Assembly and gain uniformity measurements of a new large area PICOSEC detector

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on behalf of the CERN EP-DT-DD GDD group and of the PICOSEC collaboration

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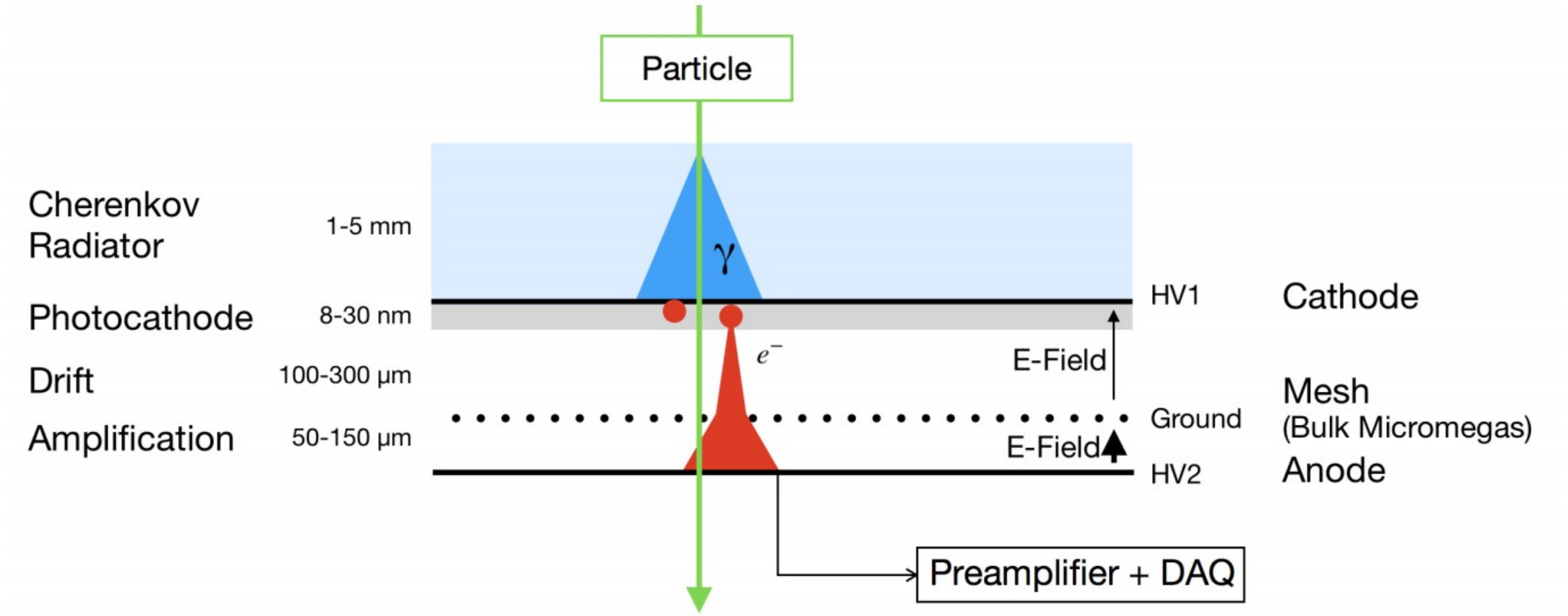
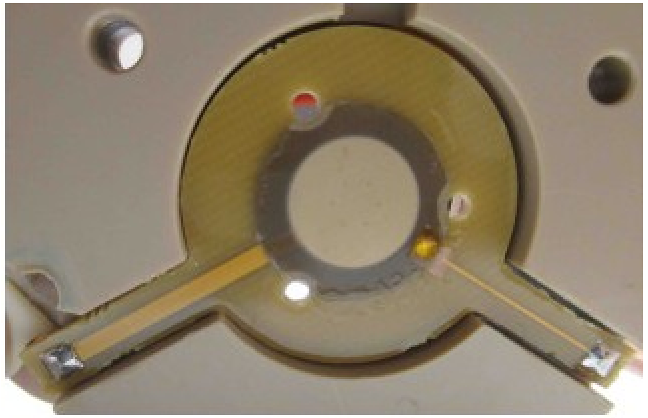
PICOSEC detector concept



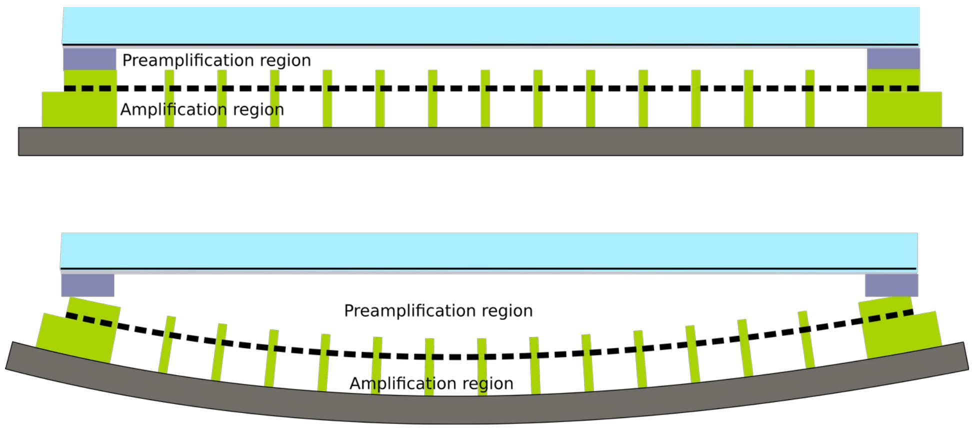


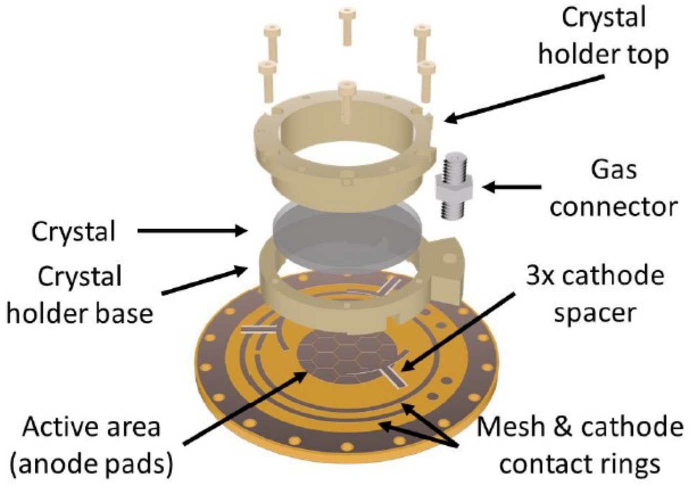
- Purpose: give **precise timing** information in the passage of the particle. Timing resolution of order of tens ps.
- **Cherenkov radiator:** passage of relativistic charged particle creates UV photons.
- **Photocathode:** conversion of UV photons into electrons.
- **Drift /preamplification region:** Preamplification of electrons in high drift field region (~20 kV/cm)
- **Anode/amplification region:** final electron amplification in high electric field (~40 kV/cm)
- Arrival of the amplified electrons to the anode creates a signal.
- First single pad detector prototype->time resolution below 25~ps.

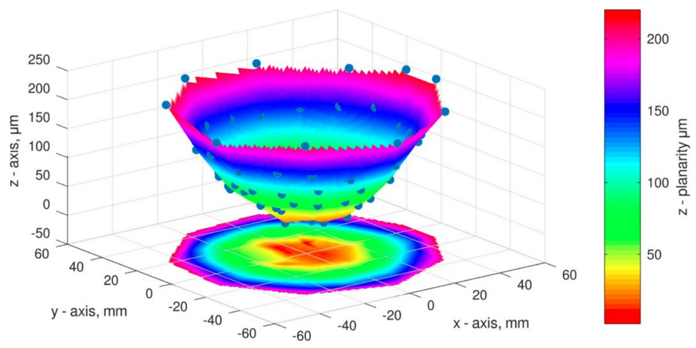
Bortfeldt, J., et al. "PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector." *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 903 (2018): 317-325.

First picosec multipad detector

- **Drift/ preamplification region:** similar thickness (~150 um) and similar electric field as amplification.
- Uniform detector response->uniform gap over entire active area.
    - Change in a drift gap thickness-> change in the **drift field** and **length** of preamplification avalanche evolution.
    - This would affect detector gain and timing performance.
- **First multi pad PICOSEC detector:** observed deformations in range of **30 µm** in **active area** (due to the attachment to the chamber & non flatness of the board itself).
- Gap height difference of **15 µm** would result in time error of **100 ps**.





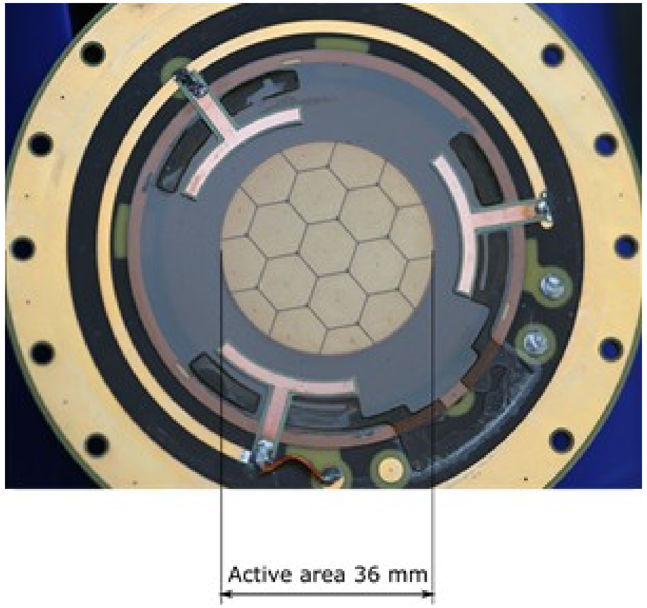


Aune, S., et al. "Timing performance of a multi-pad PICOSEC-Micromegas detector prototype." *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* (2021): 165076.

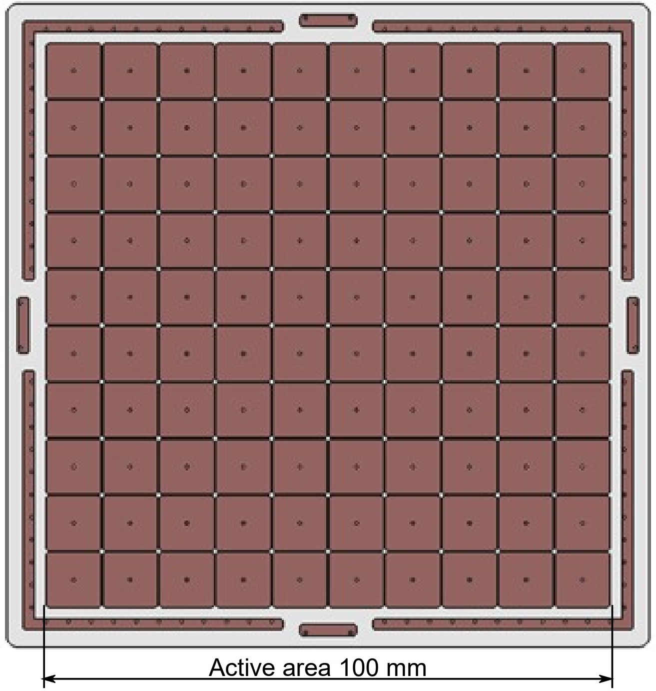
Towards new PICOSEC multipad

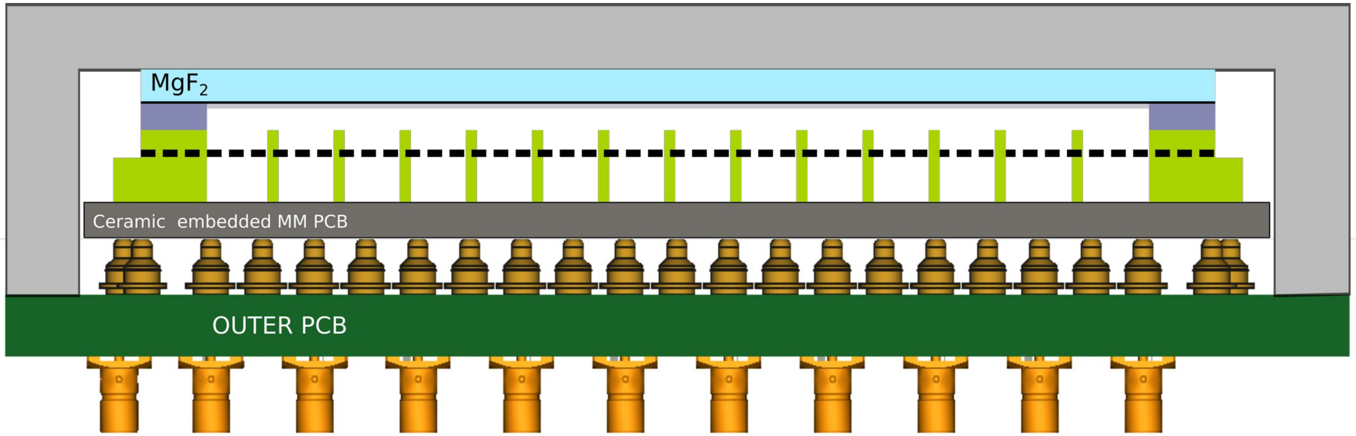
- Increase in active area (≈10 times) AND number of channels (19->100)
- Much larger active area-> deformation will be even more pronounced.
- Main challange: make detector with unfirom gaps (below 10 um) over the entire 10 cm x 10 cm active area.
    - Detach the Micromegas board from the housing.
    - Micromegas board with planarity in 10 um range over the entire active area.

First PICOSEC MM board



New larger area PICOSEC MM board





Planarity simulation driven design of MM PCB

- Structural simulation of board deformations under mesh tension resulted in the usage of a thicker board stack and more rigid core material.
- **Material:** hybrid ceramic instead FR4
- **Thickness:** 4,85 mm instead of 3 mm.
- **Design requirements:** PCB flatness within 10 um over the active area.
- Objective: follow the manufacturing process and conduct the planarity measurments on each of the production steps.
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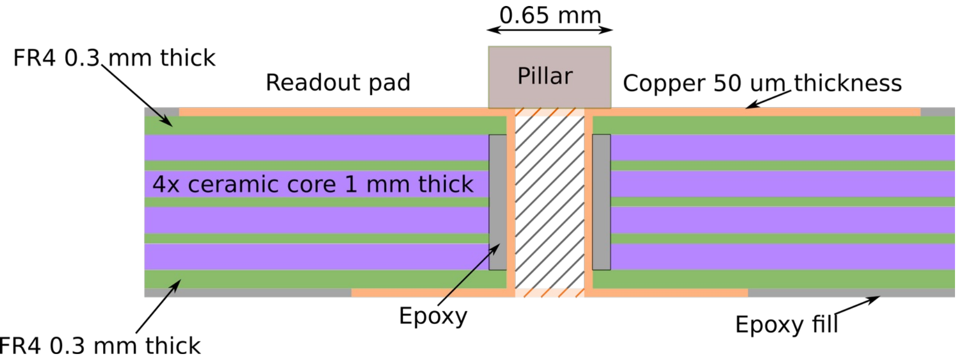
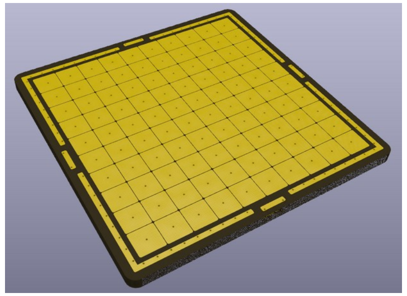
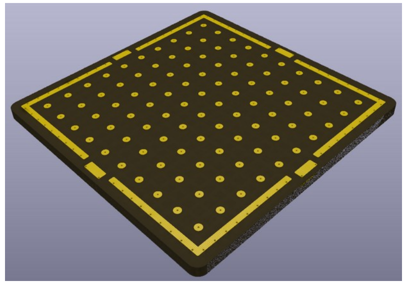
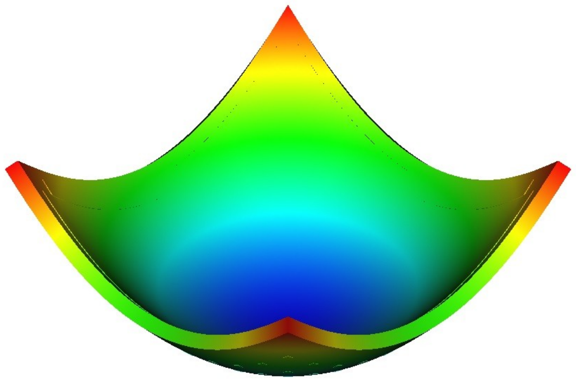
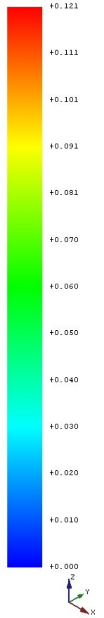


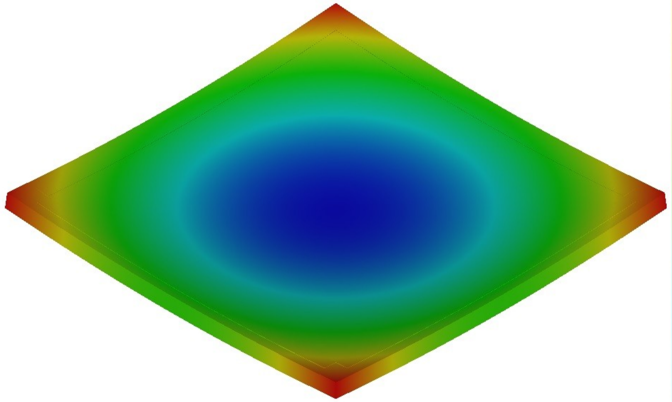


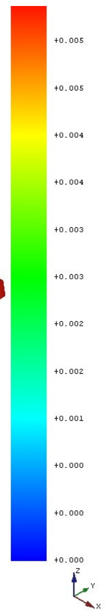






FR4 (3 mm thickness): Max displacment in the active area is around 100 um.



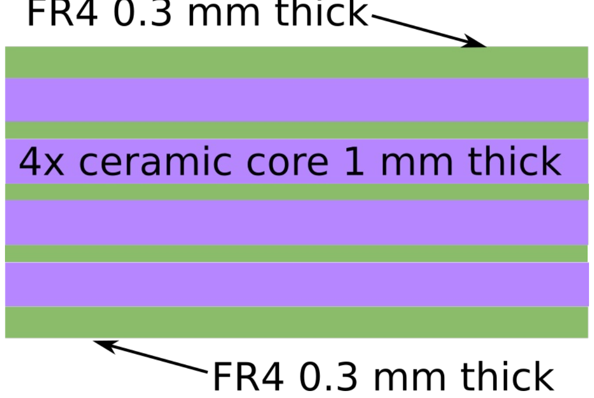


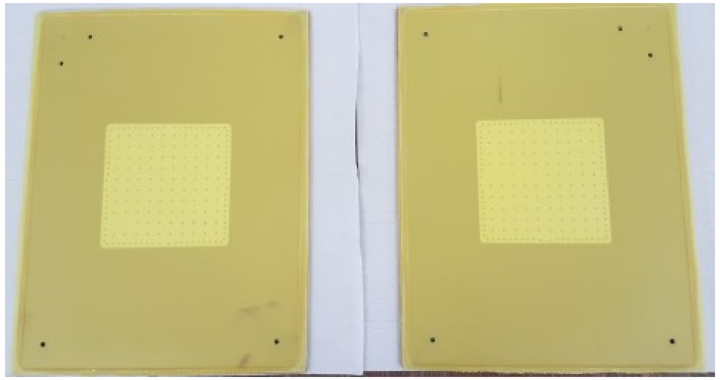
Ceramic (4 mm thickness) Max displacment in the active area is around 4 um.

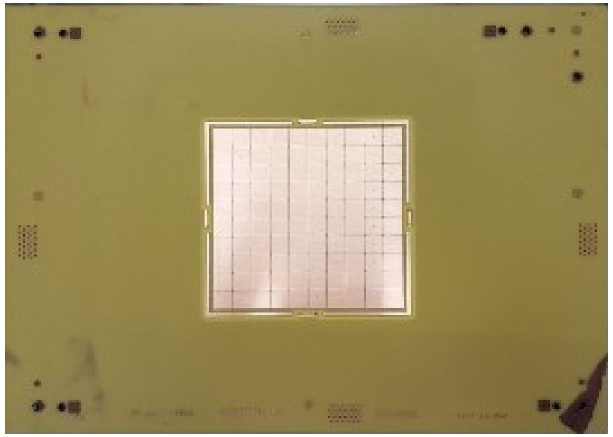
More details on new PICOSEC planarity simulations: Antonija Utrobicic, RD51 CM June 2020, *https://indico.cern.ch/event/911950/sessions/348123/#20200626*

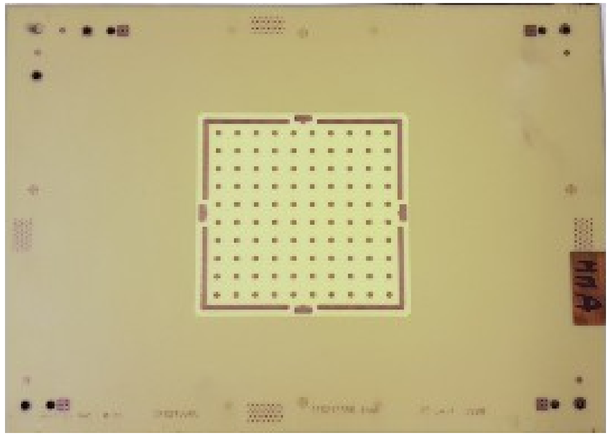
Picosec Mircomegas: anode board production

1. **Production of the ceramic substrate:** gluing 4x1 mm ceramic boards and covering with 0,3 mm thin FR4 layer on top and bottom side.
   - Polishing of the top side FR4 layer-> planarity measurements.
   - **Planarity below 15 um (MMB) and 23 um (MMA).**
2. **Epoxy coating and copper deposition** (55 um) on the top and bottom side of the board.
   - Planarity measurements → polishing → planarity measurements.
   - **Planarity below 9 um (MMB) and 11,5 um (MMA).**
3. **Copper etching.**
   - **Planarity below 7,8 um (MMB) and 7,2 um (MMA).**
4. **Epoxy fill between the copper** traces/readout pads and polishing.
   - **Planarity below 7,6 um (MMB) and 8 um (MMA).**





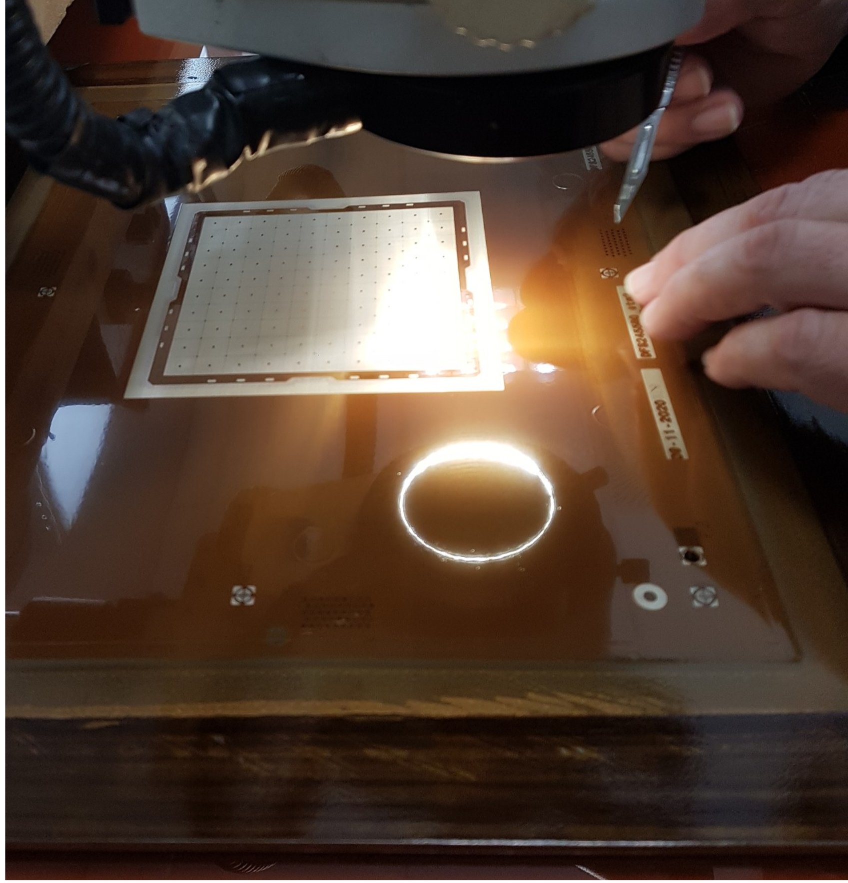




Top side / PADs side

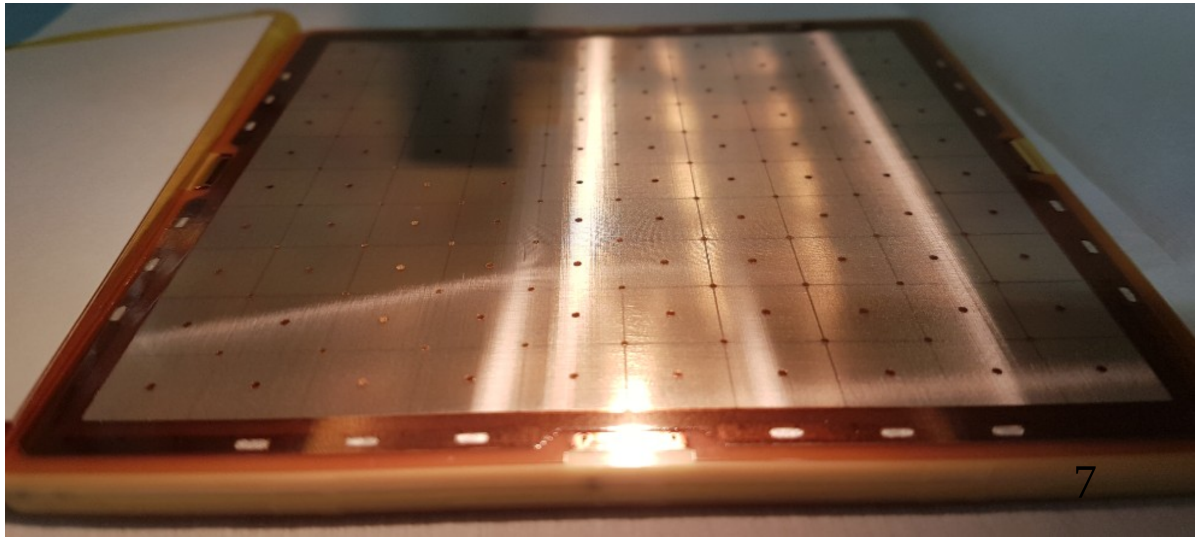
Bottom side / Pogo pins side

More details on new PICOSEC planarity measurements: Antonija Utrobicic, RD51 CM October 2020, *https://indico.cern.ch/event/889369/sessions/355853/#20201009*

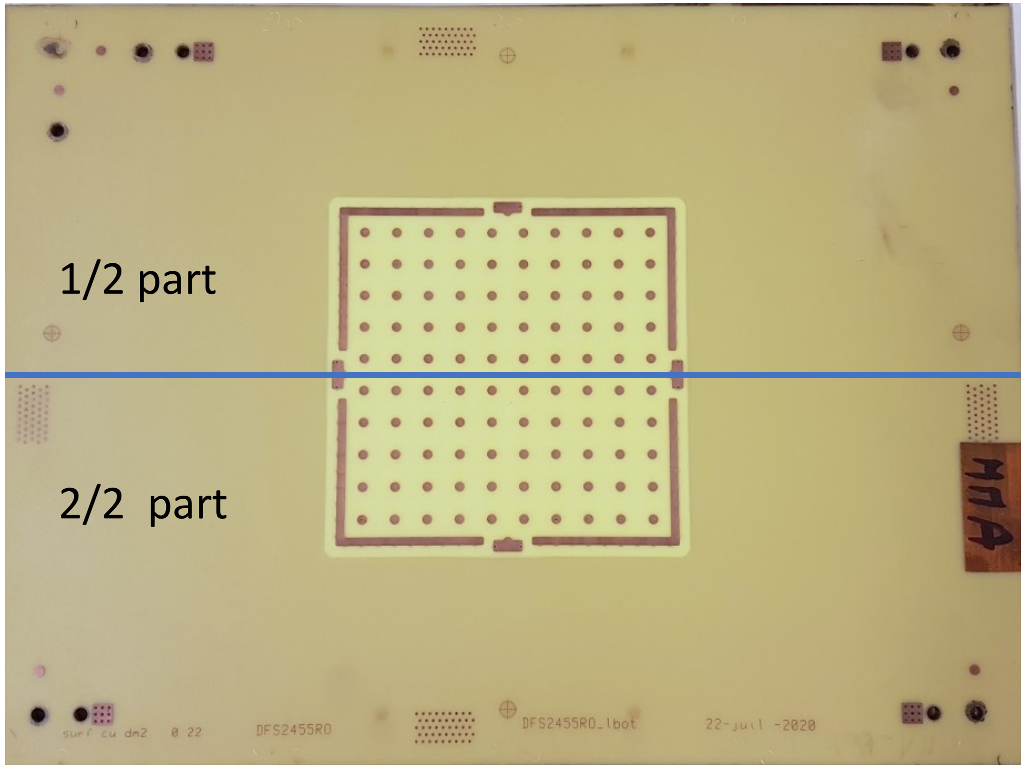


Micromegas bulking

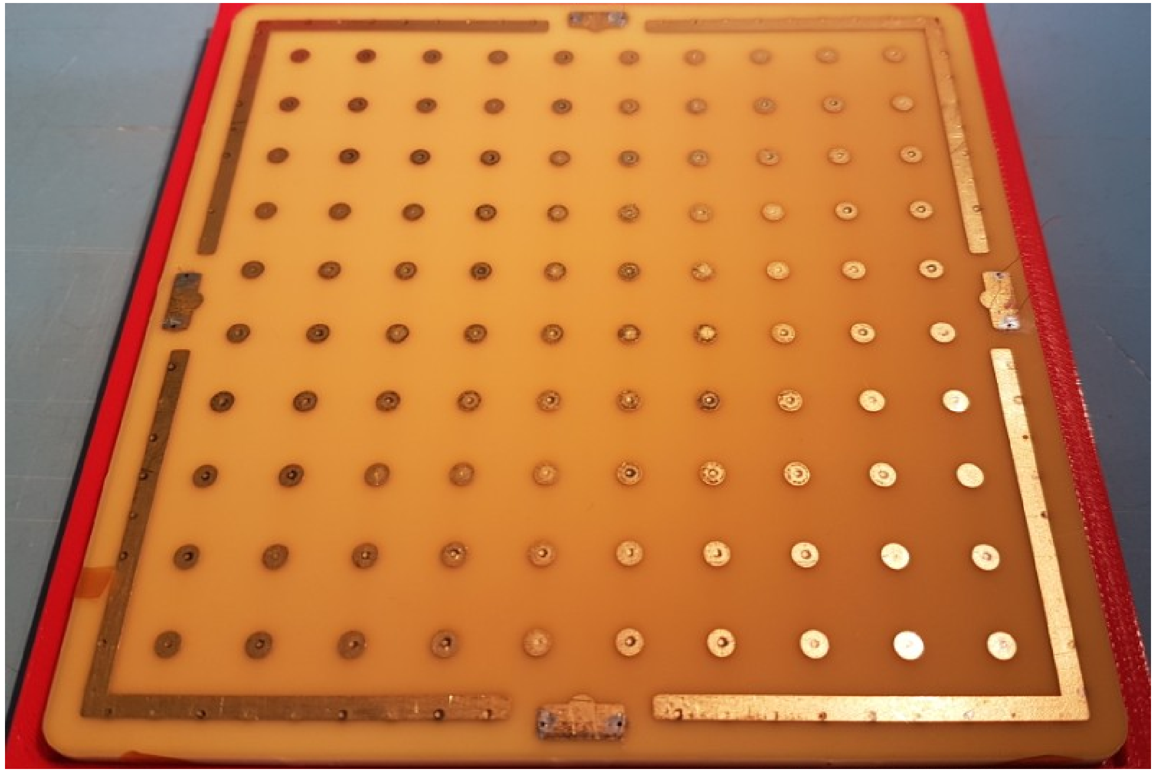
Huge thanks to Rui, Antonio, Olivier and Bertrand! ☺



Picosec Micromegas: back side board planarity measurements

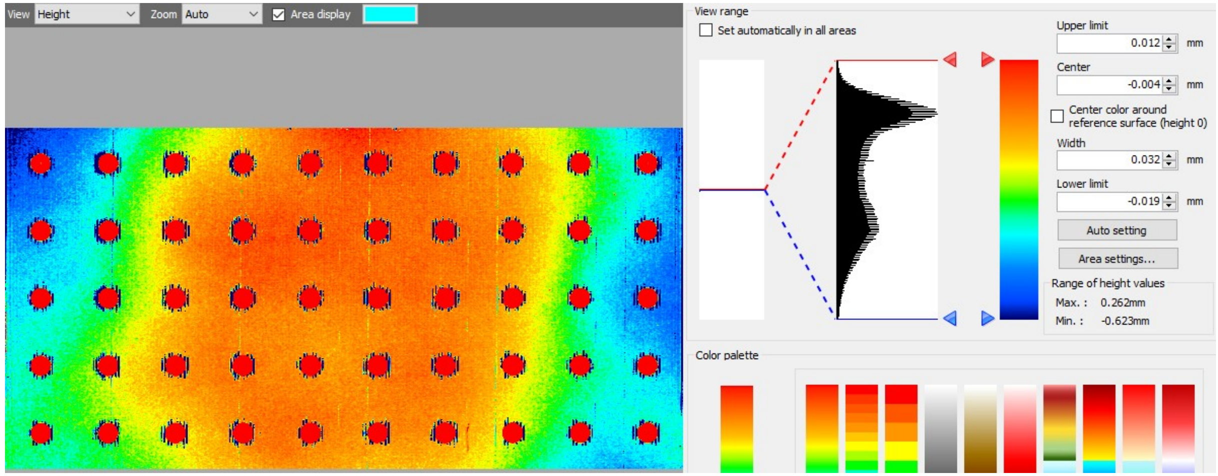


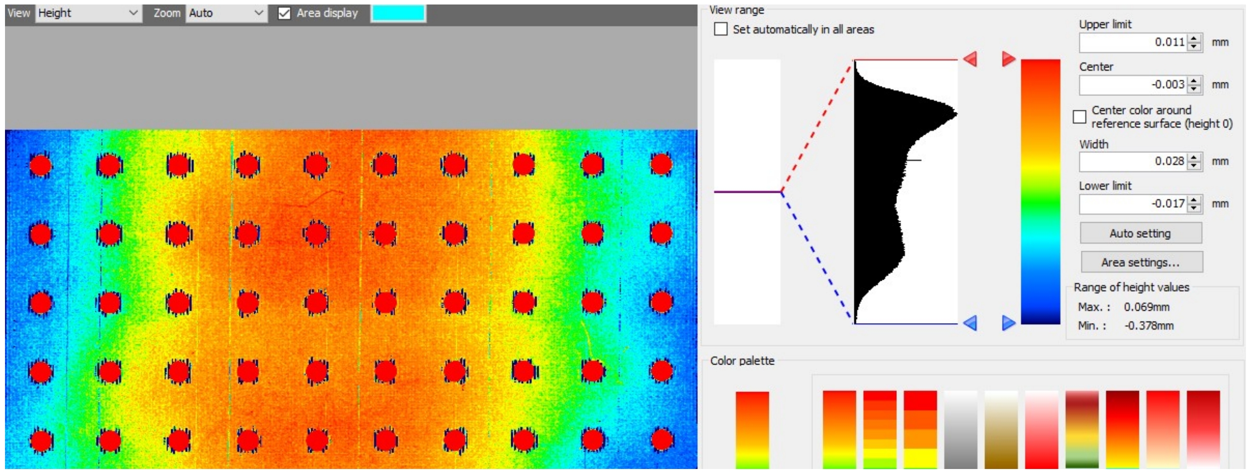
Back side of the board before bulking

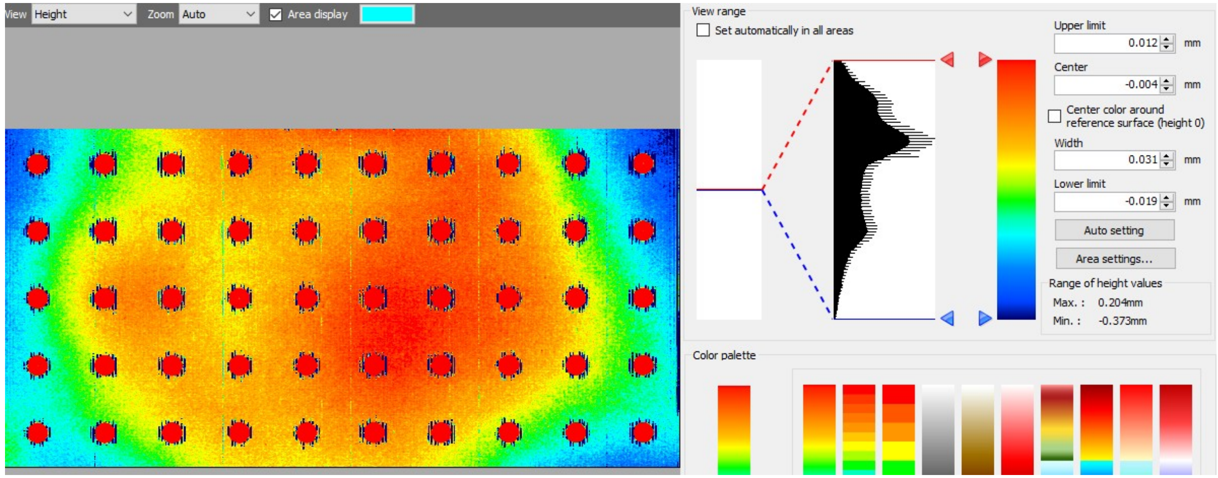


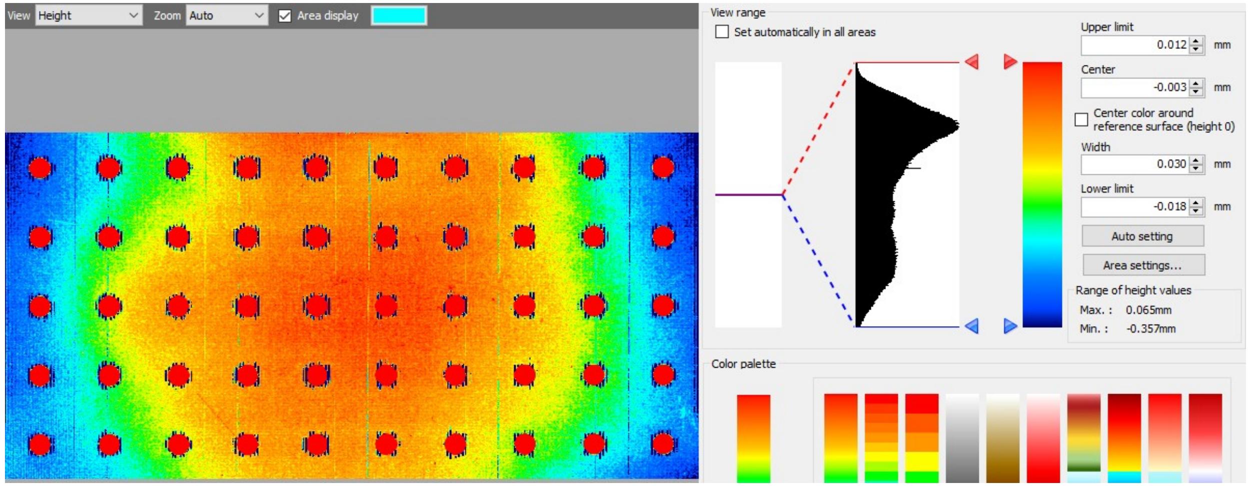
Back side of the board afer bulking

Picosec Micromegas planarity measurements







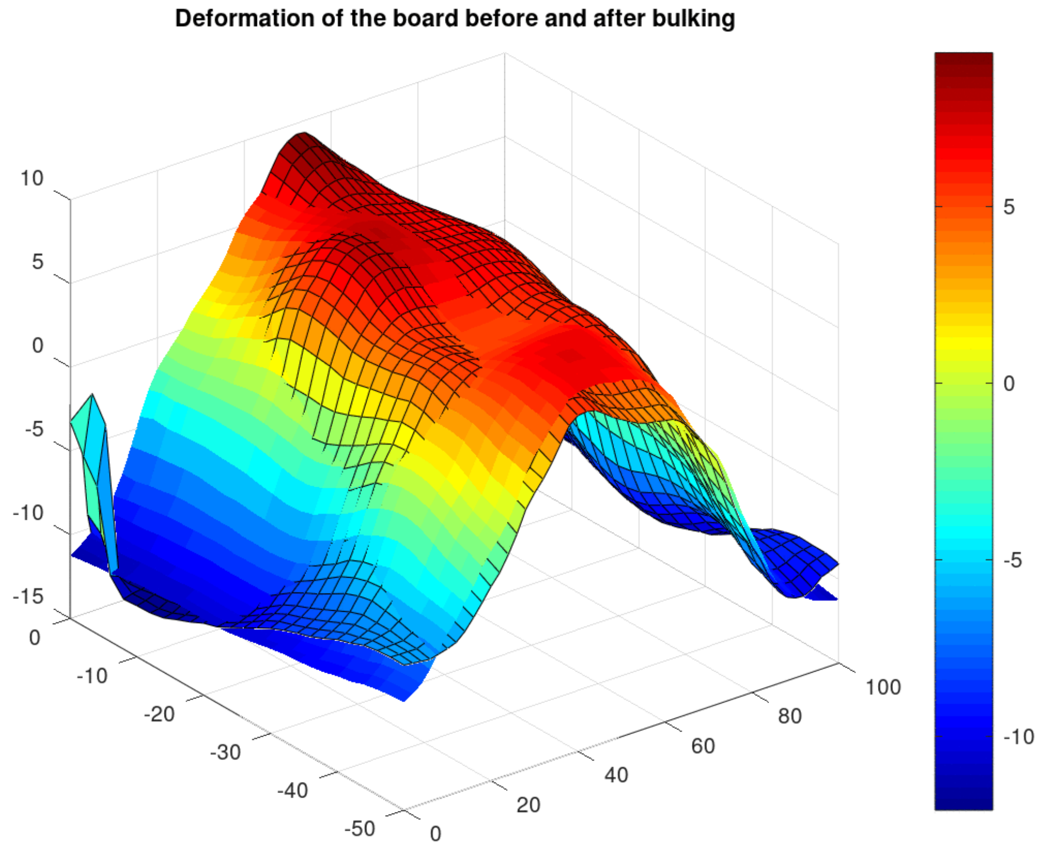


Height range around 30 um

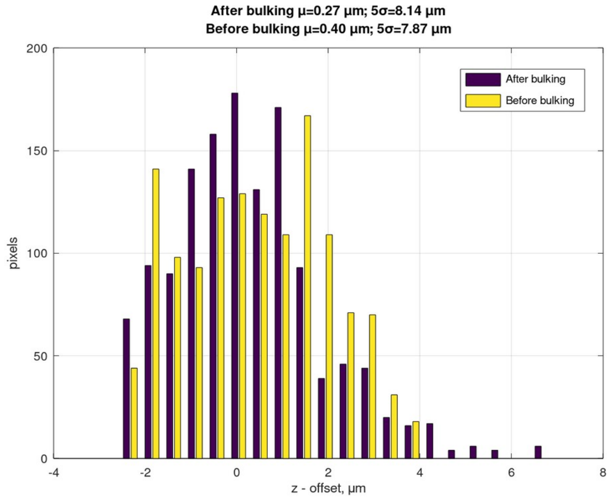
Height almost the same as before bulking

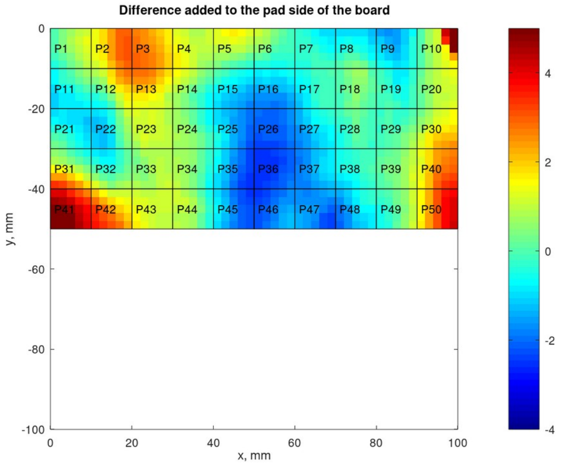
How to interpret back side measurements

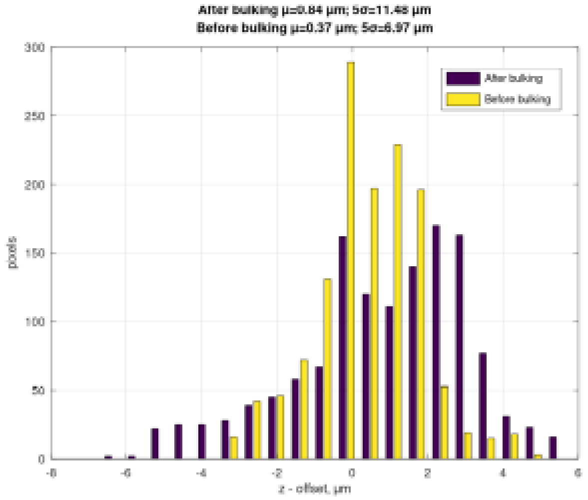
- **Very rough estimation:**
  - The deformations have propagated through the board on the top side, the thickness of the board is preserved.
  - Due to the MESH it is not possible to make planarity measurements on the top side.
- **Procedure:**
  - Make before and after comparison analysis of the back side of the board.
  - Calculate the difference.
  - Add the difference to the height top side before bulking.

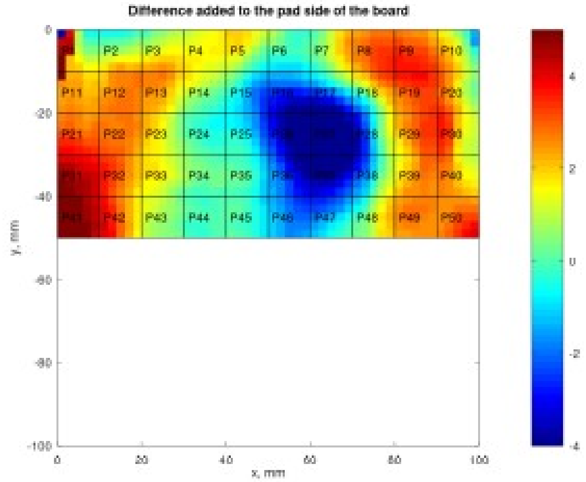


Planarity of the board after bulking



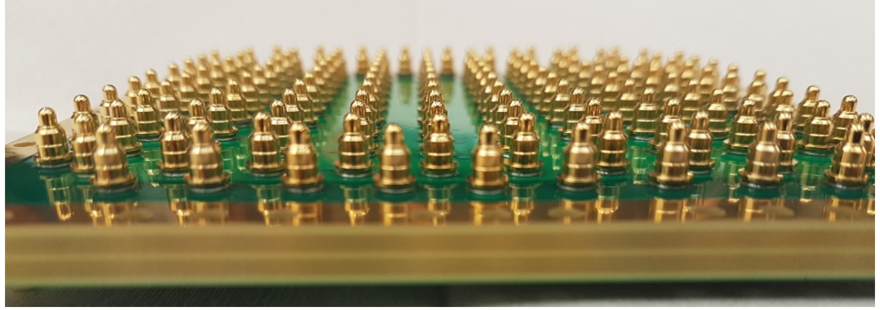


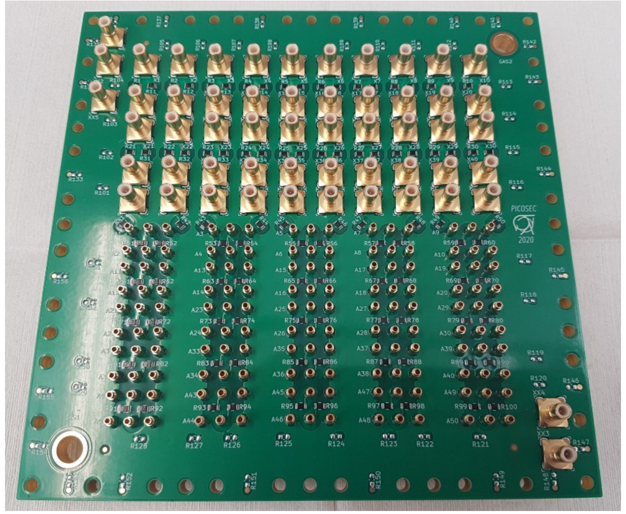




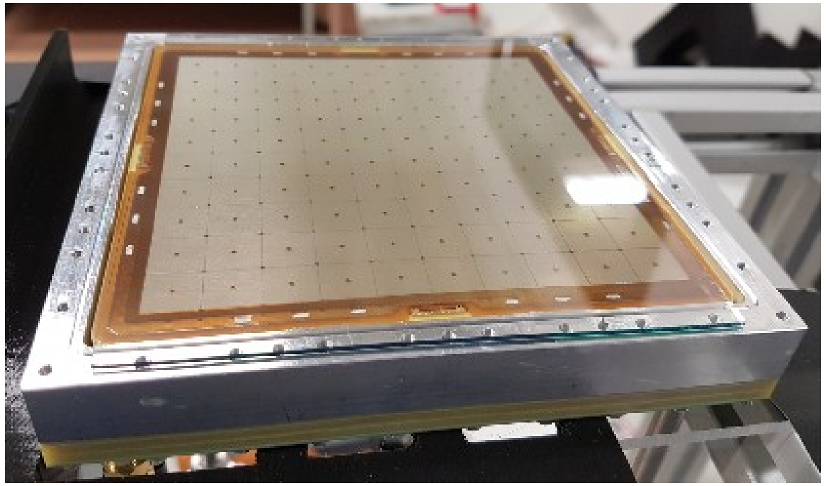
- Planarity measurements of the backside after bulking show that there were **no large deformations due to the bulking process**.
- Analysis of the planarity measurement data shows that **a very rough estimation is that the overall planarity on the pads side is still below 10 um**.
- Better information from the uniformity tests after detector assembly.

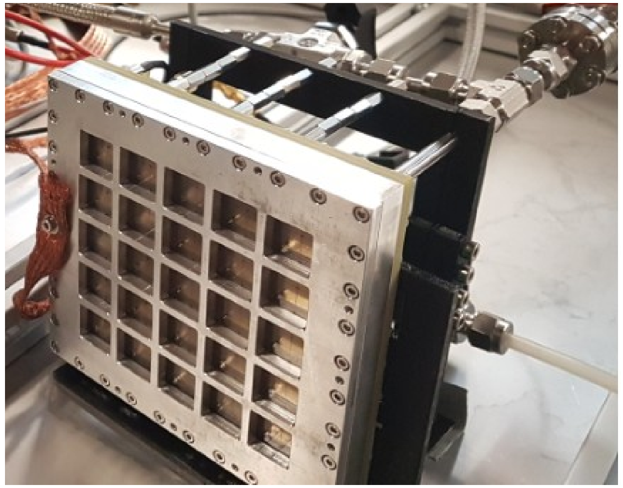
Detector assembly: first HV and gas tightness tests

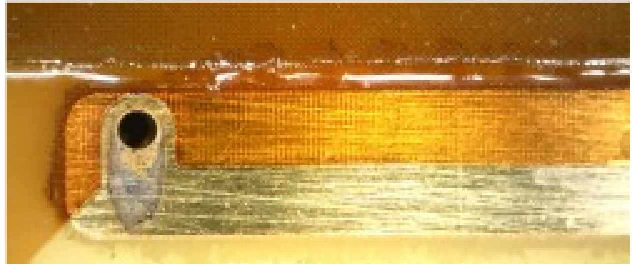


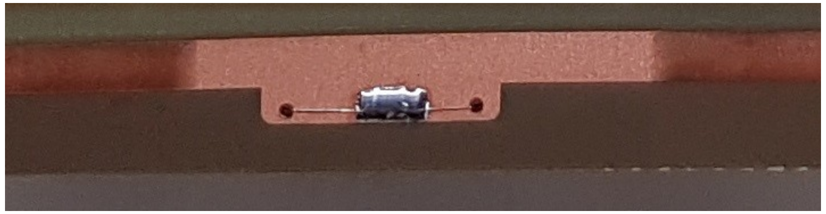


- HV stability test of the Outer board: cathode, anode and MESH connections stable up **1300 V**.
- HV stability test of the MM board (in air):
  - Anode: applying the voltage to all pads → **stable up to 900 V**
  - Cathode connection: **stable up to 900 V**
- Mounting the flange with Cr coated MgF_2 window and closing the chamber.
- Chamber leak rate: 2.1e-5 mbar l / s.

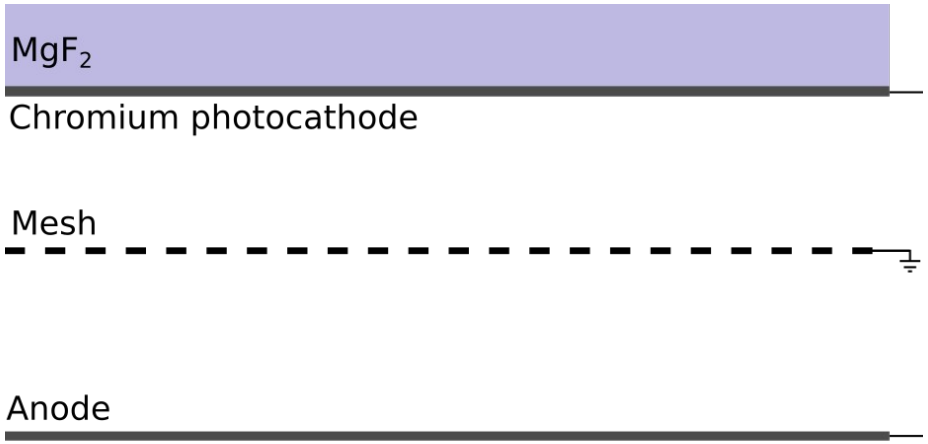


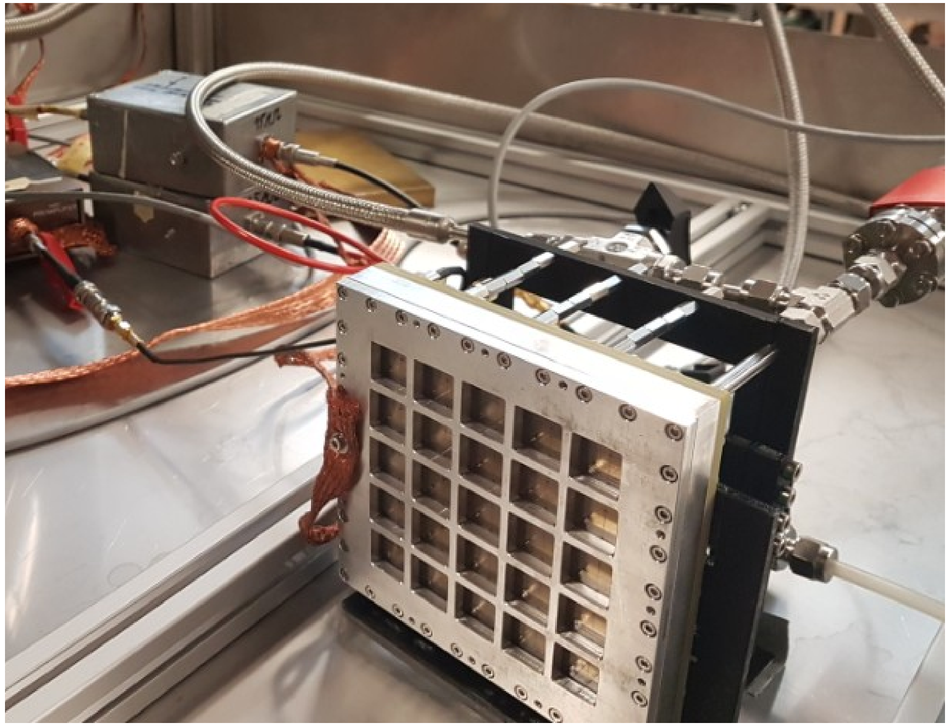


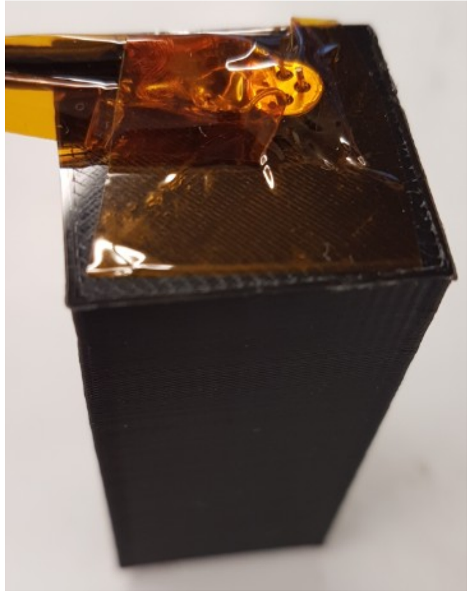


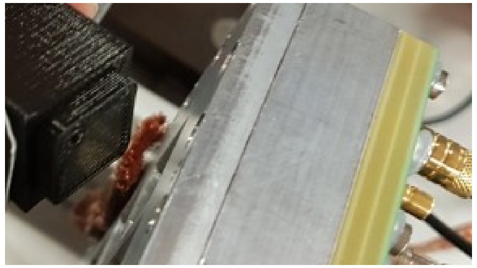


New multipad PICOSEC: Hello world



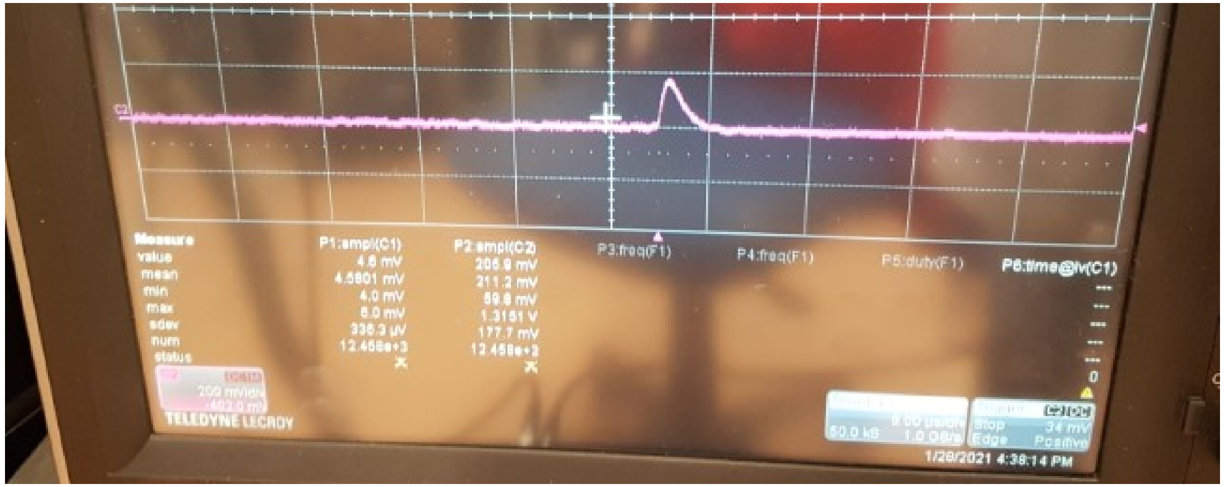






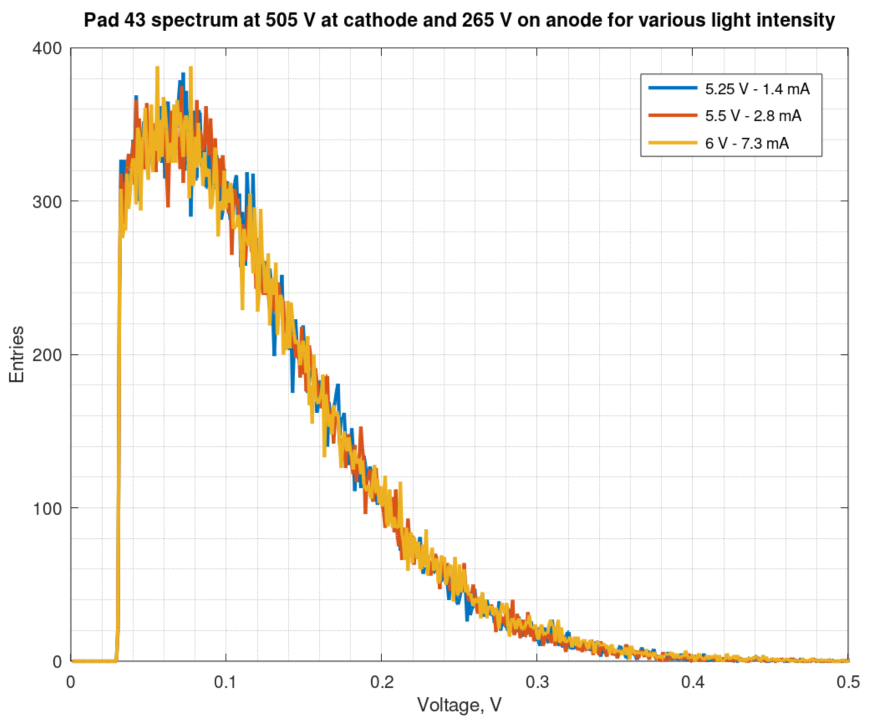
Measurement equipment:

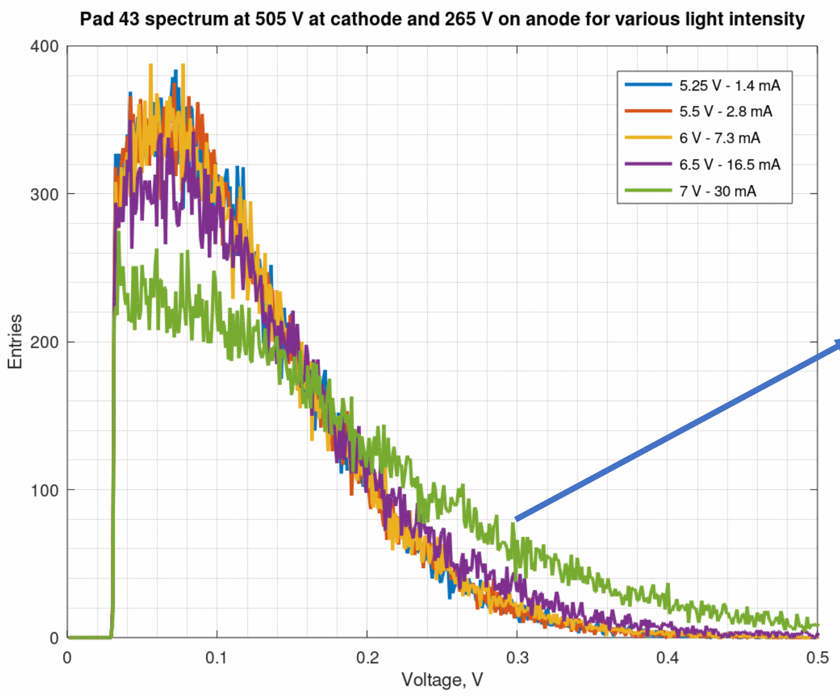
- Ortec 142 IH preamplifier.
- Oretc 474 timing filter amplifier.
- Caen N471A PS.
- MCA 8000D.
- UV diode-240 nm (model: UVTOP240TO18BL).
- Collimator (ϕ=2mm) 5 cm long to contain the light within one pad.



First spectrum

- Measurements with different diode light intensity and fixed detector gain were made to have single p.e condition.
- Diode current was increased until difference in spectrum was observed.
  - For LED current above cca. 30 mA the spectrum shape changes significantly.
  - It is possible that the time between two consecutive single p.e events is shorter than the shaping time of the amplifier causing signal pile-up.
  - These events could be resolved in time in measurements with a fast preamplifier. ...to be done soon.
- Gain uniformity measurements were made with small LED light intensity in order not to have signal pile-up.

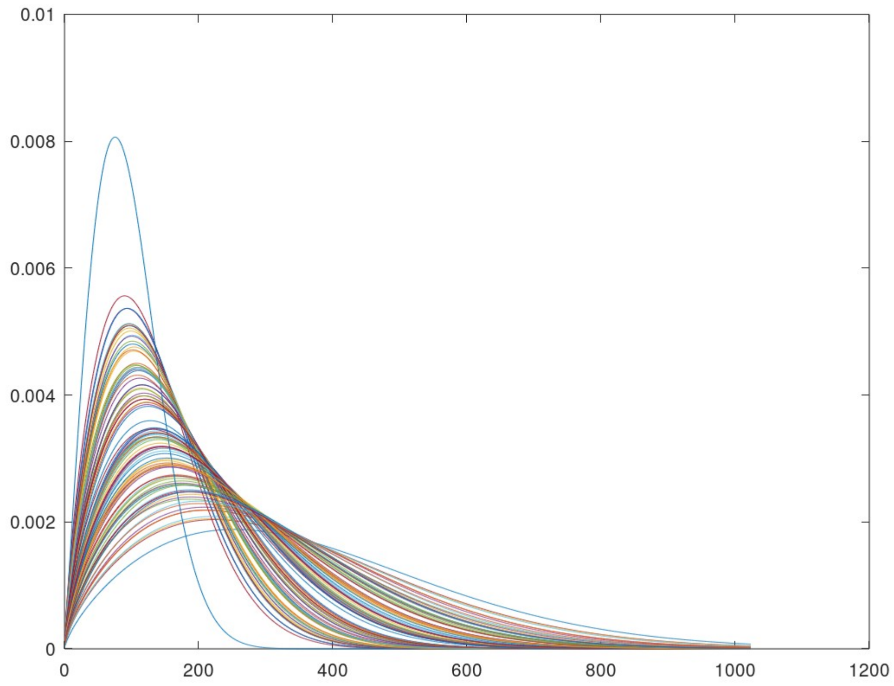


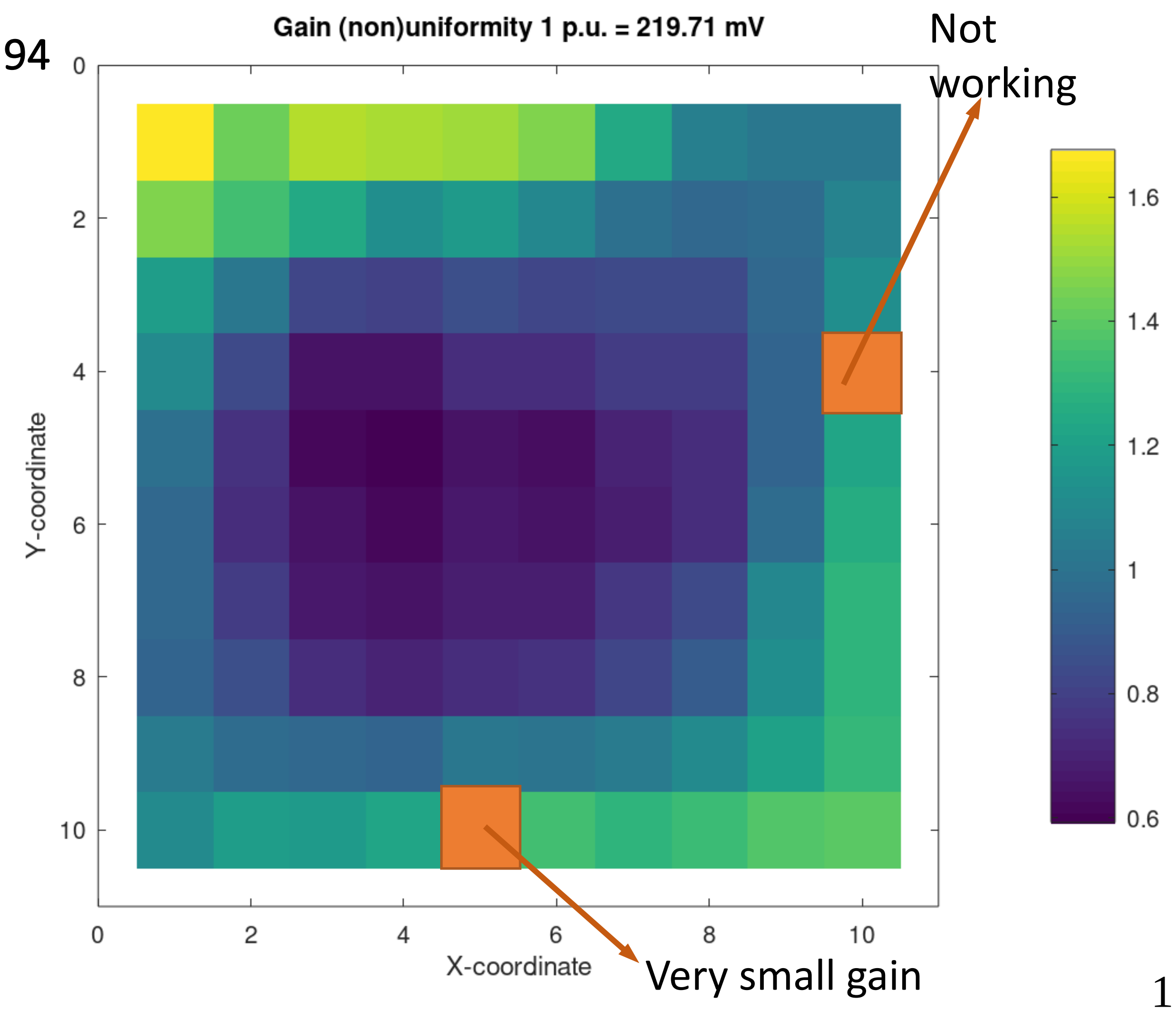


Lot of pile-up events after shaper.

Gain uniformity measurements in sealed mode

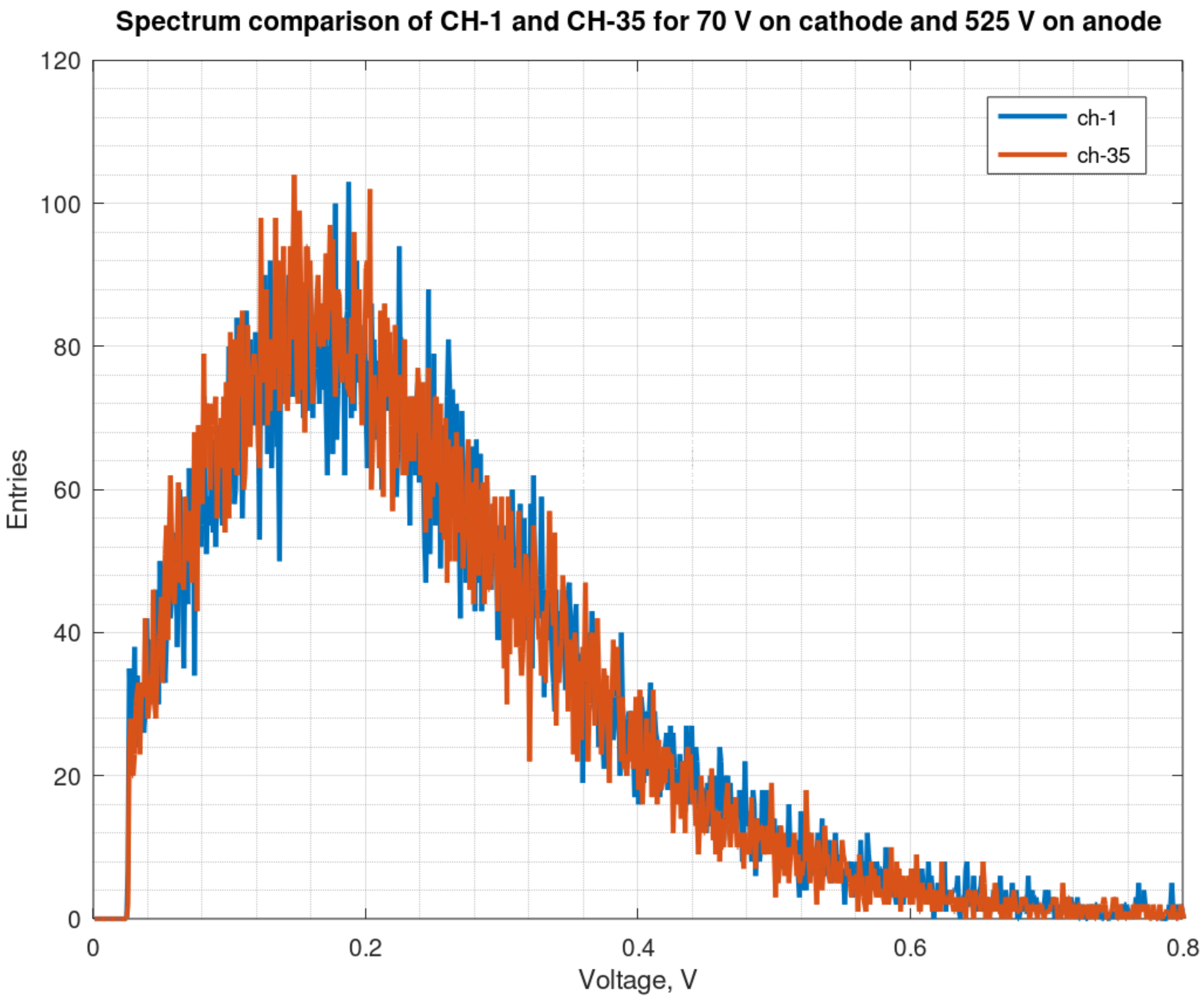
- Cathode voltage: 525 V
- Anode voltage: 265 V
- Problem with 2 channels (orange color on map): **channel 94** is not working and **channel 50** has very low gain.
- Polya fit was used to extract the mean of the spectrum.
- Large variation in gain observed





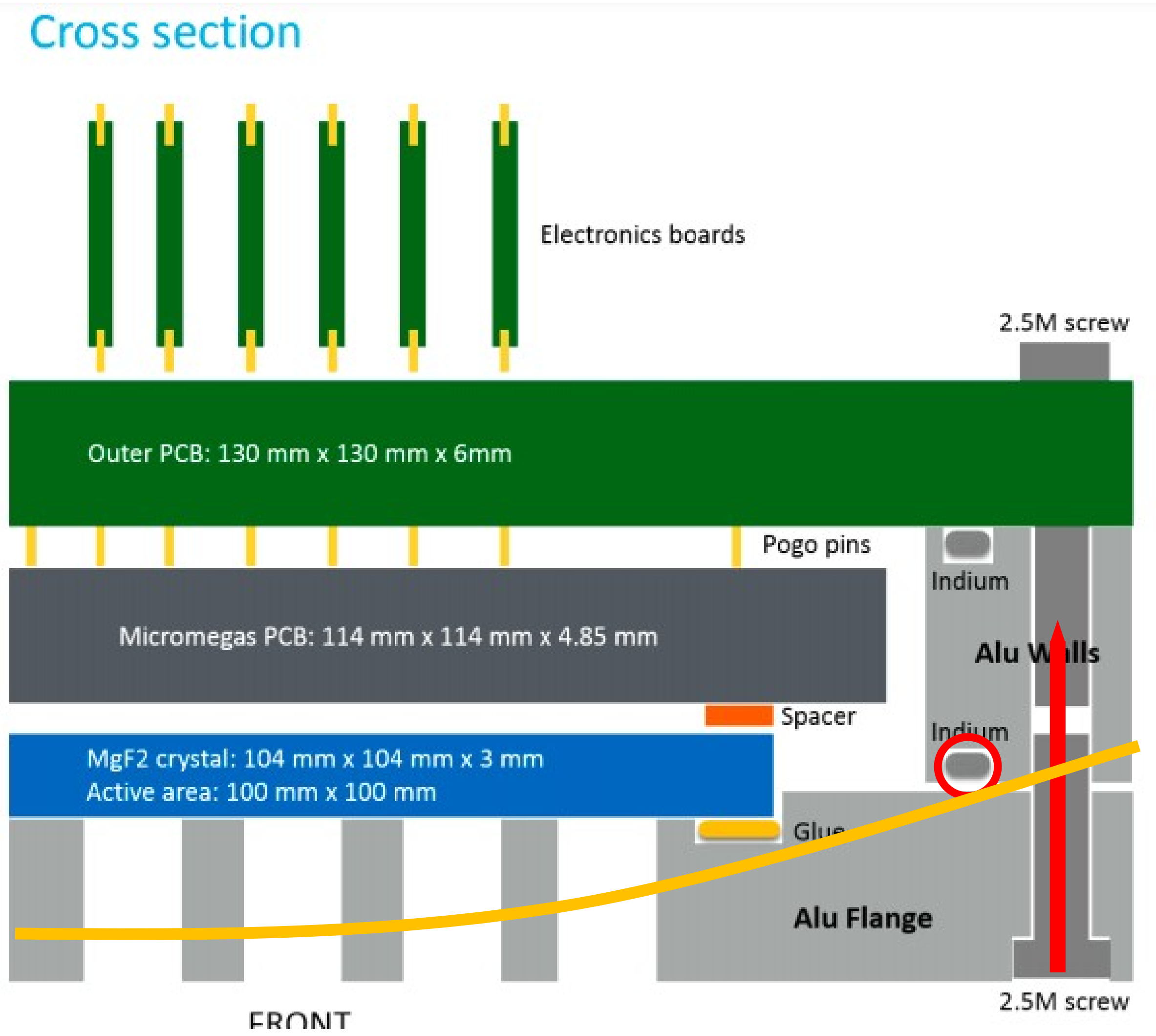
Gain uniformity measurements in sealed mode

- Cathode: 70 V
- Anode: 525 V
- Gain comparison of the pads with the largest gain difference in the previous test (CH-1 and CH-35).
- Gain is uniform- excludes possible non-uniformities from the mesh.
- The gain non-uniformity comes from the preamplification region – uneven preamplification gap.



Sources of the gap-nonuniformity

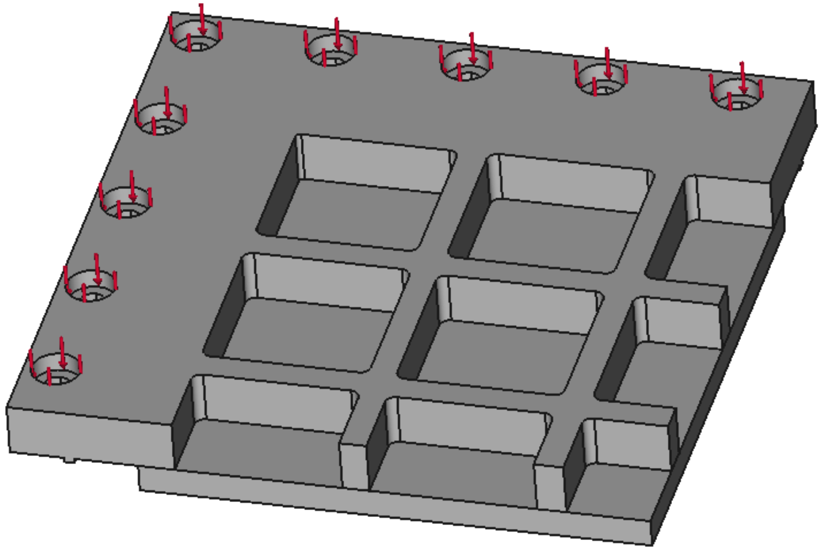
- Micromegas board is fully decoupled from housing and thoroughly tested to flatness specs.
- MgF_2 crystal is glued to the aluminum flange that is tightened with M2.5 screws to the chamber housing.
- Pressing force from each M2.5 screw torqued to 0.6 Nm is around 119 kg.
- Total: 36x119 kg = 4284 kg.
- MgF_2:
  - Poisson ratio: 0.276
  - Youngs modulus: 138 GPa
- Aluminum
  - Poisson ratio:0.33
  - Youngs modulus: 69 GPa
- Flange can bend over the Indium o-ring when being pressed with the screws.

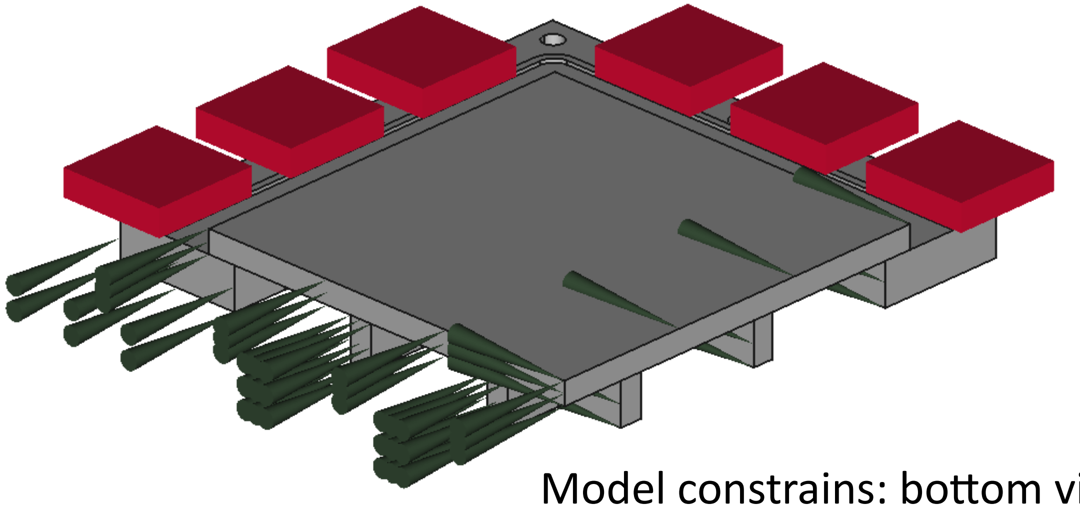


More details on new PICOSEC module: Marta Lisowska, RD51 CM October 2020, *https://indico.cern.ch/event/889369/sessions/355853/#20201009*

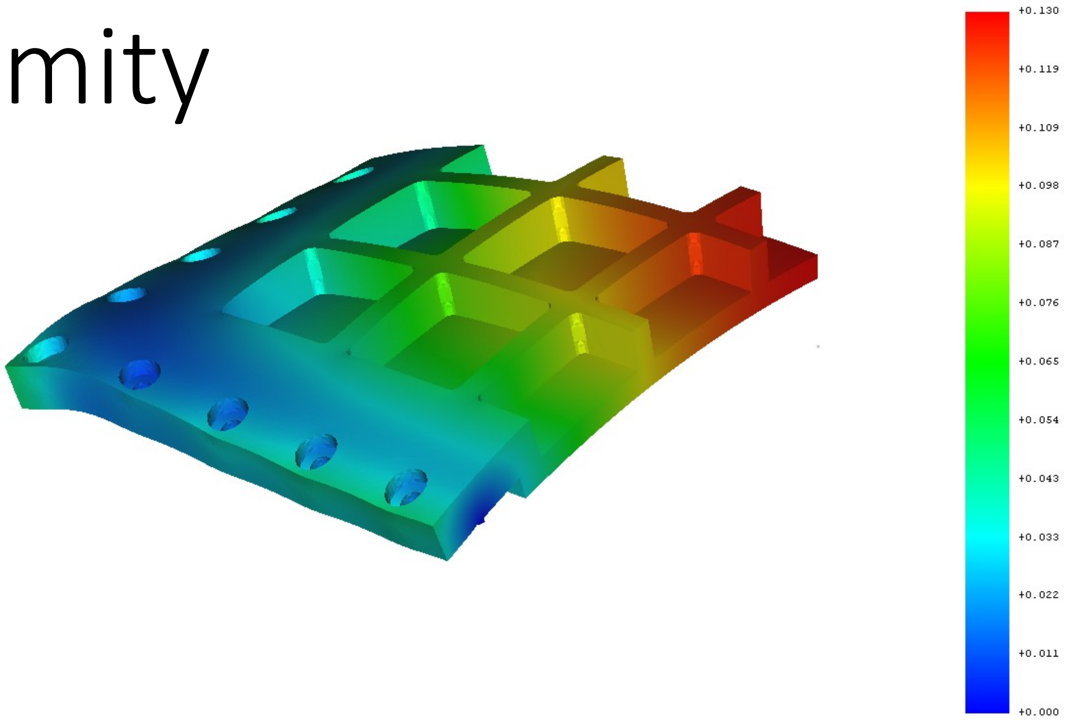
Sources of the gap-nonuniformity

Applied force: top view





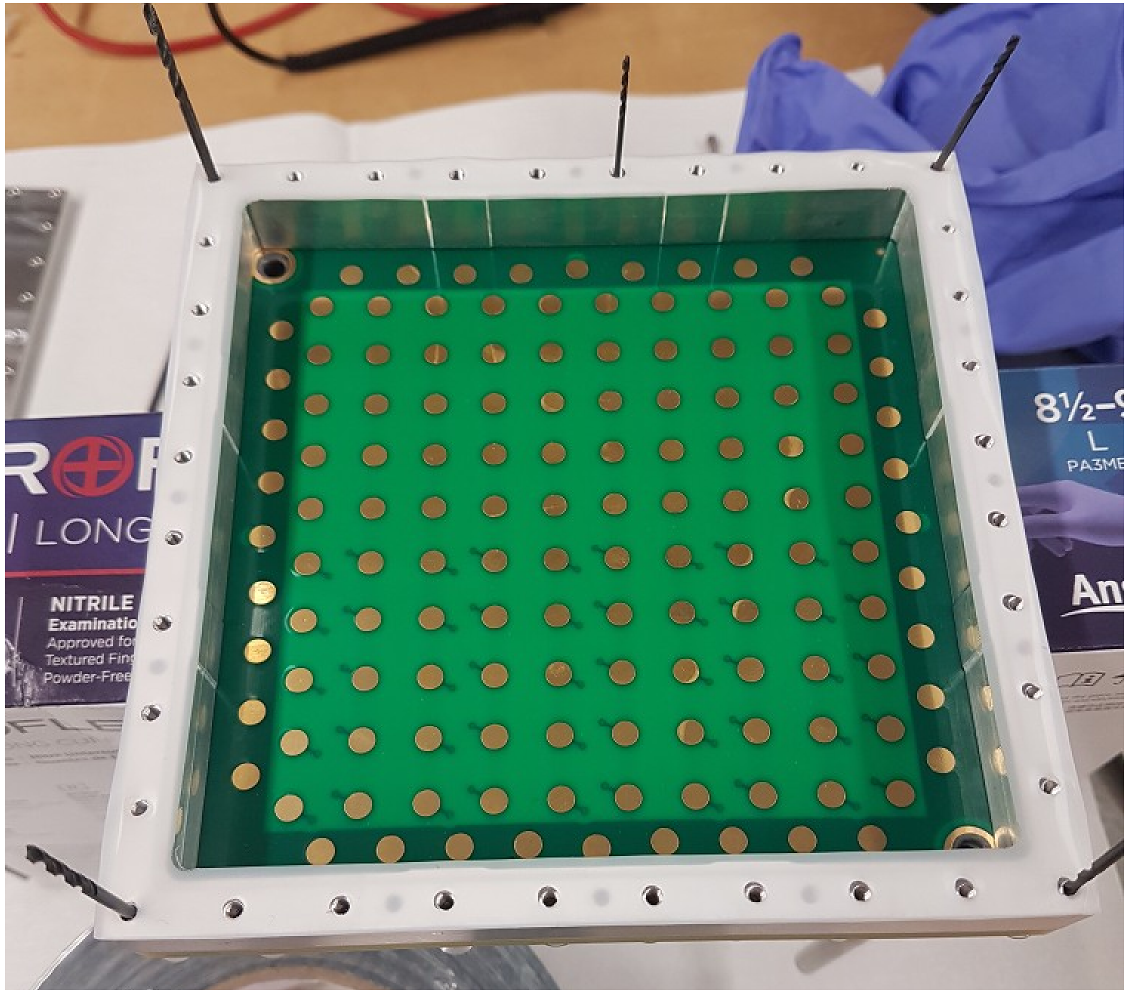
Model constrains: bottom view



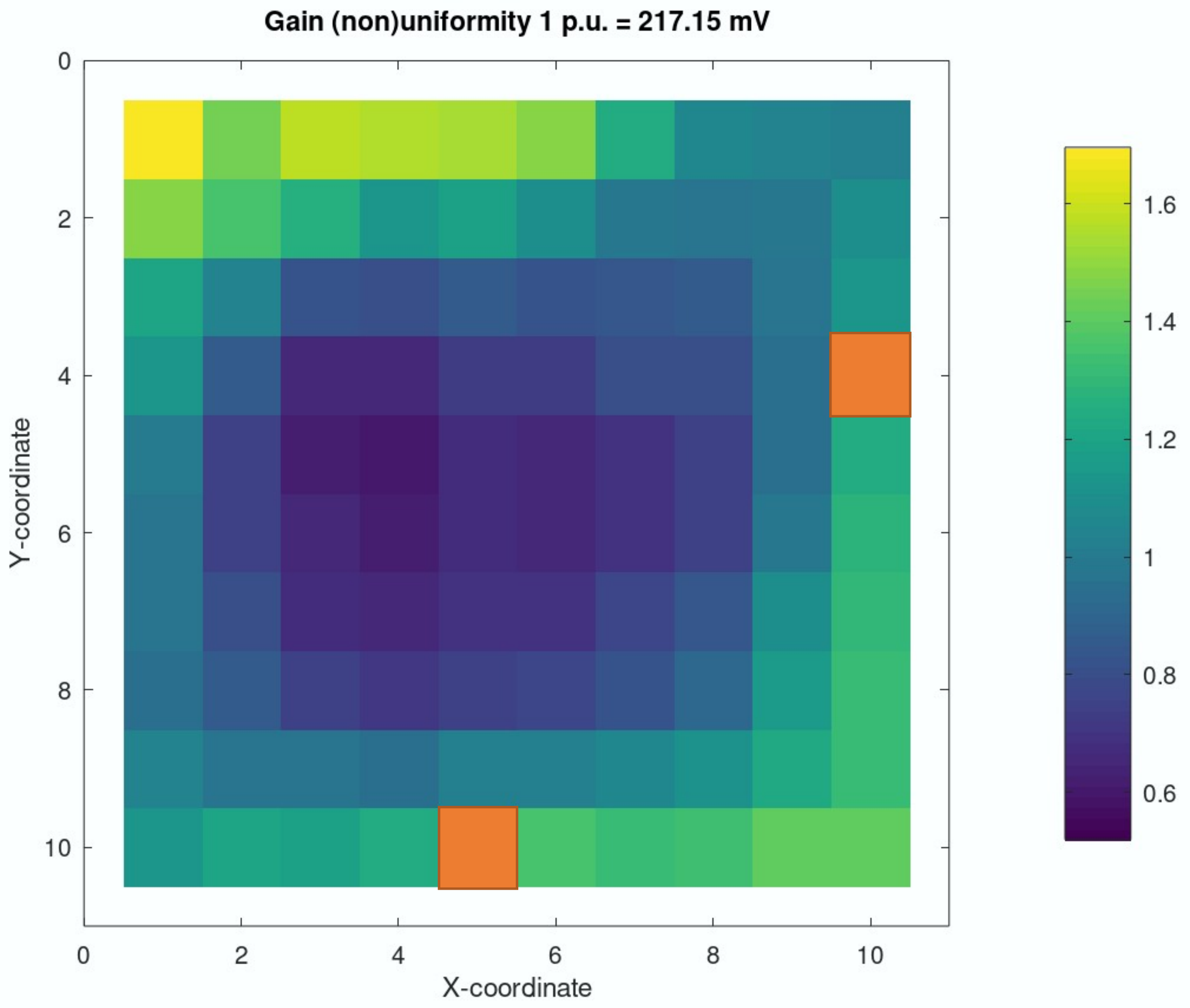
- Dispacment has a similar shape as the gain non-uniformity.
- Deformation is in the range of 130 μm.
  - Minimal deformation is at the corner and maximal displacement is in the crystal center.

Test with the flat PTFE gasket

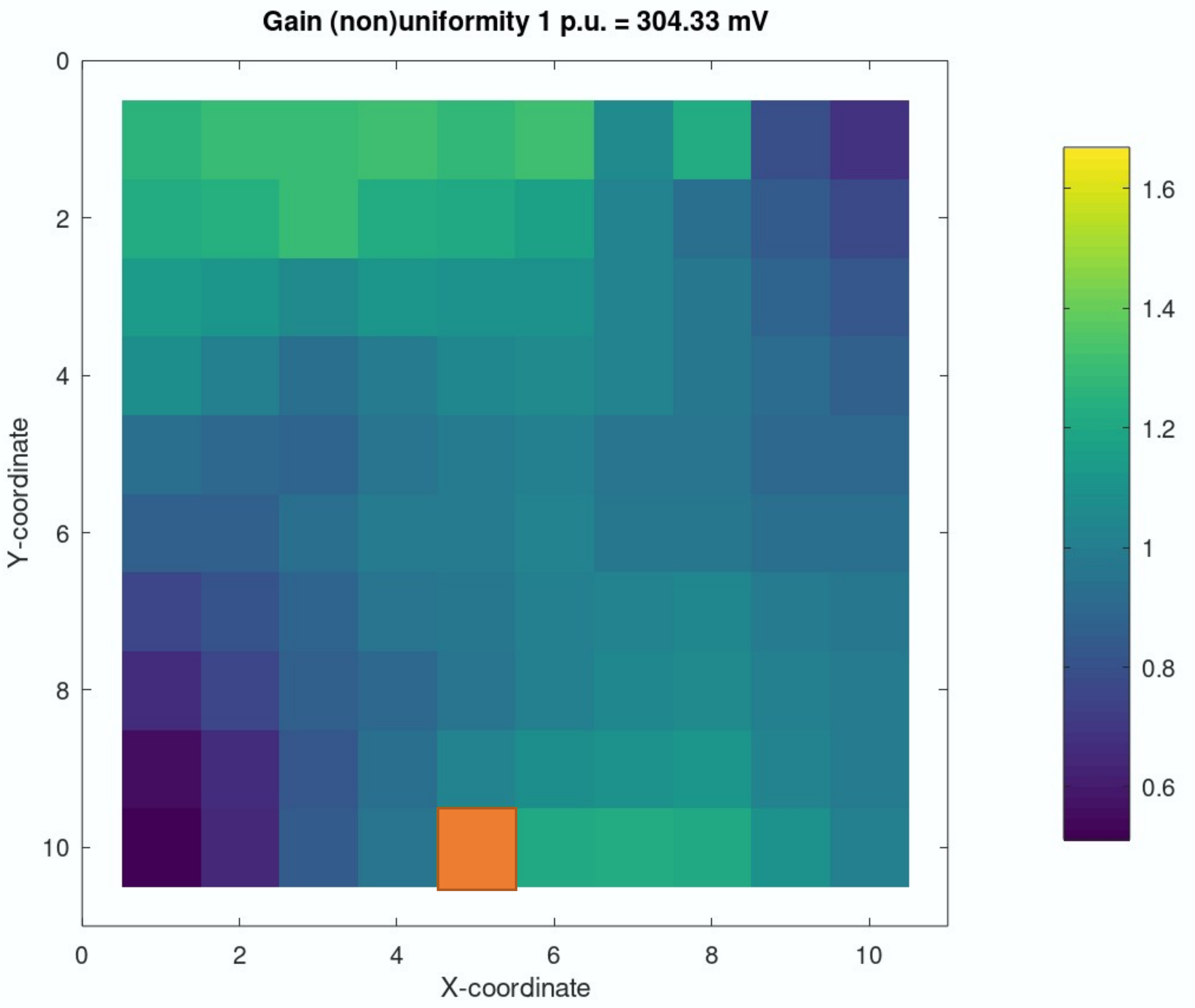
- To test if the crystal is bending over the indium gasket, a replacement flat gasket was made.
- Gasket was made out of 0.1 mm thick PTFE sheet.
- The PTFE gasket was mounted only on the side of the crystal. The PCB witht the connectors was still sealed using indium o-ring.
- PTFE gasket was uniformly torqued to 0.6 Nm.



Comparison of uniformity o-ring vs. flat gasket



O-ring nonuniformity: σ = 28 %



Flat gasket nonuniformity: σ = 16 %

Conclusion

- Production of the embedded ceramic Micormegas was successfully finalized.
- Detector was assembled and the first tests show stable operation.
- **Planarity issues:**
  - The gain mapping of the detector showed poor gain uniformity. It was found out that it comes from the preamplification region.
  - Mechanical simulation suggests that the possible reason is the bending of the flange and the crystal.
  - Reassembly of the detector with the flat PTFE gasket resulted in a significantly different gain uniformity figure.
  - It is most likely that gain uniformity will not be fixed by the alternation of the flange sealing and the crystal should be also mechanically decoupled from the casing.
  - Modification of the casing and flange is necessary.

Thank you for your attention ☺

Questions?