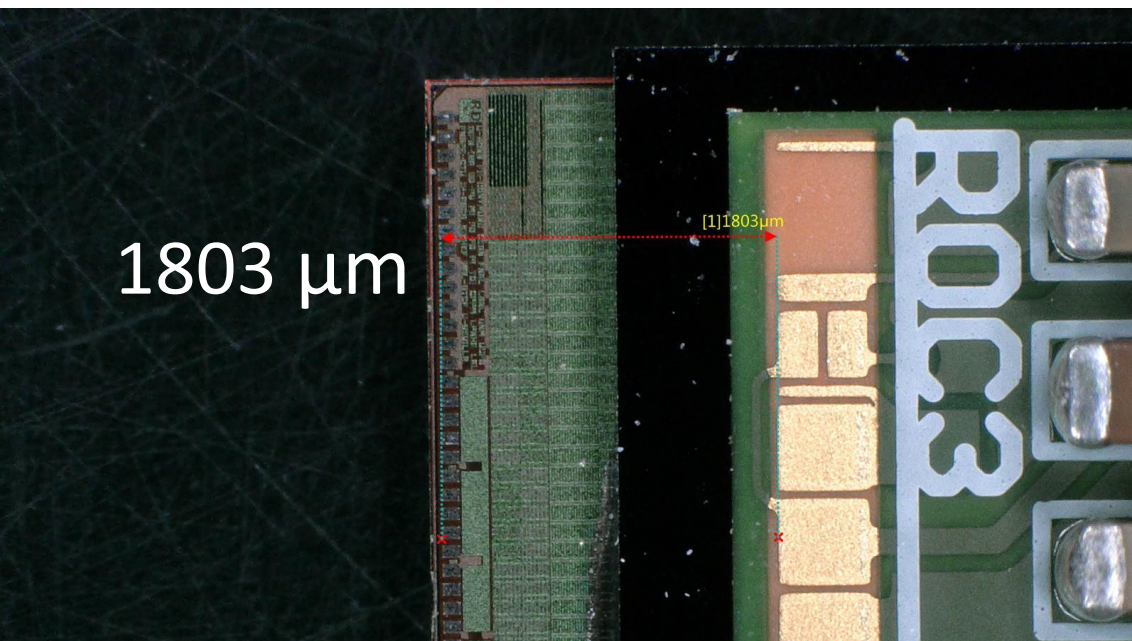


First module assembly

- 3 “red” and 1 “yellow” ROCs used
- Following the procedure with a TBPX applicator
- Result: HDI was not properly glued, long edges were “hanging” in the air
- Glue should be spread across the whole HDI, especially along the edges = under the wire bond pads
- Glue applicator is narrower than the HDI
 - Narrow applicator means that the glue cannot reach both edges
 - The glue used more viscous than foreseen
- Due to this, wire bonding not possible

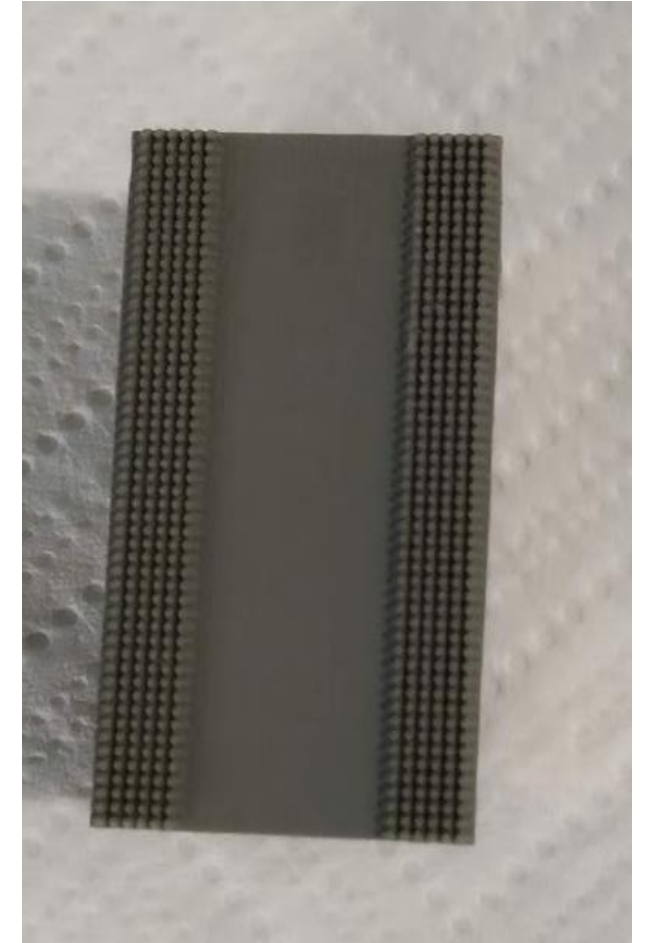


First module: distance between ROC and HDI wire-bond pads

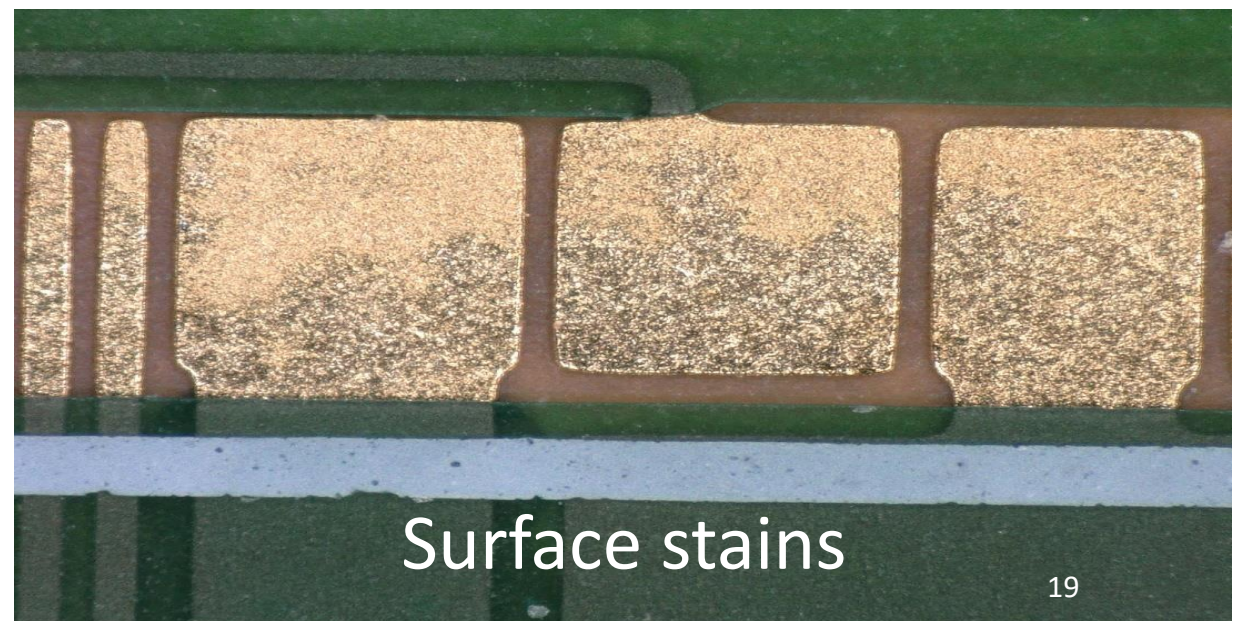
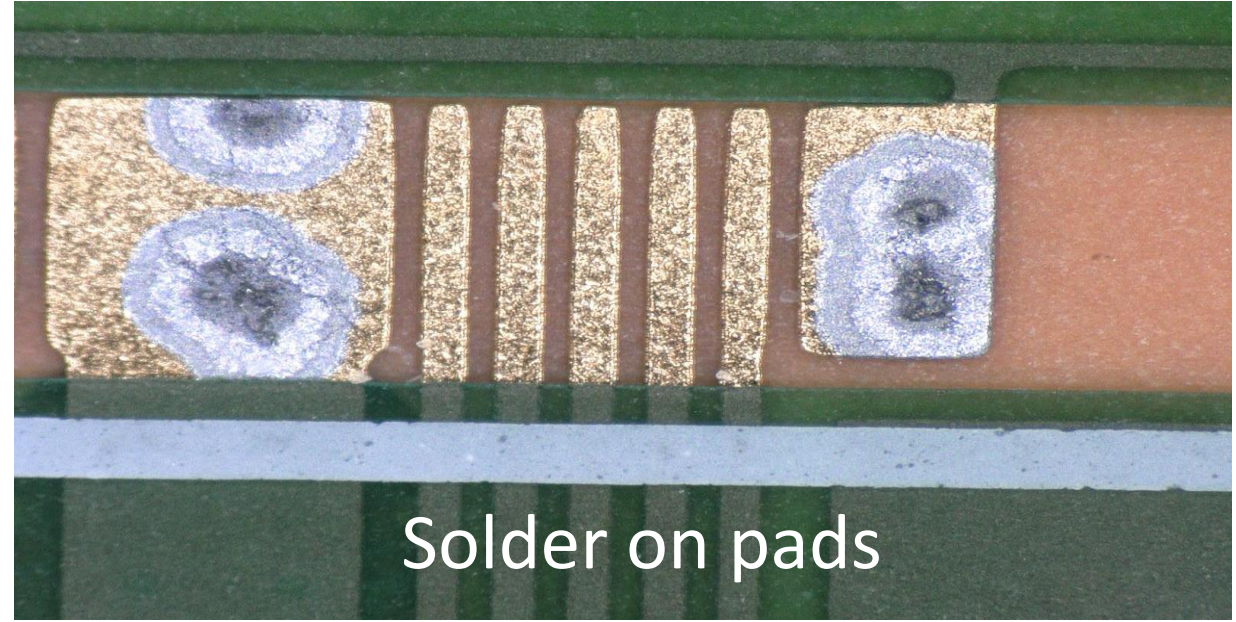
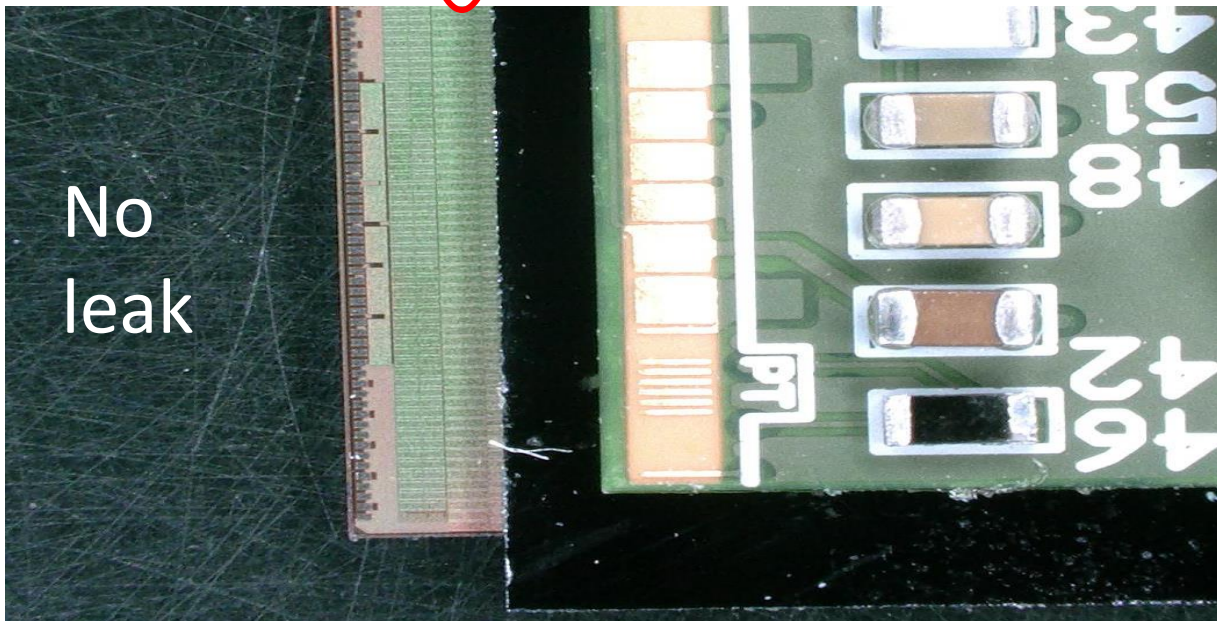
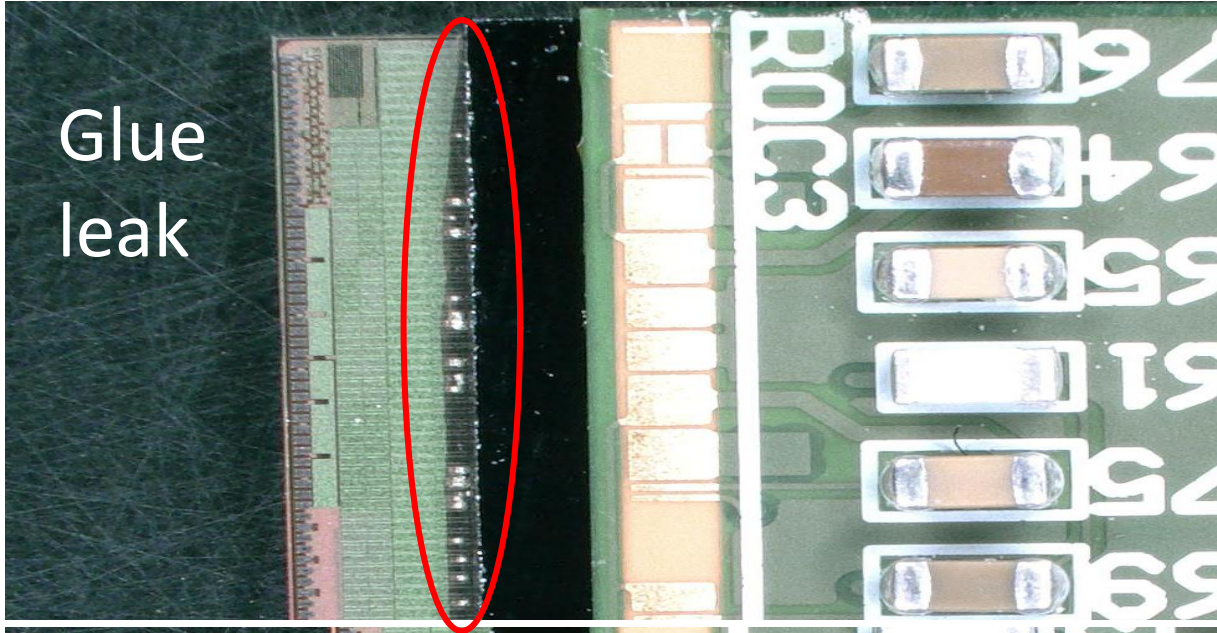


Second module assembly

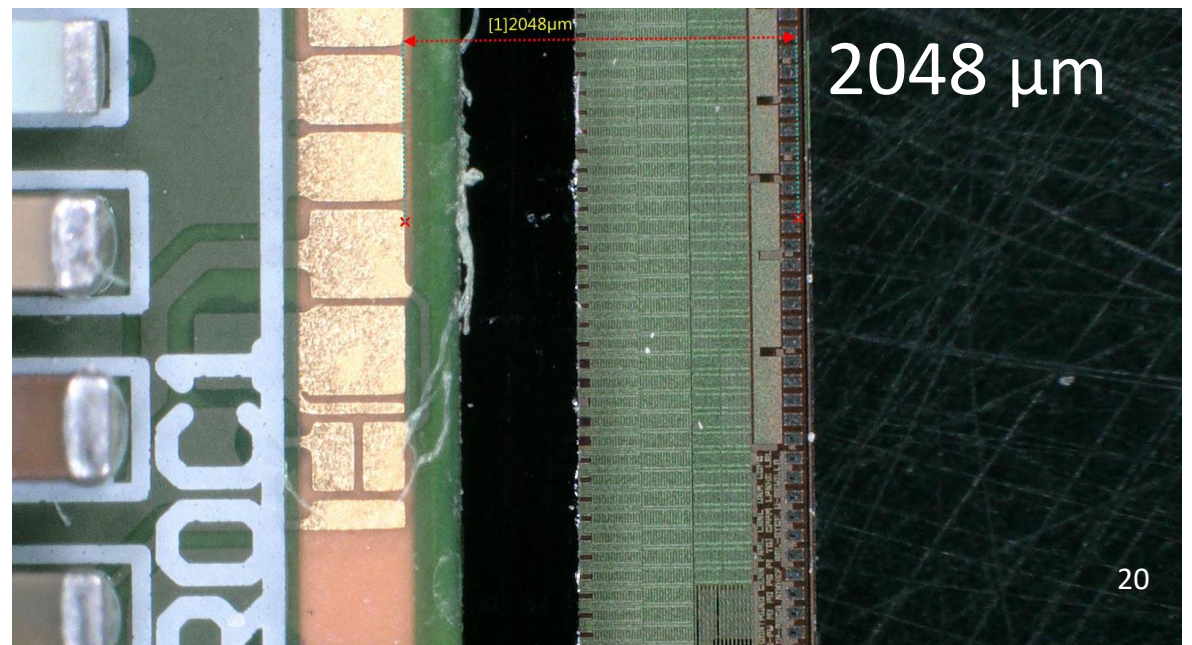
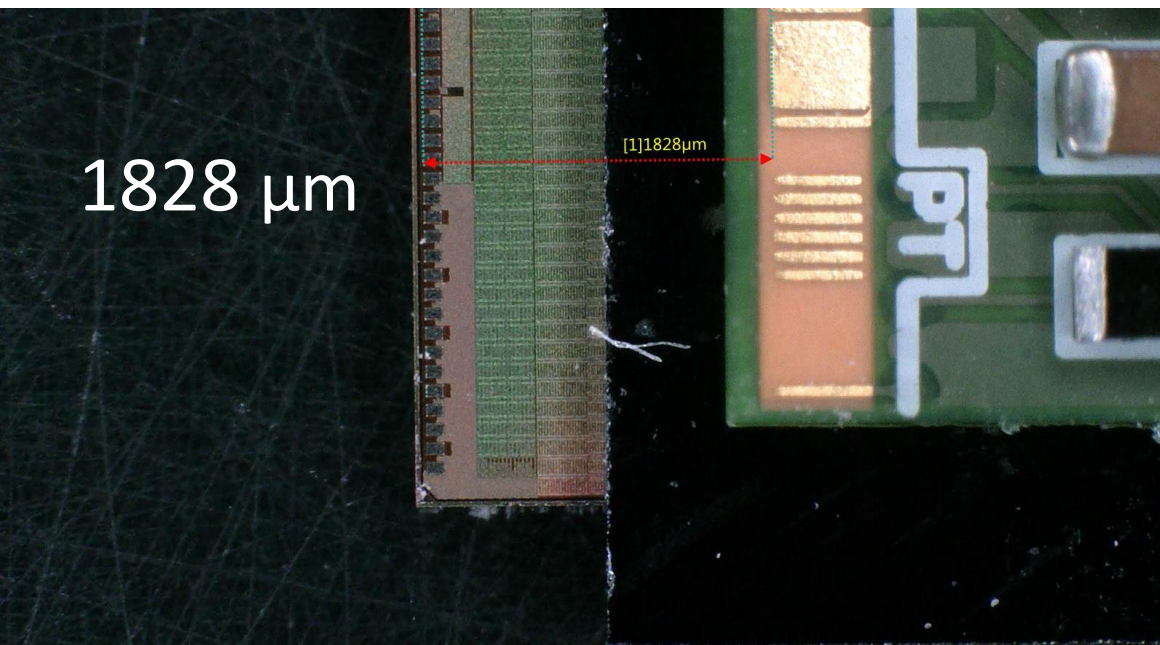
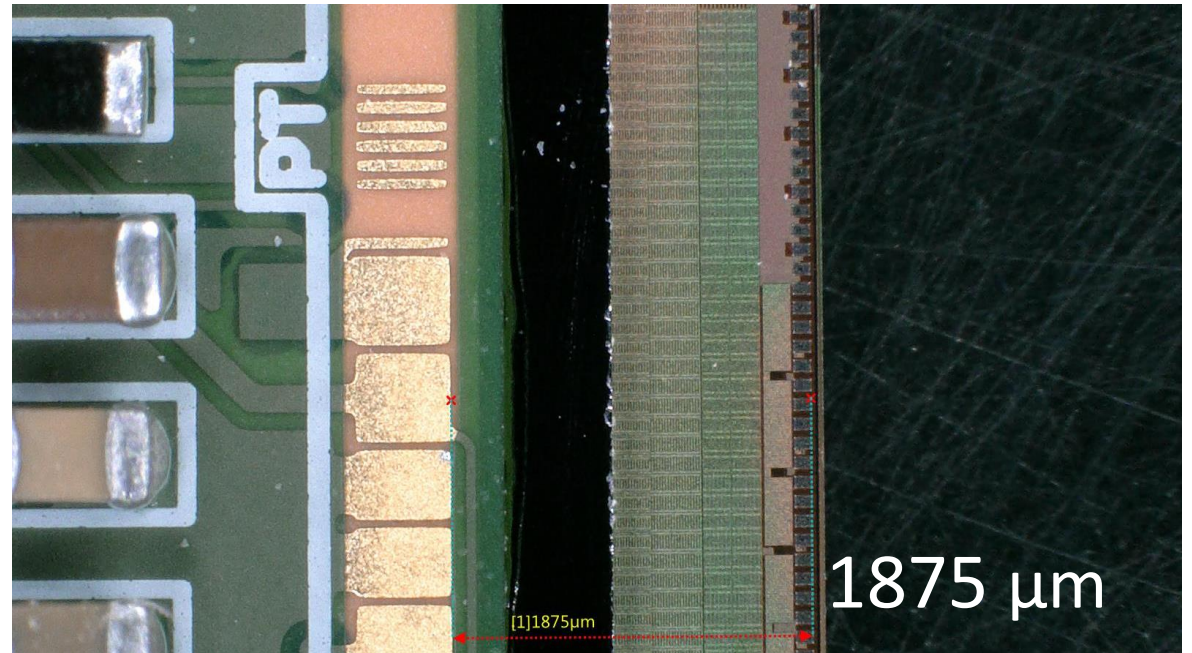
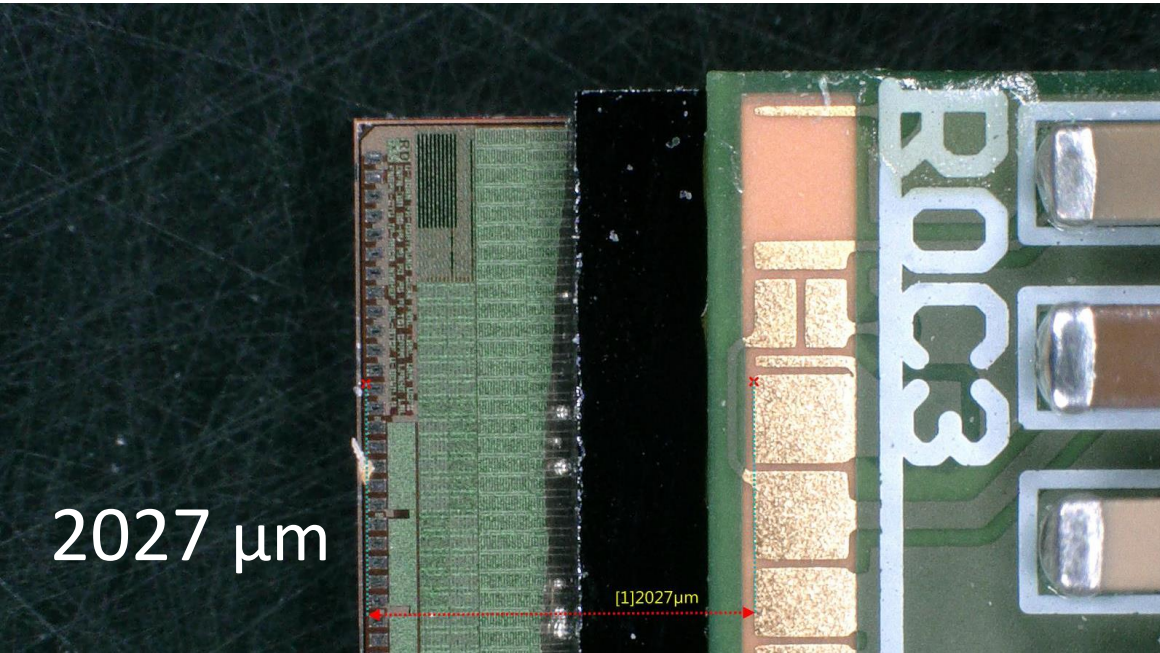
- 4 “green” ROCs used
- Glue applied to HDI with TEPX glue applicator that is slightly wider than the HDI
- One corner of the HDI not glued properly
 - To be understood
- Module not wire-bonded



Second module observations



Second module: distance between ROC and HDI wire-bond pads



- Assembled 2 digital modules without wire-bonding
- Manual alignment seems to work fine, ~200 micron deviations, equal to <math><0.5</math> degree tilt
- Gluing the HDI is the trickiest part
 - HDI is very stiff and prone to be uneven
 - Glue should be distributed almost all the way to the edges
 - Ensuring its flatness during gluing is crucial
- Tools are being improved at ETHZ
- Further practice with module assembling planned
- More ROCs of various quality needed